Developing biotech products, making cars, creating video games:

Disentangling knowledge bases in three German regions

Doctoral dissertation

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Acknowledgements

Fortunately, three years of working on one and the same topic does not mean three years of working in complete isolation. Family, friends, and colleagues supported my sometimes exhausting work invaluably, both, in terms of encouraging me (particularly during the stressful last weeks of my working process) as well as by providing constructive criticism. First of all, I would like to express my warmest gratitude to Robert Hassink for his outstanding supervision and support throughout the process of my PhD. I have learnt a lot from him, both professionally and personally. I could list a number of positive things in this respect; however, what I want to highlight the most is his exceedingly friendly, uncomplicated, and honest personality. I am sure that particularly these attitudes created such an outstanding, positive atmosphere within our working group (better saying: working TEAM) in Kiel. A special thanks goes to Claudia Klaerding for her exceptional support in reading, commenting, and reviewing some of the chapters of this book, and for the great time during our team work. Furthermore, Malte Bukowski, Simone Claßen, Levke Gloyer, Janne Kaiser, Lars Michelsen, Arne Rickmers, Robin Pfaff, and Petra Sinuraya (in alphabetic order) deserve special acknowledgements for their immense support. In addition, I would like to express my grateful appreciation to the firms' representatives as well as to the group of industry-experts for sharing their time with me. My warmest regards to my parents, Käthe and Hans-Willi. Danke für Eure tolle Unterstützung über die vielen Jahre! Thank you also to Sonja and Marco for their encouraging words and for their interest. Finally, I want to express a special tribute to Andrea: You are wonderful!

Preface

- How did I first get in touch with the topic of my dissertation? -

My *personal approach of disentangling knowledge bases*, I would say, started by the end of 2007 when I was in the final stage of writing my master's thesis (Magisterarbeit) at the RWTH Aachen University. My thesis included already some of the key words that I use quite frequently throughout this book (such as *knowledge*, *learning*, *innovations*, or *networks*). Though this matter of fact may rightly be interpreted as stating an obvious connection to the research that I present within this book, I would not argue that this was *my first approach of disentangling knowledge bases*.

The rather unconscious way of getting in touch with the idea of *knowledge bases* at first, however, was when I read a particular announcement that an unoccupied position should be staffed. This announcement was posted at the Department of Geography in Aachen. Professor Robert Hassink, Department of Geography at the University of Kiel, was searching for someone who was ready to carry out research on exactly the buzz words that I dealt with in my master's thesis. "Yes, I can do this" was what I thought by myself.

However, before I started writing my letter of motivation carefully, and before I thought about how to include all these 'signal words' in order to show to Professor Hassink that I am the 'perfect PhD candidate' whom he was looking for, I had to ask myself what the *crucial knowledge (base)* exactly was that qualifies myself as the best choice as a future staff member.

Having started my PhD in Kiel on April 2nd in 2008, one could argue, Robert Hassink must have believed that I had already acquired (at least parts of) this *crucial knowledge* he was searching for in order to carry out research on a topic that deals with finding out *what the crucial knowledge* exactly is, that *firms* need, in order to bring their products to the market successfully.

Summary

My dissertation deals with *industry-specific processes of knowledge formation and innovation* in a spatial perspective. *Knowledge*, *learning*, *innovations*, and *networks* are typical buzz words in the current literature in economic geography and related fields of study. These terms highlight the crucial role of knowledge creation and interactive innovation processes for the competitiveness of firms, industries, regions, and whole nations. Although a number of *territorial innovation models* (TIMs) have definitely contributed to the understanding of knowledge and innovation processes mainly at the regional level, they remain on a relatively high level of abstraction at the expense of overlooking obvious differences between industries in the way they create knowledge and the way they generate innovations. This is the point where the *knowledge base concept* (KBC) comes into play. The KBC stresses that industries differ substantially with regard to their specific knowledge base, of which three are to be distinguished from each other: *analytical* (science based); *synthetic* (engineering based); and *symbolic* (creativity based). Given that the idea to distinguish between three knowledge bases is relatively new, there is obviously a lack of studies in which this concept has been applied and tested empirically. In addition, there is still a gap in the KBC literature concerning the systematic and comprehensive integration of (i) theoretical clarification, (ii) empirical application, and (iii) identification of potentials and limits concerning its theoretical contribution, but also with regard to its operationalizability for analysis and policy formulation purposes.

This book aims to fill at least parts of these gaps. It goes beyond the mere description of the key assumptions that are related to each knowledge base by elaborating a fine-grained picture of the KBC within a wider theoretical context. The title of my dissertation is a clear hint to its most striking contribution, namely the empirical insights it provides into the underlying *knowledge base configurations* of *three regional industries in Germany*, that is, the *biotechnology industry* in the *Aachen Technology Region*, the *automotive industry* in *Southwest Saxony*, and the *video game development industry* in *Hamburg*. In total, more than a hundred firm representatives have been interviewed. Enriched with a number of expert interviews, the resultant data enables me to scrutinize the elementary but sometimes hidden differences regarding the crucial knowledge that drives innovations and competitiveness of the corresponding firms. Further considerations refer to the potentials and limits of the KBC as a tool for policy formulation, which is closely connected to the issue of operationalization. Though my conclusion is largely rooted in the theoretical and empirical elaborations which are presented throughout the entire book, the last chapter also raises a number of questions for future research that is going to deal with knowledge bases. Therefore, it can be understood as an attempt to trigger the development of the KBC through pushing it up the research agenda of economic geographers in upcoming years.

Zusammenfassung

Die vorliegende Doktorarbeit befasst sich mit *industriespezifischen Prozessen der Wissensbildung und Innovation* in räumlicher Perspektive. *Wissen*, *Lernen*, *Innovationen*, und *Netzwerke* sind typische Schlüsselworte in der heutigen Wirtschaftsgeographie-Literatur sowie in verwandten Forschungszweigen. Gleichzeitig verweisen diese Begriffe auf die zentrale Rolle der Wissensentstehung und der interaktiven Innovationsprozesse für die Wettbewerbsfähigkeit von Betrieben, Regionen und gesamten Ländern. Obwohl einige *Territoriale Innovationsmodelle* (TIMs) unbestritten zum Verständnis von Wissens- und Innovationsprozessen – vor allem auf der regionalen Ebene – beitragen, verbleiben sie doch auf einem verhältnismäßig hohen Abstraktionsniveau. Dies geht häufig zu Lasten einer Berücksichtigung der Unterschiede zwischen Industrien hinsichtlich ihrer Eigenheiten, Wissen zu kreieren und Innovationen zu generieren. Genau an dieser Stelle kommt dem *Konzept der Wissensbasen* (KWB) (engl. = *knowledge base concept*, KBC) eine bedeutende Rolle zu. Das KWB betont, dass sich Wirtschaftszweige fundamental im Hinblick auf Ihre spezifische Wissensbasis unterscheiden. Es werden drei Wissensbasen unterschieden: die *analytische* (wissenschaftsbasierte), die *synthetische* (technisch/technologisch basierte) sowie die *symbolische* (kreative) Wissensbasis. Da die Unterscheidung zwischen diesen drei Wissensbasen noch sehr jung ist, besteht ein entsprechender Mangel in ihrer empirischen Anwendung. Eine weitere Forschungslücke in der KBW-Literatur bezieht sich auf die (bislang ungenügende) systematische und umfassende Verknüpfung der Bausteine: (i) theoretische Erläuterungen, (ii) empirische Anwendung, und der (iii) Identifikation von Grenzen und Potentialen in Bezug sowohl auf den theoretischen Mehrwert, den das KBW zu liefern vermag, als auch bezogen auf die Operationalisierung für Analysezwecke und zum Zweck der Politikberatung.

Dieses Buch möchte einen Beitrag leisten, zumindest Teile dieser Lücken zu füllen. Es geht dabei über die bloße Beschreibung der Kernannahmen einer jeden Wissensbasis hinaus, indem es ein feingliedriges Abbild des KWBs in seiner theoretischen Einbettung herausarbeitet. Der Titel der Dissertation versteht sich als ein deutlicher Hinweis auf ihren bedeutendsten Beitrag. Gemeint sind die auf empirischen Beiträgen fußenden Einblicke in die *Wissensbasiskonfigurationen dreier regionaler Industrien in Deutschland*: der *Biotechnologieindustrie* in der *Technologieregion Aachen*, der *Automobilindustrie* in der *Region Südwestsachsen* und der *Videospiele-Entwicklung* in *Hamburg*. Insgesamt wurden mehr als hundert leitende Angestellte bzw. Geschäftsführer aus den entsprechenden Unternehmen befragt. Angereichert durch weitere Experteninterviews, konnten auf dieser Datengrundlage die elementaren, häufig auch latenten Unterschiede in Bezug auf die bedeutenden Wissensinputs herausgestellt werden, die für den Innovationsprozess und die Wettbewerbsfähigkeit der entsprechenden Unternehmen unabdingbar sind. Weiterhin beschäftigt sich das Buch mit den Potentialen und Grenzen des KWB als Instrument der Politikberatung, wenngleich diese Überlegungen immer auch die

Frage der Operationalisierung insgesamt einbeziehen. Obschon meine Schlussfolgerungen weitestgehend auf den theoretischen und empirischen Beiträgen vorangegangener Kapitel beruhen, werden im letzten Kapitel auch Forschungsfragen für zukünftige Arbeiten zum KWB aufgeworfen. Damit soll der Schlussteil auch als Versuch verstanden werden, die Entwicklung des KWB – insbesondere in der Wirtschaftsgeographie – weiter voranzutreiben.

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Abbreviations

AutoSWS	automotive industry in Southwest Saxony
BioAC	biotechnology industry in the Aachen Technology Region
DUI	doing, using, interacting
EEG	evolutionary economic geography
EG	economic geography
KBC	knowledge base concept
KBConfi	knowledge base configuration
KBCP	knowledge base configuration problem
MKN	market knowledge network
OEM	original equipment manufacturer
R&D	research and development
REG	relational economic geography
SSI	sectoral system of innovation
STI	science, technology, innovation
TKN	technological knowledge network
TIM	territorial innovation model
VgdHH	video game developing industry in Hamburg

1. Introduction

Within the introduction to my dissertation I shortly introduce the idea behind the knowledge base concept (from here on KBC) and the value it adds to the field of economic geography (from here on EG). At the same time I identify two decisive research gaps that come along with the use and with the development of the KBC up to the day of publication of this book. Filling these gaps, in turn, constitutes my motivation. Moreover, the introductory chapter specifies my central aims as well as the research questions I seek to answer within this book. This chapter finishes with an overview of the following chapters.

1.1. Using knowledge bases in economic geography: a plea for a closer look

Knowledge, *learning, innovations* and *networks* are typical buzz words in today's EG literature highlighting the crucial role of knowledge creation and interactive innovation processes for the competitiveness of firms, industries, regions, and whole nations. Moreover, a great deal of recent research about the geographies of knowledge flows and interactive learning stresses the region to be the key level at which systemic interactions lead to innovations, and where economic processes are coordinated and governed (Fritsch & Stephan 2005). This is the case for partly overlapping theoretical templates (Vallance 2007), such as clusters (Malmberg et al. 1996; Porter 2000), industrial districts (Pyke et al. 1990), innovative milieus (Camagni 1991), regional and metropolitan innovation systems (Cooke & Morgan 1998; Diez 2002), and learning regions (Morgan 1997), that are summarized by Moulaert and Sekia (2003) as territorial innovation models (from here on TIMs).

Although each of these approaches definitely enhances our perception of the relation between innovation, knowledge, interactive learning and geography, they remain on a high level of abstraction neglecting the differences between industries. For instance, interorganizational networks of knowledge transfers of firms which develop pharmaceutical products on the basis of a biotechnological process can be assumed to take a significantly other shape in contrast to the networks of automotive suppliers, producing parts, modules, and whole systems for original equipment manufacturers (OEMs). Why, one may ask? A starting point, I argue, is the difference in products, each of them requiring different knowledge inputs. The two firms produce completely different products; pharmaceuticals have not very much in common with cars, both in technological terms and with regard to the market conditions. The consequence is that as different as these products are, as different is the knowledge that firms put into their products in order to bring them successfully to the market. As a result, biotechnology firms search for other knowledge sources than automotive firms do. This, in turn, affects the pattern of their knowledge networks, both in terms of the type of network partners they prefer to exchange knowledge with as well as regarding the spatial dimension and the nature of knowledge flows.

This is the point where the KBC comes into play. The KBC, based on the findings by Laestadius (1998) and further elaborated in a geographical context by Asheim and Gertler (2005), stresses that industries differ substantially with regard to their specific knowledge base, of which three are to be distinguished: analytical (science based); synthetic (engineering based); and symbolic (creativity based). However, introducing the KBC is not only to be seen as an attempt of systematically analyzing the type of knowledge that is crucial and that constitutes the competitive core of an industry. Supporters of this approach go beyond the analytical dimension by highlighting its potential to be used for fine-tuning policy instruments that aim at fostering the regional economy. According to them, policies that aim at constructing regional advantage cannot rely on one best practice model; ideally, policies should be adjusted to the different conditions of the respective regions, including, among others, the dominating knowledge base of local industries.

The title I have chosen for this introductory section – *Using knowledge bases in economic geography: a plea for a closer look* – can be understood in two ways: First, the idea of differentiating knowledge bases asks for looking closer at the elementary, but sometimes hidden differences between regional industries with regard to the crucial knowledge that drives innovations and competitiveness of the respective firms. Second, we have to look closer at the KBC itself by critically testing its conceptual added value to EG as well as its operationalizability, both for the purpose of analysis and for developing policy recommendations.[1]

1.2. Contributions, aims, and research questions

The aim of my dissertation is to contribute to the emerging body of literature in EG revolving around the KBC in two ways, accordingly: First, the idea to distinguish between three knowledge bases is a relatively new one. This fact usually goes in line with a lack of studies in which this concept has been applied and tested empirically. My case studies about three different regional industries in Germany contribute to fill at least parts of this research gap. Second, neither a book nor a special journal issue has been published yet, which combine theory-based reflections, empirical work, and critical appraisal on the KBC in a systematic and comprehensive way. Accordingly, the second prior aim of this

[1] The whole body of research carried out for this dissertation belongs to a European collaborative research project called “Constructing regional advantage. Towards state-of-the-art regional innovation system policies in Europe?”. The aim of this project was to find out how policies for constructing regional advantage can work in different regional, institutional and sectoral settings in seven European countries. The project was co-funded by the Research Council of Norway and the European Science Foundation.

dissertation is to start reducing this lack of research as well.[2] My contribution refers to the concept's theoretical clarification and in particular to its empirical application as well as to the identification of its potentials and limits in theory and practice which, in turn, paves the way to future research (Figure 1). Filling both gaps which have been identified above and, with it, contributing to the literature in EG that deals with knowledge, innovations, networks, and learning (the buzz words I referred to at the beginning of this introduction) represent my motivation in elaborating on the KBC.

Even though Chapter 8 and 9 (Figure 2) contain some first reflections on using the KBC for policy recommendations, it is *not* the main objective of my research to write a handbook to support policy-makers à la *which policy for which knowledge base?* First of all, this book adds to the indispensable steps *before* being able to define recommendations based on the KBC at all, since I am convinced that we, at first hand, have to answer *what we are precisely talking about* before telling *what we should do (or not do)*. In other words: Each advice based on the idea of differentiating knowledge bases between regional industries requires, on the one hand, a profound understanding of the theoretical idea behind the KBC. On the other hand, we need a precise picture of the particular knowledge base configuration (from here on KBConfi) that drives the respective regional industry (the empirical dimension) before we are in the position to give advice to anyone by using this concept. These steps are often overseen in face of a multitude of recommendations based on no more than anecdotal evidences (Markusen 1999), or on simply copying (regional) role models in a *one-size-fits-all* manner (Tödtling & Trippl 2005).

Figure 1 provides an overview of the central aims of my dissertation. As written before, within this book I am concentrating first and foremost on the theoretical clarification of the KBC, as well as on the empirical contribution to the concept. Both, the empirical as well as the theoretical building blocks are not isolated or independent from each other. In contrast, I aim to connect both parts in a circular and reflexive way (cf. Chapter 3.4). As a result, my case studies on three regional industries in Germany (Chapters 4 to 7) are based on theoretical assumptions that are derived from the KBC (Chapter 2) while simultaneously the empirical findings and methodological experiences are used to contribute to the theoretical development of the concept (Chapter 9.5).

[2] There are at least two special journal issues that have not been published yet, but which may have the potential to fulfill these requirements, too. The first one, edited by Bjørn T. Asheim, Jerker Moodysson and Franz Tödtling, carries the title "Constructing Regional Advantage: towards state-of-the-art regional innovation system policies in Europe?". This issue is forthcoming in *European Planning Studies* (2011b). The second one, preliminarily titled "Innovation and Knowledge Networks", is now in revision for *European Urban and Regional Studies*. The potential editors are Franz Tödtling, Bjørn T. Asheim, and Ron Boschma. In contrast to my dissertation which focuses on case studies within only one country, these issues include case studies carried out across different countries and, therefore, allows for cross-country comparisons. Two of the papers that I present within my dissertation are part of these issues (cf. Chapter 1.3).

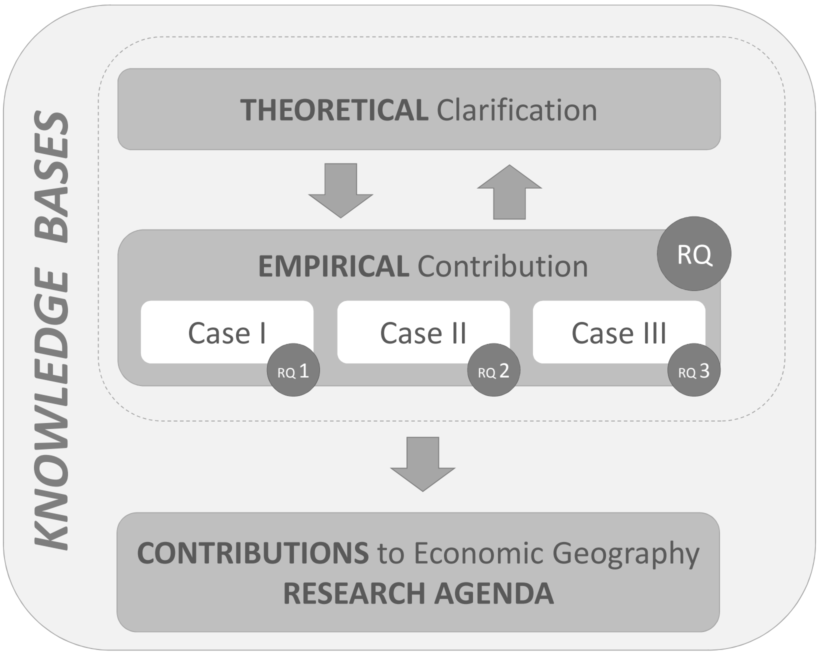

Figure 1. *Overview of aims and research questions*

The central research question (RQ, see Figure 1) which guides my empirical analyses is: *Which knowledge base configuration drives knowledge formation and innovation processes in selected regional industries in Germany?* Paraphrasing this question, I could ask as well: *What is the type of knowledge that is crucial for firms' competitiveness and constitutes the core of the industry's innovation efforts in the selected region?*

The corresponding sub-questions with regard to each case study are:

- *Which knowledge base is the crucial one for creating innovations in the biotechnology industry of the Aachen Technology Region? (RQ 1, Chapters 4 and 6)*
- *On which knowledge base do automotive firms in Southwest Saxony rely on in order to stay competitive? (RQ 2, Chapters 5 and 6)*
- *Which knowledge base configuration drives video game development in Hamburg? (RQ 3, Chapter 7)*

Based on the results of my research, I aim to critically appraise the concept's contribution in bringing forward conceptual thinking and empirical research in the field of knowledge formation and innovation processes in EG. These reflections lead me to my final aim which is to suggest future research paths targeting the scientific and practical use of the KBC (Chapter 9).

1.3. Book structure and overview of papers

My dissertation is structured on the basis of Figure 1 in order to thoroughly meet the pre-defined aims and to answer the corresponding research questions in the best possible way (see Chapter 1.2). The resultant outline is presented in Figure 2. In Chapter 1, I introduce the book's main point, the KBC, along with the typical reference to aims, research questions, and structure. A more detailed theoretical discussion about the concept can be found in Chapter 2.

Thoroughly, Chapter 2.1 elaborates the conceptual origin, the motivation, and the underlying assumptions of the KBC. In Chapter 2.2, I highlight the conceptual inflows to the KBC in greater detail, followed by a presentation of the key characteristics of each knowledge base. Even though these considerations lead inevitably to redundancies in the face of some theory-led reflections within the papers that have been selected for this dissertation (Chapters 4-8), it is necessary to discuss the conceptual inflows and key characteristics thoroughly in this sub-chapter in order to understand my interpretation of the overall theoretical embedding of the concept in Chapter 2.3 completely.

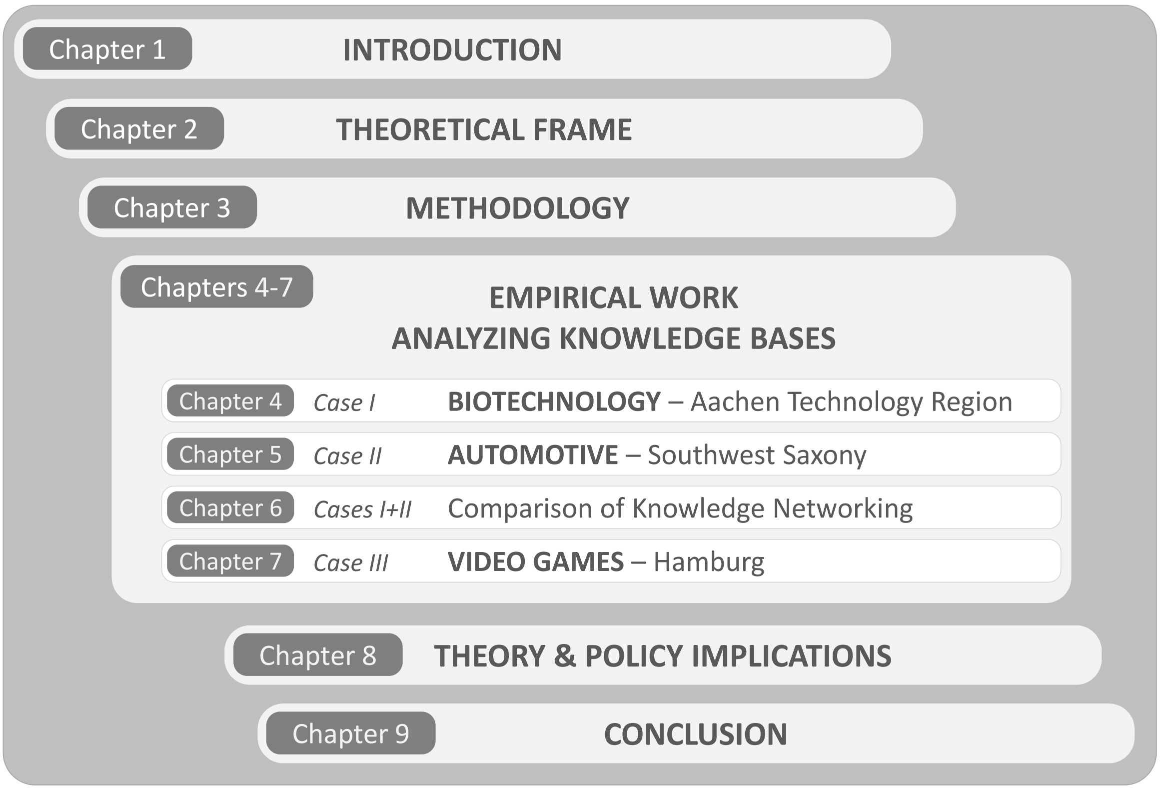

Figure 2. *Book structure*

Before I present the empirical results in Chapters 4 to 7, Chapter 3 addresses some methodological considerations. In doing so, I refer to the overarching research strategy and to the concrete methodological steps of my fieldwork in three different regions in Germany. In detail, I pay attention to the reason for choosing the case study method as the dominant research strategy (Chapter 3.1), the definition of my research design (Chapter 3.2), the method of collecting data (Chapter 3.3), and the methods of analysis (Chapter 3.4). This is complemented by some reflections on potential limitations of my empirical findings and on the underlying methodology respectively (Chapter 9.2).

The core of my contribution to recent debates in EG is the empirical analysis of the respective knowledge base constellation that drives knowledge formation and innovation processes in three regional industries. The corresponding research covers four out of five papers that have been selected for this dissertation, rearranged in Chapters 4, 5, 6, and 7. My empirical findings therein are mainly based on knowledge network analyses and common descriptive statistics. In Figure 3 I refer in greater detail to the individual papers.

PAPER	PUBLICATION STATUS	OWN CONTRIBUTION			
		Intro	Theory	Empirical Work	Conclusion
Chapter 4 On the nature and geography of innovation and interactive learning: a case study of the biotechnology industry in the Aachen Technology Region, Germany *(Case I)*	Forthcoming in ***European Planning Studies***	●	●	●	◐
Chapter 5 Analytical vs. synthetic knowledge: Which knowledge base configuration drives Southwest Saxony's automotive firms? *(Case II)*	Accepted with major revision for ***European Urban and Regional Studies***	●	●	●	●
Chapter 6 Comparing knowledge networking in different knowledge bases in Germany *(Cases I+II)*	Published in ***Papers in Regional Science***	◐	◐	●	◐
Chapter 7 Modern Pac-Men fed by the Symbolic Knowledge Base? Knowledge networks and innovation processes of Hamburg's video game developers *(Case III)*	Accepted with major revision for ***Industry and Innovation***	●	●	●	●
Chapter 8 Wissensbasen als Typisierung für eine maßgeschneiderte regionale Innovationspolitik von morgen?	Forthcoming (book chapter) in ***Räume der Wissensarbeit – Theoretische und methodische Fragen zur Rolle von Nähe und Distanz in der wissensbasierten Wirtschaft***	◐	●	not applicable	◐

● completely own contribution ◐ jointly written

Figure 3. *Overview of individual papers and own contribution*

The four already mentioned papers that are presented in Chapters 4 to 7 were all submitted for publication in double-blind peer reviewed journals. The book chapter – within my dissertation reprinted in Chapter 8 – was peer-reviewed as well, albeit not blindly. The four journals and the book are, among other fields of study, specialized in topics for regional economic development with particularly high relevance for economic geographers who deal with knowledge and innovation processes in different industries and regions. In the following, I will go through each paper in short: highlighting its title and publication status; stating my own contribution (since some of them have been composed and written in cooperation with Robert Hassink); and referring to its main topic.

Chapter 4: *'On the nature and geography of innovation and interactive learning: a case study of the biotechnology industry in the Aachen Technology Region, Germany'*, co-authored with Robert Hassink and forthcoming in *European Planning Studies*, targets RQ1 (see Chapter 1.2). Within this paper we differentiate between the analytical and the synthetic knowledge base in order to characterize the nature of critical knowledge that is indispensable for innovation activities in the biotechnology industry of the Aachen Technology Region. The conclusion is jointly written, whereas the introduction, the theoretical reflections, as well as the empirical analyses are based on my own elaborations.

Chapter 5: *'Analytical vs. synthetic knowledge: Which knowledge base configuration drives Southwest Saxony's automotive firms?'*, accepted with major revision for *European Urban and Regional Studies,* single-authored, addresses RQ 2 (see Chapter 1.2). This paper aims to investigate the nature and geography of knowledge sourcing and interactive innovation processes of Southwest Saxony's automotive firms. Again, the synthetic as well as the analytical knowledge base are employed to shed light on the underlying mechanisms and the way these firms generate the competences they need in order to increase or at least ensure their competitive role in spatially distributed production networks. Moreover, the paper questions whether the knowledge base constellation which turns out to drive the automotive firms in this region will safeguard the clusters' competitiveness in the long run.

Chapter 6: *'Comparing knowledge networking in different knowledge bases in Germany'*, co-authored with Robert Hassink and published in *Papers in Regional Science*, combines selected results of the two aforementioned papers in a comparative and contrasting manner. In this paper we highlight and explain differences in knowledge networking by using the KBC, comparing knowledge exchange patterns of biotechnology firms of the Aachen Technology Region with those of Southwest Saxony's automotive firms. The introductory section and the theoretical section, as well as the conclusion are a product resulting from collaboration between Robert Hassink and me. The empirical analyses, in turn, were entirely written on my own.

Chapter 7: *'Modern Pac-Men fed by the Symbolic Knowledge Base? Knowledge networks and innovation processes of Hamburg's video game developers'*, accepted with major revision for *Industry and Innovation*, single-authored, provides the answer to RQ 3 (see Chapter 1.2). Within this paper, I have a closer look on knowledge production and innovation processes in one of the fastest growing subsectors of the creative economy by investigating the video game development industry in Hamburg out of a knowledge base perspective. In doing so, the paper challenges the prevalent assumption that creative industries rely first and foremost on the symbolic knowledge inputs.

Chapter 8: *'Wissensbasen als Typisierung für eine maßgeschneiderte regionale Innovationspolitik von morgen?'*, co-authored with Robert Hassink and forthcoming as a book chapter in a multidisciplinary volume of papers written in German, titled *Räume der Wissensarbeit - Theoretische und methodische Fragen zur Rolle von Nähe und Distanz in der wissensbasierten Wirtschaft*, starts with theorizing the KBC. The corresponding sections of this paper are composed of considerations concerning the key characteristics of each of the three knowledge bases, enriched by a number of examples illustrating conspicuous differences between industries or activities that rely on different knowledge bases. The concluding section of this paper raises some first recommendations for regional innovation policies which are based on the idea to distinguish industrial knowledge bases. We finish the paper with a short appraisal on the concept's chance of success in informing policies. Contrary to the other papers in Chapters 4 to 7, this paper contains no empirical work. The theoretical reflections were fully accomplished by me, whereas both, the introduction as well as the concluding part, rest upon cooperative work.

My dissertation finishes with Chapter 9. This concluding chapter contains the common summary of the key findings (Chapter 9.1) as well as some reflections on the limitations of my empirical work (Chapter 9.2). Further considerations refer to the potentials and limits of the KBC as a tool for policy formulation, which is closely connected to the issue of operationalization (Chapter 9.3). In addition, I target the key contributions of this book concerning the research of industry-specific knowledge creation and innovation patterns in EG and related sub-disciplines (Chapter 9.4). Though my conclusion is largely rooted in the theoretical and empirical elaborations presented throughout the entire book, the last chapter also raises a number of questions for future research that deals with knowledge bases. Therefore, it can be understood as an attempt to trigger the development of the KBC through pushing it up the research agenda of economic geographers in upcoming years (Chapter 9.5).

2. Knowledge bases in theory

In Chapter 2, I develop the theoretical framework of my dissertation by discussing the conceptual background of the KBC. The corresponding questions that guide me through the theoretical clarification of the concept are as follows: What are the theoretical roots of the KBC in general and how is it interlinked particularly with concepts in EG? What are the most influential theories that are borrowed from other disciplines? Which are the criteria along with which the analytical, the synthetic, and the symbolic knowledge base can be distinguished from each other, and which are the theoretical assumptions informing these criteria? And lastly, what, then, are the particular differences between the knowledge bases according to the differentiation criteria of the concept? In sum, these questions are helpful to elaborate a more fine-grained picture of the position of the KBC within a wider theoretical context. As such, I apply an inductive way of reasoning which constructs a generalized picture (i.e. the wider theoretical embedding) that is based on individual arguments (i.e. the sequence of conceptual insights on which the distinctive differentiation criteria are relying). Thus, this chapter goes beyond merely summarizing the conceptual parts of the papers that have been selected for this book (Chapters 4 to 8).

2.1. Knowledge bases: conceptual origin, motivation, and basic assumptions

The differentiation of knowledge bases roots in the findings by Laestadius who argues that knowledge formation, technology level, and competitiveness in paper manufacturing cannot sufficiently be explained by a too narrowly “science and technology perspective” (1998, p.212). He questions the widely kept belief which claims that measured R&D intensity reflects and explains innovative activity along the whole range of industrial sectors. This refers particularly to the engineering based industries like the pulp and paper industry, which seldomly count their product and process development activities as R&D. Therefore, he asks for taking a closer look at the *origin* of knowledge formation (instead of collecting R&D indicators) when it comes to the differentiation of innovation activities in distinct industrial sectors. “Unlike some ‘high-tech’ industries like pharmaceuticals”, he argues, “paper technology does not originate in academia but in improved craft and traditional engineering skills on the shop floor” (1998, p.222).

Laestadius (1998) concludes the book chapter by differentiating between *analytical activities* on the one hand, and *synthetical activities* on the other hand. Those notions can be seen to be the ‘conceptual ancestors’ of the differentiation between the *analytical knowledge base* and the *synthetic knowledge base* in Asheim and Gertler (2005). Whereas the analytical knowledge base is said to be particularly important for science based industries, the synthetic knowledge base is assumed to be crucial for engineering based industries (Gertler & Wolfe 2006). Later on, the *symbolic knowledge base* was added to the KBC (Asheim 2007) in order to account for the growing economic importance of the creative and cultural industries respectively. However, the original idea to add the symbolic knowledge base was already brought forward in 2001, based on contributions by Bjørn Asheim, Franz Tödtling, Gernot Grabher, Åge Mariussen, Robert Hassink, Meric Gertler, Alice Lam, Phil Cooke, Fiorenza Belussi, and Trond Einar Pedersen (Asheim et al. 2007a).

As soon as all three knowledge bases get bundled in a comparative approach, differences between various sectors of modern economy can be unfold due to the fact that each knowledge base indicates “different mixes of tacit and codified knowledge, codification possibilities and limits, qualifications and skills, required organizations and institutions involved, as well as specific innovation challenges and pressures from the globalizing economy” (Asheim 2007, p.225).

Various TIMs (Moulaert & Sekia 2003) – first of all clusters (Porter 2000), industrial districts (Pyke et al. 1990), learning regions (Morgan 1997), metropolitan, regional and national innovation systems (Diez 2002; Cooke & Morgan 1998; Lundvall 1992), and innovative milieus (Camagni 1991) – are regularly applied in a multitude of case studies about distinct regional and local industries. The oftentimes apparent differences between industrial sectors concerning knowledge and innovation processes, and the geography thereof, however, are neither explicitly nor sufficiently theorized therein. In other words – using the terminology of the KBC: There are neither *engineering based* clusters, nor *science based* industrial districts, not to mention *creativity based* innovation systems which show that inter-industrial differences in the exploration, exploitation, and diffusion of knowledge are taken seriously. Therefore, another crucial motivation that leads to a differentiation of knowledge bases – apart from the one that led to the distinction made by Laestadius (1998) – is deeply rooted in the attempt to overcome the conceptual neglect of inter-industrial differences in TIMs.

2.2. Disentangling the horizontal and the vertical dimension: conceptual inflows to the knowledge base concept and ideal-typical characteristics

Table 1 provides an overview of the three knowledge bases and its key characteristics. As with many other theories and concepts, the KBC provides a simplified picture of a phenomenon that we can observe in the real world, that is the differences in knowledge formation and innovation processes between industrial sectors. Therefore, the distinction of the analytical, the synthetic, and the symbolic knowledge base has to be understood as an *ideal-typical* comparison along a number of selected criteria. In the ‘real world’ economy most activities comprise more than one knowledge base, and the degree to which a particular knowledge base dominates varies between industries, firms, and different types of activities (Asheim et al. 2011a).

Whereas several concepts in EG – particularly those which exhibit a spatial dimension – have their manifestation in 'catchy' graphical interpretations[3], the categorization of knowledge bases in the form of a table can be interpreted as being the most noticeable conceptual artifact of the KBC (cf. Table 1). In Chapters 2.2.1 and 2.2.2, I disentangle the theoretical-conceptual influences which inform the vertical as well as the horizontal dimension of the KBC table. Then, as a kind of synthesis of both sub-chapters, in Chapter 2.2.3 I present the key characteristics of each knowledge base.

Table 1. *Ideal-typical characteristics of knowledge bases in comparison*

CRITERIA	ANALYTICAL	SYNTHETIC	SYMBOLIC
1 main rationale	**science** based	**engineering** based	**creativity** based
2 nature of knowledge	**codified** (documentation in patents and publications)	**tacit** (concrete know-how, craft and practical skills)	**tacit** (concrete know-how, craft, practical and search skills)
3 process of knowledge creation	**deductive** process, **formal** models, **know why**	**inductive** process, **applied**, problem related, **know how**	**interactive**, **informal**, **creative**, problem oriented, **know who**
4 type of innovation	**radical** innovation by creation of **new** knowledge	**incremental** innovation by application and by combination of **existing** knowledge	innovation by creative recombination of **existing** knowledge and by creation of **new ideas and images**
5 mode of knowledge networking	**research collaboration** between firms (R&D departments) and research organizations	interactive learning with **customers and suppliers**	interaction in **professional communities, learning from youth/ street/ 'fine' culture**
6 importance of spatial proximity	**low to medium**	**medium to high**	**medium to high**

Source: Own modification of Asheim and Gertler (2005), Asheim (2007), Moodysson et al. (2008), and Asheim et al. (2011a)

2.2.1. Differentiation criteria and related concepts and theories – the vertical dimension

Step by step, I seek to clarify the conceptual background by informing each of the vertically organized differentiation criteria that can be found in the left column of the KBC table (cf. Table 1). In doing so, the solution to the puzzle of conceptual insights from EG and other disciplines that influence the KBC

[3] Good examples within the EG literature are the visual conceptualizations of TIMs, like those highlighting the key features of innovative or creative milieus (e.g. Fromhold-Eisebith 1999, p.171) and regional innovation systems (e.g. Autio 1998, p.134). Another memorable example in this context is the illustration of the local buzz and global pipelines concept (e.g. Bathelt et al. 2004, p.46).

takes form gradually. The final picture of the concept's theoretical embedding will be presented in Chapter 2.3 (see Figure 4 and Figure 5).

Criterion 1: Main rationale behind each knowledge base

Considerations within the KBC table that refer to Criterion 1 are particularly informed by theoretical frameworks which aim to identify, analyze, and explain differences between economic sectors in the way they produce knowledge and innovations (Pavitt 1984; Malerba 2002; Jensen et al. 2007). Moreover, the extensive body of case studies on regional industries can be identified as a major source of motivation to have a closer look at the differences of industries with regard to the nature and geography of learning and innovation. Even though Criterion 1 belongs to the vertically organized range of selected features, it refers primarily to the horizontal dimension of the KBC table. Thus, I will come back to that point of theoretical clarification in more detail in Chapter 2.2.2.

Criterion 2: Nature of knowledge

Criterion 2 and related considerations on the nature of knowledge rely on conceptualizations of the *tacit* vs. *codified* dichotomy (Polanyi 1966; Nelson & Winter 1982; Nonaka & Takeuchi 1995; Gertler 2003). Contrary to explicit or codified forms of knowledge, tacit or implicit knowledge is thought to be much stronger affected by context and place in which it is created, and also by the people who embody this type of knowledge as a result of experienced-based learning. Whereas codified knowledge is, due to its definition, comparatively easy to make explicit in terms of written documents (e.g. in the form of publications, blueprints, formulas, patents, or manuals) and therefore easier to transfer and to communicate on a global scale, tacit knowledge is particularly complicated to relocate and to explain in a comprehensible manner (MacKinnon et al. 2002; Gertler 2003). Amin and Cohendet (2004) provide a vivid example by referring to the (tacit) know-how of glass-blowers. They argue that the respective knowledge that enables someone to produce glass by using this blowing technique is still considered as non-articulable, though this technique has been in use for centuries.

Even if the KBC employs this rather polarized picture of knowledge types in order to, for instance, explain inter-sectoral differences in the geography of knowledge networking (cf. Criterion 6), it takes into account that tacit and codified forms of knowledge are not substitutes, but complements to each other (Amin & Cohendet 2004). This goes in line with Nonaka and Tekeuchi (1995) who stress that the process of knowledge formation and exploitation requires a dynamic interplay between, and transformation of, tacit and codified knowledge. Therefore, it is argued that each knowledge base implicates specific combinations of tacit *and* codified knowledge (Asheim & Gertler 2005).

Criterion 3: Process of knowledge creation

The KBC's perspective on sector-specific attributes of knowledge generation processes opposes de*ductive* to *inductive* as well as *informal* to *formal* forms of knowledge creation. The distinction between *deductive* and *inductive* contrasts two ways of knowledge creation: The *deductive* way refers to processes in which knowledge is created through deducing possible consequences for a particular problem in the 'real world' from assumptions made by general scientific laws (the deductive case). The *inductive* way of knowledge creation, in turn, refers to forms of reasoning that moves from specific to general by deploying knowledge from testing, experimentation, or practical work, in order to develop general laws (Harvey 1969; Gregory et al. 2009; Asheim et al. 2011a). The distinction between deductive and inductive ways of reasoning within the context of knowledge creation is informed by *cross-disciplinary innovation studies*. Furthermore, it implicates a *dynamic or evolutionary perspective* on how knowledge is generated.

Opposing *informal* to *formal* ways of generating knowledge can be interpreted in different ways. One way refers to the *formalization of knowledge*. In contrast to the rather informal knowledge which is based on experiences, formalized knowledge arises in models that build upon, for example, mathematical and statistical rules respectively. Another interpretation of the formal – informal dualism refers to the *formalization of education*, comparing formal education in the form of vocational training and university graduation (according to the respective curricula) with the informal education in terms of learning-by-doing during every day work (Jensen et al. 2007). A third possibility to oppose informal to formal ways of knowledge creation can be due to the degree of *formalization of knowledge transfers* between organizations or individuals (Asheim et al. 2011a). Whereas some knowledge transfers are highly formalized in terms of official, contractual agreements, others appear rather informally on the basis of mutual trust.[4] In sum, the theoretical reasoning behind the distinction of informal and formalized processes of knowledge creation at the intra- and inter-organizational level of analysis is not localizable in one particular field of study. It is rather the outcome of findings derived from a range of different scientific areas, such as *organizational analysis* and *knowledge management studies* (Coombs & Hull 1998; Allen et al. 2007), or *institutional economics* (Hodgson 1988; North 1990; Storper 1997).

In addition to the *deductive* – *inductive* and *formal* – *informal* split concerning knowledge creation, the stylized facts within the corresponding table row include a threefold distinction between *know why*, *know how*, and *know who*, which goes back to Lundvall and Johnson's seminal work on the *learning economy* (1994). According to the authors, "*[k]now-why* refers to scientific knowledge of

[4] In this respect, see also the debate on *traded and untraded interdependencies* (Storper 1997).

principles and laws of motion in nature, in the human mind and in society", which is seen to be especially important for technological development in R&D intensive industries (ibid., p.27). *Know who*, in turn, "refers to specific and selective social relations" and emphasizes the awareness of "who knows what and can do what" to be extremely important to the success in innovation (ibid., p.28). *Know who* is therefore closely interwoven with innovation processes which exhibit a highly interactive character. *Know how*, the third and last *know-mode* within the knowledge base framework that is rooted in the differentiation by Lundvall and Johnson (1994) "refers to skills – i.e. the capability to do different kinds of things on a practical level" (ibid., p.28).

The relation between the KBC and the work of Lundvall and Johnson (1994) that I highlighted above allows another insight into the theoretical-conceptual embedding of the concept. Interestingly enough, the theorization of the process of knowledge formation within the KBC is rather built on the rationale behind the *learning economy* (Asheim & Coenen 2005) instead of the underlying principle of the more commonly used notion of the *knowledge economy* (Machlup 1962; Kerr & Riain 2009). Knowledge is not primarily seen as a (static) resource within the economy. It is rather perceived to be the result of a (dynamic) learning process. This sort of bias, again, underlines the concept's tendency towards a more evolutionary perception of the way knowledge is created within different industrial sectors. As I will emphasize with regard to the conceptual influence of the *relational economic geography* (REG) literature (cf. Criterion 5), the KBC, indeed, relies partly on ideas from *evolutionary economics* (Nelson & Winter 1982; Arthur 1994; Schamp 2009).

Further notions that are used within the conceptual context of Criterion 3 refer to the question whether the process of shaping knowledge is first and foremost driven by the attempt to *solve a concrete, product- or process related problem*, or whether it is primarily dedicated to the *development of a completely new product or process*. The underlying assumptions are closely connected to the literature on innovation processes, which I will discuss with reference to Criterion 4.

Criterion 4: Process and type of innovation

Criteria 3 and 4 are closely connected with each other given that the type of innovation can be understood to be the consequence of the mode of knowledge creation. Although the innovation concept can be applied to noneconomic phenomena as well (e.g. organizational and social innovations) (Sternberg 2009), the hitherto existing theoretical and empirical contributions dedicated to the KBC rather concentrate on the economic dimension of innovations by focusing at (mostly technical) improvements and novelties with regard to products and processes.

Unquestionable, Schumpeter's (1934) notion of what an innovation is – namely a new combination of production factors that leads to creative destruction – has influenced reasoning on innovation processes along a wide range of disciplines and related concepts, including EG in general and the KBC in particular (Sternberg 2009). Nevertheless, over the past decades there have been extensive refinements of the theorization related to the phenomenon of innovations which still influence the way in which innovation processes are understood within the KBC. It is particularly the more *evolutionary interpretations* of innovation processes[5], such as those of Dosi (1988) and Storper (1997), which inform the threefold differentiation of knowledge bases. They perceive the creation of new products or processes as an interactive social process (cf. Criterion 5) characterized by numerous linkages and feedbacks between various stages, ranging from the original invention to development, testing, production and commercialization. Corresponding models are the chain-linked model introduced by Kline & Rosenberg (1986, p.290) as well as its modification by Malecki (1991, p.116).

A key differentiation with reference to Criterion 4 is the one of *radical* vs. *incremental* innovations. *Incremental* forms of innovation refer to relatively minor improvements of products, processes, or organizations. *Radical* innovations, in contrast, constitute a breakthrough in terms of revolutionary changes (Freeman & Soete 1997; Koschatzky 2001). Whereas inside the KBC framework radical innovations are seen to be frequently the result of the creation of new knowledge which is often based on systematic R&D, incremental innovations are understood to be the typical outcome of the application and combination of already existing knowledge (Asheim et al. 2011a). Unlike the accentuation of the technological dimension of product or process innovations – as it is typical for the analytical and the synthetic knowledge base – the symbolic knowledge base stresses the more intangible attributes of innovations in the form of new ideas and images.

The pronunciation of the *interactive* character of innovation processes, both in terms of theoretical reasoning as well as with regard to empirical contributions, reveals the strong influence of *relational frameworks* (Yeung 2005; Bathelt & Glückler 2011) on the KBC, and it becomes manifested in net-

[5] Schamp refers to this vein of literature as a "neo-schumpeterian perspective of evolutionary economics" (2009, p.70). The proposed epistemological paradigm of *evolutionary economic geography* (EEG) (Boschma & Frenken 2006; Boschma & Martin 2007), one might argue, is just as closely related to the way knowledge creation and innovation processes are theorized within the KBC. Alone the simple fact that I frequently combine the terms *evolutionary* and *EG* within the theoretical part of my dissertation could be interpreted as an indicator for the high relevance of EEG for the KBC. However, EEG is still at an embryonic stage of development (Hassink & Klaerding 2011), what makes this approach somewhat 'volatile' and therefore hard to use for theoretical clarification within this context. Another reason to neglect EEG within this contribution is its almost exclusive reasoning from the firm level leading to a relatively weak consideration of *institutions*, *multi-scalar interrelatedness* and *embeddedness* of firms (Pike et al. 2009; MacKinnon et al. 2009), i.e. those terms which definitely play a role in the explanation of industrial knowledge bases, particularly with regard to knowledge networking (cf. Criterion 5).

works of knowledge flows between different actors who are involved in this process. In what is following, with regard to Criterion 5, I will address the key conceptual issues that inform the way knowledge networking is theorized within the KBC.

Criterion 5: Mode of knowledge networking

Criterion 5 synthesizes part of the conceptual reasoning on the other selected criteria in Table 1 by putting it into a *relational* perspective, or – analogous to the terminology used within the KBC – in a knowledge network perspective. In my view, it is particularly these inter-organizational networks of knowledge flows that are at the heart of the KBC, both theoretically (cf. Chapter 2) and empirically (cf. Chapters 4 to 7).

Networks attracted much attention over the past two decades in EG and are still on the top of research agendas for the upcoming years (Benner et al. 2011). But why is this network perspective so crucial for the differentiation of knowledge bases? The reason is that analyzing knowledge networks reveals a number of important insights into the KBConfi that drives a certain industry within a region. Related indicators refer to, for example, the *geography* of knowledge network relations (cf. Criterion 6), and the type of *knowledge sources* (i.e. organizations) which are part of these networks, or the *kind of knowledge* that is exchanged (cf. criteria 2 and 3).

Recent theoretical and empirical contributions about knowledge networking within the KBC literature build – to a great extent – on insights derived from *REG* in the way that they take over the relational view of economic action and interaction in a network perspective (Grabher 2006; Grabher 2009; Rantisi & Boggs 2009; Ibert 2009). REG, in turn, combines insights from EG and other social sciences, first of all economics and sociology (Bathelt & Glückler 2003). To be more precise, it is particularly the work of *institutional and evolutionary economists* (Nelson & Winter 1982; Arthur 1994; Nelson & Winter 2002) and *economic sociologists* (Granovetter 1973, 1985) that is brought together in a relational economic geographical perspective (MacKinnon et al. 2002; Bathelt & Glückler 2003; Yeung 2005; Amin & Cohendet 2005; Schamp 2008, 2009). Accordingly, Bathelt and Glückler (2011, p.6) argue that the relational "approach is based on evolutionary and institutional conceptions and focuses on a relational understanding of economic action which is analyzed in spatial perspective. The core categories of analysis revolve around interactive learning and organizational, evolutionary, and innovation processes." The potentially new paradigm[6] in EG is described

[6] While in their paper "Toward a relational economic geography" Bathelt and Glückler (2003) refer to the REG to be the product of a *paradigmatic* shift in EG, it is remarkable that in the introductory chapter of their recent book on "the relational economy" (2011) the term *paradigm* is avoided even though the relational turn in EG, again, constitutes the core of their work. Instead, they term it a "relational conceptualization of economic action and interaction in spatial perspective" (2011, p.2).

similarly by Yeung (2005) to be the outcome of what is often referred to as the *relational turn* in EG that "focuses primarily on the ways in which socio-spatial relations of economic actors are intertwined with processes of economic change at various geographical scales" (ibid., p.37).

Parallels in the use of terms and literature can be taken as indicators for the strong interrelation between conceptualizations revolving around REG and those revolving around the KBC. A great deal of the terminology used within the debates on REG can be found in the KBC literature as well (e.g. 'innovation processes', or 'interorganizational learning'). In addition, there are parallels to be found with regard to the four *ions* of a REG introduced by Bathelt and Glückler (2002; 2003), namely the conceptualizations of organizat*ion*, evolut*ion*, innovat*ion*, and interact*ion*. This can, on the one hand, be proved by a look at the ideal-typical characteristics of knowledge bases presented in Table 1, which I am referring to within Chapters 2.2.1 and 2.2.2 in some greater detail. On the other hand, a look at the lists of references of both, the body of literature focusing on REG and the KBC literature, reveals decisive overlaps.

To a large extent, the theoretical building blocks of TIMs go in line with the conceptual cornerstones of the REG. Actually, this is not surprising, since the well-established (e.g. Bathelt & Glückler 2003; Yeung 2005) as well as the more recent contributions (e.g. Bathelt & Glückler 2011; Hassink & Klaerding 2011) on the conceptual genesis of the relational turn in EG refer to a number of TIMs as 'spatial manifestations' of relational thinking in EG. Even in their seminal work on the differentiation of industrial knowledge bases, Asheim and Gertler (2005) refer to TIMs – *learning regions* and *regional innovation systems* – in order to elucidate inter-sectoral differences in the geographical pattern of knowledge networks.

The way knowledge networking is theorized within the KBC also leads to the literature on *communities of knowing/knowledge* (Amin & Cohendet 2004). Therein, it is argued that communities of knowing constitute key entities which drive the firm's activities in creating knowledge (cf. Criterion 3). Until now, numerous papers that refer to the concept of knowledge bases build on insights derived from this literary body, distinguishing predominantly between *communities of practice* (Brown & Duguid 1991, 2002; Wenger 1998), *epistemic communities* (Knorr-Cetina 1999), and *professional communities* (Cohendet & Simon 2007).

According to the discussions of distance sensitivity of knowledge spillovers and tacit knowledge, processes of inter- and intraregional knowledge exchanges within knowledge and innovation networks apparently have spatial implications (Sternberg 2009). The influence of spatial proximity on knowledge transfers within networks of innovation, and related concepts, will be highlighted with reference to Criterion 6.

Criterion 6: Importance of spatial proximity for knowledge transfers

It is particularly the conceptual reasoning aiming at the relation between knowledge and space (e.g. Amin & Cohendet 2004, 2005) that informs Criterion 6. Part of these findings relies on conceptualizations of the tacit/local vs. codified/global dichotomy (see also Criterion 2). The main argument here is that while codified knowledge can be made ubiquitous by dislocating it from its originating setting, tacit knowledge is rather context-specific and spatially sticky. This line of argument corresponds with the key assumptions derived from *agglomeration economies* (Porter 1996; Asheim & Isaksen 1997; Audretsch 1998; Morgan 2004) and *knowledge spillover theories* (Audretsch & Feldman 2004; Acs et al. 2009). It is argued, that spatial proximity between knowledge network partners facilitates face-to-face interactions, short cognitive distances, common language, trustful relations, easier observations, and immediate comparisons. As such, spatial proximity is seen to enhance interactive learning and innovation processes which makes innovation systems tend to be constituted at the local or regional level (Audretsch 1998; Malmberg & Maskell 2002; Audretsch & Feldman 2004).

The aforementioned theorization of the relation between space and knowledge goes in line with the pronunciation of *endogenous development* and *economies of agglomeration* as it can be found in the literature on TIMs (Moulaert & Sekia 2003; Morgan 2004). Though it is reasonable to suggest a strong influence of TIMs on the conceptualization of knowledge in space within the KBC (see also my reflections on Criterion 5), it resists the temptation to perceive cities or regions as *islands of innovation* (Amin & Cohendet 2004, p.87) – a potential shortcoming of too narrowly focused TIMs at the risk of local fetishism. Apart from the binary perception of tacit/local vs. codified/global forms of knowledge networking – that definitely informs various argumentations based on the KBC – the KBC considers as well the consequences of an increasingly globalized economy for the circulation of different types of knowledge. This refers, first and foremost, to the increasing worldwide interconnectedness of business units via ICT and the growing significance of virtual communities for interactive innovation processes, complemented by the growing spatial mobilization of – also tacit – knowledge through face-to-face encounters as the result of travel activities (Amin & Cohendet 2005; Coenen 2006; Hassink & Ibert 2009; Ibert 2009).

There are further examples in the literature about knowledge bases showing the openness of the concept towards relations at a distance. A look at the spatial reach of knowledge networks, as they are understood and analyzed within the KBC literature (cf. Criterion 5), reveals that *global production* *networks* (Dicken 2007; Coe et al. 2008) and related knowledge flows among regions – as Oinas and Malecki (2002) postulate – are taken into account. Conceptualizations of *local buzz and global pipelines* (Bathelt et al. 2004) and *knowledge communities* (cf. Criterion 5) (Amin & Cohendet 2004) inform the KBC as well (Asheim & Gertler 2005; Asheim et al. 2007b).

In sum, I argue that, it is not only the locally or regionally oriented TIMs, but also the concepts which combine the local with the global in *REG*, that influence the KBC's understanding of the importance of spatial proximity between knowledge network partners to the greatest extent.

2.2.2. Theorizing inter-industrial differences – the horizontal dimension

The theory-based argumentation along the vertical dimension of the KBC (Chapter 2.2.1) only tells one part of the story about the most influential theoretical-conceptual inflows to this concept. The other crucial part of the story refers to the horizontal dimension. Therefore, in the following, I address those conceptualizations which mainly inform the inter-industrial differences in knowledge formation and innovation processes. In the end, it is particularly this horizontal dimension of the KBC which leads to the taxonomy of the analytical, synthetic, and the symbolic knowledge base (Table 1).

There are a number of concepts that scholars refer to when researching sector-specific patterns of innovation behavior and knowledge production. Of particular importance for the development of the KBC are, in my view, the *Pavitt's taxonomy* (Pavitt 1984), the *sectoral system of innovation* (SSI) (Malerba 2002), and the *DUI-STI duality* which distinguishes two modes of innovation (Jensen et al. 2004). All concepts are similar to the ideal-typical knowledge base classification and are explicitly addressed in the initial KBC literature as well. Since these concepts have appeared slightly earlier on the research agenda of scholars in EG and related disciplines, they are assumed to play a prominent role in the becoming of the KBC.

Thus, I will briefly highlight the key features of each concept and relate them to the KBC. What I do not refer to within this sub-chapter is the vast body of empirical *sectoral studies* which definitely informs and motivates the trinomial categorization of knowledge bases. These studies will be stronger emphasized within the empirical part of this book, i.e. in Chapters 4 to 7.

Pavitt's taxonomy

The *Pavitt's taxonomy* goes back to Keith Pavitt's work on 'Sectoral patterns of technical change: Towards a taxonomy and a theory' which was published in *Research Policy* in 1984. The idea of this paper was to describe, explain, and compare sectoral patterns of technical change based on a data set of about 2000 innovations in Great Britain produced in firms since 1945. The main outcome of this paper is the three part classification of industries – the *Pavitt's taxonomy* – that distinguishes between *supplier dominated*, *production intensive*, and *science based* industries.

Supplier dominated industries include agriculture and traditional manufacturing sectors (e.g. textiles), whereas production intensive industries contain scale-intensive sectors like steel, consumer durables, or automobiles. The combination of both categories corresponds strongly to the observations made by Asheim and Gertler (2005) about industries that rely predominantly on the synthetic knowledge base. Science based industries, in turn, imply electronics and chemicals (including pharmaceuticals). This category, in turn, is similar to the analytical category within the KBC (cf. Chapter 2.2.3) (Pavitt 1984; Asheim & Gertler 2005).

Sectoral system of innovation (SSI)

Gertler and Wolfe (2006) mention Malerba's conceptualization of the *SSI* (2002; 2005) in the same breath with Pavitt's taxonomy (1984), stating that both concepts take into account that "knowledge bases tend to vary systematically by industry" (2006, p.225). Malerba highlights five key aspects which he considers as being central for the notion of the SSI: "First, it focuses on supply as well as on demand and markets. Second, it examines other types of agents in addition to firms. Third, it places considerable emphasis on non-market as well as market interaction. Fourth, it pays attention to institutions. Fifth, it focuses on the processes of transformation of the system and does not consider sectoral boundaries as given and static" (2004, p.16). Simultaneously, the SSI framework provides a three dimensional methodology for the analysis and comparison of industrial sectors by distinguishing between the *knowledge and technological domain*[7], *actors and networks*, and *institutions* (Malerba 2005).

Taking these dimensions together with the five key aspects of the SSI, one finds considerable overlaps with the multidimensional, integrated, and dynamic view of innovation in sectors as it is proposed by the KBC. However, though attempts have been undertaken to identify regularities among sectors (Malerba 2004, 2005), there is no taxonomy of sectoral systems to be found in the SSI literature that classifies industrial sectors comparable to Pavitt's taxonomy and the KBC respectively. Therefore, I consider analogies in the categorization of industries to be lesser pronounced between the KBC and the SSI compared to those between the KBC and Pavitt's taxonomy.

[7] Interestingly, Malerba (2005) makes use of the term 'knowledge base' being one of the three characteristics (besides 'technologies' and 'inputs') that help to identify sectoral boundaries. The notion of the term 'knowledge base' as it is used within the SSI, however, exhibits a much narrower perception of 'knowledge' compared to the way it is used within the KBC.

DUI and STI mode of innovation

Jensen et al. (2004; 2007) as well as Lorenz and Lundvall (2006) differentiate two modes of innovation and learning, that is the *DUI mode* and the *STI mode of innovation*. Both modes are used regularly within the KBC literature in order to describe and explain characteristic patterns by sector regarding the formation of knowledge.

DUI is the acronym for *doing, using* and *interacting*. The corresponding mode of learning and innovation is highlighted by Freeman to be "tremendous[ly] importan[t] […] in the process of technical change and diffusion of innovation" (1993, pp.9-10). It is based on informal processes of learning and on experience based know-how (cf. Criterion 3, Chapter 2.2.1). The DUI mode is market-, demand- and/or user-driven (cf. Criterion 5) and it is closely related to the incremental way of innovation processes (cf. Criterion 4), and to the inductive and interactive process of knowledge creation (cf. Criterion 3) (Asheim & Gertler 2005; Lorenz & Lundvall 2006; Jensen et al. 2007). As such, the DUI mode of innovation corresponds particularly to the synthetic knowledge base and – to a lesser extent – to the symbolic knowledge base of the KBC (see Chapter 2.2.3).

STI is the acronym for *science*, *technology* and *innovation*. The rationale behind the STI mode of learning and innovation shows decisive overlaps with the assumptions made in connection with the analytical knowledge base within the KBC (cf. Chapter 2.2.3). The STI mode can be characterized by more formalized innovation processes for which know-why plays a crucial role (cf. Criterion 3, Chapter 2.2.1). Radical innovations (cf. Criterion 4) are often based on scientific inputs and are often the result of deductive ways of reasoning (cf. Criterion 3). As such, knowledge creation is rather science pushed (cf. Criterion 5) and supply driven respectively (Jensen et al. 2004, 2007).

2.2.3. Ideal-typical characteristics: differentiating knowledge bases

By combining both, the considerations which underlie the vertically organized differentiation criteria (Chapter 2.2.1) and the conceptual reasoning which informs the classification of science, engineering, and creativity based activities in the horizontal perspective (Chapter 2.2.2), we are able to fill the KBC table with descriptions of the ideal-typical characteristics (cf. Table 1). I highlight these key features in the following for each of the three knowledge bases, since they constitute the theoretical core of the empirical chapters within this book.

Analytical knowledge base

Rooted in the Aristotelian *epistèmè* notion, the analytical knowledge base refers particularly to universal and theoretical knowledge in order to understand and explain features of the (natural) world (science based/ know-why) (Johnson et al. 2002). Innovation processes within industrial settings that draw on this knowledge base are strongly depending on scientific knowledge input (Gertler & Wolfe 2006; Asheim 2007). Knowledge creation is often based on deductive cognitive and rational processes, or on formal models that require abstraction skills. Examples are laboratory-based research or scientific discourses. Basic and applied research as well as systematic product and process development both belong to the core activities of firms. In order to turn knowledge successfully into innovation, firms often have their own R&D departments, but also heavily rely on research results of universities and other research organizations. Therefore, university-industry links and scientific networks in the context of *epistemic communities*[8] are common in industries that are dominated by the analytical knowledge base. The strong influence coming from the scientific basis is also reflected by high academic spin-off activities. Knowledge inputs and outputs involved in innovation processes always include combinations of tacit and codified components (Nonaka & Takeuchi 1995; Johnson et al. 2002). Face-to-face contacts facilitate exchanges of both; nevertheless, for the analytic case, face-to-face-contacts are of minor importance than they are for the synthetic case, because knowledge is more often codified, and therefore easier to exchange between globally distributed actors (Asheim et al. 2007b). There are several reasons for the strong codified knowledge content to exist: (i) knowledge generation is often based on reviews of existing studies and (ii) the application of scientific principles and methods, (iii) innovation processes are rather formally organized (e.g. in R&D departments) and (iv) results tend to be documented in reports, electronic files or patent descriptions. These activities require people who have some specific qualifications and capabilities such as analytical skills, abstraction, theory building and testing, and documentation. As a consequence, the core of the work-force needs university education and / or research experience. The application of knowledge in such industries is often integrated in more radical product or process innovations. These innovations build starting points for new start-ups and spin-offs on a regular basis (Asheim & Coenen 2005; Asheim et al. 2007a; Asheim et al. 2011a).

Synthetic knowledge base

The synthetic knowledge base derives from the Aristotelian *technè* notion. Hence, it refers more to knowledge that is instrumental, context specific and practice related for the purpose of designing or constructing something to attain functional goals (engineering based/ know-how) (Johnson et al. 2002). Product and process innovation takes place mainly via the application or (new) combination of

[8] Amin and Cohendet (2004, p.75) describe epistemic communities as follows: "Epistemic communities […] are involved in the deliberate production of knowledge and may include employees in an R&D unit, international groups of scientists, or task forces set up to launch new advertising campaigns. […] What characterizes the knowledge activities within these communities is that they are deliberately focused on the production of new knowledge with little a priori reference to the different contexts in which the new knowledge produced will be used." See also Knorr-Cetina (1999).

existing knowledge with the aim to solve a specific problem that rises up in the interaction with clients and suppliers. Insofar, knowledge formation is characterized as a more inductive process. Characteristic activities are, for example, system design, prototyping, fine tuning, testing, and practical work in general. R&D intensity is in general lower than in the first type. Overall, the accentuation within R&D refers more to the 'D-part' in the form of product or process development. If research is a matter of interest, it is mainly applied research, even within industry-university relationships. Although collaboration with universities and other research organizations can play a significant role for firms' innovation processes, interactive learning is often dominated by industry-industry links, and shows frequently features of *communities of practice*[9]. Knowledge embodied in a particular technical solution or engineering work is at least partially codified (e.g. technical blueprints). However, due to the fact that knowledge often arises from experience which is gained at the workplace, and via learning by doing, using and interacting, tacit knowledge is typically more important than in the analytical knowledge base (Nonaka & Takeuchi 1995; Johnson et al. 2002; Jensen et al. 2007). The strong tacit nature of knowledge almost always requires being at the same time at the same place in order to share this knowledge (Audretsch 1998). As a result, the synthetic type shows a relatively stronger sensitivity towards spatial proximity between innovation partners. Professional and polytechnic schools are of particular importance as well as on-the-job trainings to provide an adequate educational background facilitating concrete know-how, crafts and practical skills. The knowledge creation process and the application process are dominated by the modification of existing products and processes with the aim of achieving higher efficiency and reliability of new solutions, or to raise the practical utility and user friendliness of products from the customers' perspectives. Accordingly, innovation processes in such industries have a mainly incremental nature. They most often take place in already existing firms, whereas spin-offs are relatively less frequent (Asheim & Coenen 2005; Asheim et al. 2007a; Asheim et al. 2011a).

Symbolic knowledge base

Creative and cultural industries, such as film making, music, design, fashion, publishing or advertising (Scott 1997; De Propris et al. 2009), are good examples of economic sectors for which symbolic knowledge inputs are of fundamental importance. As can be seen in Table 1, some of the key features of the symbolic knowledge base are similar to those of the synthetic knowledge base. By contrast, analogies with the analytical knowledge base are rather subordinate. The main argument for distinguishing between the symbolic and the synthetic knowledge base can be found in the tangible-

[9] Amin and Cohendet (2004, p.76) define communities of practice as "groups of persons engaged in the same practice, and communicating regularly with one another about their activities. […] Communities of practice (for example, repair engineers or insurance claims processors) are bound by common skills and tend to learn as a by-product of working together." For further considerations on the concept of communities of practice, see Wenger (1998) and Gertler (2008).

ness of the end-products of the respective innovation processes. Products of industries driven by the synthetic knowledge base are generally tangible (e.g. automobiles, machine tools). Industrial activities which rely on the symbolic knowledge base, however, particularly target the intangible, aesthetic attributes of a product, the creation of designs and images as well as the economic use of various forms of cultural artifacts (Asheim 2007). The creation of sign-value is more important than the mere use-value of products (Lash & Urry 1994). "Knowledge is therefore incorporated and transmitted in aesthetic symbols, images, (de)signs, artifacts, sounds and narratives. This type of knowledge is strongly linked to a deep understanding of the habits and norms and 'everyday culture' of specific social groups, and is, therefore, characterized by a strong tacit component" (Asheim 2007, p.226). Since the development of new products or processes is particularly based on creativity, aesthetic sense, imagination, interpretative and artistic skills rather than cognitive information processing or the application of scientific rules, formal qualifications and university degrees are usually relatively unimportant for recruitment decisions (Martin & Moodysson 2011). Potential employees acquire relevant skills by practice in a range of steps within the creative process. Given that those predominantly tacit capabilities are hard to transfer from one individual to another, the know-who of potential collaborators working in the respective professional community defines a crucial strategy (Nachum & Keeble 2003) to combine complementary talents within temporary project settings in a fruitful arrangement (Grabher 2002a, 2002b, 2002c, 2004a, 2004b). Projects are "seen as arenas of productive tensions and creative conflicts that trigger innovation" (Asheim et al. 2007b, p.665). The importance of buzz and face-to-face-contacts leads to a relatively high sensitivity for spatial proximity between potential project partners. Urban environments rather than sparsely populated spaces provide the appropriate setting for inspiration and acquaintance to people who make the difference in creativity-driven innovation processes (Scott 1997).

2.3. Putting the puzzle together: an overview of the theoretical embedding of the knowledge base concept

The aim of Chapter 2 – as I have defined at the beginning of this chapter – is to develop the book's theoretical framework by elaborating the overall theoretical embedding of the KBC. Important building blocks have been worked out, that is the concept's origin (Chapter 2.1), the disentanglement of two fundamental dimensions of theoretical input (Chapters 2.2.1 and 2.2.2), and the conjunction of both dimensions by presenting the key characteristics of each knowledge base (Chapter 2.2.3). In Chapter 2.3, I combine these building blocks like putting the conceptual pieces of the KBC puzzle to fit together. I present the resulting picture in two different ways: Figure 4 shows the global perspective of the KBC at the intersection of sub-disciplinary boundaries, whereas Figure 5 provides a more fine-grained picture of the concept's theoretical context.

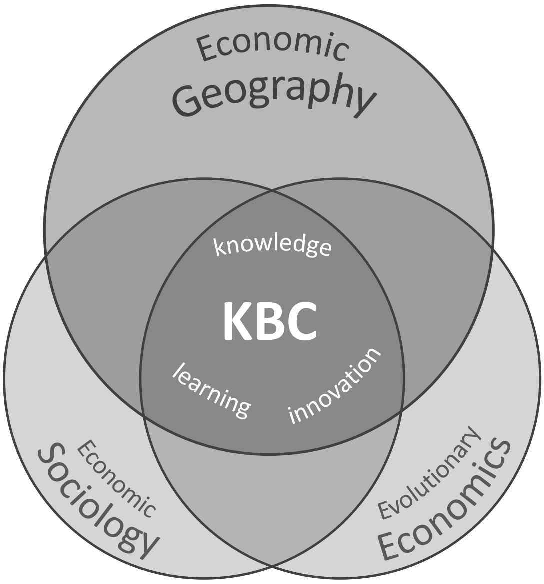

Figure 4. *The KBC at the intersection of sub-disciplinary boundaries – the global perspective*

As I have argued so far, the KBC is mainly affected by theoretical contributions in EG that try to explain learning, knowledge, and innovation processes of organizations and networks thereof, within and beyond local, regional and national boundaries. However, a look at Figure 4 reveals that this is not a field of study that remains exclusively to economic geographers. Other sub-disciplines, first of all economic sociology and evolutionary economics, exhibit considerable impacts on these topics as well, though to a lesser extent with regard to the spatial dimension.[10]

Taking the overlapping circles in Figure 4 as a starting point, in Figure 5 I suggest a more detailed perspective on the theoretical embedding of the KBC. The aim of this illustration is to structure the extensive conceptual input to the KBC in a clearly arranged and meaningful manner with the help of the vertical-horizontal-duality of the dimensions I referred to in Chapters 2.2.1 and 2.2.2. Whereas the vertical dimension of the KBC table is particularly informed by a (relational) conceptualization of knowledge, learning, innovation and space, the differentiation of the knowledge bases along the horizontal dimension is mainly informed by theorizations of inter-industrial differences.

The REG approach plays a prominent role within the theoretical framework of the KBC as a whole. Accordingly, a great deal of what I refer to in the course of Chapter 2 is informed by a relational

[10] The positioning of the terms 'knowledge', 'learning', and 'innovation' within the overlapping area between the three circles that are illustrated in Figure 4 is arbitrary.

perspective on economic action and interaction in a spatial perspective. A closer look at the elaborations throughout this chapter reveals, however, that it is particularly the vertically organized criteria of the KBC table which build upon REG (cf. Chapter 2.2.1).

REG is based on and influenced by a number of conceptualizations that deal with knowledge, learning, innovation, and space. These conceptualizations, in turn, are closely interwoven with each other. They include regionally-oriented *TIMs*[11] and *'local-global'* models (which, in addition, account for the global dimension of economic action), as well as conceptualizations of the *learning economy*, *communities of knowing*, *emdeddness* and *networks*, *agglomeration economies*, and *knowledge spillover theories*. As Figure 5 indicates, this body of concepts exhibits remarkable overlaps with theorizations of knowledge creation and innovation processes from the viewpoint of evolutionary and institutional economists, and economic sociologists (see also Figure 4).

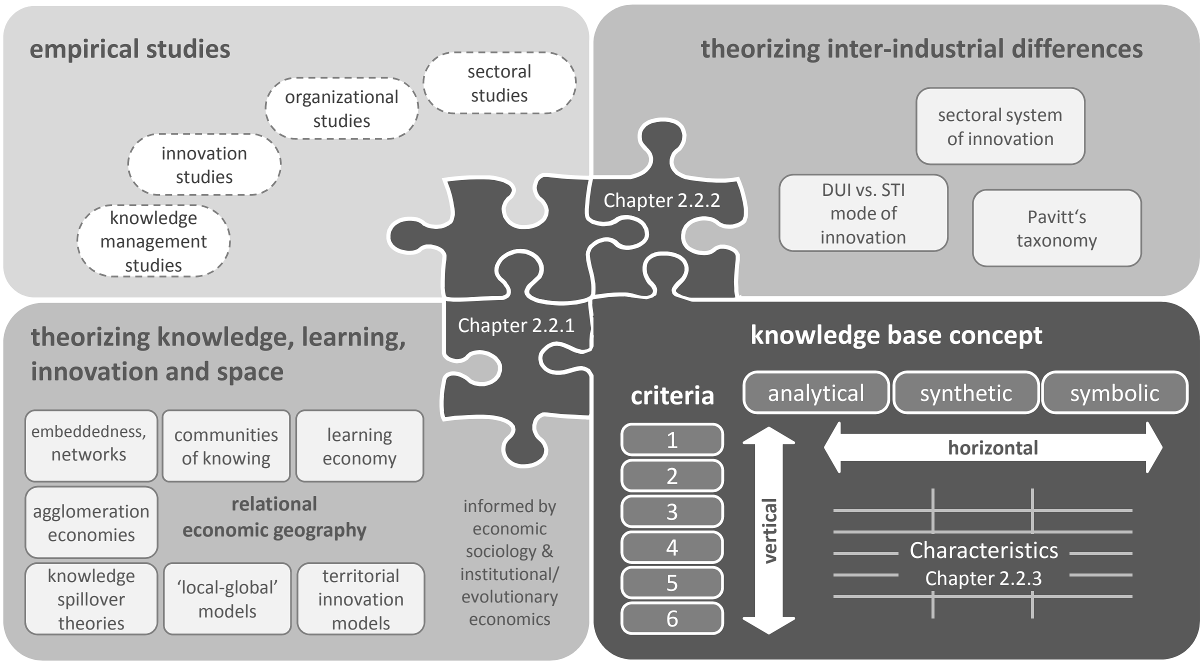

Figure 5. *Theoretical embedding of the KBC – the fine-grained perspective*

The horizontal dimension of the KBC, by contrast, is first of all informed by theoretical reasoning on sector-specific patterns of knowledge formation and innovation behavior. In Chapter 2.2.2, I highlight

[11] Interestingly, or paradoxically, in Chapter 2.1 I stressed the imperfectness of precisely the TIMs in terms of theorizing inter-industrial differences to be a source for motivation to differentiate between three knowledge bases. Even though these models exhibit such sort of shortcoming, they, a fortiori, gain explanatory momentum for the KBC as soon as they get combined with reasoning on sector-specific differences in knowledge formation and innovation processes. This (latter) type of conceptual work, in turn, informs the horizontal dimension, that is the differentiation between science based, engineering based and creativity based activities (Chapter 2.2.2).

three concepts to be of particular importance in this regard, that is the *Pavitt's taxonomy*, the *sectoral system of innovation*, and the distinction between *DUI and STI modes of learning and innovation*.

The strong accentuation of a binary architecture of the KBC according to the vertical and horizontal dimension of theoretical-conceptual inflows, however, is *not* to be understood in a too strict sense in the way that concepts informing the horizontally organized criteria within the KBC table have nothing in common with those concepts that inform the horizontal dimension, and vice versa. Quite the contrary, there are a number of logical interconnections in-between.

These interconnections can be seen, for example, with regard to my elaborations on the *DUI and STI* mode of innovation (horizontal dimension, see Chapter 2.2.2) wherein I point to the criterions which I discuss with reference to the vertical dimension (Chapter 2.2.1). Another, even more obvious proof of the conceptual conjunction of both dimensions is Chapter 2.2.3, in which I highlight the key characteristics of each of the three knowledge bases by synthesizing conceptual insights from Chapters 2.2.1 and 2.2.2. And lastly, it is also the empirical work of *knowledge management*, *innovation*, *organizational*, and *sectoral studies* that plays a crucial role in this respect. It can be compared to adding a missing piece to a puzzle, for the empirical findings inform (and link) both, the horizontal and the vertical dimension of the KBC architecture at the same time (see Figure 5).

To sum up, Chapter 2 contributes to the theoretical clarification of the KBC – one of the central aims of my dissertation that I previously defined in the introductory Chapter (Figure 1). As such, Chapter 2 provides a basis for discussing and understanding my empirical work on three regional industries which I present in Chapters 4 to 7. Before, I will refer to some methodological considerations which underlie these case studies in Chapter 3. Therein, I will as well draw on the theoretical building blocks of the KBC in order to elaborate the theoretical substantiation of both, the methods of collecting data, and the methods of analysis.

3. Research design and methodology

According to Maskell et al., "[t]he weak point […] in contemporary research in economic geography and neighbouring disciplines, is empirical validation" (1998, p.193). Even though this rather general comment is not taken from a book that has been published recently, it fits quite well to the present lack of empirical work on the emerging KBC. As mentioned in the introductory chapter (cf. Chapter 1.2), the target of my research is to fill at least parts of this research gap by presenting my empirical work on three regional industries in Germany.

Quite clearly, empirical validation requires well-defined methods. For that reason, within this chapter, I seek to elaborate a sound methodological basis. More precise, my empirical contributions rely on the case study method, and I use both qualitative as well as quantitative methods in order to generate and analyze data. Inspired by Vang's line of argument within the methodology chapter of his dissertation (2006), I begin this chapter by introducing the case study method as a research strategy in general. At the same time, I explain why it makes sense to use this method within my research context (Chapter 3.1). Then, in more detail, I refer to the way the case study method is used within this book. This includes some remarks on the corresponding research design (Chapter 3.2), the data collection (Chapter 3.3), and, finally, on the analysis of data (Chapter 3.4). These considerations are complemented by the conclusion in Chapter 9, in which I am going to discuss the limitations of my research.

3.1. Why case studies?

Case studies belong to the sort of methodological equipment that is preferred by scholars, when (i) *how* or *why* questions are posed in order to explain some present circumstance, when (ii) the researcher has little or no control of the phenomenon under analysis, and when (iii) the cases focus on contemporary issues (Yin 2009). In my dissertation (i) I seek to explain how and why regional industries differ from each other with regard to their specific knowledge base. In contrast to, for example, research in laboratories, (ii) there is no or, at least, very limited chance to manipulate the knowledge and innovation processes within the regional industries that I investigate. And lastly, (iii) the phenomenon that I study is situated in the present. Since all three conditions are given within my dissertation, it can be argued that case studies, indeed, provide an adequate research method therein.

In addition, a case study is particularly helpful as a research method when in-depth examination of the particularities of a certain phenomenon is more important than the generalization of results on the basis of large samples (Flyvbjerg 2006). According to Vang, "[w]ithin economic geography, it is generally acknowledged that specificities play an important role in economic activities and that a dialog between theory and case(s) is the means for identifying the extent to which a result can be generalized" (2006, p.34). In my dissertation, I analyze three cases of regional industries, which is far from being a large sample that can be used for generalization. It is rather the in-depth and context-oriented analysis of the particular KBConfi of some pre-selected industrial settings that awakens my research interest and that fits best to the research questions posed in Chapter 1.2. It is not my aim to generate universal laws. Rather as in the quote of Vang (2006) it is the interrelation between the KBC and the three cases that leads to an understanding of the extent to which these findings can be generalized (cf. Chapter 9.2). Taking the considerations on specification vs. generalization as a whole, it definitely makes sense to use case studies to be the overarching research strategy within my thesis.

Lastly, case studies are useful for both exploratory and explanatory research (Yin 2009). This kind of multifunctional perspective of case studies fits well to my overall aims and research questions. On the one hand, the case study method enables me to explore the KBConfi of a certain industry within a region. On the other hand, I use the case study in order to explain knowledge and innovation processes through the KBC lens.

Taking the case study as the overall *research strategy* within my dissertation, following Yin (2009), three major steps can be distinguished (Figure 6). The first step is to define the *research design* (Chapter 3.2), the second is to *collect data* (Chapter 3.3), and the third and last step is to *analyze data* (Chapter 3.4). In the following, I will go into deeper detail regarding each of these steps and the way in which I interpret them within my dissertation.

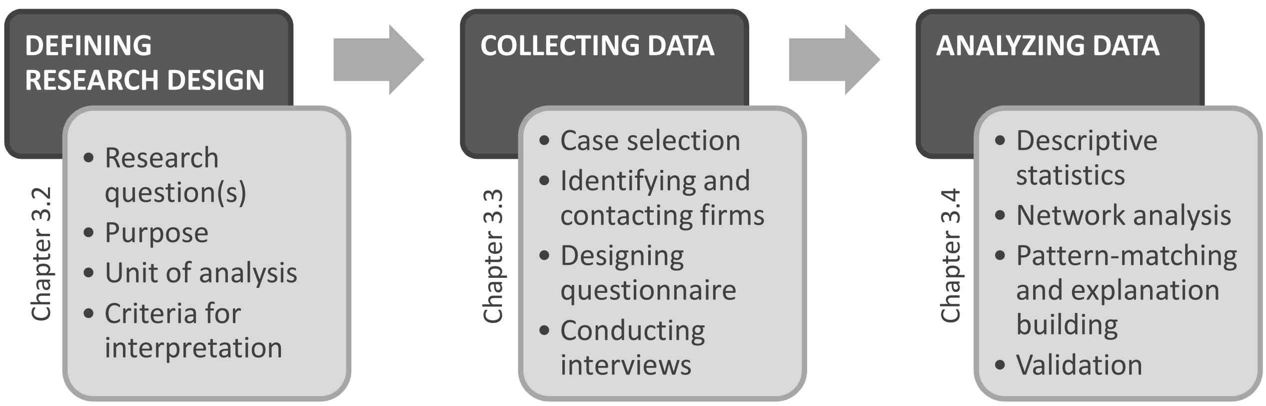

Figure 6. *The case study as a research strategy in three steps*

3.2. Research design

The *research design* can be understood as a plan or "logical model of proof" that guides the investigator through "the process of collecting, analyzing and interpreting observations" (Nachmias & Nachmias 1992, pp.77-78). Similarly to Lee's (1999) and Yin's (2009) subcategorization of the research design, I address four components: (i) the study's underlying *research question*; (ii) its *purpose*; (iii) its *unit of analysis*; (iv) and the *criteria for interpretation*.

Research question

As mentioned in the introduction (Chapter 1.2), the central *research question* within my dissertation is: *Which knowledge base configuration drives knowledge formation and innovation processes in selected regional industries in Germany?* Even though I could have chosen just one single case and answer this question correspondingly, the in-depth analyses of multiple cases generates more valid results and more credible conclusions, because it allows for comparisons, and comparisons help to relativize the results. The study of multiple cases helps to investigate how conditions are combined in different ways and contexts (Ragin 1994). This leads, in turn, to a deeper understanding of the particularities of each case.

Purpose

Accordingly, the *purpose* of my research is to find out *how* regional industries differ from each other with regard to the type of knowledge they need in order to procure competitiveness. As such, the purpose is exploratory in nature. Simultaneously, the purpose of my research strategy is explanatory in nature, because I explain *why* knowledge creation and innovation processes differ from each other within different economic sectors by using the theoretical assumptions that can be derived from the KBC (cf. Chapter 3.1).

Unit of analysis

The *unit of analysis* has to be defined in order to specify the term 'case'. My empirical investigations are above all based on interviews at the firm level. For that reason, the firm could be interpreted to constitute a case and the main unit of analysis respectively. However, a closer look at the analyses throughout this book reveals that it is rather the inter-organizational level in the form of networks between firms and other organizations that takes center stage here (see Chapters 4 to 7). My aim is to analyze a set of firms of the same sector within the same German region. It is not the in-depth analysis of one particular firm but the aggregated view on – and the in-depth analysis of – the firm's 'average' innovation and knowledge creation behavior. Therefore, I argue that the main unit of analysis (i.e. the case) within this book is the *industry within a region*, whereas the firm can be regarded as the sub-unit of analysis.

A second dimension of the unit of analysis refers to the *spatial level*. Similarly to the firm vs. industry discussion, the definition of the spatial unit of analysis requires some reflections. One may argue that the region constitutes the main spatial unit of analysis within my thesis, because merely the firms within one particular region have been interviewed. One might continue suggesting that, in addition, regions are the key level at which systemic interactions lead to innovations, and where economic processes are shaped (cf. Chapter 1.1). However, since the KBC takes into account that interactive knowledge and innovation processes do not stop at the regional boundaries, the spatial unit of analysis within this thesis can be interpreted to be *regionally focused, but 'open towards the global'* at the same time.

Criteria for interpretation

Apart from defining what data are to be collected, the research design indicates as well what has to be done thereafter (Yin 2009). In my view, it is particularly this 'thereafter-step' which constitutes the core of a research design that claims to be the *logical model of proof* as defined by Nachmias and Nachmias (1992). Here, the crucial step is to interpret the results by connecting them to the theoretical framework and related assumptions, or by comparing cases.

In Chapter 2.2.1, I systematically elaborated a number of vertically organized differentiation criteria of the KBC. In combination with the horizontal dimension that highlights in particular sector-specific patterns (Chapter 2.2.2), these criteria provide the basis for my empirical work in the following chapters. As a consequence, most of the questions posed within the firm interviews can be traced back – implicitly or explicitly – to at least part of them. The comparison between industry-region-cases can be linked back to the vertically and horizontally arranged criteria as well (cf. Chapters 6 and 9). I will come back to that point in more detail in Chapter 3.3 when I refer to the questionnaire used within the firm interviews.

3.3. Data collection

According to the research design, the next building block of the overall research strategy (cf. Figure 6) specifies the method of *data collection*. I differentiate between four sub-steps of data collection and its preparation: (i) the *selection of the cases* to be investigated; (ii) the *design of the interview questionnaire* (iii); the *identification of the firms* and the process of *contacting the interviewees*; and, lastly, (iv) the actual act of collecting data, i.e. the *firm interview* itself.

Selecting the cases

The selection of the cases has to go in line with the research design. Accordingly, the cases have to be selected so that the *research questions* can be answered best possible; the *purpose* of research has to be taken into account as well; and lastly, the cases are to be selected according to the pre-defined *unit of analysis*. In order to meet these requirements, I have deliberately chosen to analyze three different regional industries in Germany. This is the biotechnology industry in the Aachen Technology Region (from here on BioAC; cf. RQ 1, Chapters 4 and 6), the automotive industry in Southwest Saxony (AutoSWS; RQ 2, Chapters 5 and 6), and the video game developing industry in Hamburg (VgdHH; RQ 3, Chapter 7).

Each of these regional industries constitutes a single case as defined by the unit of analysis. Studying each case by using the same theoretical and methodological basis, however, allows for comparisons of the underlying KBConfis (cf. Chapters 6 and 9). Given that the set of industries is very heterogeneous concerning, for example, the end-products they offer, differences in the way they generate knowledge and innovations can be assumed to become more obvious. This, in turn, leads to a deeper understanding of the particularities of each case as regards its specific knowledge base composition which, ultimately, results in more profound answers to the questions posed in the introduction.

The selection of the regions in which the case studies have been carried out depends on the design of the overall European collaborative research project to which my investigations belong to (cf. footnotes 1 and 2, Chapter 1). Hence, the research should not only aim to reveal differences in knowledge formation and innovation processes between sectors, but also uncover how policies for constructing regional advantage function in different regional settings. However, whereas the deliberate choice of different industry cases provides particular advantages for answering my research questions best possible, the choice of different regions within Germany bears the risk of 'comparing apples and oranges'. I will get back to this point within the critical reflection of the used methodology in Chapter 9.2.

Given the book's focus on disentangling *industrial* knowledge bases, the first step was to identify the industries that I wanted to analyze. Not till then, I selected the regions in which these industries are located. To be more precise: As soon as the decision was made concerning the industries to be investigated, only those regions came into consideration in which a certain extent of activities within these industries could be assumed to exist due to some preliminary findings derived from secondary sources.[12]

[12] See also my considerations on 'identifying firms and contacting interviewees' within the same sub-chapter.

Designing the interview questionnaire

The interview questionnaire is my central tool for collecting primary data, because it allows for "gathering statistical information about the attributes, attitudes, or actions of a population by a structured set of questions" (Preston 2009, p.46). My questions target in particular the firm's attributes as well as those actions which help to reveal the crucial type of knowledge that is indispensable for each firm and the regional industry respectively (cf. Table 2 and Appendix 1). The questionnaire requests both, quantitative information as well as qualitative evaluations. Due to the fact that the questionnaire contains a number of items that require in-depth guidance in order to be answered thoroughly, I decided against merely sending the questionnaire via mail or email.

Since all questions are standardized, every interviewee was asked "about the same things in the same way" (Buckingham & Saunders 2004, p.13), no matter which industry was analyzed. Posing identical questions to all firms of *one* of the pre-selected regional industries enables me to construe an aggregated and average picture of the mixture of knowledge bases the distinct population relies on. Moreover, having asked the same questions *across each of the three* regional industry cases facilitates comparative studies between the populations, too.

With the aid of Table 2 I deconstruct the questionnaire into four parts. Part I targets some basic firm *attributes* which provide an insight into the spectrum of firms involved in each case study. The resultant information refers to the firm's name and address, the year of foundation, previous mergers or acquisitions (if any), owner structure, and the number of employees. Parts II, III and IV represent the core of the questionnaire survey since they are particularly important for the identification of the crucial knowledge base(s). In the following, I will briefly refer to each part individually. In line with Preston's (2009) demand for linking the questions of a survey back to the theory that has been used, and according to the 'criteria for interpretation' which I referred to in Chapter 3.2, I will pay special attention to the extent to which the questions relate to the underlying KBC.

The questions and related items belonging to Part II target particularly the firm's *human capital*. They refer to the employees' education as well as to the recruitment sources for highly skilled labor. Taking questions 5 to 9 together, Part II is in particular related to the first three of the vertically organized criteria of the KBC table and to related assumptions (cf. Table 1, Chapter 2.2.1). These include the main rationale behind each knowledge base (criterion 1)[13], the dominating nature of

[13] Whenever it is referred to the 'main rationale behind each knowledge base' (criterion 1), the respective part of the questionnaire relates not only to the conceptual reasoning which informs in particular the vertical dimension of the KBC but also to the one that informs the horizontal dimension (cf. Chapters 2.2 and 2.3).

knowledge that is needed in particular (criterion 2), as well as the specific process of creating knowledge (criterion 3).

Table 2. *Deconstructing the interview questionnaire*

PART	QUESTION [1]	THEORY LINK [2]
Part I	1.-4. Firm attributes	not applicable
Part II: Personnel & recruiting activities	5. Educational level of employees?	main rationale (1) nature of knowledge (2) process of knowledge creation (3)
	6. Educational background of employees?	nature of knowledge (2) process of knowledge creation (3)
	7. Recruiting sources for highly skilled employees?	nature of knowledge (2) process of knowledge creation (3)
	8. Question 7 + spatial differentiation	nature of knowledge (2) importance of spatial proximity (6)
	9. Most important sectors to recruit from?	main rationale (1)
Part III: Knowledge exchange networks & knowledge sourcing	10. Ratio between knowledge acquired in-/ outside the firm?	mode of knowledge networking (5)
	11./13. Market/ Technological knowledge network (MKN/TKN) partners:	mode of knowledge networking (5)
	a) Name?	not applicable
	b) Type?	mode of knowledge networking (5)
	c) Location?	importance of spatial proximity (6)
	d) Importance?	all criteria (1-6)
	e) Sector?	main rationale (1) mode of knowledge networking (5)
	f) Similarity of knowledge?	mode of knowledge networking (5)
	g) Practical, scientific, or both? (only TKN)	main rationale (1) nature of knowledge (2) process of knowledge creation (3) type of innovation (4)
	12./14. Importance of selected information sources for market/ technological knowledge?	nature of knowledge (2) process of knowledge creation (3)
Part IV: Innovation performance	15. Activities for achieving competitiveness?	main rationale (1) process of knowledge creation (3) type of innovation (4)
	16. Changes carried out in the last three years?	type of innovation (4)
	17. Turnover: Relation between radical, incremental innovations, and no changes?	type of innovation (4)
	18. Applied for (co-) patents?	nature of knowledge (2) type of innovation (4)
	19. R&D-employees? R&D-department? Time dedicated to R&D?	main rationale (1) nature of knowledge (2) process of knowledge creation (3) type of innovation (4)

[1] The complete questions can be found in Appendix 1.
[2] Each theory link can be traced back to the theory-based considerations on the KBC in Chapter 2 in general and to the differentiation criteria (numbered 1 to 6) in Chapter 2.2.1 in particular.

Part III of the questionnaire (i.e., questions 10 to 14) refers to the firm's *interorganizational networks of knowledge transfers* and to *supplementary knowledge sources* external to the firm. Two types of networks are differentiated: the technological knowledge network (from now on TKN) and the market knowledge network (from now on MKN). Related questions refer to some attributes of each mentioned knowledge exchange partner (e.g. name, location, and sector), as well as to the respective relation itself (e.g. supplier- or customer-relation, its importance, and the similarity of knowledge exchanged). The corresponding attributional and relational data is primarily used for the purpose of network analysis (cf. Chapter 3.4). Thus, Part III is first and foremost connected to the theoretical reasoning on knowledge networking, represented by criterion 5 in Chapter 2.2.1. The remaining criteria of the KBC are affected as well, albeit not that explicitly. Again, there is a link back to criteria 1, 2, and 3 of the KBC table (cf. Table 1). Another theory link of Part III of the interview questionnaire refers to the type of innovation (criterion 4). And finally, the sub-question which highlights in particular the spatial dimension of the mentioned knowledge interactions can be traced back to the theoretical assumptions in reference to criterion 6.

Finally, Part IV of the questionnaire asks for information on the firm's *innovation behavior* in order to get further evidence for the underlying knowledge base(s). Each of the questions 15 to 19 are closely related to criterion 4 which refers to the type of innovation that is crucial. Further theory links go back to criteria 1 to 3.

Identifying firms and contacting interviewees

As mentioned earlier, before the regions in which to conduct the interviews were chosen, I determined the industries that I wanted to examine. The identification of the firm populations[14] to be investigated, however, requires a clear definition of the economic sectors that these firms belong to as well as of the activities they procure.

Accordingly, (i) the population of firms that belong to the biotechnology industry was defined to include only businesses having either performed R&D into particular biotechnology techniques, businesses that introduced a biotechnology product or process onto the market, or businesses that provide their knowledge of biotechnology techniques in terms of consulting services. (ii) The population of firms that belong to the automotive industry was restricted to manufacturing firms which focus on producing automotive parts, components, modules and whole systems, or firms that produce bodies and trailers. And finally, (iii) the population of firms that belong to the video game developing industry was defined to include firms that develop video games as their exclusive line of business, and 'hybrid' firms which publish these games as well.

[14] Here, the term 'population' is to be understood as the entire group of firms which belong to a pre-defined regional industry in Germany which I aim to describe or draw conclusions about.

Although questionnaire surveys are "usually conducted by sampling from a population rather than contacting all of its members" (Parfitt 2005, p.94), my case studies target the whole population of firms that are active within the previously defined industries in the respective regions. The reason is that the analysis of inter-organizational knowledge networks requires information on the greatest possible share of the population (cf. Chapter 3.4). Otherwise, too many blind spots would remain within the knowledge exchange networks between the interviewed firms. As a consequence, analyses which target the whole system of interactive learning processes within (and beyond) a regional industry would lose in validity. However, using questionnaires for interviewing as many firms as possible was – due to time and money constraints – only feasible under the condition that the population sizes for each case were not too large compared to, for example, nationwide censuses that require sampling (Lo 2009).

Due to preliminary findings on some regions in Germany which display economic activities in at least one of the three pre-defined sectors, I have chosen to analyze the cases of biotechnology in the Aachen Technology Region, automotive in Southwest Saxony, and video game development in Hamburg.[15] The identification of the whole population of BioAC-, AutoSWS-, and VgdHH-firms was based on reviewing a number of different data sources. I used in particular business directories that were accessible in the internet. Sometimes, parts of the data were not accessible to the public, but available on request at least for the purpose of research. Additional company lists were provided by the regional cluster initiatives and chambers of commerce, and by economic development agencies at the local and federal state level. Though these sources provided a good starting point to identify the firms that match my industry definitions, they were often incomplete, too imprecise with regard to the firms' business activities, or out-of-date concerning the contact details of potential interviewees. Therefore, I had to search for further information that is provided by the firms themselves on their public web pages. Newspaper articles were used sporadically as a supplementary source of information, too.

The populations that I identified on the basis of these sources were as follows: For the BioAC case I identified in sum 27 firms, for the AutoSWS case it was 112 firms, and for the VgdHH case 25 firms were identified (cf. Table 3). The first step of contacting the potential interviewees was procured in

[15] Each regional case matches both underlying selective criteria: First, they exhibit considerable business activities in the respective sectors as were measured by the total number of firms, whereas, at the same time, the firm population sizes remain manageable for the purpose of in-depth case study research on the basis of face-to-face interviews. Second, policy tools (e.g. cluster strategies) can be identified to target the competitiveness of the respective regional industry for at least five years. Though it is of minor importance with regard to my dissertation, this latter criterion was due to the research strategy of the overall European collaborative project in order to analyze how policies for constructing regional advantage can work in such different settings.

written form, either in the form of an official letter (BioAC, AutoSWS), or via email (VgdHH). Nearly all of the potential interviewees – which mainly belonged to the firm's executive staff – were addressed personally. The corresponding letter (or email) informed about the background and the purpose of my research, it appealed to take part in the interviews, and it referred to the benefit for the firm, given it participates.[16] Finally, the second step was to contact the potential interviewee by phone. The main objective here was to create trust, answer questions if desired, and, if still necessary, to convince the firm executive to take part in the case study.

As can be seen in Table 3, the response rates are particularly high with regard to the first (BioAC) and the third case (VgdHH). Whereas for the first case 23 out of potentially 27 firms could be interviewed (85%), for the third case it was 20 out of 25 firms (80%). 58 out of 112 possible interviews have been conducted with representatives of the AutoSWS firms (52%). Even though also this response rate can be seen to be sufficient to get a comprehensive picture of the regional industry's knowledge base as a whole, it is significantly lower in comparison to the other case. The reason is that when the second case study was carried out, numerous AutoSWS firms had to concentrate all their resources on fighting the effects of the economic crisis.

Table 3. *Overview of firm interviews*

	Case I – BioAC	Case II - AutoSWS	Case III - VgdHH	Cases I - III
period of time	06/08 – 01/09	03/09 – 10/09	05/10 – 10/10	06/08 – 10/10
population	27	112	25	∑ 164
no. of firms interviewed	23	58	20	∑ 101
response rate	85%	52%	80%	Ø 72%

Conducting firm interviews

In total, 101 firm interviews have been conducted between June 2008 and October 2010.[17] Due to plausibility checks, all of them could be taken into account for further analysis. Whereas most of the interviews were conducted in situ on a face-to-face base with the firms' CEOs and executives, only a few interviews had to be conducted by phone afterwards owing to short-term cancellations of appointments.

[16] The main benefit to the firm was to receive the resulting paper which presents the central outcomes of the respective case study. The firms can use the results for the purpose of benchmarking, for example.

[17] 13 interviews were conducted by student assistants, of which the first two were assisted by me. All other firm interviews represent my own work.

Each interview started with a brief introduction concerning background information and referring to the purpose of my research. This first step offered interview partners the opportunity to ask questions, if anything was unclear. Part I, though it contains important questions concerning some of the firm's attributes, fulfilled simultaneously a kind of 'warming up' task in preparation to the more complex questions in Parts II, III and IV (cf. Table 2 and Appendix 1). On average, Part III took most of the interview time. Depending on how many knowledge network partners were mentioned, this part took 30 up to 60 minutes.

Overall, most firm interviews lasted between 60 to 90 minutes, with some exceptions ranging from 45 to 180 minutes. Even though the questionnaire contains mainly standardized questions, the documentation by tape recording turned out to be helpful in order to rework data inconsistencies that often came up not until the data was analyzed. In addition, some interviewees went beyond merely answering the standardized questions by 'telling their story' about the industry and the knowledge base it builds on. In this case, the audio record was helpful as well in order to allow for supplementary qualitative analysis.

For the success of the interviews and thus to receive the required information, it was essential to create trust between the interviewer and the interviewee. Especially information about the firm's most important knowledge exchange partners are only accessible in a trustworthy atmosphere. Due to the strategic significance of many of these relations, each interviewee was guaranteed full anonymity and confidentiality with regard to this research project. Therefore, all firm names were encoded, both, the names of the interviewed firms themselves and the names of their knowledge network partners (e.g. DE018, or US002). Another aspect concerning trust referred to tape recording. The interviewees were asked for permission to record the dialogue. At the same time, they were assured to decide themselves if they wished the tape to be erased at the end of the interview. And lastly, I made the experience that creating a trustful atmosphere presupposes that the interviewer's 'language' and the interviewee's 'language' are not too different from each other. In comparison to, say, car makers or developers of biotech products, video game developers tend to use other vocabulary to explain what kind of knowledge they need or what kind of innovation they produce. Therefore, I adjusted my style of communication to a certain extent.

3.4. Data analysis

The third and last building block of the overall research strategy (cf. Figure 6) delineates the methods that I used in order to *analyze* the survey data and to *validate* the corresponding results. Accordingly, I stress three sub-steps in the following, which is (i) the application of *descriptive statistics* and *net-*

work analysis, (ii) the interpretation through *pattern matching* and *explanation building*, and, lastly, (iii) the *validation* of the corresponding results by emphasizing particularly the role of the expert interviews.

Descriptive statistics and network analysis

The firm interviews constitute the data which forms the basis of my empirical investigations. It was particularly analyzed by using *descriptive statistics* as well as by applying *network analyses*. According to Robinson (2009), the first stage after data collection is to describe the outcome. Given the data is quantifiable, this is most often done by using descriptive statistics, such as minimum, maximum, mean, median and standard deviation values. By analyzing these indicators, I generate insights into the particular KBConfi of each of the three selected regional industry cases. In addition, descriptive statistics help to compare how data series differ from each other (Lee 2009). Hence, within the comparative paper that I present in Chapter 6, arithmetic means belong to the more frequently used indicators in order to reveal and differentiate between case-specific innovation patterns and processes of knowledge production.

I argue that tracing interorganizational knowledge networks enlightens our understanding of the nature and spatial dimension of innovation and interactive learning in the particular regional industrial setting. As a result, a great deal of my empirical work that refers to the collected network data builds upon sociometric techniques in the form of network analysis (Wasserman & Faust 1994; Scott 2000; Borgatti & Foster 2003; Jackson 2008).

According to Cross et al. (2002), social network analysis can be used to make the invisible visible and the intangible tangible. However, it is not only the capacity of illustrating complex networks which strengthens the use of this technique within this particular field of research. A key advantage of network analyses that is of major importance for my research is located in the transformation of qualitative into quantitative information and vice-versa. In other words, network analyses are especially valuable when it comes to the quantification and mapping of the rather ‘soft’ (qualitative) dimension of relations between organizations, such as knowledge flows. These (now quantified) knowledge flows, in turn, lead to qualitative interpretations of the overall network (Cross et al. 2001; Borgatti & Molina 2003).

As I already mentioned with regard to Part III of the questionnaire (Chapter 3.3), a number of questions have been applied in the firm interviews which aimed at collecting relational data as well as attributes data. In order to make these data sets usable for the purpose of network analysis, they were processed through specific matrix operations. The program that was used to run these and further operations of network analyses is called UCINET 6 (Borgatti et al. 2002). UCINET 6 works in tandem with NetDraw, a program for visualizing networks. With the aid of UCINET, some sociocentric network indicators have been computed in order to analyze the network structure between the interviewed firms themselves in particular. As such, I make use of the so-called 'graph theory', which analyzes the topology of networks (Kuby et al. 2009).

Pattern matching and explanation building

Yin (2009) suggests five different analytic techniques for the purpose of case study research. These techniques are pattern matching, explanation building, time-series analysis, logic models, and cross-case synthesis. The dominating techniques that I use throughout this book are *pattern-matching* and, particularly with regard to the concluding chapter, *explanation building*.

Pattern matching enables the researcher to compare an empirical pattern with a predicted pattern (Trochim 1989). With regard to my research, the empirical pattern is the results of my case study analysis, whereas the predicted pattern is the theoretical assumptions which are based on the KBC. Hence, within the multiple case studies in Chapters 4, 5, 6 and 7 I have 'pattern-matched' the observations on innovation and knowledge creation patterns for each of the three regional industries with the different theoretical predictions that are related to the analytical, the synthetic, and the symbolic knowledge base pattern. As a result, each case could be matched to a certain knowledge base, or to hybrid forms thereof.

Compared to the pattern matching technique, *explanation building* is "a more interactive technique as the researcher does not start with a predicted pattern but builds it as a result of the analysis and comparison of different case studies" (Vang 2006, p.43). Though my elaborations in Chapters 4 to 7 were predominantly driven by the pattern matching technique, by contributing to fill the empirical gap with regard to the KBC my case studies automatically add to the concept's systematic testing. As such, the three case studies can be interpreted to be part of the ongoing process of explanation building. In the concluding chapter I will raise some issues for future research on the KBC that is clearly focused on contributing to the explanation building that refers to the typology of knowledge bases.

The simultaneous use of the pattern matching and the explanation building technique can be recovered in Figure 1 as well: Whereas the left arrow – which points forwards, i.e. from the theory-block to the empirical-block – symbolizes the process of pattern matching, the right arrow – which points backwards, i.e. from the empirical-block to the theory – denotes the process of explanation building.

Validation of results

For the purpose of validation, the collected questionnaire data and the corresponding analysis were always *triangulated* for each case (Nightingale 2009). This was done by conducting in-depth, semi-structured expert interviews, by using information from firm homepages (e.g. company reports), by presenting and discussing the results within the academic community (e.g. at conferences, or project meetings), as well as by exploiting the existing literature (including mainly papers of scientific journals that are validated by blind-peer review processes). Such a procedure goes well in line with Hardwick, who claims that “case study research most often involves a multimethod approach that is well grounded in data triangulation. This approach helps confirm the validity of findings on the particular case study and may employ an overlapping set of both qualitative and quantitative methods” (2009, p.442).

Particularly the discussions of some preliminary results with overall 24 experts enriched my interpretations through numerous qualitative aspects. All but two conversations with experts were carried out on a face-to-face basis. Similarly to the way Longhurst (2009) refers to in depth, semi-structured interviews, the expert interviews that I conducted usually unfolded in a conversational manner offering the experts the chance to pursue issues they felt to be pivotal. Given the few cases that the interviews were conducted with two experts at the same time, the interviews turned more into open and sometimes unstructured discussions.

As Table 4 shows, the group of the interviewed experts is relatively heterogeneous in terms of their perspectives on the respective regional industry. The outcome is a sort of ‘triangulation of expert perspectives’ in its own right. The group includes (i) representatives of cluster initiatives at the local and regional level as well as network coordinators at the regional, State, federal and European level. This group provided in particular useful information about the systemic character of each of the industries within and beyond the pre-selected regions. Supplementary interviews were conducted with (ii) representatives of State ministries to take into account considerations from an economic- and innovation-political point of view as well. In addition, (iii) representatives of public research and education facilities were asked to discuss the role that these facilities play for the development of the regional industry’s knowledge base. Finally, (iv) academic experts – most of them with a scientific background in economic geography – helped me to interpret and validate the questionnaire data particularly against the theoretical background of my dissertation.

Table 4. *Overview of expert interviews*

	Case I/BioAC	CaseII/AutoSWS	Case III/VgdHH	Cases I-III
Period of time	01/09	03/10	01/11 - 02/11	01/09 - 02/11
No. of experts interviewed	9	8	7	∑ 24
Thereof:				
Cluster managers and network coordinators	4	3	4	∑ 11
Representatives of State ministries	1	1	-	∑ 2
Representatives of public research/ education organizations	2	1	1	∑ 4
Academic experts	2	3	2	∑ 7

4. On the nature and geography of innovation and interactive learning: a case study of the biotechnology industry in the Aachen Technology Region, Germany

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Abstract

So far, relatively little research has been done on sectoral differences of innovation processes. In order to learn more about these differences, we apply the knowledge base concept which helps us to characterize the nature of critical knowledge that is indispensable for innovation activities. Two knowledge bases are distinguished: the analytical (science based) and the synthetic (engineering based) knowledge base. This paper focuses on the emerging biotechnology industry in the Aachen Technology Region in Germany. It aims to identify the knowledge base which is crucial for the development of new products and processes. Additional questions are as follows: How intense are cross-sectoral knowledge transfers and labour mobility? In which way can we observe innovation-oriented systemic interactions within the region and to which extent are the biotechnology firms connected to extra-regional knowledge sources? In order to investigate these questions, we apply social network analyses and descriptive statistics. Our results show that the knowledge base that is crucial for innovation activities is primarily of analytical nature. Interactive learning of biotechnology firms within the region is clearly dominated by industry–university links, while the vertical dimension of co-operative innovation processes is rather shaped on national and global scales for most firms.

1. Introduction

The growing importance of knowledge as a key factor of competitiveness for firms, industries, regions and whole nations is indicated by the emergence of the so-called *knowledge economy*. However, in order to emphasize the more dynamic notion of creating new knowledge and innovations, we prefer to argue in terms of the *learning economy* (Asheim & Coenen, 2005). *Learning economies* are characterized by innovation processes based on interactive learning on different geographical scales (Lundvall, 1992). An extensive body of literature on geographies of knowledge flows and interactive learning identifies the region as the key level at which systemic interactions lead to innovations and where economic processes are coordinated and governed (Fritsch & Stephan, 2005). Examples can be seen in partly overlapping theoretical templates such as clusters (Porter, 2000), industrial districts (Pyke *et al.*, 1990), innovative milieus (Camagni, 1991), learning regions (Morgan, 1997) and regional innovation systems (RIS) (Cooke & Morgan, 1998). The most recent refinements of theoretical discussions about the relation between innovation, knowledge, interactive learning and geography revolve around *knowledge bases* (Asheim & Gertler, 2005). Industries differ substantially with regard to their specific knowledge base, of which two are distinguished: *analytical* (science based) and *synthetic* (engineering based).

This paper aims to identify the knowledge base which is crucial for the emerging biotechnology industry in the formerly old industrial Aachen Technology Region (Aachen TR) in Germany. The research question concerning this field of interest accordingly is the following one: Which *knowledge base* is essential for the process of shaping new knowledge and innovations? Additional questions which will lead us to a more fine-grained picture of the nature and geography of innovation and interactive learning are as follows: How intense are cross-sectoral knowledge transfers and labour mobility (*related variety*)? In which way can we observe innovation-oriented systemic interactions within the region (RIS) and to which extent are the firms connected to *extra-regional knowledge sources*? In order to shed light on these questions, we apply social network analysis (SNA) and descriptive statistics. The results are based on 23 standardized firm interviews and eight expert interviews. All interviews were conducted between June 2008 and January 2009 on a face-to-face basis.

This paper is structured as follows. Section 2 gives an overview of the theoretical framework, which includes *knowledge bases* and related concepts, namely *related variety* and *nationally and globally distributed knowledge networks*. Section 3 provides the main empirical results of our case study. Section 4 completes the paper by providing the key findings.[1]

2. Theoretical framework: knowledge bases and related concepts

In the following, we will discuss the *knowledge bases*, in particular, the analytical and, to a lesser extent, the synthetic knowledge base. In order to thoroughly analyse the nature and geography of innovation and interactive learning in the biotechnology industry in Aachen, we introduce the concepts of *related variety* as well as *nationally and globally distributed knowledge networks*. We will

[1] This paper is written in the context of an international research project called "Constructing Regional Advantage: Towards State-of-the-Art Regional Innovation System Policies in Europe?" The project is co-funded by the European Science Foundation and the Research Council of Norway.

also provide a brief literature-based section on the particular characteristics of innovation processes and knowledge sourcing in the biotechnology sector.

2.1 Knowledge bases

Following Asheim and Gertler (2005), we argue that innovation processes of firms and industries differ substantially between various sectors and are strongly shaped by their specific *knowledge base*. Due to this idea, two types of *knowledge bases* and related activities can be distinguished: *analytical* (science based) and *synthetic* (engineering based) (Laestadius, 1998). This typology goes beyond traditional knowledge typologies and thus provides a better understanding of knowledge creation in certain industries. It helps to characterize the nature of the critical knowledge which the innovation activity cannot do without.

Each single *knowledge base* implicates specific combinations of tacit and codified knowledge (Polanyi, 1966; Nonaka & Takeuchi, 1995), qualifications and skills that are required by organizations as well as different innovation challenges and patterns of knowledge exchange, which, in turn, affect the sensitivity to geographical distance for interactive learning (Amin & Cohendet, 2004). Asheim *et al.* (2011, p. 6) indicate that the distinction of knowledge bases "refers to ideal-types, most activities are in practice comprised of more than one *knowledge base*. The degree to which certain *knowledge bases* dominates, however, varies and is contingent on the characteristics of firms and industries as well as between different type of activities (for example, research and production)".

The biotechnology industry is often said to be a prototype for the *analytical* case (Gertler & Wolfe, 2006). Nevertheless, the literature on innovation processes that refers to biotechnology gives rise to expectations that consider specific biotechnological innovation processes to show characteristics of the *synthetic* type as well (Coenen *et al.*, 2006). Consequently, in the following, we will describe the key features of the *analytical* and the *synthetic* mode of knowledge creation (Table 1).

Innovation processes within industrial settings that draw on the *analytical knowledge base* strongly depend on scientific knowledge input. Knowledge creation is often based on deductive cognitive and rational processes or on formal models that require abstraction skills. Examples with relevance to the biotechnology industry are laboratory-based research or scientific discourses. Basic and applied research as well as systematic product and process development belong to the core activities of the firms. In order to turn knowledge into innovation successfully, firms often have their own R&D departments, but they also rely profoundly on research results of universities and other research organizations. The strong influence that comes from the scientific basis is also reflected by the high academic spin-off activities. Knowledge inputs and outputs involved in innovation processes include always combinations of tacit and codified components (Nonaka & Takeuchi, 1995; Johnson *et al.*, 2002). Face-to-face-contacts facilitate exchanges of both; nevertheless, for the *analytical* case, face-to-face-contacts are less important than they are for the *synthetic* case, because knowledge is more often codified and, therefore, easier to exchange between globally distributed actors (Asheim *et al.*, 2007c). There are several reasons for the existence of strong codified knowledge content: (i) knowledge generation is often based on reviews of existing studies and (ii) the application of scientific principles and methods, (iii) innovation processes are rather formally organised (e.g. in R&D departments), and (iv) results tend to be documented in reports, electronic files or patent descriptions. These activities require people with specific qualifications and capabilities such as analytical skills, abstraction, theory building and testing, and documentation. As a consequence, the core of the work force needs university education and/or research experience. The application of knowledge in such industries is often integrated in more radical product or process innovations. These innovations build the starting points for new start-ups and spin-offs on a regular basis (Asheim & Coenen, 2005; Asheim *et al.*, 2011, 2007b).

Table 1. *Synthetic vs. analytical knowledge base*

Analytical (science based)	Synthetic (engineering based)
Scientific inputs, often based on deductive processes and formal models	Applied, problem related knowledge often based on inductive processes
Radical innovations by creation of new knowledge/ know why	Incremental innovations by application or (new) combination of existing knowledge/ know how
Learning by exploring and interacting	Learning by doing, using and interacting
Research collaboration with firms (R&D department) and research organisations	Interactive learning with customers and suppliers
Strong codified knowledge content	Strong tacit knowledge content
Low sensitiveness for spatial proximity	High importance of spatial proximity
Laboratory-based research, scientific discourse	System design, prototyping, fine tuning, testing, practical work

Source: Own modification of Asheim and Gertler (2005) and Moodysson et al. (2008)

Product and process innovations within industries that draw on the *synthetic knowledge base* take place mainly through the application or (new) combination of existing knowledge with the aim of solving a specific problem that comes up in the interaction with clients and suppliers. Insofar, knowledge formation is characterized as a more inductive process. Characteristic activities are, to mention some examples, system design, prototyping, fine-tuning, testing and practical work in general. Some of these activities are visible in specific areas within the biotechnology industry. The R&D intensity is lower than that in the first type in general. Overall, the accentuation within “R&D” refers more to the “D-part” in the form of product or process development. If research is a matter of interest, it is mainly an applied research, even within industry–university relationships. Although collaboration with universities and other research organizations can play a significant role in firms' innovation processes, interactive learning is often dominated by industry–industry links. Knowledge embodied in a particular technical solution or engineering work is at least partially codified (e.g. technical blue-prints). However, due to the fact that knowledge often arises from experience gained at the workplace and through learning by doing, using and interacting, tacit knowledge is typically more important than in the *analytical knowledge base* (Nonaka & Takeuchi, 1995; Johnson *et al.*, 2002). The strong tacit nature of knowledge almost always requires being at the same time at the same place in order to share this knowledge (Audretsch, 1998). As a result, the *synthetic type* shows a relatively stronger sensitivity towards spatial proximity between innovation partners. Professional and polytechnic schools as well as on-the-job trainings are of particular importance to provide an adequate educational background facilitating concrete know-how, craft and practical skills. The knowledge creation process as well as the application process is dominated by the modification of existing products and processes with the aim of achieving higher efficiency and reliability of new solutions or of raising the practical utility and user friendliness of products from the customers' perspectives. Accordingly, innovation processes in such industries have a mainly incremental nature. They mostly take place in existing firms, whereas spin-offs are relatively less frequent (Asheim & Coenen, 2005; Asheim *et al.*, 2011, 2007c).

2.2 Related variety and regional development

Empirical results indicate that regional economies showing a high degree of *related variety* tend to display higher job growth and increased competitiveness of firms (Frenken *et al.*, 2007; Boschma & Iammarino, 2009). Asheim *et al.* (2007a, p. 4) define *related variety* as "sectors that are related in terms of shared or complementary knowledge bases and competences. [. . .] [I]t is not regional diversity (which involves too large cognitive distance) or regional specialization per se (resulting in too much cognitive proximity) that stimulates real innovations, but regional specialization in related variety that is more likely to induce interactive learning and innovation. [. . .] [M]ajor innovations are more likely to occur when knowledge spills over between sectors, rather than within one sector, but only as long as the sectors are related in terms of shared competences". It is also conceivable that related variety is brought into the regional economy through inter-sectoral knowledge exchanges with nationally and globally distributed actors (Boschma & Iammarino, 2009) (Section 2.3).

Platform technologies hold particularly high potentials of fostering *related variety* within regional economies, since they link and mix competences of different industrial sectors and research discip-lines. Biotechnology is a good example, as it covers several platform technologies such as genetic engineering, cell and tissue engineering and bioinformatics (OECD, 2005; Cooke, 2007). In the empirical part, we will examine whether the biotechnology industry in the Aachen TR already displays preconditions for *related variety* in terms of strong inter-sectoral intra- and extra-regional connectedness within various strands of biotechnology R&D and applications.

2.3 Nationally and globally distributed knowledge networks

There is a widespread consensus among scholars that spatial proximity between various actors carries the potential for intensified face-to-face interactions, short cognitive distances, common language, trustful relations, easier observations and immediate comparisons. As a result, spatial proximity seems to enhance interactive learning and innovation processes, and therefore, innovation systems should be assumed to have a specifically localized or regionalized component (Audretsch, 1998; Malmberg & Maskell, 2002). However, regional industrial settings are usually no self-sustaining units (Amin & Cohendet, 2004). Links to national and globally distributed actors and innovation systems are mandatory for absorbing extra-regional complementary knowledge resources which firms or research organizations would not find within the limited context of the region (Fromhold-Eisebith, 2007; Hassink & Ibert, 2009). Therefore, we introduced the distributed knowledge network perspective to modify a too strictly endogenous perspective.

By hosting firms and research organizations that are strongly interwoven within nationally and globally distributed knowledge networks, RIS may reduce the risks of lock-in effects (Hassink, 2005). Also, one cannot automatically assume that all organizations which have established a multitude of global pipelines (Bathelt *et al.*, 2004) contribute to the diffusion of knowledge within the region, that is, acting as gatekeepers (Giuliani & Bell, 2005; Graf, 2011). A necessary precondition for surrounding actors to be able to benefit from these organizations' capabilities is sufficient absorptive capacity—the ability to recognize and exploit relevant external knowledge (Cohen & Levinthal, 1990). The absorptive capacity of firms can be strengthened through, for example, higher investments in the R&D activities or upgrading of human capital. Strong absorptive capacities, in turn, strengthen the ability to identify extra-regional knowledge resources.

2.4 Innovation processes and knowledge sourcing in the biotechnology industry

Recently, many studies have been carried out on the biotechnology industry and its knowledge networks in a regional economic context (see, among others, Cooke, 2002; Owen-Smith & Powell, 2004; Tödtling & Trippl, 2007; Waxell & Malmberg, 2007). Most authors agree upon some basic characteristics, such as the science-based character of the industry, the use of mainly codified knowledge, the importance of both internal R&D capacities and external knowledge sources and the "high pace of innovation, a substantial degree of uncertainty as well as long development times and high development costs" (Tödtling & Trippl, 2007, p. 347). These characteristics go in line with the attributes ascribed to the *analytical knowledge base* mentioned above. However, there is a disagreement in the literature on the exact characteristics of the external links (Tödtling & Trippl, 2007). Concerning these external linkages, there are, for example, different opinions about the role of the market and the nature of knowledge spillovers as well as about the structure and spatial organization of knowledge networks. The latter debated issue clearly refers to the above-discussed *nationally and globally distributed knowledge networks*. These disputed issues apparently are empirical questions, which we will need to solve within our case study of the biotechnology firms within the Aachen TR.

To summarize, we have argued that (i) industries with an *analytical knowledge base* are characterized by scientific inputs, the development of radical innovations and learning by exploring and interacting. They often carry out laboratory-based research and exchange codified knowledge content due to documentation in patents and publications. The research collaboration often takes place between firms (R&D department) and research organizations, and there is, in general, a relatively low sensitiveness for spatial proximity. (ii) *Related variety* means that there would be a strong intersectoral connectedness within various strands of biotechnology R&D and applications. (iii) Links to *national and globally distributed actors* are seen as mandatory for absorbing extra-regional complementary knowledge resources which biotechnology firms would not find within the region.

3. Innovation and interactive learning: empirical evidence from the biotechnology industry in the Aachen TR, Germany

The preceding unpacking of the theoretical building blocks provides a differentiated theoretical basis that helps us interpreting the empirical results of our analysis of the biotechnology industry in the Aachen TR. We will start this section by addressing data and methodology issues, followed by pointing the key characteristics of the regional economic and institutional settings the biotechnology firms are embedded in. Then, in more detail, we will present and discuss empirical data on basic firm characteristics and preconditions for achieving competitiveness, firms' innovation performances and knowledge exchange patterns.

3.1 Data and methodology

Our case study is based on the standardized personal interviews with CEOs or executives of 23 of the 27 firms (85%) in the Aachen TR that are engaged in biotechnology activities. Therefore, the sample can be considered highly representative for the population as a whole.[2] All interviews with the firm representatives were conducted during June and July 2008 and contained primarily quantitative elements. Moreover, in January 2009, we conducted eight semi-standardized expert interviews in order to discuss the interpretation of some preliminary results. This group of experts contains cluster coordinators, policy advisors, representatives of public research and education organizations, and contact partners of ministries of the State of North Rhine-Westphalia (NRW).

The identification of regional firms showing biotechnology activities is based on our own desktop research and different member lists offered by business associations, cluster initiatives and the regional chamber of commerce. Our sample includes either firms having performed R&D on particular biotechnology techniques, firms having introduced a biotechnology product or process into the market, or firms that provide their knowledge of biotechnology techniques in terms of consulting services. Among these, we found dedicated (core) biotechnology firms with biotechnology as their main field of activity. Additionally, there are firms with some reported biotechnology activities which are not part of the firms' core business. Firms that supply biotechnology equipments only are excluded.

In order to understand the nature and spatial dimension of innovation and interactive learning in the particular regional, institutional and sectoral settings, we applied a mix of common descriptive statistics and revealing sociometric techniques in the form of SNA (Wasserman & Faust, 1994; Scott, 2000). SNA is based upon relational data and upon attributes data, which enables us to identify, to map and to value knowledge flows between different biotechnology firms and other actors involved in interactive learning within and beyond the Aachen TR. Recently, SNA has been increasingly applied in economic geography and regional economics, as can be observed in studies carried out by Graf (2011), Boschma and Ter Wal (2007), Cantner and Graf (2006), Giuliani and Bell (2005), Morrison (2008), Brandt *et al.* (2009), Krätke (2002, 2010), and Krätke and Brandt (2009) (for a more general and analytical article on the use of SNA in economic geography, see Ter Wal & Boschma, 2009).

Upgrading of *technological* knowledge is a precondition for biotechnology firms to further product and process innovation. However, in order to successfully bring innovations into the market, knowledge of *market* issues (concerning new market developments, consumer preferences, competitors, product faults, etc.) is a crucial factor for firms' performance, too (Boschma & Ter Wal, 2007). We consider this distinction to gain a more fine-grained insight regarding the question with whom the

[2] We also collected information on some basic characteristics of the four remaining firms that did not take part in our case study. Since none of them shows significant differences (with regard to size or age) compared with the other 23 firms, the results should be highly relevant for the regional biotechnology industry as a whole.

biotechnology firms in the Aachen TR exchange knowledge of market issues in comparison to partners with whom they share knowledge concerning technological issues. Nevertheless, we have to keep in mind that some of the interviewed biotechnology firms are still in the pure R&D or testing phase, that is, they have not entered the market with fully developed products yet.

3.2 The Aachen TR: framework conditions for an emerging biotechnology industry

The formerly old industrial Aachen TR is located in the very western part of the State of NRW and borders on Belgium and the Netherlands. The population is about 1.3 million and stretches across five counties (Kreise) and the major city, Aachen (240.000). In the past few decades, the region underwent intense restructuring processes (Fromhold-Eisebith & Eisebith, 2005). Supported by a strong research/education infrastructure and restructuring policies, it seems that lock-ins hampering the exploration of new economic development paths have been overcome. Today, the regional economy is in the process of developing competences in a couple of high-tech industries. The biotechnology industry is one of those industries that are profiting from the spatial proximity to world-renowned research and education facilities (Figure 1).

The Aachen TR is part of the BioRegio Rhineland, one of the three German key biotechnology regions that have won the BioRegio contest organised by the Federal Ministry of Education, Science, Research and Technology (BMBF) (Dohse, 2000; Cooke, 2002). Regarding the differentiation of RIS subsystems with focus on the biotechnology industry, the Aachen TR shows an emerging knowledge exploitation subsystem, a strong knowledge generation subsystem and a relatively thick supportive infrastructure. The *knowledge exploitation subsystem* comprises the 27 biotechnology firms mentioned above. They strongly benefit from knowledge interactions and human capital flows with organizations of the well-built *knowledge generation subsystem* (Figure 1) which exhibits competences in different biotechnology techniques. Almost half of the interviewed firms are spin-offs from organizations of the regional knowledge generation subsystem. Most of them spun off from institutes of the RWTH Aachen University, one of the 10 German “excellence universities”. This university is, in particular, well known for its competences in a wide range of engineering and natural sciences. Both the University Hospital Aachen and the Fraunhofer Institute for Molecular Biology and Applied Ecology (IME) are situated directly next to the RWTH Aachen University. They are important knowledge exchange partners for regional biotechnology firms. Jülich is the other “hot spot” within the Aachen TR exhibiting expertise in science and education with relevance to the biotechnology industry. The Jülich Research Centre (FZJ), a member of the Helmholtz Association, is one of the largest research centres in Europe. It pursues interdisciplinary research in the fields of health, energy and the environment, and information technologies. Besides the FZJ, the Aachen University of Applied

Sciences[3] runs some of its research and education facilities in Jülich, thereof the department for chemistry and biotechnology.

Figure 1. *Biotechnology firms in the Aachen Technology Region. Geographical overview*
Source: Cartographic elaborations based on own research data.

Innovation policies in Germany are mainly carried out at the state level (for the Aachen TR, it is NRW). Nevertheless, there are a number of organizations in the Aachen TR which, all taken together, build up a fairly thick *supportive infrastructure* that aims at facilitating the competitiveness of the regional economy. LifeTecAachen-Jülich e.V. is the central cluster initiative for life science activities in the Aachen TR. It aims at establishing networks between relevant stakeholders from science, industry, development agencies and capital involved in and giving support to innovation processes in life

[3] The German "Fachhochschulen" (engl. = universities of applied sciences) are comparable with technical colleges or polytechnics in other countries.

sciences with particular focus on biotechnology and medical engineering. Other organizations that target the regional industry's development, though without a special focus on biotechnology, are the regional development agency for the Aachen TR (AGIT mbH) and the Regional Chamber of Industry and Commerce supplemented by the local governments whereof each has its own economic promotion department. Three offices of knowledge and technology transfer, at the RWTH Aachen University, the Aachen University of Applied Sciences and the Research Centre Jülich, particularly direct for building bridges between science/education and industry. The Aachen TR hosts 13 technology incubators in order to promote particularly young and technology-oriented firms. Some of them offer laboratory and cleanroom areas frequently used by emerging biotechnology firms. Due to the well-directed efforts to attract biotechnology firms in recent years, one incubator, the ITS International Technology and Service Centre in Baesweiler, shows the highest concentration of biotechnology firms outside Aachen and Jülich (Figure 1).

3.3 Basic firm characteristics

The 23 interviewed biotechnology firms cover a broad spectrum of different products and services. According to the colour-coded categorization, almost all fields of application of biotechnology techniques can be observed in the region, whereof the red biotechnology (medical processes) and the white biotechnology (industrial processes) are the most common areas of application.[4] Table 2 provides a deeper insight into which biotechnology activities the regional biotechnology firms are involved in.

Table 2. *Biotechnology activities of biotechnology firms (n=23) within the Aachen TR according to OECD list based definition (OECD, 2005)*

Biotechnology technique	**Research** (frequency)	**Development** (frequency)	**Use in Production** (frequency)
DNA/ RNA	4	7	1
Proteins and other molecules	7	10	1
Cell and tissue culture and engineering	6	8	4
Process biotechnology techniques	4	6	3
Gene and RNA vectors	2	2	0
Bioinformatics	1	1	0
Nanobiotechnology	1	2	0
Other	1	1	0
Total[1]	26	37	9

[1]Multiple responses were possible.

[4] We are aware that innovation processes might differ between these different strands of biotechnology. However, we do not subdivide our sample any further in order to avoid a lack of representativeness due to low case numbers.

We can see that the firms cover the whole range of the previously defined techniques. Nonetheless, proteins and other molecules, cell and tissue culture and engineering, process biotechnology techniques and DNA/RNA are the main fields of biotechnological expertise within the Aachen TR. These techniques are used primarily for product or process development. It is also remarkable that quite many firms proceed their own research activities.

Referring to our theoretical concepts, the widespread R&D activities given in Table 2 are the first hints to a strong *analytical knowledge base* that can be seen as the crucial type of knowledge creation in the biotechnology industry within the region. The intense variety of different platform techniques points to the high potential of strengthening *related variety*.

Further results confirm the outcomes of the earlier studies that pronounced the latecomer status of the German biotechnology industry (Rehfeld, 2005). Merely three firms out of 23 firms were established before 1995. Given that the Aachen TR is part of one of the winning BioRegios, the increasing foundation activities, which started in the second half of the 1990s, can be interpreted as a positive effect of the German BioRegio initiative launched in 1995 to a certain extent. In addition to the federal funding, the State of NRW undertook strong efforts to support biotechnology start-ups (Cooke, 2002). Even though the growth rate decreased somewhat, an ongoing vigorous foundation activity can be noticed till today, particularly due to the ongoing academic spin-off activities.

Another indicator of the continuing growth of the regional biotechnology industry is the total number of employees measured in the full-time equivalents. This number had a growth potential of 39.3% from 2005 to 2008. Other data, which are presented in Table 3, point to a rather micro and small enterprise structure of the biotechnology industry in the Aachen TR.

Table 3. *Size of the biotechnology firms in the Aachen TR*

Employees (FTE)	Total	Mean	Median	Min	Max
2005 (n=19)	252	13.3	11	2	50
2008 (n=23)	351	15.3	10	2	64

3.4 Human capital and recruitment sources

Since the strengthening of the firms' absorptive capacity plays a key role for surviving in highly competitive markets (Section 2.3), firms aim at improving their human capital basis by recruiting highly qualified personnel. Table 4 marks which qualifications in terms of employees' educational background are most demanded, whereas Table 5 indicates from which particular sources firms derive their skilled staff. As Table 4 proves, more than two-thirds of the personnel employed by the regional biotechnology firms hold at least a bachelor's degree, the largest group of them being educated in natural sciences. However, we should not neglect that competences in particular fields of engineering are also needed to advance the product and process innovations for some firms.

Table 4. *Educational level of employees of biotechnology firms (n=23) in the Aachen TR*

Educational background	**Percentage**	
Higher than or equal to bachelor's degree	68.9	(100.0)
Thereof:		
Natural sciences		76.0
Engineering		20.7
Artistic studies (e.g. arts, media)		0.0
Others (e.g. business studies)		3.3
Lower than bachelor's degree	31.1	
Total	100.0	

There is a strong emphasis on highly qualified labour with scientific background. Accordingly, universities are valued as the most important recruitment sources, followed by universities of applied sciences (Table 5). Other firms of the same and even more of different sectors are of minor interest. Spatial proximity matters in a way that organizations tend to be valued higher as recruitment sources, the shorter the spatial distance to the firms is. So far, systematic screening for labour on a global scale seems to be rather seldom.

Table 5. *Recruitment sources for biotechnology firms (n=23) in the Aachen TR*

Recruitment source	**"Very important"/ "important"** (percentage)	**Average importance**[1]		
		Regional	**National**	**International**
Universities	82.6	3.4	3.3	2.1
Universities of applied sciences[2]	65.2	3.1	2.6	1.5
Firms of the same sector	30.4	2.5	2.3	1.9
Firms of different sectors	26.1	1.7	1.8	1.6
Average		2.7	2.5	1.8

[1] 1 = not important, 5 = very important
[2] The German "Fachhochschulen" (engl. = universities of applied sciences) are comparable with technical colleges or polytechnics in other countries

We might deduce from these outcomes that there are unexploited potentials of *globally distributed knowledge sources*. Labour mobility between the knowledge generation and the knowledge exploitation subsystem of the innovation system is comparatively vibrant, whereas labour mobility between firms themselves is of less importance. In terms of *related variety*, the relatively low significance of other sectors as recruitment sources might be valued as rather unfavourable concerning the strengthening of innovation potentials. The relatively strong emphasis on universities as primary recruitment sources indicates once more the great importance of the *analytical knowledge base*.

3.5 Firms' innovation performances

Further results show the firms' concrete engagement in particularly innovation activities. Considering the period from 2005 until 2008, more than 90% of the biotechnology firms in the Aachen TR claim to have conducted process innovations, followed by ca. 83% of those that have developed and commercialized new products (including services) whereof almost all products were not merely new to the firms, but new to the relevant markets as well. A considerably lower share of firms changed strategies or marketing concepts compared with the technological innovations we have addressed so far. New or significantly changed organizational structures were rare.

The statistic representing the turnover rate is a useful indicator that documents the strong tendency of regional biotechnology firms towards rather radical technological innovations than incremental technological innovations—a feature of the *analytical knowledge base*. On average, during 2005 and 2008, nearly half of the firms' turnovers resulted from the sale of definitely new products or services. Incremental changes cover one-fifth of the average turnover. The remaining one-third refers to the unchanged products or services.[5]

Patent statistics provide another common measure to value firms' innovativeness.[6] The results give further hints to the high relevance of rather radical innovations, since a relatively high share of firms (61%) applied for patents during 2005 and 2008, on average 8.1 patents per patenting firm, while the median number of patents is 3.5. Furthermore, at least one-fifth of the firms had applied for co-patents. Patents taken as a kind of transmitter of codified innovation-related information are typical for the *analytical knowledge base*.

Looking at the allocation of the R&D employees (i.e. personnel that is primarily occupied with the development of new products, services and processes), 14 firms indicated to employ R&D employees, which is an average of 6.4 FTE (full-time equivalent). Regarding the nine remaining firms

[5] However, those results have to be interpreted carefully since standard deviation figures indicate high disparities regarding the specifications made by the firms.

[6] Firms with no patents mentioned several reasons for not applying for patents so far. One firm indicated that all rights for the developed methods were contractually held by its customers. Even two firms argued that they did not apply for patents so far to protect themselves against unintended knowledge and technology transfer. Other reasons were that the levels of complexity and the costs of patent application processes (one mention in each case) were too high. Also, one young firm was totally at the beginning of the inventory process with no products or processes to hold the potential to be patented.

which do not employ any full-time R&D employees, the average share of time that workers spend on R&D is one-third of their entire working time.

According to what has been said so far, we can conclude that the highly innovative biotechnology industry in the Aachen TR exhibits strong R&D efforts in order to bring new or significantly changed products or processes into the market.

3.6 Knowledge exchange patterns: market and technological knowledge networks

In addition to the previous results, which rather focus on in-house preconditions for creating knowledge, we asked our interviewees to evaluate different sources of information that are external to the firms (Table 6). Academic journals, the internet, R&D co-operations, as well as fairs, exhibitions and congresses are the main sources for biotechnology firms in the Aachen TR to get access to technological knowledge. The high relevance of academic journals and inter-organizational R&D collaboration backs our assumption that innovation processes in the biotechnology industry strongly depend on the *analytical knowledge base*. The internet, as well as fairs, exhibitions and congresses are the most important sources for market-related knowledge.

Table 6. *Importance of different sources of information for biotechnology firms (n=23) in the Aachen TR*

Information source	Technological knowledge "Very important"/ "important" (percentage)	Market Knowledge "Very important"/ "important" (percentage)
Academic journals	95.7	47.8
Internet	87.0	82.6
R&D co-operation	69.6	-
Fairs, exhibitions, congresses	65.2	78.3
Specialized magazines	56.5	52.2
Licenses, machines, software, etc.	34.8	-
Market surveys	4.3	26.1

The network illustrations in Figures 2 and 3 show some general results of our graph-based SNA.[7] They provide the first overview concerning the question with whom biotechnology firms in the Aachen TR

[7] We distinguish two different types of organizations within both network illustrations. First there are knowledge-generating organizations (i.e. university institutes and public research organizations) and second there are knowledge-exploiting organizations (i.e. industrial companies) (Autio, 1998). This rather simplistic distinction highlights the crucial role that these organizations play from the perspective of the (regional) innovation system approach. The network figures roughly indicate a first impression of the high involvement of university institutes, or research laboratories that play a decisive role in providing the system with new knowledge which is relevant for biotechnology. However, we have to be aware of the fact that the production of new knowledge and problem solutions can also occur within and between collaborating firms, too, even though their role within the system of innovation is rather to exploit knowledge in order to enhance the potential for commercializing biotechnology products.

exchange technological and market-related knowledge and where these knowledge partners are located. Since our case study rather focuses on the (regional) systemic perspective and *not* on the individual firms' perspective, we should keep in mind that the aggregated results, which follow hereafter, do not necessarily mirror the knowledge exchange pattern of one particular biotechnology firm. Both graphs indicate that there are obvious differences between the individual firms, for example, concerning their international interconnectedness. Unlike others, some draw intensely on extra-regional knowledge sources. They might keep the potential to function as gatekeepers of knowledge (Giuliani & Bell, 2005; Graf, 2011). There are further disparities in terms of the sheer number of knowledge links that each firm features as well. The range goes from 2 to 21 contacts per firm for the technological knowledge network (TKN) and from 0 to 19 contacts for the market knowledge network (MKN). And finally, there is also no absolute uniform picture with regard to the contact types that seem to be the most important contacts for the individual firms' innovation performance.

The selection of SNA indicators given in Table 7 concentrates on the networking activities between the 23 interviewed regional biotechnology firms themselves. These figures help us to quantify particular dimensions of network structures and network positions from a *sociocentric* perspective. The network *density* is expressed as a ratio between the actual number of ties and the maximum number of potential ties (Wasserman & Faust, 1994). While the TKN has an average density of 0.0198 (i.e. 2% of all potential inter-firm relationships within the Aachen TR are exploited), this number is even lower with 0.0059 for the MKN. Both figures clearly demonstrate that interactive learning between biotechnology firms within the region is, so far, very rare concerning technological knowledge and with regard to the market network that is almost nonexistent. Firms that might keep the potential to function as gatekeepers typically do not diffuse relevant technological or market-related knowledge through the investigated cluster.

Table 7. *Knowledge flows between 23 biotechnology firms in the Aachen TR: summary of sociocentric network indicators*

Indicator	TKN	MKN
Number of ties	10	3
Density	0.0198	0.0059
Components	14	20
In-degree centralisation/ dicho	0.1219	0.0413
In-degree centralisation/ valued	0.0583	0.0418
Out-degree centralisation/ dicho	0.2169	0.0413
Out-degree centralisation/ valued	0.1652	0.0418
Hybrid reciprocity	0.1111	0.0000

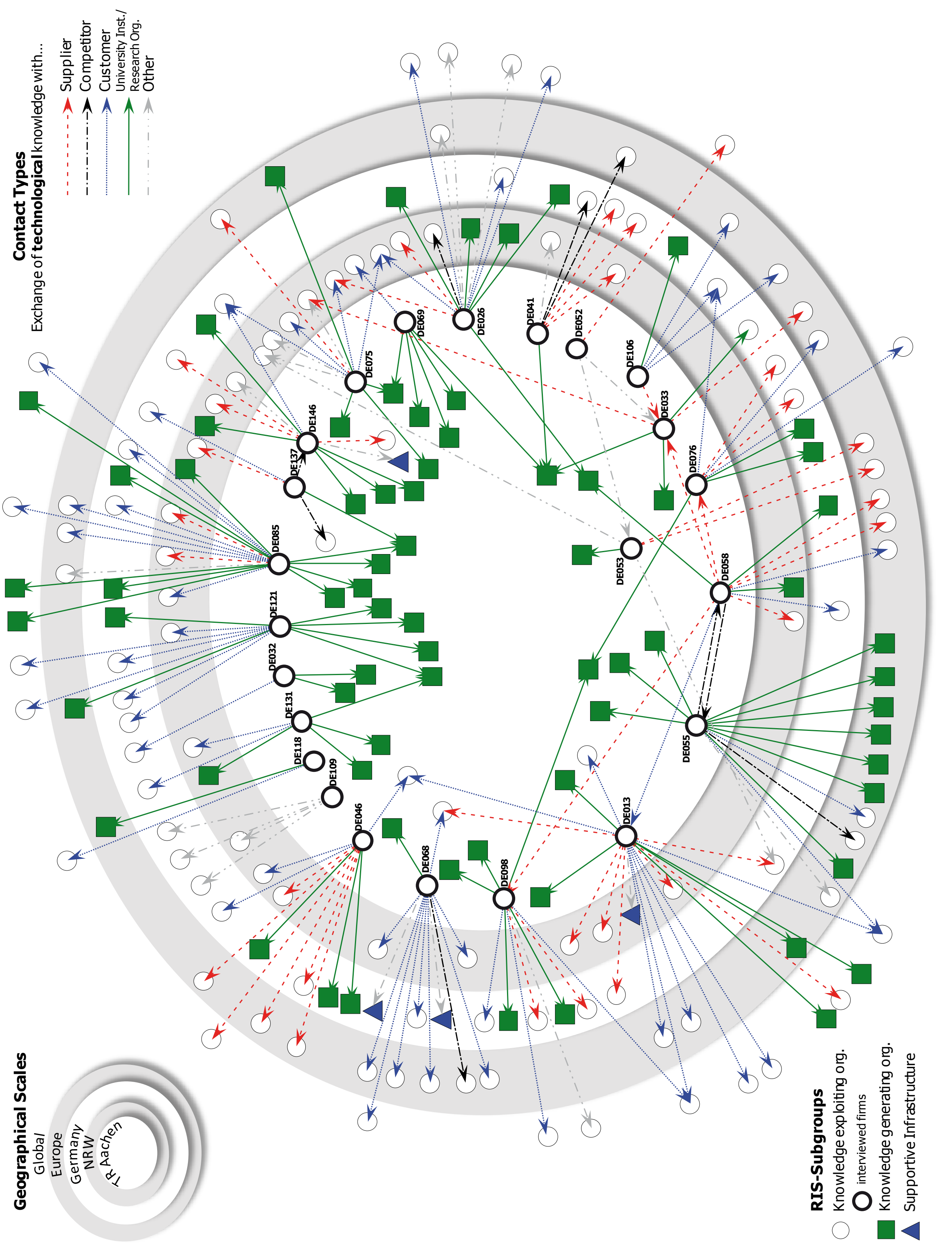

Figure 2. *TKN of biotechnology firms (n=23) in the Aachen Technology Region.*
Source: UCINET 6, elaborations based on own research data.

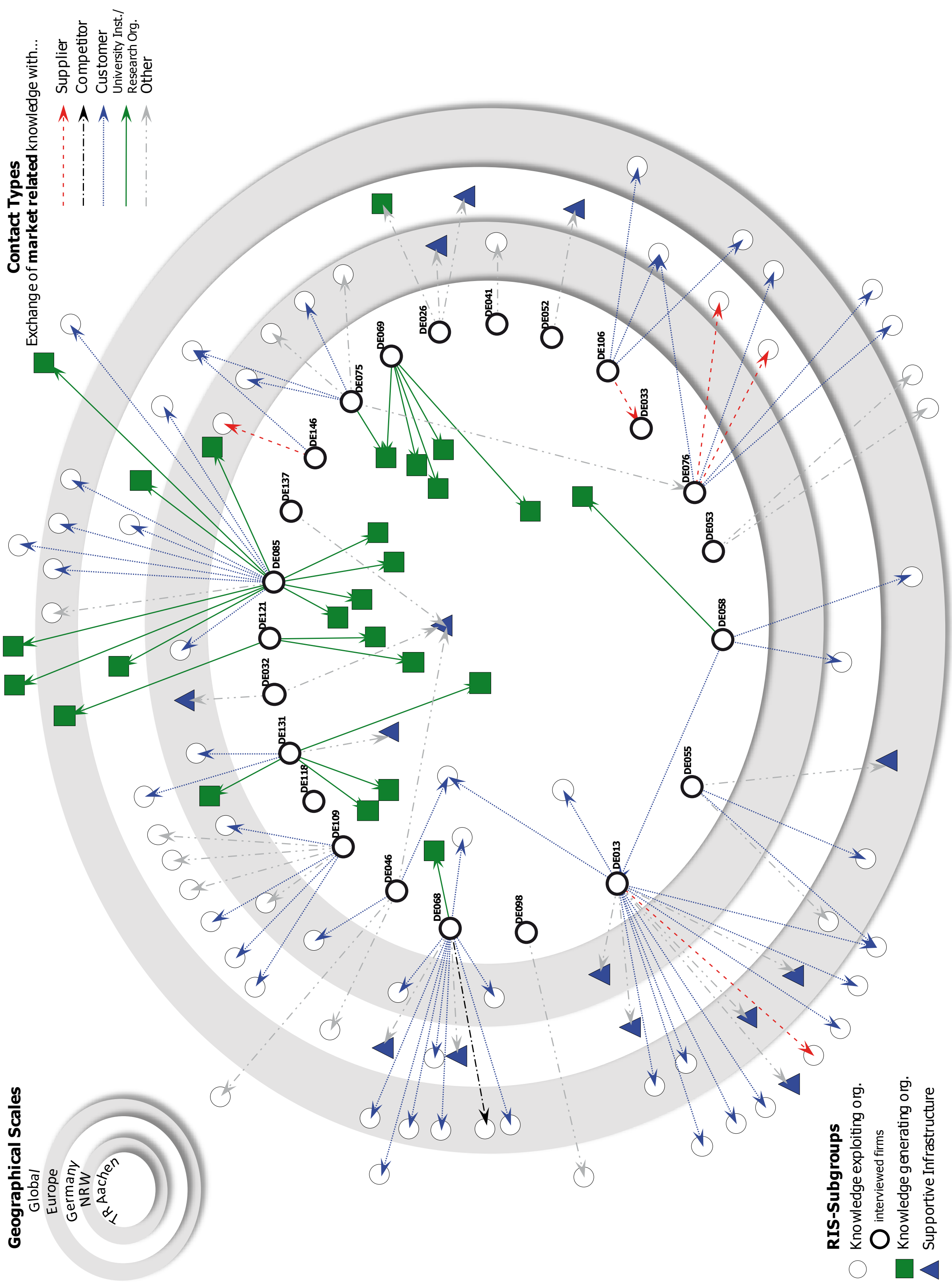

Figure 3. *MKN of biotechnology firms (n=23) in the Aachen Technology Region.*
Source: UCINET 6, elaborations based on own research data.

The relatively high number of network *components* gives hints to the rather fragmented character of both networks. The TKN consists of one component connecting nine firms and another linking just two firms. Taken together with the 12 remaining isolated firms, we find 14 components. The market-related network consists of 20 components: 17 isolated firms and 3 small components, each connecting two firms.

This lack of intra-regional inter-firm learning might be explained due to a rather low cognitive, social or institutional proximity between potential collaborators. Furthermore, the strong specialization of activities related to the development of biotechnology products and processes reduces the scope of relevant knowledge network partners.

In addition to these indicators, we used valued and dichotomous in- and out-degree *centralization* measures to determine how "centralized" both inter-firm networks are within the region as a whole and how unequal the distribution of centrality is, respectively.[8] We can conclude that both networks are rather homogenous in hierarchical structure, that is, there is no substantial centralization. Only the out-degree centralization measures with regard to the exchange of technological knowledge show little centralization tendencies due to one firm (see Figure 2, firm code DE058) that indicated five local biotechnology firms with whom the firm exchanges knowledge. In combination with the very low network density numbers, we can presume that this homogeneity of network positions is situated on a very low level of inter-firm knowledge exchange activities within the regional biotechnology industry.

If the indicator that measures the degree of *hybrid reciprocity* listed at last in Table 7 had been 1.0000, we would have said that all of the mentioned knowledge flows would have been symmetric, that is, firm X mentions firm Y and firm Y mentions firm X, etc. In our case, the hybrid reciprocity levels are very low (0.1111 and 0.0000), showing that the few mentioned network contacts are far from reciprocal/symmetrical relationships. This lack of reciprocity can be interpreted as a sign of a

[8] *Degree centrality* refers to the knowledge exchange links that one firm has with the other firms. *In-degree* centrality measures the extent to which knowledge is acquired by a firm from other local firms by counting the number of technological/market knowledge exchange ties incident *to* the firm. *Out-degree* centrality measures the extent to which knowledge originates from a firm to be used by other local firms by counting the number of ties incident *from* the firm. Both indicators are calculated in two ways: dichotomous and valued. The *dichotomous* indicator reflects the sheer presence/absence of a linkage, while the *valued* one analyses the value given to each linkage (i.e. importance of each link for the firm's innovative performance; a 1–5 range) by the knowledge-using firm. The centralization measures refer to the network populations as a whole and express the degree of inequality or variance in both networks as a percentage of that of a perfect star network of the same sizes. In the current case, for example, the dichotomous outdegree centralization of the inter-firm TKN within the region is 22%, while the in-degree centralization is 12% of the theoretical 100% centralization maximum. For further information on network centralization measures, see, for example, Borgatti et al. (1999); Freeman (1979), or Hanneman and Riddle (2005).

rather imbalanced system of knowledge relations between biotechnology firms in the Aachen TR: while one firm identifies another firm as a knowledge exchange partner, this does not necessarily mean that the same is true vice versa, that is, the potential knowledge exchange partner does not necessarily verify this statement due to a different notion of the relationship.

Although for the following data analyses, we do not require that the ties have to be reciprocated in order to identify a linkage between two actors, we should keep possible asymmetries in mind when talking about knowledge *exchange* relationships.

In what follows, we will leave the *sociocentric* perspective (which was restricted to the networking activities only between the interviewed firms themselves) and widen our scope towards the aggregated analysis of the firms' complete *egocentric* knowledge networks. Table 8 refers to the geographical distribution of all the mentioned technological as well as market-related knowledge sources. The main conclusion here is that the local, regional, national and global knowledge pipelines matter at the same time for the biotechnology industry in the Aachen TR. While the former examinations might have given rise to expectations that the local/regional level was rather unimportant regarding networking activities, we are able to observe now that spatial proximity to (other) network partners definitely plays a crucial role in order to gain access to the firms' external knowledge (Table 8). Nevertheless, many firms frequently use distant links to draw on complementary knowledge that is not available in the nearby organizations.

The geography of the TKN looks as follows: More than every fourth of the knowledge transfer relationships established by the biotechnology firms stays within the Aachen TR. When we add the surrounding State of NRW and refer to the whole as the wider regional context, nearly half of all the 216 contacts are regionally bounded. However, the slight majority of the organizations with whom the biotechnology firms exchange technological knowledge are situated outside the wider regional context. Every fourth tie refers to the wider national context (without Aachen TR and NRW) and almost every third link connects the regional biotechnology industry to organizations on a European or global scale. On average, contacts within Germany are ranked marginally above international contacts when we refer to their *importance* for the firms' innovation performance. The degree to which the technological knowledge exchanged is *similar* to that of the interviewed firms seems to be relatively independent from the spatial distances between the interacting organizations. However, the comparatively high similarity of exchanged knowledge within the Aachen TR stands out to a certain extent. In terms of *related variety* (cf. Section 2.2), it can be argued that the knowledge which is cognitively more distant may be brought into the regional biotechnology industry via linkages with nationally as well as globally distributed actors (cf. Section 2.3).

Table 8. *Geography of the TKN and MKN*

	TKN				MKN			
Geographical scale	**n**	**%**	**AvImp**	**AvSim**	**n**	**%**	**AvImp**	**AvSim**
Aachen TR	59	27.3	3.8	3.2	28	24.6	4	2.7
NRW	39	18.1	3.9	2.7	18	15.8	4	2.9
Germany	52	24.1	3.9	2.6	26	22.8	4.1	2.7
Europe	39	18.1	3.5	2	21	18.4	3.2	3
Global	27	12.5	3.7	2.7	21	18.4	3.8	2.9
Total	216	100.0	3.8	2.7	114	100.0	3.8	2.8

Notes: n = number of knowledge links, AvImp = average importance for firms' innovation performance (1 = not important, 5 = very important), AvSim = average similarity of exchanged knowledge (1 = not similar, 5 = very similar)

The MKN consists of 114 contacts. In comparison with the TKN, the international level within the MKN is a little stronger emphasized, at least when we refer to the share of contacts. However, regional and national links still cover the major part of the network. They are also ranked above international relationships regarding their average *importance* for the firms' innovation performance. There is obviously no correlation between the *similarity* of market-related knowledge and spatial distances between firms and their knowledge exchange partners (Table 8).

Overall, we can back up the assumption that the Aachen TR biotechnology industry exhibits a relatively balanced local node–global network pattern of knowledge exchange relationships. With respect to the share of all the mentioned contacts, we might deduce a slight tendency in a way that short distances between network partners matter somewhat more for the exchange of technological knowledge compared with the market-oriented knowledge. This goes in line with the assumption that technological knowledge, relatively to the market-related knowledge, contains more implicit elements and, therefore, is strongly reliant on spatial proximity between the transmitter and the receiver.

In addition to the spatial organization of knowledge flows, we tried to identify the most important knowledge exchange partners by distinguishing between suppliers, competitors, customers, university institutes and research organizations, and others (Table 9). Starting again with the TKN, we can see that the biotechnology firms in the Aachen TR above all use technological expertise of university institutes and research organizations (including clinics at university hospitals) in order to improve products or processes. The figures support the general assumption that the emerging biotechnology industry serves as a prime example for science-driven innovation processes (see *analytical knowledge base*, Section 2.1). Competitors were rather seldom mentioned in terms of “official” knowledge exchange partners. Having a look at the *importance* classification, we get another hint that institutes at universities and/or research organizations are the central providers of technology-related knowledge. Except for competitors, the technological knowledge which is shared with other organizations covers, more or less in equal parts, the whole range from “very *similar*” to “not *similar*”, that is, both the complementary and the more comparable knowledge components are crucial for the firms’ innovation efforts. On average, competitors deal with comparable technical topics, and thus they generate relatively similar knowledge. Relationships with suppliers and customers tend to make technology-oriented knowledge assets which are more dissimilar to each other meet. However, these relations still exhibit a medium level of shared expertise.

Table 9. *Contact types within the TKN and MKN*

	TKN				MKN			
Contact type	**n**	**%**	**AvImp**	**AvSim**	**n**	**%**	**AvImp**	**AvSim**
Supplier	41	19.0	3.3	2.4	5	4.4	3.8	3.2
Competitor	9	4.2	3.4	3.7	1	0.9	3.0	3
Customer	64	29.6	3.7	2.4	51	44.7	3.7	2.8
University institutes/ research orgs.	78	36.1	4.2	2.8	26	22.8	4.3	2.3
Other	24	11.1	3.9	2.7	31	27.2	3.6	3.3
Total	216	100.0	3.8	2.7	114	100.0	3.8	2.8

Notes: n = number of knowledge links, AvImp = average importance for firms’ innovation performance (1 = not important, 5 = very important), AvSim = average similarity of exchanged knowledge (1 = not similar, 5 = very similar)

As measured by the frequency of mentions, customers are the main partners in the MKN. Their knowledge helps to estimate sales potentials of new inventions and improved products, respectively. Suppliers are rather unimportant sources for the market knowledge. Similar to the TKN, competitors do not play a role at all. While we could have expected the strong position of academia within the TKN before, it might be somewhat surprising that these types of organizations were—even though on a lower level—frequently mentioned sources of knowledge related to market issues, too. One reason might be that today’s scientists are often involved in the R&D activities of private companies so that they accumulate market-relevant knowledge over time and share this expertise now with other firms. The relatively high average *importance* rating underlines the relevance of market knowledge provided by scientists, which is even higher ranked than that of the customers. When we compare the degree to which knowledge on market issues is similar to that of the biotechnology firms, we can see again a wide range of *similarity* values. The market-related knowledge provided by university institutes and research organizations differs the most from the one that is provided by the biotechnology firms. In the end, we should not neglect the considerable residual amount of "other" contact types.[9] Nearly every third tie refers to contacts of this type.

Table 10 combines the contents given in Tables 8 and 9. The effect is that we get an impression about which contact type dominates a certain spatial level. Knowledge exchanges within the Aachen TR are clearly dominated by links with university institutes and scientific research laboratories. Besides the strong emphasis on science-driven innovations, it seems that individual biographies play a decisive role in explaining the strong connection with local research-oriented organizations: Many of the entrepreneurs profit from the already existing social networks that they have established during their study period and/or scientific career at one of these institutions. The more we enlarge the radius of knowledge flows, the more the biotechnology firms are able to complement the more science-oriented input with innovation-relevant knowledge from partners—in particular, customers—along their value chains. Nevertheless, universities and research organizations remain essential sources for technological knowledge in the wider spatial context as well.

Table 10. *Dominance of different contact types depending on geographical scales of the network links*

Contact type	**TKN** (n=216)					**MKN** (n=114)				
	Aachen TR (59)	**NRW** (39)	**GER** (52)	**EU** (39)	**Global** (27)	**Aachen TR** (28)	**NRW** (18)	**GER** (26)	**EU** (21)	**Global** (21)
Supplier	10.2	33.3	19.2	23.1	11.1	3.6	5.6	7.7	0.0	4.8
Competitor	6.8	2.6	1.9	7.7	0.0	0.0	0.0	0.0	4.8	0.0
Customer	8.5	28.2	36.5	33.3	59.3	17.9	44.4	46.2	66.7	57.1
Univ. inst./ ROGs	69.5	15.4	28.8	28.2	18.5	60.7	11.1	11.5	4.8	14.3
Other	5.1	20.5	13.5	7.7	11.1	17.9	38.9	34.6	23.8	23.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Notes: n = number of knowledge links, univ. inst. = university institutes, ROGs = research organizations

Even though it is often claimed that scientific knowledge is the key input factor for biotechnological innovation processes, we cannot assume automatically that every technology-related knowledge exchange is scientific by nature, that is, the knowledge that is shared is predominantly of scientific content. While no more than 22% of all the reported knowledge exchanges are primarily scientific, 34% display a mixture of science- and practical work-oriented elements and 44% of the knowledge exchanges are primarily practical work oriented. In conclusion, we can see that the flows of technological knowledge between biotechnology firms of the Aachen TR and other organizations exhibit

[9] With regard to the MKN, this type of network contacts contains organizations such as business membership organizations, economic development and transfer agencies, sister and mother companies, co-operation partners (which consist, in principle, of firms that could not be definitely attached to single categories along the value chain), consultants, financial service providers and organizers of conventions and trade shows.

characteristics not only of the *analytical knowledge base* but also of the *synthetic knowledge base* (Section 2.1).

Finally, by using the NACE classification (Eurostat, 2008), we discovered that the TKN and MKN include a relatively wide range of different industrial sectors. Additionally, on average, knowledge similarities lie approximately in the middle of the similarity scale, that is, the shared knowledge comprises a well-balanced mix of comparatively similar and dissimilar knowledge components. The combination of both outcomes leads us to the proposition that the Aachen TR biotechnology industry meets the requirements of *related variety* (cf. Section 2.2).

4. Conclusion

This paper aims to identify the *knowledge base* which is essential for the process of shaping new knowledge and innovations in the biotechnology industry in the Aachen TR in Germany. Several research findings have confirmed that innovation processes within the biotechnology industry in the Aachen TR are clearly based on an *analytical knowledge base*. First, it is characterized by widespread R&D activities. Secondly, there is a strong emphasis on highly qualified labour with a scientific background. Thirdly, we have observed a high relevance of academic journals and inter-organizational R&D collaboration. Fourthly, the primary recruitment sources are universities. Fifthly, science-oriented organizations such as university institutes, clinics and other public research organizations are the most important knowledge exchange partners with regard to the technological issues. Interactive learning along the value chain—especially with customers—plays a stronger role only when it comes to the exchange of the market-related knowledge. Lastly, the regional biotechnology firms tend to achieve radical technological innovations rather than incremental technological innovations.

The intense variety of different platform techniques, the wide range of various industrial sectors that are involved in the knowledge networks and the fact that the exchanged technological knowledge covers the whole range of complementary as well as more comparable knowledge components point to the high potential of strengthening *related variety*. The relatively low significance of other sectors as recruitment sources, however, might be valued as rather unfavourable concerning the strengthening of innovation potentials in terms of encouraging *related variety*.

Concerning systemic knowledge exchanges within the region (RIS), we observed a multiplicity of knowledge exchanges between the biotechnology firms and knowledge-generating organizations, whereas inter-firm interactions were very rare. Possible reasons for this lack of regional knowledge exchanges between biotechnology firms might be based on too low cognitive, social or institutional proximity. Another possible explanation for the deficiency of knowledge transfers with other firms at the regional level refers to a functional shortcoming: customers and suppliers are scarce within the immediate environment. Furthermore, the strong specialization of activities related to the development of biotechnology products and processes reduces the scope of potential collaborators within the region.

The more we enlarge the geographical radius of our empirical findings towards *nationally and globally distributed knowledge networks*, the more we can notice that the biotechnology firms are able to complement the science-oriented knowledge input with rather market-oriented knowledge from partners along their value chains. As explained in the context of the *analytical knowledge base*, the formalized nature of knowledge facilitates these knowledge transfers over long distances. In comparison with the market-related knowledge, technological knowledge contains more implicit elements, and therefore, it relies strongly on spatial proximity between the transmitter and the receiver. All in all, we have observed a relatively balanced local node–global network pattern of knowledge exchange relationships.

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5. Analytical vs. synthetic knowledge: which knowledge base configuration drives Southwest Saxony's automotive firms?

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Abstract

So far little research has been done on analysing automotive clusters from a *knowledge base* perspective. Existing studies provide ambiguous hints at which knowledge base is the crucial one for automotive manufacturing and innovation processes. This paper aims to investigate the nature and geography of knowledge sourcing and interactive innovation processes of Southwest Saxony's automotive firms. Drawing on face-to-face interviews with representatives of 58 firms and social network analyses of knowledge transfers I show that the firms rely heavily on the *synthetic knowledge base* whereas the *analytical knowledge base* is comparatively weak. In the face of its precarious position between the highly innovative western automotive centres and the low-cost sites in Central and Eastern Europe, it is at least uncertain whether this *knowledge base* configuration will safeguard the clusters' competitiveness in the long run.

1. Introduction

A wide body of literature identifies knowledge as a crucial factor for firms, industries, regions, and whole nations as a basis to strengthen their competitiveness. There is also a widespread consensus that knowledge and innovation processes have to be seen and analysed as highly complex phenomena which differ substantially between different industries (Malerba, 2005; Pavitt, 1984). Recently, the knowledge base concept was introduced to this field of theoretical discussion by Laestadius (1998) and Asheim and Gertler (2005). The authors argue that knowledge sourcing and interactive innovation processes in industries are strongly shaped by their specific knowledge base. They distinguish the *analytical* from the *synthetic knowledge base*, each implying particular combinations of tacit and codified knowledge, different knowledge exchange partners and knowledge sources, various types of innovation, and different spatial dimensions of knowledge transfer relations.

The actual array of literature on the automotive industry draws ambiguous pictures concerning the crucial knowledge base for *automotive* manufacturing: Frequently, industries like the automotive industry or the machinery sector are said to be shaped in particular by the *synthetic knowledge base*. According to this body of literature, these industries strongly rely on engineering expertise and tacit knowledge, and interactive learning appears mainly along the value chain between customer and supplier (Dicken, 2007; Sturgeon et al., 2008). However, there is also literature to be found on science-based activities in the automotive industry, such as Krätke (2010), Frenken et al. (2004), Calabrese (2001), Becker and Peters (2000), Thomke (1998), or Peters and Becker (1997). Their findings give rise to expectations that developing and producing automobiles are primarily reliant on *analytical knowledge* input. Though all these studies provide hints to which *knowledge base* is the crucial one in this industry, so far little research has been done in terms of analysing one particular automotive cluster by explicitly drawing on the *knowledge base* concept.

In this paper I investigate the nature and geography of knowledge sourcing and interactive innovation processes of Southwest Saxony's automotive firms (from now on AutoSWS firms) in order to answer the central research question: On which *knowledge base* configuration rely the AutoSWS firms?

Moreover, SWS still is the unchallenged centre of automotive manufacturing in eastern Germany. However, its automotive industry finds itself in an uncertain position, stuck in the middle between the highly innovative western automotive centres driven by large investments in R&D, and low-cost sites in Central and Eastern European countries (Juergens and Meißner, 2008). Since SWS is not competitive with its eastern counterparts concerning labour costs, it will be exceedingly interesting to figure out upon which *knowledge base* the AutoSWS firms rely to stay competitive, and whether this special orientation will actually be beneficial for that region in the end.

In order to shed light on the nature and geography of knowledge sourcing and interactive innovation processes, I apply common descriptive statistics as well as social network analysis (SNA). The results are based on 58 standardised firm interviews and seven expert interviews. All the interviews were conducted between March 2009 and March 2010, mostly on a face-to-face base. Further details on the methods and interview partners will be given in Section 3. Before the empirical results will be presented in that section as well, Section 2 provides the conceptual background. Finally, in Section 4 I will summarize the key findings and draw some conclusions.

2. Comparing the synthetic with the analytical knowledge base

Following Asheim and Gertler (2005), I argue that innovation processes of firms and industries differ substantially between various sectors and are strongly shaped by their specific *knowledge base*. Due to this idea, two types of *knowledge bases* and related activities can be distinguished: *analytical* (science-based) and *synthetic* (engineering based) (Laestadius, 1998). This typology goes beyond traditional knowledge typologies (e.g. the tacit-codified dichotomy) and thus provides a better understanding of knowledge creation in diverse industries. It helps to characterise the nature of the critical knowledge which the production process and innovation activity cannot do without. According to Asheim et al. (2007a, p.12), this distinction always "refers to ideal-types, most activities are in practice comprised of more than one knowledge base. The degree to which certain knowledge bases dominates, however, varies and is contingent on the characteristics of the firms and industries". Each *knowledge base* implicates specific combinations of tacit and codified knowledge (Polanyi, 1966; Nonaka and Takeuchi, 1995), qualifications and skills that are required by organisations as well as different innovation challenges and patterns of knowledge exchange, which in turn affect the sensitivity to geographical distance for interactive learning (Amin and Cohendet, 2004).

Product and process innovations within industries that draw on the *synthetic knowledge base* take place mainly through the application or (new) combination of existing knowledge with the aim to solve a specific problem that comes up in the interaction with clients and suppliers (Table 1). Insofar, knowledge formation is characterised as a more inductive process. Characteristic activities are, to mention some examples, practical work in general, but also system design, prototyping, fine tuning, and testing. Many of these activities are visible within the automotive industry. The accentuation within "R&D" refers more to the "D-part" in the form of product or process development. If research is a matter of interest, it is mainly applied research, even within industry-university relationships. Although collaboration with universities and other research organisations can play a significant role for firms' innovation processes, interactive learning is often dominated by industry-industry links. Knowledge embodied in a particular technical solution or engineering work is at least partially codified (e.g. technical blueprints). However, due to the fact that knowledge often arises from experience gained at the workplace, and through learning by doing, using and interacting, tacit knowledge is typically more important than in the *analytical knowledge base* (Nonaka and Takeuchi, 1995; Johnson et al., 2002). The strong tacit nature of knowledge mostly requires being at the same time at the same place in order to share this knowledge (Audretsch, 1998). As a result, the *synthetic type* shows a relatively stronger sensitivity towards spatial proximity between innovation and production partners. Professional and polytechnic schools as well as on-the-job trainings are of particular importance to provide an adequate educational background facilitating concrete know-how, craft and practical skills. The knowledge creation and application process is dominated by the modification of existing products and processes with the aim of achieving higher efficiency and reliability of new solutions, or to raise the practical utility and user friendliness of products from the customers' perspectives. Accordingly, innovation processes in such industries have a mainly incremental nature. They mostly take place in existing firms, whereas spin-offs are relatively less frequent (Asheim and Coenen, 2005; Asheim et al., 2007a; Asheim et al., 2007b). Empirical research that refers to the automotive industry in Saxony in particular (Borras and Tsagdis, 2008; Beckord, 2007) or in eastern Germany in general (Juergens and Meißner, 2008; Scheuplein et al., 2007) strengthens expectations considering some of these characteristics to be found with regard to the AutoSWS firms, too.

Innovation processes within industrial settings that draw on the *analytical knowledge base* strongly depend on scientific knowledge input (Table 1). Knowledge creation is often based on deductive cognitive and rational processes, or on formal models that require abstraction skills. Examples are laboratory-based research or scientific discourses. Basic and applied research as well as systematic product and process development belong to the core activities of firms. In order to turn knowledge into innovation successfully, firms often have their own R&D departments, but also rely profoundly on research results of universities and other research organisations. The strong influence that comes from the scientific basis is also reflected by high academic spin-off activities. Knowledge inputs and outputs involved in innovation processes always include combinations of tacit and codified components (Nonaka and Takeuchi, 1995; Johnson et al., 2002). Face-to-face contacts facilitate exchanges of both; nevertheless, for the *analytic* case face-to-face-contacts are less important than they are for the *synthetic* case, because knowledge is more often codified, and therefore easier to exchange between globally distributed actors (Asheim et al., 2007b). There are several reasons for the strong codified knowledge content to exist: knowledge generation is often based on reviews of existing studies and the application of scientific principles and methods, innovation processes are rather formally organised (e.g. in R&D departments) and results tend to be documented in reports, electronic files or patent descriptions. These activities require people with specific qualifications and capabilities such as analytical skills, abstraction, theory building and testing, and documentation. As a consequence, the core of the work-force needs university education and/ or research experience. The application of knowledge in such industries is often integrated in more radical product or process innovations. These innovations often build starting points for new start-ups and spin-offs (Asheim and Coenen, 2005; Asheim et al., 2007a; Asheim et al., 2007b). Since SWS is relatively well-endowed with R&D-oriented public organisations that are focused on automotive topics (see 3.1), the AutoSWS cluster is potentially driven by a strong *analytical knowledge base*.

Table 1. *Synthetic vs. analytical knowledge base*

	Synthetic knowledge base	Analytical knowledge base
Main rationale	Engineering based (know-how)	Science based (know why)
Knowledge creation	Inductive process, applied, problem related	Deductive process, formal models
Innovation process	Incremental innovation by application/ combination of existing knowledge	Radical innovation by creation of new knowledge
Knowledge exchange partners	Interactive learning with customers and suppliers	Research collaboration between firms (R&D departments) and research orgs.
Knowledge content	Strong tacit knowledge content (concrete know-how, craft, practical skill)	Strong codified knowledge content (documentation in patents and publications)
Spatial proximity	High importance of spatial proximity	Low sensitivity for spatial proximity

Source: Own modification of Asheim and Gertler (2005) and Moodysson et al. (2008)

In the following empirical section of this paper I will analyse a number of indicators with the aim of identifying which *knowledge base* is the crucial one for the production and innovation process of the AutoSWS firms.

3. Knowledge sourcing and interactive innovation of automotive firms in Southwest Saxony

Before I will go further into detail concerning the empirical results of this case study, I will describe the regional economic and institutional setting the AutoSWS firms are embedded in (3.1). After that I will refer to data and methodology issues (3.2) as well as the basic firm characteristics (3.3). The core of my empirical work deals with the recruitment sources (3.4), the firms' innovation performances (3.5), and lastly I will profoundly analyse the firms' knowledge networks (3.6).

3.1 Southwest Saxony: institutional framework for the development of the automotive industry

Southwest Saxony (SWS) is located in the south-western part of the Free State of Saxony and borders on the federal states of Thuringia and Bavaria in the West, and the Czech Republic in the South (see Fig. 1). The population of SWS is about 1.6 million and stretches across four counties and the major city, Chemnitz (244.000). As the region was part of the former GDR, its economic system had to undergo extensive transformation processes after the Collapse of Communism in 1989. In 2009, the unemployment rate in SWS (13%) was still considerably higher than the German average (8%). The region is strongly shaped by its manufacturing activities: whereas SWS's employment share in the manufacturing sector was 27% in 2009, the corresponding value for Germany was 19% (IHK Chemnitz, 2010; Bundesagentur für Arbeit, 2010; Statistisches Bundesamt, 2010).

Figure 1. *Location of automotive firms interviewed*
Source: Cartographic elaborations based on own research data.

SWS has a rich history in producing cars and is still the unchallenged centre of automotive manufacturing in eastern Germany (Scheuplein et al., 2007). The 58 automotive firms interviewed do not only profit by the spatial proximity to adjacent OEMs (Volkswagen in Mosel, Chemnitz and Dresden, as well as BMW and Porsche in Leipzig). They also benefit from specialised research and education facilities nearby (see Fig. 1) (Blöcker et al., 2009).

Besides, there are a number of organisations in SWS which build up a fairly thick supportive infrastructure targeting the competitiveness of the regional economy. The Saxony automotive supplier network AMZ is the central cluster initiative that promotes networking between automotive suppliers along the value chain (Scholta, 2005). Parallel network initiatives are run by Volkswagen Sachsen GmbH and the Automotive Cluster Ostdeutschland ACOD. Other institutions that target the regional industry's development, though without a special focus on the automotive industry, are the regional Chamber of Industry and Commerce in Chemnitz as well as the Saxony's Economic Development Agency in Dresden (Beckord, 2006; Borras and Tsagdis, 2008).

3.2 Data and methodology

The case study is based on standardised personal interviews with CEOs or executives of 58 of the 112 automotive firms (52%) I identified in Southwest Saxony. My sample is restricted to manufacturing firms which clearly focus on producing automotive parts, components, modules and whole systems, or firms that produce bodies and trailers (see Table 2). The identification of regional automotive firms is based on own desktop research and different data bases offered by the regional automotive cluster initiative AMZ, the Saxony Economic Development Corporation, and Creditreform.

All interviews with firm representatives were conducted between March and October in 2009 and contained primarily quantitative elements. In March 2010 seven semi-standardised expert interviews followed in order to discuss the interpretation of some preliminary results. One general outcome of these expert interviews was that the sample and its subgroups (see 3.3) can be seen to be representative for the whole population. Correspondingly, the picture I will draw in the course of the following analyses should provide a comprehensible understanding of knowledge sourcing and innovation processes in the SWS automotive industry *as a whole*.

In order to analyse knowledge sourcing and interactive innovation processes, I apply a combination of descriptive statistics and sociometric techniques in the form of social network analysis (SNA) (Wasserman and Faust, 1994; Scott, 2000; Ter Wal and Boschma, 2009). Thus, my study contributes to a growing body of case studies in economic geography and regional economics applying SNA (see, for example, Krätke, 2010; Graf, 2010; Boschma and Ter Wal, 2007; Giuliani and Bell, 2005; Morrison, 2008). The analysis contains 630 technology-oriented knowledge relations as well as 480 market knowledge relations.

3.3 Basic firm characteristics

Nearly half of the 58 participating firms categorise themselves as second-tier-suppliers (i.e. suppliers of automotive components). First-tier-suppliers (i.e. suppliers of modules and whole systems), third-tier-suppliers (i.e. suppliers of standard parts and materials), and manufacturers of bodies and trailers make up the second half in more or less equal parts. Two thirds of all interviewed firms maintain direct supplier relationships with OEMs either partly or exclusively (Table 2).

Furthermore, we identify a predominating SME structure, on average 169 employees per firm. Only every fifth firm is large-sized. In comparison to their western German counterparts, eastern German automotive firms are on average considerably smaller (Günther et al., 2005; Scheuplein et al., 2007). The sample consists mainly of firms which have been founded right after the Fall of the Wall. Nevertheless, SWS shows a long tradition of automotive manufacturing. The region was not only the cradle of eastern Germany's automotive industry but also one of the three places in Germany (besides Ruesselsheim and Stuttgart) which produces cars since more than one hundred years (Boch, 2001). Therefore, it is not surprising that seven out of 58 firms show trajectories reaching back to the 19th century.

Lastly, the sample shows a balanced picture of independent firms and those which are owned by another company. In the last mentioned case, most of the owning companies are located in western Germany. They usually influence the daily business at the SWS' production sites. According to what Scheuplein (2007) already stated with regard to the eastern German automotive industry in general, a number of location decisions are made outside the region. This can be interpreted as a risk factor for this region when it comes to declines in automotive production.

Table 2. *Categorisation of automotive firms (n=58) within SWS*

Firm features			**n**	**%**
Function	1st-tier-supplier		13	22
	2nd-tier-supplier		26	45
	3rd-tier-supplier		9	16
	Manufacturer of bodies and trailers		10	17
Size by employees (FTE)	large	>250	11	19
	medium	50-249	29	50
	small	<50	18	31
Founding year	established before 1990		22	38
	established 1990-2009		36	62
Owner structure	owned		30	52
	independent		28	48
Total (for each feature)			58	100

3.4 Human capital and recruitment sources

The investigation of human capital and recruitment sources provides a first hint to figure out which *knowledge base* is the crucial basis for automotive firms within SWS in order to meet market requirements. The figures presented in Table 3 clearly go in line with the assumption that the automotive firms located in SWS provide good examples of an industry that strongly depends on the *synthetic knowledge base*. The by far highest share of labour consists of workers which took part in practical oriented vocational education and on-the-job-trainings. Only one out of ten employees shows an academic degree. Thereof, the great majority has an educational background in engineering studies reflecting the high importance of technical know-how. At least every tenth graduate is educated in other subjects, for example business administration, which typically represents the white collar management positions. Natural scientific education plays a minor role whereas artistic studies with a rather creative background do not play a role at all as the group of firms interviewed shows.

Table 3. *Educational background of employees of automotive firms (n=58) in SWS*

Educational background	**Percentage**	
Higher than or equal to bachelor's degree	9.7	(100.0)
Thereof:		
Engineering		81.7
Natural sciences		5.4
Artistic studies (e.g. arts, media)		0.0
Others (e.g. business studies)		12.9
Lower than bachelor's degree	90.3	
Total	100.0	

Table 4 underlines the clear tendency of AutoSWS firms to build on applied and problem-related know-how rather than to search for talented people doing basic research (know why), which is said to be pivotal for developing the *analytical knowledge base*. Universities as a source of recruitment are ranked considerably minor in importance in comparison to universities of applied sciences: More than 70% of the participating firms value universities of applied sciences as "very important" or at least "important" for recruiting highly qualified labour whereas the corresponding share for universities does not even score half that value. At least more than 40% indicated other firms of the automotive sector to be "(very) important". The potential of profiting from *related variety* – i.e. raising innovative power through cross-sectoral labour mobility (Boschma et al., 2009; Frenken et al., 2007) – seems to be widely unexploited so far. If other sectors play a role as a recruit source, the firm representatives most frequently mentioned the mechanical engineering sector. Since this "neighbouring" cluster managed to develop and keep high sophisticated engineering competences over decades in SWS as well, and due to the fact that modern automotive production lines strongly depend on using tailor-made machines, there is a strong potential within this region to profit from strengthening *related variety* through inter-cluster labour mobility.

Besides these differences in evaluating diverse kinds of recruitment sources, we notice that selecting highly skilled labour is mainly concentrated on SWS: the average automotive firm in SWS gains its personnel from recruitment sources in close spatial proximity rather than from universities or companies far away from their own location. On the one hand, this regional focus might be due to SWS's traditionally well established system of higher education, particularly in terms of engineering-oriented degrees. On the other hand, firm representatives alluded that SWS, although having undergone decisive restructuring processes since the destruction of the Iron Curtain, has difficulties to compete with automotive clusters from western Germany or other European countries in attracting highly qualified workers from other regions. This is considered as being a result of the comparatively lower attractiveness in terms of income levels and living conditions. A relatively low share of high potentials weakens the firms' *absorptive capacity* which is the ability to recognize and exploit relevant external knowledge (Cohen and Levinthal, 1990).

Table 4. *Recruitment sources for automotive firms (n=58) in SWS*

Recruitment source	"Very important"/ "important" (percentage)	Average importance[1]		
		Regional	National	International
Universities of applied sciences[2]	72.4	4.1	2.4	1.2
Firms of the same sector	43.1	3.0	2.3	1.3
Universities	29.3	3.1	2.2	1.2
Firms of different sectors	5.2	2.2	1.6	1.2
Average		3.1	2.1	1.2

[1] 1 = not important, 5 = very important
[2] The German "Fachhochschulen" (engl. = universities of applied sciences) are comparable with technical colleges or polytechnics in other countries

If the results that can be sketched out of Table 3 and Table 4 are combined, we see that both, the relatively high importance of applied and engineering-based knowledge as well as spatial proximity to recruitment sources, are further hints to the fact that the *synthetic knowledge base* is of particular importance for the working process in SWS's automotive cluster.

3.5 Firms' innovation performances

Table 5 provides an overview of the firms' concrete engagement in particularly innovative activities. Considering the period from 2006 until 2009, more than 80% of the 58 analysed AutoSWS firms claim to have conducted process innovations. This is followed by ca. 60% of firms that have developed and commercialised new products (including services) whereof two-thirds were not merely new to the firm, but new to the relevant market as well. In nearly 50% of all cases organisational structures have been fundamentally changed during this period, reflecting the ongoing restructuring processes within the automotive industry in general, and within eastern Germany's economy in particular. A considerably lower share of firms changed market related strategies or marketing concepts. Behind these aggregated figures we discover that branch plants are stronger in process innovations while the "independents" are better in developing product innovations.[1] One possible explanation for this difference can be found in Scheuplein (2007) who discovered that extra-regional mother companies (especially OEMs) often see eastern Germany as an experimental ground for testing new production and logistic processes.

Table 5. *Percentage of automotive firms (n=58) in SWS engaged in innovative activities 2006-2009*

Innovative activities (2006-2009)	Percentage
Process innovation	82.8
Product / service innovation	62.1
New / significantly changed organisational structures	46.6
Product / service innovation - new to market	41.4
New / significantly changed strategy	36.2
New / significantly changed marketing concept	31.0

On average, between 2006 and 2009 only one fourth of the firms' turnovers resulted from the sale of definitely new products or new services (Table 6). The weak performance of regional automotive firms in generating radical technological innovations indicates that the *analytical knowledge base* is rather underpronounced. However, it is not true to state conversely that incremental innovations are of higher importance instead – which would rather be a feature of the *synthetic knowledge base*. Slightly modified services and products only account for another fourth of the firms' turnovers. The remaining half – the major share – refers to unchanged products or services, indicating the low efforts of many firms in coming up with new technical solutions.[2]

Table 6. *Average share of SWS automotive firms' turnover (n=58) with new products 2006-2009*

Average share of turnover (2006-2009) with:	Percentage
New products / services	25.6
Slightly changed products / services	24.8
Unchanged products / services	49.6
Total	100.0

Patent statistics give further hints that radical innovations are rather seldom in the SWS automotive sector: Only one fourth of the tested firms has applied for patents between 2006 and 2009, on average five patents per firm, whereof almost every third patent was a co-production with one or even

[1] For a deeper understanding of the acquisition of 'competencies' in subsidiaries of manufacturing companies, see, for example, Fuchs (2008).
[2] These results have to be interpreted carefully because standard deviation figures indicate high disparities regarding the specifications made by the firms.

more organisations external to the firm (Table 7). In contrast to industries that draw stronger on the *analytical knowledge base* (cf. the work of Plum and Hassink (2011) on biotechnology firms in another German region) we can conclude that patents as a kind of transmitter of codified innovation related information are rather underrepresented in the automotive industry of SWS.

Table 7. *Patent activities of automotive firms (n=58) in SWS 2006-2009*

Patent statistics (2006-2009)	
Share of firms that have applied for patents (n=58)	24 %
... thereof share of firms that have applied for co-patents (n=14)	29 %
Average number of patent applications (n=14)	4.8
Median number of patent applications (n=14)	2.5

When we have a look at the allocation of R&D employees (i.e. personnel that is primarily occupied with the development of new products, services and processes), only every third firm indicated to employ R&D employees, namely 6.5 (FTE) on average and 5.0 (FTE) as the median number (Table 8). With regard to the 39 remaining firms that do not employ any full-time R&D staff the average share of time of workers dedicated to R&D is no more than 2% of their working time. In addition, only every tenth firm indicated to run an own R&D department.[3] As such, basic research and development plays a minor role in contrast to the application or new combination of existing knowledge, indicating a strong concentration on the *synthetic mode of knowledge creation*. Besides the relatively low performance in developing human capital (Section 3.4), low investments in R&D activities hold the risk of decreasing the firms' *absorptive capacity* – a critical aspect of achieving competitiveness.

Table 8. *R&D Employees in SWS automotive firms (n=58)*

R&D Employees (FTE)	
Share of firms with R&D employees (n=58)	33 %
Average number of R&D employees (n=19)	6.5
Median number of R&D employees (n=19)	5.0
Share of firms with an R&D department (n=58)	10 %
Average share of time of the other workers[1] dedicated to R&D (n=39)	2.0

[1]Other workers refer to the personnel in firms with no R&D employees (n=39)

3.6 Knowledge exchange patterns: market and technological knowledge networks

Gaining access to technological knowledge is a precondition for automotive firms to further product and process innovation. However, in order to bring successfully innovations to the market, know-

[3] In the case of the automotive industry R&D department has to be understood in a broader sense. The work of such departments regularly does not (only) include basic research and development but (also) processes which would better be described as applied engineering.

ledge of market issues is a crucial factor for firms' competitiveness, too (Boschma and Ter Wal, 2007). This type of knowledge includes, for example, information concerning consumer preferences, market developments, competitors' strategies, or product faults. I consider this distinction to gain a more fine-grained insight regarding the question with whom and over what distances the AutoSWS firms exchange market related knowledge in comparison to partners with whom they share knowledge concerning technological issues (Figures 2 and 3). The case study focuses on the whole system of knowledge linkages appearing within SWS' automotive cluster and crossing its boundaries. Thus, the aggregated data following hereafter does not necessarily reflect the particular knowledge network structure of one specific firm.

Knowledge flows between AutoSWS firms

Table 9 concentrates on potential knowledge flows between the 58 interviewed firms themselves. Fading out all other mentioned contacts, we are able to quantify particular dimensions of network structures and network positions within the region from a *sociocentric* perspective. Nevertheless, these network indicators have to be interpreted carefully: Although I try to give an overview of network activities within SWS's automotive cluster in general, we have to take into account that 58 out of 112 participated in our study. Hence blind spots within the clusters' network are inevitable.

Table 9. *Knowledge flows between 58 automotive firms in SWS: summary of sociocentric network indicators*

Indicator	TKN	MKN
Number of ties	9	8
Density	0.0027	0.0024
Components	50	50
In-degree centralisation/ dicho	0.0329	0.0332
In-degree centralisation/ valued	0.0228	0.0299
Out-degree centralisation/ dicho	0.0151	0.0332
Out-degree centralisation/ valued	0.0156	0.0299
Hybrid reciprocity	0.125	0.0000

As a result of the low number of identified ties (i.e. knowledge flows) between the 58 firms, the calculated network *densities* – expressed as a ratio between the actual number of ties and the maximum number of potential ties (Wasserman and Faust, 1994) – are quite low. While the Technological Knowledge Network (from now on TKN) is characterised by a density of 0.0027 (i.e. 0.27% of all potential inter-firm relationships between the interviewed firms are exploited), for the Market Knowledge Network (from now on MKN) this number is low as well with 0.0024. Both figures clearly demonstrate that continuous directed interactive learning between automotive firms within the region is scarce. Potential *gatekeepers* (Giuliani and Bell, 2005; Graf, 2010) typically do not diffuse innovation relevant knowledge throughout the cluster.

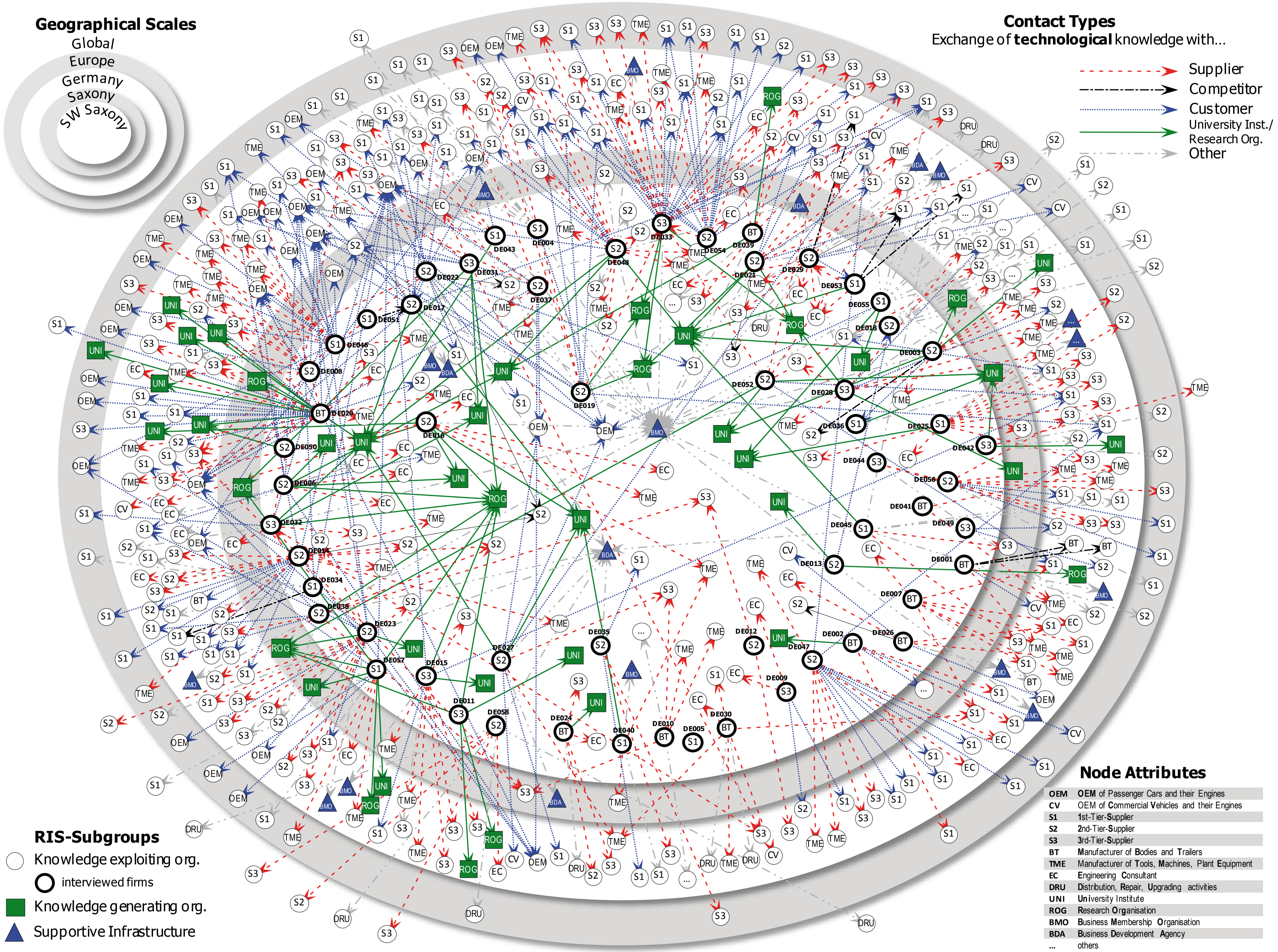

Figure 2. *Technological knowledge network of automotive firms (n=58) in SWS.*
Source: UCINET 6, elaborations based on own research data.

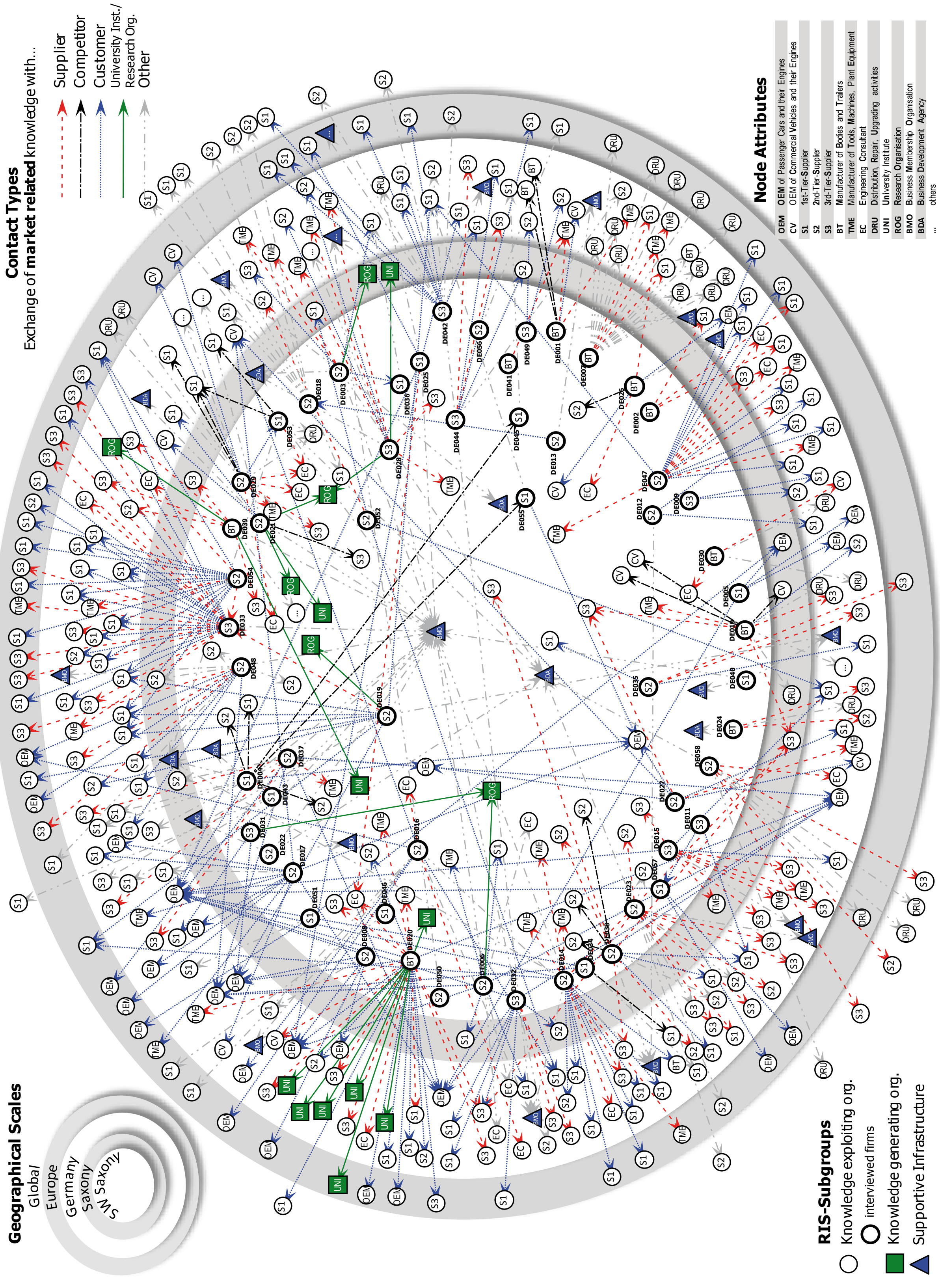

Figure 3. *Market knowledge network of automotive firms (n=58) in SWS.*
Source: UCINET 6, elaborations based on own research data.

According to the high number of network *components* we can deduce that the TKN as well as the MKN are of a rather fragmented nature. Each network consists of 50 components out of potentially 58 ones. In detail, they show completely identical component structures: Each network contains four dyadic components and two components with three members in each case. All other firms remain completely isolated. Another similar indicator that is helpful to analyse network structures is the degree of *centralisation*. The stronger a network is centralised, the more hierarchical is its architecture. In this case, all centralisation indices are relatively low and therefore point to a rather homogeneous structure. Combined with the very low network *densities* it becomes obvious that this homogeneity of network positions is situated on a very low level of inter-firm knowledge exchange activities within the regional automotive industry.

The *hybrid reciprocity* measure indicates the share of reciprocal relations. For the TKN, only one out of nine relations is reciprocal, i.e. only in one case both firms designate each other to be a knowledge exchange partner. For the MKN there are no reciprocal relations at all. This finding shows that even though firm X mentioned another firm Y to be an important knowledge source, this does not necessarily mean that firm Y points out firm X as a relevant knowledge network partner in return. As a consequence, knowledge flows are not automatically bidirectional. Nevertheless, I will use the term knowledge *exchange* relationships in the following keeping this peculiarity in mind.

Nature of knowledge flows

Table 10 shows how the average AutoSWS firm describes the characteristics of *technology oriented* knowledge interactions by differentiating between practical vs. scientific oriented knowledge transfers and those which contain a mixture of both. In doing so we are about to leave the *sociocentric* perspective (which was restricted to the networking activities between the interviewed firms only) and refer to the aggregated examination of the firms' complete *egocentric* knowledge networks. Seven out of ten knowledge interactions are clearly practical-oriented. Hence, interactive learning between AutoSWS firms and other organisations are rather characterised by inductive processes. These firms use the knowledge provided by collaborators in order to solve a specific product- or process-related problem. They learn and create knowledge predominantly by doing, using and interacting (the "DUI"-mode). However, at least one third of all knowledge interactions contains scientific content as well, indicating that although the *synthetic, engineering-based knowledge* content is prevalent, production and innovation processes in SWS' automotive industry cannot work without any *analytical, science-based knowledge* input. The additional average importance measures highlight the high relevance of practical oriented knowledge, though the minority of "mixed knowledge flows" is ranked highest.

Table 10. *Characteristics of knowledge flows*

Knowledge Content	TKN		
	n	%	AvImp
practical	423	67.1	3.6
scientific	50	7.9	2.9
both	157	24.9	4.0
Total	630	100.0	3.7

Notes: n = number of knowledge links, AvImp = Average importance for firms' innovation performance (1 = not important, 5 = very important)

Spatial organisation of knowledge flows

Furthermore, we observe that relatively close distances to network partners are important to gain access to other knowledge sources that are external to the firm (Table 11). One possible explanation for this spatial boundedness of knowledge flows – a feature of the *synthetic knowledge base* – is the great deal of practical oriented knowledge which is highly tacit in nature (Sturgeon et al., 2008), demanding face-to-face interactions on a regular basis. Another explanation for this rather regionally and nationally bounded pattern of knowledge flows can be found in the geographical distribution of supply chains. Companies with whom SWS automotive firms exchange knowledge are typically companies with whom they are connected along commodity chains as well. Production networks and knowledge networks co-evolve in this industry. Knowledge is typically product-based, not only in terms of technological knowledge, but also concerning market potentials. Since Germany can be regarded as the core of the European automotive manufacturing (VDA, 2010) as well as of machinery engineering (VDW, 2010), it should not be surprising that the product-based knowledge flows remain mainly within the national borders.

Going into greater detail, the geography of interactive innovation processes within the TKN looks as follows: Three out of ten knowledge relationships stay within SWS. Since only 5% of all 630 contacts refer to the wider regional context, i.e. the rest of Saxony, it seems to be a justifiable stating that SWS is the core of automotive expertise in Saxony, while Saxony itself is regarded as being the unchallenged centre of automotive competence in eastern Germany as a whole (Scheuplein et al., 2007). Nevertheless, the gross of contacts refers to the wider national context. In fact, a considerable share of knowledge pipelines connects the SWS automotive cluster with other (western) German automotive hot spots like the regions around Wolfsburg (with Volkswagen's headquarters) in Lower Saxony, Stuttgart (Porsche and Daimler) in Baden-Württemberg, or Munich (BMW) and Ingolstadt (Audi) in Bavaria. Knowledge flows on an international scale make up only 16% of all relations, clearly dominated by intra-European knowledge flows. According to the evaluation of each contact with respect to its *importance* for the firms' innovation performance, knowledge flows on the national level rank the highest score in contrast to global contacts which rank lowest. This rather qualitative finding highlights the mere quantitative outcomes described before, i.e. the dominant integration on the national level and the rare use of knowledge from the "outside".

Compared to the share of contacts indicated for the TKN, the extra-regional relations within the MKN play a more important role. Nevertheless, international contacts stay clearly underrepresented, too. The indicator describing the average *importance* of contacts shows that there is no clear picture indicating that short distance relationships are of greater or minor significance in order to receive market information in comparison to relationships that transcend regional or national boundaries.

Table 11. *Geography of the TKN and MKN*

	TKN			MKN		
Geographical scale	**n**	**%**	**AvImp**	**n**	**%**	**AvImp**
Southwest Saxony	178	28.3	3.5	104	21.7	3.8
Saxony	33	5.2	3.5	23	4.8	3.6
Germany	318	50.5	3.9	266	55.4	3.8
Europe	84	13.3	3.5	69	14.4	3.5
Global	17	2.7	3.0	18	3.8	3.4
Total	630	100.0	3.7	480	100.0	3.8

Notes: n = number of knowledge links, AvImp = average importance for firms' innovation performance (1 = not important, 5 = very important)

Contact types

In addition to the spatial dimension of knowledge flows, I examined which *types of contacts* are particularly important to exchange technological or market related knowledge in order to strengthen the firms' capacity (Table 12). No matter if we refer to the TKN or the MKN, knowledge is mostly exchanged with suppliers and customers along the value chain. This group of contact types makes up more than two thirds of total relations each. As such, this general finding corresponds with the assumption that the *synthetic knowledge base* is particularly relevant for the enhancement of competences adapted to automotive products and related processes.

According to the sheer number of contacts, knowledge formation along the value chain within the TKN is rather supplier-driven, whereas customers rank higher with respect to their average *importance* for firms' innovation performance. Suppliers of parts, components, and whole systems form due to their sum in total the largest sub-section of the supplier group. Half as much supplier-oriented ties refer to suppliers of tools, machines, and plant equipment (TME) with a stronger focus on process innovations compared to product innovations. Engineering consultants (EC) as "suppliers" of engineering and R&D services, technical testing, and analysis, are not that relevant, indicating the low efforts of AutoSWS firms in developing new products. In terms of deliberately chosen network partners, competitors play a minor role only. Customers rank directly below suppliers. Today, more and more frequently OEMs do not simply specify product-related requirements to their suppliers, they more and more delegate engineering responsibilities especially to first-tier-suppliers. Insofar, interactive learning along buyer-supplier-relations is highly relevant for innovation processes within the automotive industry (Sturgeon et al., 2008). In contrast to the *analytical knowledge base*, sharing knowledge with university institutes and research organisations is rather seldom. We may assume that other automotive clusters (e.g. around Stuttgart, Munich, or Wolfsburg) feature a higher percentage of science-oriented relations particularly due to a higher level of *absorptive capacity* of the clusters' firms (cf. sections 3.4 and 3.5). Almost 20% of all contacts within the TKN refer to the remaining group of other organisations. This group is clearly dominated by relationships either with sister, mother or daughter enterprises (SMD), or with business membership organisations and business development agencies (BMO/BDA) as representatives of the supportive infrastructure. Nearly one out of ten technological oriented knowledge transfers stay in-house (SMD). These contacts rank relatively high with regard to their *importance* for the firms' innovativeness. BMOs and BDAs score 7.3% and therefore may play a role in the firms' TKNs as well. They function as knowledge brokers. These bodies screen and provide technical information as well as market insights, and they try to increase networking between firms. According to the frequency of mentions, the cluster initiative AMZ is the major intermediary within this network (see the central blue triangle "BMO" in Figures 2 and 3).

To which extent can we observe different ranking orders of contact types for the MKN? According to the total number of mentions, again interactive learning along the value chain is of particular importance. However, the "centre of gravity" has moved to the customer side. If one takes the perspective of the AutoSWS firms, the customers are closer to the market. They can provide the latest data on market issues which is crucial for evaluating future market trends, and it helps to estimate market potentials of further developed products as well. University institutes and research organisations lost a considerable number of mentions in favour of other contact types. When we have a closer look at the sub-categories of others, we recognize a reverse order in comparison with the TKN: The share of mentions for BMOs and BDAs has slightly increased, whereas the corresponding share for the category of SMD remained nearly at the same level. In terms of the *importance* rating we observe relatively equal evaluations between the TKN and the MKN.

Table 12. *Contact types within the TKN and MKN*

Contact type	TKN			MKN		
	n	%	AvImp	n	%	AvImp
Supplier	223	35.4	3.5	122	25.4	3.6
1st-/ 2nd-/ 3rd-tier-supplier	126	20.0	3.5	74	15.4	3.4
TME	67	10.6	3.5	31	6.5	3.8
EC	30	4.8	3.7	17	3.5	4.2
Competitor	14	2.2	3.2	20	4.2	3.5
Customer	191	30.3	4.0	188	39.2	3.9
University inst. / Research orgs.	80	12.7	3.5	18	3.8	3.6
Other	122	19.4	3.6	132	27.5	3.7
DRU	10	1.6	3.1	26	5.4	3.3
SMD	58	9.2	3.9	45	9.4	4.1
BMO/BDA	46	7.3	3.2	53	11.0	3.4
Other	6	1.3	4.0	8	1.7	4.0
Total	630	100.0	3.7	480	100.0	3.8

Notes: n = number of knowledge links; AvImp = average importance for firms' innovation performance (1 = not important, 5 = very important); TME = manufacturers of tools, machines and plant equipment; EC = engineering consultants (providers of engineering and R&D services, technical testing and analysis); DRU = providers of distribution, repair and upgrading services (concentration on wholesale and retail trade and/ or repairing (and upgrading) of motor vehicles and parts); SMD = sister/ mother/ daughter company; BMO/BDA = business membership organisations/ business development agencies

Combining contact types and spatial scales

Table 13 shows which contact type dominates a certain spatial level. Technology oriented knowledge flows that stay within the regional boundaries exhibit relatively high shares in contacts with suppliers. In contrast, the corresponding proportion of knowledge transfers with customers is more dominant on the wider national and European scale. Furthermore, for the local and regional level we can identify a relatively high proportion of relations with research oriented institutions as well as with bodies of the supportive infrastructure. This finding hints to a well-balanced Triple Helix system within SWS, connecting industry, state and academia (Etzkowitz and Leydesdorff, 2000). The comparatively high percentage of TKN links to SMD companies at the national and international level goes in line with the assumption that a considerable number of SWS automotive firms is influenced by company internal decisions taken outside the region. Lastly, the more detailed sub-categorization of contact types within the TKN reveals a strong endogenous potential for engineering-based knowledge inputs (cf. the corresponding data for contacts to TME and EC).

The most striking differences of the MKN's spatial distribution of different knowledge exchange partners in comparison to the TKN's distribution are the following two: First, at the national and European level the share of relations with customers even exceeds the corresponding shares for the TKN at the expense of the supplier shares. As such, customers who are located in other parts of Germany and Europe are – by number – the most important sources to receive market information from. Second, a closer look at the data presented in Table 13 confirms the visual impression caused by Figure 3 that BMOs and BDAs act as central providers of market knowledge at the local and regional level.

Table 13. *Dominance of different Contact Types depending on geographical scales of knowledge network links*

Contact type	**TKN** (n=630)					**MKN** (n=480)				
	SWS (178)	**Saxony** (33)	**GER** (318)	**EU** (84)	**Global** (17)	**SWS** (104)	**Saxony** (23)	**GER** (266)	**EU** (69)	**Global** (18)
Supplier	35.4	33.3	37.7	28.6	29.4	29.8	21.7	26.7	17.4	16.7
1st-/ 2nd-/ 3rd-Tier-Suppl.	13.5	21.2	22.6	22.6	23.5	11.5	17.4	16.9	14.5	16.7
TME	11.8	6.1	11.9	6.0	5.9	9.6	4.3	6.8	2.9	0.0
EC	10.1	6.1	3.1	0.0	0.0	8.7	0.0	3.0	0.0	0.0
Competitor	3.9	0.0	2.2	0.0	0.0	11.5	4.3	2.6	0.0	0.0
Customer	10.7	12.1	39.6	48.8	5.9	14.4	26.1	46.6	59.4	11.1
University inst./ ROGs	28.7	39.4	4.7	1.2	0.0	8.7	8.7	2.3	1.4	0.0
Other	21.3	15.2	15.7	21.4	64.7	35.6	39.1	21.8	21.7	72.2
DRU	0.6	0.0	0.9	3.6	17.6	1.9	4.3	4.5	11.6	16.7
SMD	2.2	3.0	9.4	17.9	47.1	4.8	8.7	8.3	8.7	55.6
BMO/BDA	17.4	12.1	3.5	0.0	0.0	27.9	26.1	6.8	0.0	0.0
Other	1.1	0.0	1.9	0.0	0.0	1.0	0.0	2.3	1.4	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Notes: TME = manufacturers of tools, machines and plant equipment; EC = engineering consultants (providers of engineering and R&D services, technical testing and analysis); ROGs = research organisations; DRU = providers of distribution, repair and upgrading services (concentration on wholesale and retail trade and/ or repairing (and upgrading) of motor vehicles and parts); SMD = sister/ mother/ daughter company; BMO/BDA = business membership organisations/ business development agencies

4. Conclusion

The aim of my paper is to analyse the nature and the geography of knowledge sourcing and interactive innovation processes of Southwest Saxony's automotive firms. The main outcome refers to the prevailing knowledge source for the AutoSWS firms. It can be said that the conventional AutoSWS firm heavily relies on the *synthetic knowledge base*, whereas the *analytical knowledge base* is less important: R&D activities are rather weak and most likely weaker than, for example, in western German automotive clusters that contain large-scale R&D facilities of OEMs and leading first-tier-suppliers. The main part of the workforce is made up by blue-collar workers who are educated on-the-job and/or through vocational training. If higher educated personnel is needed, AutoSWS firms considerably prefer graduates of engineering-oriented programmes provided by adjacent universities of applied sciences. It becomes obvious that problem-related know-how is more important than expertise in basic research. On the condition that the firms manage to generate new products or processes, these innovations are of a rather incremental nature, that is based on the application or combination of already existing knowledge. Since engineering based, applied knowledge is more important than science based knowledge, the accumulation and transfer of particularly tacit knowledge plays a decisive role within the firms' production and innovation processes. It leads to a comparatively high sensitivity for spatial proximity between the firms and their knowledge network partners. Here, the SNA turned out to provide an excellent tool to make these knowledge flows visible. Although regionally-bounded interactions between the interviewed firms themselves are rare, we observe a multiplicity of knowledge transfers between the AutoSWS firms and regional suppliers, knowledge generating and cluster supporting organisations within SWS. Overall, the firms' TKN and MKN are dominated by vertical oriented interactions, connecting the AutoSWS firms with suppliers and customers along their value chains. These knowledge flows most often end within the boundaries of Germany, merely a few surpass these boundaries and thus progress to partners in other European countries.

These outcomes are mainly limited due to the key shortcomings of singular case studies in general: the outcomes cannot be generalised[4] due to its high degree of context-specificity. The given data, its analysis as well as its interpretation, refer to a specific industry-region-time-constellation. In the case of the AutoSWS firms, a relatively high share of production sites shows typical characteristics of branch plants, doing standardised work headquarters located outside the region instruct them to do. Besides, we find a handful innovative firms, some of them regionally rooted, original Saxon companies, profiting from the rich expertise in automotive production accumulated over a century in this region. Lastly, due to the fact that SWS was part of the former GDR, some businesses have undergone strong transformation processes since the German reunification. In order to prevent hasty generalisations in the shape of one-knowledge-base-for-all-automotive-clusters, more research is needed, which focuses on identifying the crucial *knowledge base* of automotive clusters in other regions, for example.

SWS's automotive industry finds itself in a precarious situation. It is stuck between the highly innovative western automotive development and production sites, and low-cost sites in Central and Eastern Europe. On the one hand, AutoSWS firms cannot compete with their eastern counterparts in terms of labour costs. Taking part in price competition with low-cost countries by cutting labour incomes is obviously not realisable, due to considerably higher costs of living, or because of the power of trade unions in Germany. On the other hand, the firms' low performance in the analytical mode of knowledge creation holds the risk of losing the capacity to come up with highly innovative technical solutions, which is a precondition to keep pace with their western counterparts.

[4] According to Yin (2009), the limitation of generalisation refers particularly to the statistical dimension of generalisation.

In the long run, a promising way for the automotive cluster in SWS to stay competitive is to add more *analytical knowledge* to its predominantly *synthetic-oriented knowledge base*. This offers a chance for the AutoSWS firms to significantly enhance their innovative capacity and at the same time to shorten the gap to the western production sites. This includes higher investments in private and public R&D infrastructures related to future topics in automotive manufacturing, as well as raising the human capital base in the firms through increasing the share of personnel with academic education. These investments strengthen the firms' absorptive capacity, i.e. the ability to recognize and exploit relevant external knowledge sources within the region and beyond. Additional measures which focus on strengthening the *analytical knowledge base* refer to the encouragement of knowledge transfers, particularly between industry and academia. They also refer to the promotion of university spin-offs, to raising incentives for graduates to stay within the region, and also to attracting high potentials from other European regions.

Future research on the optimal mix ratio of *knowledge bases* – within different constellations of industries and regions – is needed in order to further fine-tune competitive strategies for firms, regions, and nations, which build on the idea of *industrial knowledge bases*.

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6. Comparing knowledge networking in different knowledge bases in Germany

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Abstract

In order to learn more about sectoral differences of knowledge networking in a regional development context, we apply the knowledge base concept, distinguishing the analytical (science based) and synthetic (engineering based) knowledge base. We aim at comparing knowledge networking with the help of network analyses in two knowledge bases in Germany: the analytical knowledge base with the help of the biotechnology industry in the Aachen Technology Region and the synthetic knowledge base with the help of the automotive industry in Southwest Saxony. The paper concludes that there are some main differences found in the characteristics of knowledge networking between the two different knowledge bases.

1. Introduction

An extensive body of literature on geographies of knowledge flows and interactive learning identifies the region as the key level at which systemic interactions lead to innovations, and where economic processes are co-ordinated and governed (Morgan 1997; Cooke and Morgan 1998; Fritsch and Stephan 2005). Examples can be seen in partly overlapping theoretical templates, such as clusters, regional innovation systems and learning regions, which have been summarized by Moulaert and Sekia (2003) as territorial innovation models. These models put much emphasis on agglomeration effects in explaining the characteristics and the geography of knowledge networks, stressing geographical proximity as being important for the exchange of tacit knowledge, in particular. These theoretical concepts on the relation between innovation, knowledge, interactive learning and geography are recently challenged by the concept *knowledge bases* (Asheim and Gertler 2005), which stresses that industries differ substantially with regard to their specific knowledge base, of which three are distinguished: analytical (science based); synthetic (engineering based); and symbolic (creativity based). According to this new concept, the role of the agglomeration effects concerning the formation of knowledge networks cannot be generalized, but its importance depends on the specific knowledge base of the studied industries in a region.

Our paper does not aim at testing the knowledge base concept or asking which knowledge base drives which one of the industrial clusters we will analyse in this paper; we have done that before in two empirical papers (Plum 2011; Plum and Hassink 2011). This paper aims at comparing and explaining knowledge networking in two industrial clusters in Germany with the help of the knowledge base concept: the biotechnology industry in the Aachen Technology Region (from now on BioAC) which heavily relies on the analytical knowledge base, and the automotive industry in Southwest Saxony (from now on AutoSWS) which is above all driven by the synthetic knowledge base.

In doing so, the paper not only takes into account the growing importance of collaboration networks in the process of knowledge diffusion (Autant-Bernard et al. 2007), at the same time it recognizes that knowledge and innovation processes are too complex to assume that they have the same shape in every industry. Moreover, by using the knowledge base perspective we move beyond the more traditional body of research which rather tries to explain the structure and functioning of knowledge networks by means of firm-specific determinants and region-specific or extraregional factors (see, for example, the ERIS approach described in Sternberg 2000).

Both above-mentioned case studies were deliberately chosen because they represent typical industries with contrasting knowledge bases. We decided not to select two cases in one region, as the aim of the overall European Science Foundation research project in which this paper is embedded was to find out to what extent regional innovation policies aim at the specific demand of regional industries with a certain knowledge base.

The central research question is the following one: How do both industries differ with regard to their knowledge networks and how can these differences be explained by using the knowledge base concept? Accordingly, the more precise sub-questions are: What are the differences with regard to the labour mobility networks, mirrored by the sourcing for highly qualified labour, and how can we explain them? Which information sources external to the firm are particularly important in order to enhance the firms’ technological expertise? How intensive are knowledge interactions between the interviewed firms themselves and which are the most important knowledge exchange partners at all? Where are these partners located? And lastly, which differences can we identify with regard to the nature of knowledge flows?

In order to shed light on these questions, we apply social network analysis (SNA) and descriptive statistics. The results are based on 23 standardized firm interviews in the BioAC case and 58 standardized firm interviews in the AutoSWS case, as well as 15 expert interviews in total. Before the empirical research of our case studies presented in Section 4, Section 2 will give an overview of the theoretical framework, followed by Section 3 which deals with methodological issues and further details on our interview partners.We will complete this paper by providing the key findings in Section 5.

2. Theoretical framework: knowledge bases

Challenging traditional explanations of the geographical patterns of knowledge networks in the territorial innovation models (Moulaert and Sekia 2003), and following Asheim and Gertler (2005), we argue that innovation processes of firms and industries differ substantially between various sectors and are strongly shaped by their specific knowledge base. Due to this idea, three types of knowledge bases and related activities can be distinguished: analytical (science-based), synthetic (engineering based) (Laestadius 1998), and symbolic (creativity based). This typology goes beyond traditional tacit and codified knowledge typologies and thus provides a better understanding of knowledge creation in certain industries. It helps to characterize the nature of the critical knowledge which the innovation activity cannot do without. It has, however, strong similarities with Pavitt's (1984) taxonomy of sectors, namely, science-based, specialized suppliers, scale-intensive and supplier-dominated sectors (Fagerberg 2005, p. 16), as well as with more recently developed typologies (Castellacci 2008). Asheim and Coenen (2005, p. 1177) even state: "Our observations about industries with synthetic knowledge bases correspond closely to those sectors encompassed by the first two of Pavitt's categories (supplier-dominated and production-intensive). Similarly, the analytical category corresponds directly to Pavitt's science-based industries". Moreover, there are similarities with Malerba's (2005) sectoral innovation system approach.

Each single knowledge base implicates specific combinations of tacit and codified knowledge (Polanyi 1966; Nonaka and Takeuchi 1995), qualifications and skills that are required by organizations as well as different innovation challenges and patterns of knowledge exchange, which in turn affect the sensitivity to geographical distance for interactive learning (Amin and Cohendet 2004). Additionally, Asheim et al. (2011, p. 12) state: "As this threefold distinction refers to ideal-types, most activities are in practice comprised of more than one knowledge base. The degree to which certain knowledge bases dominates, however, varies and is contingent on the characteristics of firms and industries as well as between different type of activities (e.g., research and production)".

The biotechnology industry is often said to be a prototype for the analytical case (Gertler and Wolfe 2006), and the car industry for the synthetic case (Sturgeon et al. 2008). In the following we will describe the key features of the analytical and the synthetic mode of knowledge creation (Table 1).

Table 1. *Synthetic vs. analytical knowledge based networking*

	Analytical knowledge base	Synthetic knowledge base
Main rationale	Science based (know why) knowledge networking	Engineering based (know how) knowledge networking
Knowledge creation in knowledge networks	Deductive process; sharing formal models	Inductive process; applied, problem related knowledge networking
Innovation process in knowledge networks	Radical; innovation by creation of new knowledge	Incremental; innovation by application/ combination of existing knowledge
Knowledge network partners	Research collaboration between firms (R&D departments) and research orgs.	Interactive learning with customers and suppliers
Knowledge content in knowledge networks	Codified (documentation in patents and publications)	Tacit (concrete know-how, craft and practical skill)
Spatial proximity	Lower sensitivity; higher percentage of global networking	Higher sensitivity; lower percentage of global networking

Source: Own modification of Asheim and Gertler (2005) and Moodysson et al. (2008)

Innovation processes within industrial settings that draw on the analytical knowledge base strongly depend on scientific knowledge input. Knowledge creation is often based on deductive cognitive and rational processes, or on formal models that require abstraction skills. Examples with relevance to the biotechnology industry are laboratory-based research or scientific discourses. Basic and applied research as well as systematic product and process development belong to the core activities of firms. In order to turn knowledge into innovation successfully, firms often have their own R&D departments, but also rely profoundly on the research results of universities and other research organizations. The strong influence that comes from the scientific basis is also reflected by high academic spin-off activities. Knowledge inputs and outputs involved in innovation processes always include combinations of tacit and codified components (Nonaka and Takeuchi 1995; Johnson et al. 2002). Face-to-face contacts facilitate exchanges of both; nevertheless, for the analytic case face-to-face-contacts are less important than they are for the synthetic case, because knowledge is more often codified, and therefore easier to exchange between globally distributed actors (Asheim et al. 2007; Moodysson 2008). There are several reasons for the strong codified knowledge content to exist: (*i*) knowledge generation is often based on reviews of existing studies or on (*ii*) the application of scientific principles and methods; (*iii*) innovation processes are rather formally organized (e.g., in R&D departments); and (*iv*) results tend to be documented in reports, electronic files or patent descriptions. These activities require people with specific qualifications and capabilities such as analytical skills, abstraction, theory building and testing, and documentation. As a consequence, the core of the work force needs university education and/or research experience. The application of knowledge in such industries is often integrated in more radical product or process innovations. These innovations build starting points for new start-ups and spin-offs on a regular basis (Asheim and Coenen 2005; Asheim et al. 2007, 2011).

Product and process innovations within industries that draw on the synthetic knowledge base take place mainly through the application or (new) combination of existing knowledge with the aim to solve a specific problem that comes up in the interaction with clients and suppliers. Knowledge formation is characterized as a more inductive process. Characteristic activities are, to mention some examples, system design, prototyping, fine tuning, testing, and practical work in general. Many of these activities are visible within the automotive industry. R&D intensity is in general lower than in the first type. Overall, the accentuation within 'R&D' refers more to the 'D-part' in the form of product or process development. If research is a matter of interest, it is mainly applied research, even within industry-university relationships. Although collaboration with universities and other research organizations can play a significant role for firms' innovation processes, interactive learning is often dominated by industry-industry links. Knowledge embodied in a particular technical solution or engineering work is at least partially codified (e.g., technical blueprints). However, due to the fact that knowledge often arises from experience gained at the workplace, and through learning by doing, using and interacting, tacit knowledge is typically more important than in the analytical knowledge base (Nonaka and Takeuchi 1995; Johnson et al. 2002). The strong tacit nature of knowledge almost always requires being at the same time at the same place in order to share this knowledge (Audretsch 1998). As a result, the synthetic type shows a relatively stronger sensitivity towards spatial proximity between innovation partners. Professional and polytechnic schools as well as on-the-job trainings are of particular importance to provide an adequate educational background facilitating concrete know-how, craft and practical skills. The knowledge creation process as well as the application process is dominated by the modification of existing products and processes with the aim of achieving higher efficiency and reliability of new solutions, or to raise the practical utility and user friendliness of products from the customers' perspectives. Accordingly, innovation processes in such industries have a mainly incremental nature. They mostly take place in existing firms, whereas spin-offs are relatively less frequent (Asheim and Coenen 2005; Asheim et al. 2007, 2011).

Recently many studies have been carried out on the biotechnology industry (see among others: Cooke 2002; Owen-Smith and Powell 2004; Gertler andWolfe 2006; Tödtling and Trippl 2007; Waxell and Malmberg 2007; Moodysson 2008) and the automotive industry (Scheuplein et al. 2007; Sturgeon et al. 2008; Krätke 2010), focusing on knowledge networks in a regional economic context. Concerning the biotechnology industry, most authors agree upon some basic characteristics, such as the science-based character of the industry, the use of mainly codified knowledge, the importance of both internal R&D capacities as well as external knowledge sources and the “high pace of innovation, a substantial degree of uncertainty as well as long development times and high development costs” (Tödtling and Trippl 2007, p. 347). These characteristics go in line with the attributes ascribed to the analytical knowledge base mentioned above. The same counts for the characteristics of the automotive industry in relation to the synthetic knowledge base. However, there is a disagreement in the literature on the exact characteristics of external links (Tödtling and Trippl 2007).

Previous analyses of the biotechnology cluster in the Aachen Technology Region (Plum and Hassink 2011), and of the automotive cluster in Southwest Saxony (Plum 2011), have shown, that BioAC firms predominantly rely on analytical knowledge input, whereas for the production and innovation process of AutoSWS firms synthetic knowledge is more relevant. Within the empirical part of our paper we will examine in detail what these different knowledge base configurations mean with regard to the formation of knowledge networks and how this can be explained by using the knowledge base classification.

3. Data and Methodology

Before we will go into detail concerning the empirical results of our study, we will first explain the characteristics of our collected data, as well as the chosen methods. Our comparison of knowledge networking in two case studies is based on standardized personal interviews with CEOs or executives of 23 biotechnology firms within the Aachen TR (85% response rate) and of 58 automotive firms within Southwest Saxony (52% response rate). In addition, we conducted in sum 15 semi-standardized expert interviews in order to discuss the interpretation of some preliminary results. This group of experts contains cluster co-ordinators, policy advisors, representatives of public research and education organizations, and contact partners of ministries of North Rhine-Westphalia and Saxony. The interviews were conducted during 2008, 2009 and 2010.

In order to understand the nature and geography of innovation and interactive learning in these particular regional and sectoral settings, we apply a mix of common descriptive statistics and revealing sociometric techniques in the form of social network analysis (SNA) (Wasserman and Faust 1994; Scott 2000). Recently SNA has been applied in economic geography and regional economics increasingly. Studies by Graf (2011), Boschma and TerWal (2007), Cantner and Graf (2006), Giuliani and Bell (2005), Morrison (2008), Brandt et al. (2009) can be taken as proof for this statement (for a more general and analytic article on the use of SNA in economic geography, see Ter Wal and Boschma 2009).

SNA is based upon relational and attributes data. While the former data set refers to characteristics of network ties, the latter is related to respondents' and their network partners' characteristics. All contacts were mentioned explicitly by each firm we interviewed, describing with whom these firms exchange technological knowledge, no matter if this knowledge transfer is formalized or informal. As a consequence, each tie within the networks symbolizes an exchange of technology-related knowledge between two organizations. Further information the firms provided with regard to each contact referred to: (*i*) the type of relation (i.e., supplier, customer etc.); (*ii*) the importance of each relation for the firms' innovation performance, (*iii*) the similarity of knowledge assets exchanged; (*iv*) as well as the character of knowledge transfers (i.e., practical oriented, science oriented, or both). Additionally, the interviewees were asked to provide information with regard to attributes of their knowledge network partners. In detail, these attributes refer to: (*i*) the name of each organization; (*ii*) the precise location of this network partner; as well as to (*iii*) the industrial sector this organization is mainly active in.

Combining both sorts of data, namely, the relational as well as the attributes data, enables us to identify, map and value technology-oriented knowledge flows between the interviewed firms and other actors involved in interactive learning within and beyond the Aachen TR and Southwest Saxony respectively. The SNA-based results help us to address empirically each of the theory-led knowledge base characteristics with regard to knowledge networking for both industrial clusters. Accordingly, the outcomes deal with: (*i*) the dominating knowledge exchange partners; (*ii*) the specific spatial configuration of knowledge transfers; (*iii*) the typical content of exchanged knowledge; and (*iv*) the main rationale behind those knowledge processes (see Table 1). By using network analyses in the way described above we will be able to describe and explain patterns of knowledge networking of the BioAC cluster in comparison to the AutoSWS cluster from a knowledge base perspective.

4. Comparing knowledge networking from a knowledge base perspective

We will start the empirical section by investigating knowledge networking through labour mobility in 4.1, followed by discussing the sources of technology-oriented information in 4.2. The core of the empirical discussion comprehends knowledge networks between interviewed firms within both regions in 4.3, the geography of knowledge linkages in 4.4, the different types of knowledge network partners in 4.5 and finally the nature of knowledge flows in subsection 4.6.

4.1 Recruitment sources for highly qualified labour

Given that labour mobility facilitates the transfer of knowledge between organizations, sourcing for highly qualified employees can be seen to play a crucial role in constructing knowledge networks (Trippl and Maier 2010). Table 2 outlines from which sources the firms recruit their highly qualified labour in order to strengthen their knowledge bases. Whereas BioAC firms recruit their highly qualified labour in order to strengthen in particular their repertoire of science-oriented knowledge; recruitment patterns of AutoSWS firms mirror their search for rather applied and engineering based knowledge. Having a closer look at the figures presented, it becomes obvious that there are significant differences to be found: universities are of utmost importance for the BioAC firms, whereas the AutoSWS firms prefer universities of applied sciences. Innovation processes within BioAC firms rely heavily on talented people educated in conducting basic research (know why), and in creating new knowledge. Nevertheless, when we have a look at universities of applied sciences and their corresponding numbers, we see that education which primarily imparts how to apply knowledge in order to solve a practical problem is far from being unimportant. However, in contrast, AutoSWS firms aim stronger at attracting people who are trained in the application of predominantly engineering-based academic education (know how), that is, applied R&D is more important than basic research. Recruiting highly qualified staff from firms of the same sector is more important for the AutoSWS firms. We might interpret this outcome as a sign that these firms tend to concentrate on the combination of already existing knowledge within their knowledge networks, whereas BioAC firms also search – albeit on a relatively modest level – for brainpower coming from different sectors. Given that these sectors are related in terms of shared competences, the biotechnology firms may increase their potential to create radical innovations (cf. the paper on related variety by Frenken et al. 2007).

Table 2. *Recruitment sources for highly qualified labour*[1]

Recruitment source	"Very important"/ "important" (%)		Average importance[3]					
			Regional		National		International	
	BioAC	AutoSWS	BioAC	AutoSWS	BioAC	AutoSWS	BioAC	AutoSWS
Universities	82.6	29.3	3.4	3.1	3.3	2.2	2.1	1.2
Universities of applied sciences[2]	65.2	72.4	3.1	4.1	2.6	2.4	1.5	1.2
Firms of the same sector	30.4	43.1	2.5	3.0	2.3	2.3	1.9	1.3
Firms of different sectors	26.1	5.2	1.7	2.2	1.8	1.6	1.6	1.2
Average			2.7	3.1	2.5	2.1	1.8	1.2

[1] Highly qualified labour refers to the personnel which hold at least a bachelor's degree
[2] The German "Fachhochschulen" (engl. = universities of applied sciences) are comparable with technical colleges or polytechnics in other countries
[3] 1 = not important, 5 = very important

Another result which we can conclude from the dates represented in Table 2 refers to the importance of spatial proximity between the firms and the recruitment sources for highly qualified labour: no matter whether we refer to BioAC firms, or to AutoSWS firms, all firms tend to value recruitment sources higher, the shorter the spatial distances to the particular sources are. In general, systemic screening for talents on a global scale is seldom carried out. However, we find a slight tendency that BioAC firms, which aim at sourcing for analytical knowledge to a stronger extent than the AutoSWS firms do, are relatively more open to searching for high potentials on a global scale.

4.2 Sources of technology-oriented information

Knowledge networking is not only restricted to the exchange of knowledge between organizations or to the sourcing for labour. Knowledge networking – understood in a broader sense – can also refer to the activity of searching for and exploiting of other information sources external to the firm. Table 3 summarizes the type of firm-external information source that is of particular importance for the improvement of expertise in technology-related issues.

Table 3. *Importance of different sources of technology-oriented information*

Information source		"Very important"/ "important" (%)	
		BioAC	**AutoSWS**
Academic journals	+	95.7	13.8
Internet	+	87.0	34.5
R&D co-operation	+/–	69.6	36.2
Fairs, exhibitions, congresses	+/–	65.2	50.0
Specialized magazines	+	56.5	44.8

Notes: The symbols indicate the degree of codification of knowledge transferred via the given information source: + high, +/– medium; – low

In general, we can see that the BioAC firms make massive use of a wide range of different external information sources. Fairs, exhibitions and congresses are the only category of information sources which at least half of the interviewed AutoSWS firms reckon as 'important' or as 'very important'. This type of knowledge source facilitates not only the transfer of codified knowledge; it fosters the exchange of tacit knowledge as well. The transfer of tacit knowledge is made possible by the co-presence of receiver and transmitter in one place, an important precondition to enlarge particularly the synthetic knowledge base. To give an example: An executive employee of an automotive firm in SWS visiting a trade fair is thought to help his firm in identifying the latest changes in a particular technical field, and to be aware of competitors' future plans. This does not mean that every single piece of information that is collected by this particular person is already codified and open to the public. He or she has to interact with the exhibitors who show him or her how to use the particular technical device he or she is interested in. This involves the transfer of tacit knowledge as well. Such cases of temporary proximity or temporary clusters (Maskell et al. 2006; Bathelt and Schuldt 2008) are a considerable modification of the traditional tacit = local vs. explicit = global argumentation.

BioAC firms, as already mentioned above, try to benefit more or less from all the information sources given. The characteristic that these sources share is the high degree of codification of the knowledge they provide.[1] Comparing the firms' evaluations for academic journals, it becomes obvious that scientific, codified input plays a major role for BioAC firms due to their analytical knowledge orientation whereas for AutoSWS firms this source is relatively unimportant.

4.3 Knowledge networks between interviewed firms within the region

The following network illustrations (Figures 1 and 2) show some general results of our graph-based SNA. They provide a first overview concerning the question with whom BioAC firms and AutoSWS firms exchange technological knowledge: do the university institutes and the public research organizations play the major role within these networks, or does the knowledge come from customers and suppliers? Furthermore, we get a first impression about the location of these knowledge exchange partners: How many knowledge flows transcend the regional, or the national boundaries respectively? Since our case study rather focuses on the systemic perspective, and not on the individual firms' perspective, we should keep in mind that the aggregated results, which follow hereafter, do not necessarily mirror the knowledge exchange pattern of one particular firm.

Before going forward to the interpretation of all network contacts on an aggregated level, in Table 4 we see a comparison of SNA indicators for both cases that are focusing on the respective knowledge flows solely between the interviewed firms themselves. Fading out all other contacts, we are able to quantify particular dimensions of network structures within both regions from a sociocentric point of view. Nevertheless, these network indicators have to be interpreted with great accuracy: Although we try to provide an overview of knowledge flows between the interviewed BioAC firms and between the interviewed AutoSWS firms we have to take into account that the shares of firms which participated in each case differ from each other (see Section 3). As a consequence, the lower response rate for the AutoSWS case raises the risk of unintended biases caused by blind spots within the sociocentric network. Due to a comparatively higher response rate this risk is lower for analysing the inter-firm network structure within the regional context for the BioAC case.

[1] For R&D collaborations this statement is not entirely true. R&D collaborations can be assumed to contain a decisive share of tacit knowledge components as well.

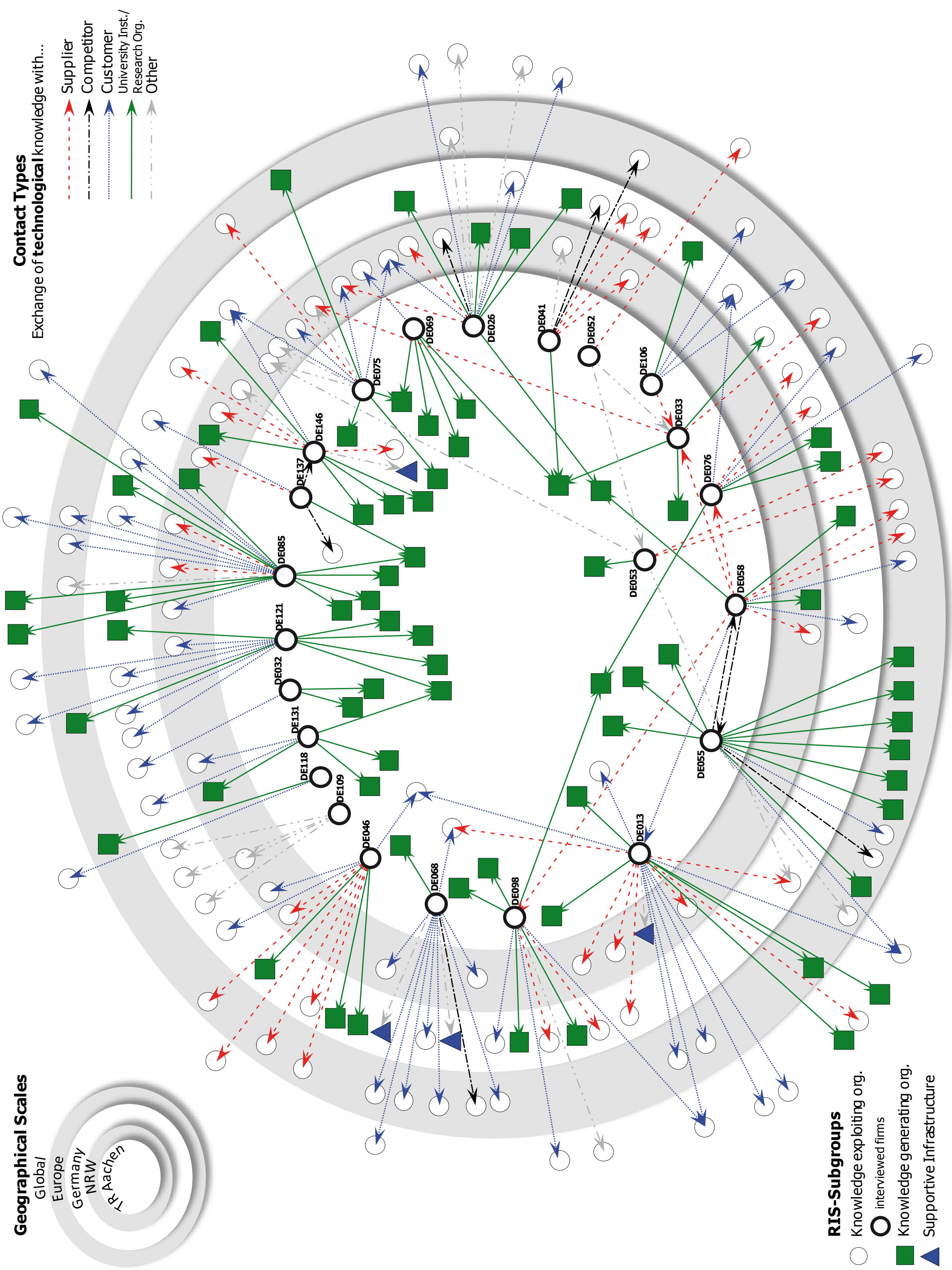

Figure 1. *Technological knowledge network of biotechnology firms (n=23) in the Aachen TR.*

Source: UCINET 6, elaborations based on own research data.

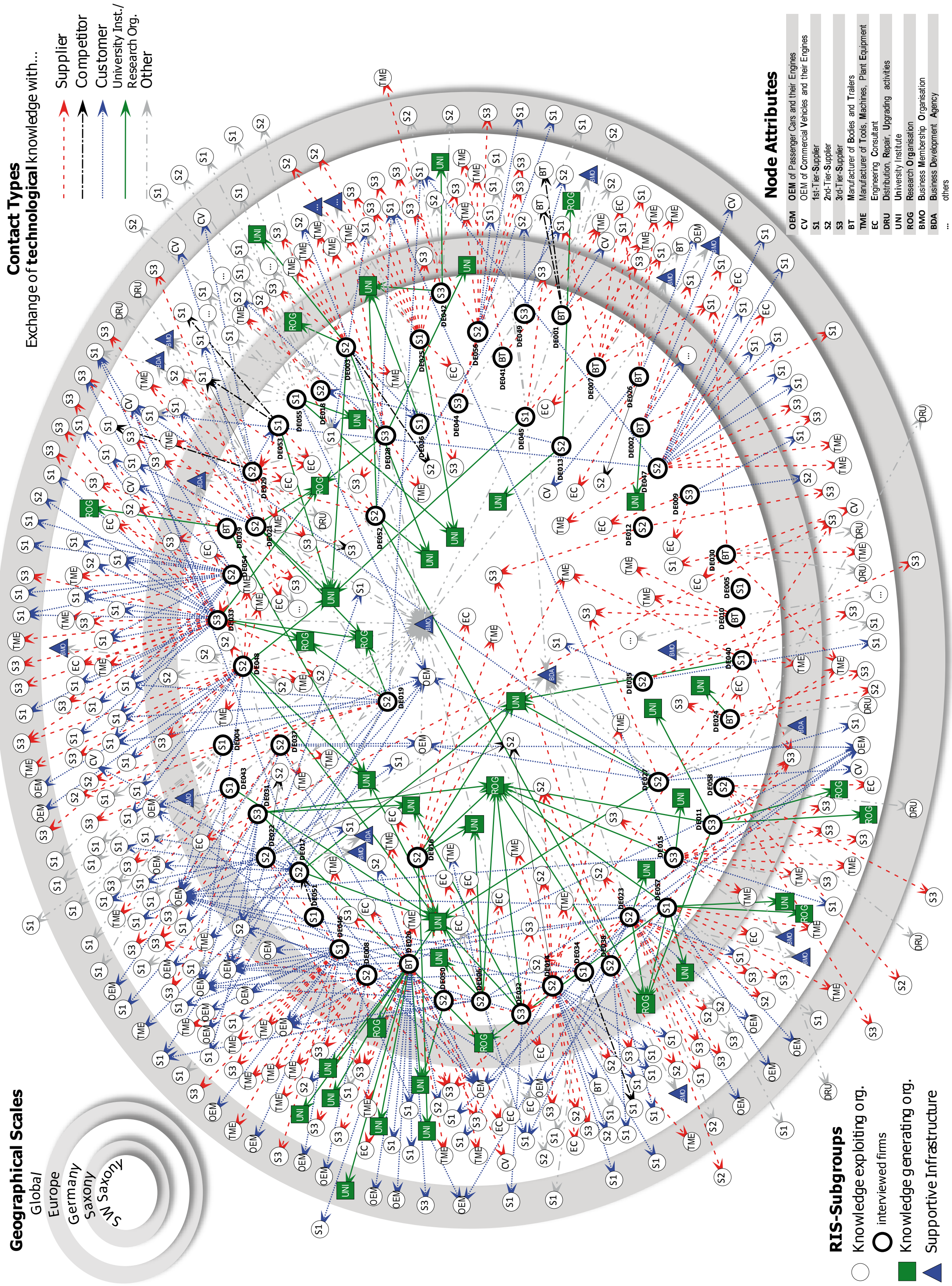

Figure 2. *Technological knowledge network of automotive firms (n=58) in SWS.*
Source: UCINET 6, elaborations based on own research data.

Table 4. *Flows of technological knowledge between interviewed firms: summary of sociocentric network indicators*

Indicator	BioAC	AutoSWS
Number of interviewed firms	23	58
Number of ties	10	9
Density	0.0198	0.0027
Components	14	50
In-degree centralisation/ dicho	0.1219	0.0329
In-degree centralisation/ valued	0.0583	0.0228
Out-degree centralisation/ dicho	0.2169	0.0151
Out-degree centralisation/ valued	0.1652	0.0156
Hybrid reciprocity	0.1111	0.125

The network densities – expressed as a ratio between the actual number of ties and the maximum number of potential ties (Wasserman and Faust 1994) – are relatively low, due to the low number of identified ties (i.e., knowledge flows), between the interviewed firms in both cases. While for the BioAC case no more than 2 per cent of all potential inter-firm relationships between the interviewed firms are exploited, the corresponding share for the AutoSWS case is even lower with 0.3 per cent. Although the network density for the BioAC case is seven times higher, both figures clearly indicate that directed interactive learning between the interviewed firms is very scarce within both regions. A corresponding measure that helps us to capture the structure of both networks is the number of components each network contains. We recognize that the AutoSWS network is to some extent more fragmented than the BioAC network: The AutoSWS network contains four dyadic components and two components with three members each, namely, 44 out of 58 firms remain isolated.[2] In contrast, the BioAC network consists of one dyadic component and another component that connects nine firms, that is 12 out of 23 firms remain isolated. Notwithstanding this differences, both cases point to a rather fragmented appearance of inter-firm networks within the regional context. In both cases, a large share of firms remains completely isolated.

In addition to these indicators, we used valued as well as dichotomous in- and out-degree centralization indices to determine how ‘centralized’ both inter-firm networks are, and how unequal the distribution of centrality is respectively. The degree centrality in our study refers to the number of knowledge exchange links that firms have with the other interviewed firms within the region. In-degree

[2] We have to take into account that the Volkswagen AG, which has two production sites within SWS, did not take part in this study. Thus, this company could not be considered for the sociocentric SNA calculations. It makes sense to assume a slightly higher density, fewer isolated firms and a higher degree of centrality concerning the network between automotive firms within SWS, if Volkswagen had been involved. This thesis can be backed by the fact that numerous firms indicated technology oriented knowledge transfers with Volkswagen in SWS.

centrality quantifies the extent to which knowledge is acquired by a firm from other local firms. Therefore, the numbers of technological knowledge exchange ties incident to the firm are counted. Out-degree centrality measures the extent to which knowledge originates from a firm to be used by other local firms. Therefore, the numbers of ties incident from the firm are counted. The dichotomous indicator reflects the sheer presence or absence of a linkage. In contrast, the valued indicator analyses the value given to each linkage (i.e., the importance of each link for the firm's innovative performance; a 1–5 range) by the knowledge- using firm.[3] The stronger a network is centralized, the more hierarchical is its architecture. In both cases, all centralization indices are relatively low and therefore point to a rather homogeneous network structure. With regard to the weak network density numbers described above, it becomes obvious that this homogeneity of network positions is situated on a very low level of inter-firm knowledge exchange activities within both, the BioAC network, which is driven by the analytical knowledge base, as well as the AutoSWS network, which is rather shaped by the synthetic knowledge base.

Finally, the hybrid reciprocity measure indicates the share of reciprocal relations. In both cases the measured levels of hybrid reciprocity are very low (0.1111 and 0.125), indicating that the few network contacts mentioned are far from being symmetrical in their relationships. For the BioAC case, we got the result that only once both firms designate each other to be knowledge exchange partners, whereas the other eight relations need to be described as being unidirectional, since firms do not agree on being partners on both sides. The picture we outline here is comparable to the one of the AutoSWS case. In just one single case two firms label each other as being knowledge exchange partners, whereas the residual seven linkages remain unidirectional. This lack of reciprocity for the BioAC case as well as for the AutoSWS case can be interpreted as a sign of rather imbalanced systems of knowledge relations between the interviewed firms in both regions: While one firm identifies another firm as a knowledge exchange partner, this does not necessarily mean that the same is true vice versa. While interpreting the whole range of indicated knowledge flows in the following sections we have to keep in mind that knowledge flows are not automatically bidirectional.

4.4 Geography of knowledge linkages

While the preceding section referred to the sociocentric examination part of the SNA (which is restricted to the linkages between the interviewed firms themselves), we will now turn to the aggre-

[3] The centralization measures refer to the network populations as a whole and express the degree of inequality or variance in both networks as a percentage of that of a perfect star network of the same sizes.With regard to the BioAC network, for example, the dichotomous out-degree centralization is 22 per cent while the in-degree centralization is 12 per cent of the theoretical 100 per cent centralization maximum. For further information on different network centralization measures, see, for example, Freeman (1979), or Borgatti et al. (1999).

gated analysis of the firms' complete egocentric networks. This step allows us to consider the whole range of all the contacts mentioned. Unlike the regionally limited network perspective discussed in the above subsection, this enlarged perspective mirrors more effectively differences of knowledge networking between two different knowledge base configurations. At this level of analysis, the AutoSWS data base includes 613 knowledge relations, whereas the BioAC data base contains 216 relations. The strong difference in the sheer number of relations for both cases is traced back to the simple fact that we interviewed three times as many automotive firms in Southwest Saxony (N = 58) compared to the biotechnology firms in the Aachen Technology Region (N = 23). Table 5 distinguishes the indicated relationships according to their geographical reach. The most obvious difference between the BioAC case and the AutoSWS case can be found in the share of technology oriented knowledge flows which transcends the national boundary: BioAC firms rely stronger on knowledge channels connecting them to organizations which are located in other European countries, or beyond, which means in total a sum of 31 per cent of all contacts. Almost half of all interviewed BioAC firms keep contacts that go beyond European countries, for example, to biotech clusters in North America, for example Boston or San Diego. These contacts provide the specific knowledge they need in order to strengthen their analytical knowledge base. The corresponding share of linkages which goes beyond Germany is just half as high for the AutoSWS firms. If these firms exchange knowledge with foreign companies, or university institutes, etc., the corresponding ties hardly reach other continents, namely, they largely remain within Europe. The number indicating the value given to each linkage by the knowledge-using firm (i.e., the importance of each link for the firm's innovative performance) underlines the outcome that building global pipelines is more important for biotechnology firms in comparison to automotive firms.

Table 5. *Geography of technological knowledge networks*

Geographical scale	BioAC (n=216)			AutoSWS (n=630)		
	%	AvImp	AvSim	%	AvImp	AvSim
Regional	27.3	3.8	3.2	28.3	3.5	2.8
Germany	42.2	3.9	2.6	55.7	3.8	3.2
Europe	18.1	3.5	2.0	13.3	3.5	3.4
Global	12.5	3.7	2.7	2.7	3.0	3.1
Total	100.0	3.8	2.7	100.0	3.7	3.1

Notes: n = number of contacts, AvImp = average importance for firms' innovation performance (1 = not important, 5 = very important), AvSim = average similarity of exchanged knowledge (1 = not similar, 5 = very similar)

Nevertheless, the regional context[4] is relatively important for both the BioAC firms as well as for the AutoSWS firms: In both cases, nearly every third contact indicates a linkage between an interviewed firm and its knowledge exchange partner which is located within the near vicinity. The residual share of knowledge flows which transcend the regional boundaries but do not exceed the national borderline is higher for the AutoSWS firms' networks.

In general, knowledge transfers of AutoSWS firms are bound more tightly within the national context when compared to the BioAC case. A fairly simple but plausible explanation for this difference refers to a 'functional' aspect. Since Germany plays a key role with regard to automotive manufacturing as well as machinery engineering throughout Europe and the whole world, it should not be surprising that the share of technology-based knowledge flows of the AutoSWS firms is relatively large at the national level (Scheuplein et al. 2007). By contrast, Germany does not play a leading role in the biotechnology industry, although this industry grew relatively fast during the last two decades (Dohse 2000). As a consequence, BioAC firms feel a stronger pressure to look for global knowledge sources.

Another explanation for this divergence which goes back to the knowledge base concept is the one that knowledge necessary for the development and production of automotive parts is rather engineering-based and more practical-oriented in its nature. Thus, the likelihood is higher that one will find more tacitness in knowledge transfers, which implies that face-to-face-contacts are of high importance. Face-to-face-contacts in turn are facilitated by spatial proximity between the knowledge exchanging organizations. Conversely, innovation processes in the biotechnology sector are rather science-based. The degree of codification of knowledge is higher and therefore the knowledge exchange partners are not forced to interact simultaneously in order to share information. These findings underline that knowledge networks in the AutoSWS case are strongly shaped by the synthetic knowledge base, whereas for the BioAC case it is rather the analytical knowledge base which determines the geography of knowledge flows (see Section 2).

Both arguments, the functional argument as well as the knowledge base argument, can be assumed to play their role in explaining the spatial configuration of the two industries. However, it has to remain in the mist which one of the two cause-and-effect chains is the more relevant one for interpreting the divergences with regard to the geographies of knowledge links.

[4] That is, the Aachen Technology Region for the biotechnology firms as well as Southwest Saxony for the automotive firms.

So far we have analysed the relative importance ascribed to the particular geographical spheres of knowledge linkages, measured by the sheer percentage of all announced contacts as well as due to the importance for the firms' innovation performance ascribed to each contact. However, from an innovation-theoretical point of view it is interesting to interrogate to what extent technical oriented knowledge that each network partner provides is similar to the one which is already available within the interviewed firm. The rationale behind this question is based on the idea of related variety which we already mentioned in the context of recruitment sources of highly qualified labour (see subsection 4.1).

In general, the BioAC firms show a well balanced set of knowledge channels. On the one hand, these channels provide very similar knowledge, and, on the other hand there are those which provide rather dissimilar knowledge, in sum leading to an overall average of 2.7 (whereas 1 = not similar, 5 = similar). The highest similarity of knowledge assets being combined via knowledge transfers can be found on the regional level. The most different input comes from the European level. In terms of related variety we may argue that the knowledge that is cognitively more distant may be brought into the regional biotechnology industry via interactions with nationally as well as globally distributed actors. AutoSWS firms tend to build networks which contain slightly more similar knowledge in comparison to their repertoire of knowledge assets that they hold in-house. The corresponding average similarity values for each spatial scale show a slight tendency in a way, that we may say that the shorter the radii of knowledge transfers are the more are the knowledge assets different to each other. In contrast, on national and international levels firms tap into the transfer of more similar knowledge assets.

4.5 Different types of knowledge network partners

In addition to the spatial dimension of knowledge networks, we examined which types of contacts are of particular importance in order to strengthen the firms' innovative capacity. Therefore, we distinguished between linkages with suppliers, competitors, and customers, as well as linkages with university institutes or research organizations, and relations to all other types of organizations. We can derive from the data represented in Table 6 that knowledge networking of BioAC firms obviously goes in line with the assumptions made for industries which rely predominantly on the analytical knowledge base. Ties to university institutes and other research organizations are crucial for these firms in order to keep pace with the latest developments in natural sciences that are relevant for biotechnological innovations. Exchanging knowledge with selected partners along their value chains is important, too. Otherwise the BioAC firms would risk that their R&D efforts may not fit to the market requirements.

However, exchanging knowledge with suppliers and customers is even more important for AutoSWS firms, both in terms of the absolute number of mentioned contacts as well as regarding the average importance value. These different weightings of contacts can be interpreted in a way that knowledge networking of the AutoSWS firms is particularly determined by the synthetic knowledge base they rely on.

Table 6. *Contact types within technological knowledge networks*

Contact type	BioAC (n=216)			AutoSWS (n=630)		
	%	AvImp	AvSim	%	AvImp	AvSim
Supplier	19.0	3.3	2.4	35.4	3.5	2.7
Competitor	4.2	3.4	3.7	2.2	3.2	4.1
Customer	29.6	3.7	2.4	30.3	4.0	3.6
University inst./ Research org.	36.1	4.2	2.8	12.7	3.5	2.9
Other	11.1	3.9	2.7	19.4	3.6	3.2
Total	100.0	3.8	2.7	100.0	3.7	3.1

Notes: n = number of contacts, AvImp = average importance for firms' innovation performance (1 = not important, 5 = very important), AvSim = average similarity of exchanged knowledge (1 = not similar, 5 = very similar)

When we compare the degree to which knowledge on technological issues is comparable to that of the BioAC and AutoSWS firms we see a wide range of similarity values. Both, the dissimilar as well as the more comparable knowledge components are crucial for the firm's innovation efforts in both cases. Not surprisingly, competitors deal with comparable technology-related issues, and thus they generate relatively similar knowledge. Relationships with suppliers tend to make technology-oriented knowledge assets meet which are more dissimilar to each other. However, these relations still exhibit a medium level of shared expertise. This is true, too, for knowledge ties linking BioAC firms with their customers. In contrast, the technological expertise of the AutoSWS firms and their customers is even more comparable to each other. In the case of the automotive industry, customers (i.e., original equipment manufacturers or higher-ranked suppliers), specify exactly which product-related requirements their suppliers have to fulfil. These specifications require that both organizations – the AutoSWS firm and its customer – have similar knowledge bases in order to understand each other. It seems that the high degree of similar knowledge assets is not such an important precondition with regard to the supplier-customer-relation for the BioAC case.

4.6 The nature of knowledge flows

The data shown in Table 7 refers to the nature of knowledge transfers between the interviewed firms and their knowledge exchange partners. Even if the BioAC firms are closely interlinked with universities, public research institutions as well as with R&D departments of other companies, we cannot automatically assume that every technology related knowledge exchange is predominantly of scientific content. Of all knowledge transfers, 22 per cent are primarily scientific whereas 34 per cent display a mixture of scientific and practical oriented elements. Actually, 44 per cent of the knowledge exchanges are primarily practical oriented, that is, the main purpose of exchanging knowledge is to solve a concrete practical problem related to a particular biotechnology product or process. Accordingly, we may conclude that knowledge networking of BioAC firms exhibit characteristics not only of the analytical (science-based) but also of the synthetic (engineering-based) knowledge base (see Section 2).

However, when we compare these outcomes with the corresponding numbers for the AutoSWS case, we realize that the share of science-oriented relationships is remarkably larger for the biotechnology firms. In contrast, only 8 per cent of all contacts mentioned by the AutoSWS firms focus solely on scientific issues which do not necessarily affect practical oriented problem solutions. Instead, interactive learning between AutoSWS firms and other organizations can rather be characterized by inductive processes. These firms use the knowledge provided by collaborators in order to solve a specific product- or process-related problem. They learn and create knowledge by doing, using and interacting (the DUI-mode). Therefore, it does not surprise that seven out of ten knowledge interactions are clearly practical-oriented.

Table 7. *Nature of knowledge flows*

	BioAC (n=216)		**AutoSWS (n=630)**	
	%	**AvImp**	**%**	**AvImp**
Practical	43.5	3.9	67.1	3.6
Scientific	22.2	4.0	7.9	2.9
Both	34.3	3.6	24.9	4.0
Total	100.0	3.8	100.0	3.7

Notes: n = number of contacts, AvImp = average importance for firms' innovation performance (1 = not important, 5 = very important), AvSim = average similarity of exchanged knowledge (1 = not similar, 5 = very similar)

These findings can be confirmed by taking into account the average degree of importance of each contact. BioAC firms value exclusively science-based knowledge transfers clearly higher (4.0) than AutoSWS firms (2.9). Hence, once more we can conclude that knowledge networks of AutoSWS firms are rather shaped by the synthetic knowledge base, whereas the average knowledge network of a typical biotechnology firm within the Aachen TR relies heavily on the analytical knowledge base as well.

5. Conclusion

The geographical patterns of knowledge networking have often been explained by pointing at agglomeration effects, in general, or the specific regional context in particular, such as the concentration of applied research institutes, universities and polytechnics. What we have shown in this paper is that although these explanatory factors play their role, it is worthwhile considering also the characteristics of the knowledge base in the dominating industry of a cluster to explain the characteristics of knowledge networking. Our research has shown that the concept of knowledge bases is useful to analyse, compare and explain knowledge exchange processes in different industries in a regional context. With the help of the knowledge base concept differences between clusters and industries in a spatial context can be explained concerning knowledge creation, innovation processes, knowledge exchange partners, knowledge content and particularly spatial proximity. Our empirical analysis has revealed that knowledge sourcing and knowledge networking in the BioAC case are rather shaped by the analytical knowledge base, whereas for the AutoSWS industry the synthetic knowledge base is the crucial one. At the same time, it was interesting to see that firms try to connect/mix dissimilar vs. comparable knowledge assets throughout their knowledge networks. Therefore the distinction between knowledge bases is neither strict (in reality we often find mixtures of knowledge bases) nor static; the position of an industry or cluster within the triangle of three knowledge bases changes through time.

Despite the usefulness of the concept of knowledge bases to explain knowledge networking, other impact factors may be important to explain the structure and functioning of knowledge networking, as well. These include firm attributes, such as size, age, owner structure within specific industry-region-combinations, the position of the firm or industry in a life cycle, the necessity to find specialized knowledge and correspondingly the scarcity of potential collaborators as a push-factor to look for sources outside the regional/national system of innovation and the influence of supportive infrastructure (cluster initiatives, financial incentives, etc.). Some of these factors are related to agglomeration effects, others to the specific regional context. In order to prevent hasty generalizations, more future research is needed on how to isolate the effects of knowledge bases on knowledge networking from agglomeration effects and the effects of the specific regional context.

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7. Modern Pac-Men fed by the symbolic knowledge base? Knowledge networks and innovation processes of Hamburg's video game developers

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Abstract

Due to its growing economic power, creative industries have climbed scholars' and policymakers' agendas in recent years. However, in comparison to a high number of cluster studies on rather traditional industries, systematic research on knowledge production and innovation processes in creative industry clusters is still underrepresented. This paper aims at filling this gap by investigating the video game development industry in Hamburg out of a knowledge base perspective. Network analyses and complementary descriptive statistics that are based on standardized firm interviews are used to identify the knowledge base configuration which drives knowledge creation and innovation processes within this cluster. The paper concludes that both, the symbolic and the synthetic knowledge, and to a lower degree the analytical knowledge, are the dominant elements that contribute to video game development in Hamburg.

1. Introduction, or what pizzas have to do with video games

Pac-Man, which is virtually synonymous with classical video games, was "the first digital superstar of the video game era, the first character to capture the attention and imagination of the world" (DeMaria & Wilson 2003, p.62). Technological know-how in order to program such a game was not the only ingredient needed to appear at thousands of displays around the globe in 1980; creativity, the power of imagination, was obviously the other clue to give life to Pac-Man, or how else can we explain what was going on in Mr. Iwatani's[1] head when he stared at a pizza with one slice missing (ibid.)?

Since Mr. Iwatani's stroke of genius, the global video game market has rapidly changed from a niche into a mass market serving various gaming platforms (computer, consoles, handheld devices), all of them underlying permanent technological improvements. In fact, today's video game industry is far

[1] Toru Iwatani, creator of Pac-Man, is a former video game designer for a Japanese company named Namco (DeMaria & Wilson 2003).

from being an economic lightweight in comparison to other creative industries, with global revenues rivaling those of film making or music publishing (Dyer-Witheford & Sharman 2005; Cadin & Guérin 2006).[2] Literature, advertising, fashion, or performing arts are further examples pointing at the multifaceted spectrum of creative – or cultural – industries the video game sector belongs to.[3] What all these industries have in common is that, at their very core, they encompass non material and symbol-intensive goods and services mixing commercial and cultural interests at the same time (Caves 2000; De Propris et al. 2009).

Even if Tschang & Vang (2008, p.2) rightly state that the "perceived importance of the creative industries has triggered extensive research in economic geography and the spatial organization of creative industries" (e.g. Scott 1997; Florida 2002; Rantisi 2002; Nachum & Keeble 2003; Pratt 2004; Bathelt 2005; Grabher & Ibert 2006; Lange 2006; Aage & Belussi 2008; Belussi & Silvia Rita Sedita 2008; Lazzeretti et al. 2008; Silvia R. Sedita 2008; Staber 2008; De Propris et al. 2009; Romein & Trip 2010; Martin & Moodysson 2011a), there is still a lack of systematic empirical research in knowledge sourcing and knowledge networking of actors producing cultural goods. This is somewhat surprising since *knowledge*, *innovation*, *network*, or *creative industry* are omnipresent buzzwords in current debates within regional development contexts or industry-specific case studies. The respective shortcoming applies even more to the digital play sector in particular, though few exceptions can be found in economic geography literature dealing with this industry (Venkatraman & Lee 2004; Izushi & Aoyama 2006; Johns 2006; Cohendet & Simon 2007; Hassink 2007; Oh 2007; Oh & Hassink 2007; Storz 2008; Tschang & Vang 2008; Lange & v. Streit 2011).

My paper contributes to this body of literature by analyzing the economic geography of knowledge sourcing and knowledge networking of Hamburg's video game developers (VGD) from a knowledge base perspective, differentiating between the *symbolic* (creativity-based), *synthetic* (engineering-based) and *analytical* (science-based) knowledge base. Due to its diversified approach, the knowledge base concept is potentially helpful to systematically unravel the complex and manifold nature of knowledge processes and its effects on the firms' patterns of knowledge sourcing and interorganizational learning within and beyond the video game cluster's boundary.[4]

[2] DFC Intelligence (2008) forecasted that global revenues from video game hardware and software would reach $ 57 billion in 2009.

[3] This paper does not elaborate the terminological differentiation between the notions revolving around creative and cultural industries, and the products and services thereof. For a more fine-grained classification, see, for example, Scott (1997), Caves (2000), Pratt (2004; 2009), De Propris (2009), or O'Connor (2010).

[4] Martin & Moodysson (2011b) use the knowledge base perspective in order to analyze knowledge sourcing and interactive learning in a similar creative industry cluster which is the moving media sector in southern Sweden.

Caused by the high relevance of symbolic knowledge and intangible values ascribed to creative industries in general and the *birth of modern Pac-Men* in particular, we might somewhat hasty assume that Hamburg's VGD firms primarily rely on the symbolic knowledge base. However, analyses on the video game industry are drawing rather ambiguous and at the same time vague pictures of which knowledge base is lying at the centre of the VGD firms' competitiveness. This paper explicitly focuses on the *developing* activities and *not* on the publishing of video games in order to capture particularly those parts of the innovation process which are assumed to make the interaction of creativity and technological know-how visible in the best possible way.

According to the focus of this paper, the central research question is: Which knowledge base configuration drives knowledge creation and innovation processes within the VGD industry in Hamburg? Related sub-questions targeting at a number of concrete knowledge base determinants are: (i) Which are the key recruitment sources? (ii) What are the dominant types of innovations realized so far? (iii) To what extent can we observe knowledge diffusion within the region and (iv) in what way are the firms connected to geographically dispersed sources? (v) Are there different knowledge exchange patterns to be found between the exchange of market related knowledge in comparison to the exchange of technological oriented knowledge? (vi) Who are the protagonists in these networks? (vii) How can we describe the nature of knowledge exchanged (practical vs. science-oriented), as well as (viii) the organization of collaborative work in time and space? And finally, (ix) what are the other information sources that are important to realize innovation achievements?

The paper is structured as follows. Section 2 introduces the knowledge base approach. By differentiating the symbolic from the analytical and the synthetic knowledge base, this section serves the theoretical building blocks for the interpretation of the empirical results presented in Section 4. After a short overview of the regional economic and institutional environment of the VGD firms in Section 3, network analyses and complementary descriptive statistics based on standardized firm interviews and additional expert interviews are used to thoroughly answer the already expressed research questions. I finish this paper with Section 5 that provides the key findings.[5]

2. Setting the frame: explaining knowledge bases

"A video game is not only made of computer programs [...] it is also a creative product made of images, sound and most of all of a non material, intangible element, the game play. This non-material element lies at the heart of the creative process and is in fact its own language [...]" (Guérin

[5] This paper is written in the context of an international research project called "Constructing Regional Advantage: Towards State-of-the-Art Regional Innovation System Policies in Europe?" The project is co-funded by the European Science Foundation and the Research Council of Norway.

2006, p.306). There are a number of additional hints in the literature about the multimedia content creation sector which indicates that both, the technological as well as the creative competences are to be brought together in the VGD process (Izushi & Aoyama 2006; Tschang & Szczypula 2006; Oh 2007; Peltoniemi 2009). However, in sum they draw rather ambiguous and imprecise pictures of the mix ratio of both knowledge ingredients, i.e., the question concerning which knowledge base lies at the centre of the VGD firms' competitiveness.

The knowledge base approach, which was recently introduced by Laestadius (1998) and Asheim and Gertler (2005), provides a promising framework that helps to reveal crucial differences in knowledge formation and related innovation processes between various industries. The authors distinguish the *analytical* (science-based) from the *synthetic* (engineering-based) and the *symbolic* (creativity-based)[6] knowledge base, each implying particular combinations of tacit and codified knowledge (Polanyi 1966; Nonaka & Takeuchi 1995), different knowledge exchange partners and knowledge sources, various types of innovation, and different spatial dimensions of knowledge transfer relations (Amin & Cohendet 2004). According to Asheim et al. (2011, p.6), the threefold distinction "refers to ideal-types, most activities are in practice comprised of more than one knowledge base. The degree to which certain knowledge bases dominates, however, varies and is contingent on the characteristics of firms and industries as well as between different type of activities (for example, research and production)."

Taking these considerations as a point of departure, it seems just natural to introduce the whole range of knowledge bases in order to interpret the empirical findings comprehensively and to find out about the specific mixture of different knowledge assets which drive Hamburg's VGD firms. Therefore, in the following of this chapter, I highlight the key aspects of each of the three theorized knowledge bases.

Symbolic knowledge base

Industrial activities which rely on the symbolic knowledge base particularly target the aesthetic attributes of a product, the creation of designs and images as well as the economic use of various forms of cultural artifacts (Asheim 2007). Creative and cultural industries, and the products and services thereof, such as film making, music, design, fashion, publishing or advertising (Scott 1997; De Propris et al. 2009) are good examples of economic sectors driven by symbolic knowledge inputs.

[6] Whereas Laestadius (1998) introduced the concepts of analytical and synthetical activities with regard to different industrial sectors, the idea to add the symbolic knowledge base was developed in 2001 in a discussion between Bjørn Asheim, Franz Tödtling, Gernot Grabher and Åge Mariussen (Asheim, Coenen, Moodysson, et al. 2007).

According to Lash & Urry (1994), the creation of sign-value in these sectors is more important than the mere use-value of products. "Knowledge is therefore incorporated and transmitted in aesthetic symbols, images, (de)signs, artefacts, sounds and narratives. This type of knowledge is strongly linked to a deep understanding of the habits and norms and 'everyday culture' of specific social groups, and is, therefore, characterized by a strong tacit component" (Asheim 2007, p.226). Since the development of new products or processes is particularly based on creativity, aesthetic sense, imagination, interpretative and artistic skills rather than cognitive information processing or the application of scientific rules, formal qualifications and university degrees are often dispensable recruitment criteria (Martin & Moodysson 2011a). Potential employees acquire relevant skills by practice in a range of steps within the creative process. Assumed that those predominantly tacit capabilities are hard to transfer from one individual to another, the know-who of potential collaborators working in the respective professional community defines a crucial strategy (Nachum & Keeble 2003) to combine complementary talents within temporary project settings in a fruitful arrangement (Grabher 2002a; Grabher 2002b; Grabher 2002c; Grabher 2004a; Grabher 2004b). "Projects requiring a symbolic knowledge base, however, are not necessarily aimed at bridging or minimizing such diversity in a straightforward fashion. They also are seen as arenas of productive tensions and creative conflicts that trigger innovation" (Asheim et al. 2007a, p.665). The importance of buzz and face-to-face-contacts leads to a relatively high sensitivity for spatial proximity between the potential project partners. Urban environments rather than sparsely populated spaces serve as the appropriate ground for inspiration and acquaintance to people who make the difference in creativity-driven innovation processes (Scott 1997). Characterizations of processes within the VGD sector derived from a number of studies (particularly the ones of Tschang and Szczypula (2006), Cohendet and Simon (2007), and Oh (2007)) raise expectations concerning the success of VGD firms' innovation efforts to be relying heavily on the symbolic knowledge base.

Synthetic knoweldge base

Industries that draw on the synthetic knowledge base most often create product and process innovations through the application or (new) combination of already existing knowledge with the aim to solve a concrete problem that comes up during the interaction with clients and suppliers. Knowledge formation is characterized as a more inductive process, and innovation processes are dominated by incremental steps. This innovation procedure can be seen, for example, in practical work in general, but also in system design, testing, fine tuning, and prototyping. According to some examples given in the literature (e.g. Allen & Kim (2005), or Izushi & Aoyoma (2006)), numerous of these activities are present in the VGD industry as well. Generally, interactive learning is dominated by industry-industry links. Research, given it plays a role in a firms' VGD process at all, is mainly use-oriented even within industry-university relationships. Similar to the symbolic knowledge base, tacit knowledge, which arises from experience gained at the workplace, and through learning by doing, using and interacting, plays a crucial role within innovation processes (Polanyi 1966; Nonaka & Takeuchi 1995). Face-to-face-contacts facilitate the transfer of engineering-based knowledge with a strong tacit nature (Audretsch 1998). Thus, firms relying on the synthetic mode facilitate their innovation processes by shortening the spatial distances especially to those of their major knowledge network partners with whom they exchange particularly highly tacit knowledge. Besides on-the-job-training, professional as well as polytechnic schools are important education channels facilitating concrete know-how, craft, and practical skills (Asheim & Coenen 2005; Asheim et al. 2007b; Lange & v. Streit 2011).

Analytical knowledge base

Science-based industries rely on the analytical knowledge base particularly. Part of the core activities of firms are basic and applied research as well as systematic product and process development. As a consequence, many of them have their own research department, but also heavily rely on research done by universities or other research-oriented organizations. More often than it is true for industries shaped predominantly by one of the other knowledge bases, innovation processes frequently lead to radically new products or processes. Deductive cognitive and rational processes as well as formal models are the common input factors for the creation of new knowledge. Characteristic examples are scientific discourses or laboratory-based research. Even though face-to-face contacts facilitate the transfer of tacit as well as of codified knowledge components, they are less important for the analytic case. This is due to the higher degree of codification – for example, scientific results tend to be documented in reports, electronic files or patent descriptions – which simplifies the exchange of knowledge across distances. The core of the work-force needs specific qualifications, such as analytical skills, the ability to abstract, theory building and testing, and documentation. University education and/ or research experience are key to get a job in an industry drawing on the analytical knowledge base (Asheim & Coenen 2005; Asheim et al. 2007b; Lange & v. Streit 2011). Rather little literature can be found giving rise to expectations that the VGD sector provides a prime example for an industry that is highly dependent on the analytical knowledge base.[7]

Table 1 summarizes the key characteristics of the symbolic, synthetic and analytical knowledge base in a comparative manner.

[7] Exceptions are, for example, the OECD (2005) highlighting the R&D-intensity of the video game sector, or Gold (2005) who describes the incorporation of academic research into a video game prototype.

Table 1. *Characterization of knowledge bases*

	Symbolic knowledge base	Synthetic knowledge base	Analytical knowledge base
Main rationale	Creativity-based (know-who)	Engineering based (know-how)	Science based (know why)
Knowledge creation	Interactive, informal, creative, problem oriented	Inductive process, applied, problem related	Deductive process Formal models
Innovation process	Innovation by creative recombination of existing knowledge and by creation of new ideas and images	Incremental innovation by application/ combination of existing knowledge	Radical innovation by creation of new knowledge
Knowledge exchange partners	Interaction in professional communities, learning from youth/ street or 'fine' culture	Interactive learning with customers and suppliers	Research collaboration between firms (R&D departments) and research orgs.
Knowledge content	Strong tacit knowledge content (concrete know-how, craft, practical and search skills)	Strong tacit knowledge content (concrete know-how, craft, practical skill)	Strong codified knowledge content (documentation in patents and publications)
Spatial proximity	High sensitivity for spatial proximity	High importance of spatial proximity	Low sensitivity for spatial proximity

Source: Own modification of Asheim and Gertler (2005) and Moodysson et al. (2008)

In Section 4 I examine a number of indicators to identify the particular knowledge base constellation which drives Hamburg's VGD firms in order to bring their product, the game, successfully to the market.

3. Hamburg: institutional framework for Pac-Man's successors

The Free and Hanseatic City of Hamburg is the second largest city in Germany due to its population of about 1.8 million (Statistical Offices of the Länder and the Statistical Federal Office 2010). Hamburg is located in the very north of Germany close to the North Sea. It is both a city and a federal state. Neighboring states are Schleswig-Holstein in the North, and Lower Saxony in the south (see. Fig.1). As the home of one of Europe's biggest seaports, Hamburg constitutes a significant hub within the global trading network. Beside the comparatively high employment share of the port related services, a glance at Hamburg's overall labor market structure points a high percentage of the tertiary sector in general which is clearly above the national average. Thereof, the relatively high share of jobs in business related services stands out most strikingly (HK Hamburg 2010). Creative industries make up around 7% of Hamburg's total employment rate (Romein & Trip 2010).[8]

[8] This share is, of course, dependent on how the creative industry sector is defined. Since the various demarcations of creative industries are often not consistent with each other, this number has to be interpreted carefully. In addition, Romein and Trip (2010) indicate data inconsistencies with regard to the Hamburg case suggesting that this figure is probably too low.

The city is one of Germany's most important hot spots of the media sector, with particularly high concentrations in publishing and advertisement (Schönert 2004; Henninger & Mayer-Ahuja 2005). There is also a well-established IT sector, and thus the accumulated expertise of both, media and IT, provides a potentially fertile basis for the evolution of the interactive game industry.

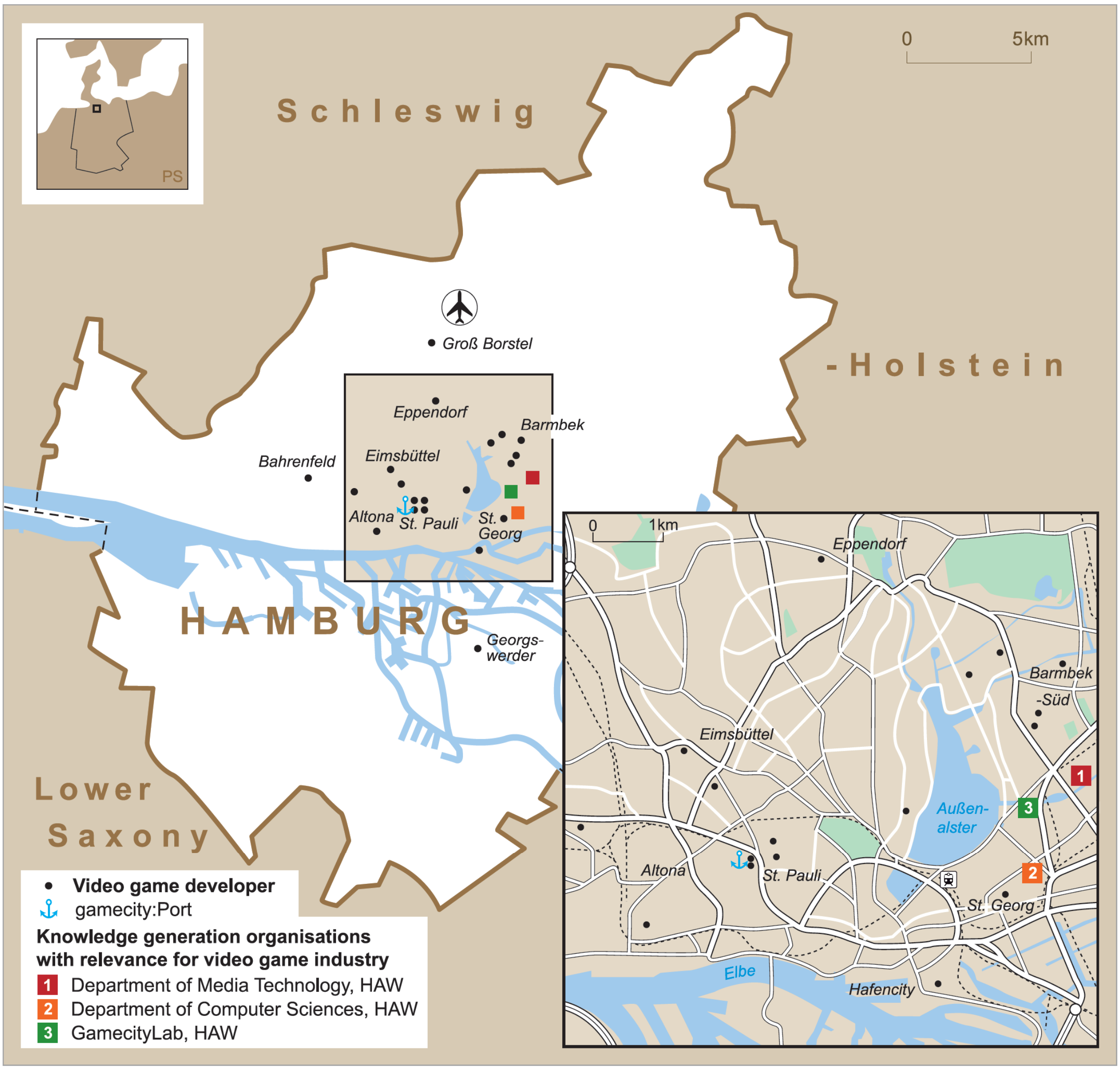

Figure 1. *Location of VGD firms interviewed*

Source: Cartographic elaborations based on own research data.

In fact, Hamburg's video game sector is, so far, relatively small in terms of labor shares and business volume compared to the overall media and IT sectors in this city. Nevertheless, in recent years its fast growth made Hamburg one of the leading centers for video game development and publishing in Germany (Walz et al. 2010). According to Walz et al. (2010) there is a consensus to be found in recent industry studies highlighting that online games to play a growing role within the global video game market. Since many of the VGD firms in Hamburg are specialized in online-games, the cluster can be expected to grow further in the near future. Actually, the headquarters of one of the worlds' leading developers of browser games is located in Hamburg.

The city's prominent position within the national context of video game production, however, has to be relativized in face of the rather weak position of Germany at the global level: so far, it is game developers and publishers from the US, Japan, Great Britain, or Canada that dominate the world market for video games (Teipen 2008; Walz et al. 2010). Nevertheless, in 2010, revenues of the German video game industry reached 1.6 billion Euros (Bundesverband Interaktive Unterhaltungssoftware e.V. 2011) and are expected to exhibit strong growth rates for the upcoming years (PricewaterhouseCoopers (PwC) 2009).

The supportive infrastructure targeting the competitiveness of the video game industry in Hamburg mirrors the typical hierarchical structure of Germany's federalist institutional support system: On the one hand, firms in Hamburg may profit from the support of the *G.A.M.E. Bundesverband der Entwickler von Computerspielen e.V.* – the overarching nationally organized business membership organization for VGD firms – which aims at boosting the German VGD industry as a whole. On the other hand, the VGD firms may make use – and indeed, many of them do – of the support activities offered by the locally organized cluster initiative *gamecity:Hamburg* (Quinke 2004). The Hamburg chapter of the *IGDA International Game Developers Association*, a non-profit membership organization serving the VGD industry on the global level, is currently inactive.

Apart from these membership organizations, attempts have been undertaken to professionalize and formalize the academic education in VGD at the *HAW Hamburg University of Applied Sciences*. The curriculum of the Master's Degree Program *Games*, for example, focuses on training students in practical skills rather than teaching them scientific rules: Designers are trained in concept art, 3D animation etc., while computer scientists are introduced to programming games. In addition, the *gamecity:Lab Hamburg*, co-founded by two departments of the HAW (the *Department of Computer Science* and the *Department of Media Technology*, cf. Figure 1) and *gamecity:Hamburg* aim at facilitating knowledge and technology transfers between industry and academia.

As can be seen in Figure 1, there are two small-sized concentrations of interviewed VGD firms within Hamburg. The first one is located within the district of St. Pauli, well-known as a hot spot for entertainment, cultural and creative industries providing various sources of inspiration as well as a multitude of meeting places. Moreover, *gamecity:Port* increases St. Pauli's attractiveness for the gaming industry. *gamecity:Port* is a property founded in 2008 by *gamecity:Hamburg*, serving as a business incubator focused on the support of video game-related start-ups. The second concentration of VGD firms is located in Barmbek-Süd near the *HAW*, surrounded by a relatively ordinary urban environment.

4. Empirical work, or how Hamburg's video game developers give birth to modern Pac-Men

In this section I present the empirical work targeting the VGD cluster of Hamburg. Data and methodology issues will be described in Section 4.1. The subsections hereafter each target the knowledge base defining characteristics discussed in Section 2. The central part of my empirical work deals with the firms' recruitment sources in Section 4.2, the firms' innovation patterns, development efforts, and external information sources in Section 4.3, and the firms' local, national and global knowledge interactions in Section 4.4.

4.1 Data and methodology

My case study of Hamburg's VGD industry cluster is based on standardized interviews with CEOs or executives of 20 of a total of 25 firms (i.e. a response rate of 80%) that develop video games (cf. Figure 1). For 8 firms, *developing* games constitutes the *exclusive* line of business. The remaining 12 VGD firms (*hybrids*) *publish* video games as well. The cluster contains predominantly micro and small enterprises; two are medium-sized, whereas one firm – the leading developer and provider of browser games mentioned in Section 3 – employed nearly 400 salaried persons (in FTE) in 2010. A look at the throughout short firm histories reveals the cluster's highly dynamic entrepreneurship scene: More than half of the VGD firms started their business in Hamburg between 2007 and 2010.

The identification of Hamburg's VGD studios is based on my own desktop research. All firm interviews were conducted between May and October 2010, followed by six semi-standardized expert interviews during the first two months in 2011 in order to discuss preliminary results. The group of experts contains a representative of the *Department of Media Technology at the HAW*, network coordinators and lobbyists supporting the video game industry on the local, national and European level, as well as researchers studying creative industries in general and the gaming industry in particular.

In order to find out which particular knowledge base configuration drives innovation processes within Hamburg's VGD industry, I apply a combination of descriptive statistics and network analyses (Wasserman & Faust, 1994; Scott, 2000). In doing so, this case study contributes to the rich body of research revolving around networking in cultural industries (see, among others, Coe 2000; Ettlinger 2003; Nachum & Keeble 2003; Grabher 2004a; Johns 2006). Access to external technological sources and market related knowledge sources both define critical competition factors in modern business (R. A. Boschma & Ter Wal 2007). Market knowledge refers to new market developments, consumer preferences, competitors, product faults and so on. Hence, the network analysis contains not only 148 knowledge interactions between the VGD firms and other organizations as well as freelancers, targeting technological issues coming up in the process of VGD. In addition, 164 market-related knowledge flows are analyzed.[9]

4.2 Human capital and recruitment sources

Typical human capital characteristics deliver a first hint to the particular knowledge base constellation that pushes the VGD firms' knowledge creation and innovation processes. Particularly striking at first sight is the fact that formalized academic education is not a sine qua non in order to be hired by one of the firms interviewed (Table 2).

Table 2. *Educational background of employees of VGD firms (n=20) in Hamburg*

Educational background	Percentage	
Higher than or equal to bachelor's degree	58.5	(100.0)
Thereof:		
Engineering (above all software engineering)		56.2
Artistic studies (e.g. arts, media, graphic design)		27.4
Natural sciences		6.3
Others (e.g. business studies)		10.1
Lower than bachelor's degree	41.5	
Total	100.0	

In fact, there are a lot of employees to be found among the remaining share of non-graduates who started academic studies, but in the end dropped tertiary education to turn passion into career as soon as possible. Nevertheless, nearly six out of ten employees have at least a Bachelor's degree, most of them in technical, engineering-based studies, first of all in software engineering. Artistic studies define another crucial ingredient within the human capital pool of Hamburg's gaming industry. Such academic programs rather concentrate on developing the student's creativity and the ability to create symbolic and aesthetic value in, for example, media, arts, or literature. Those are exactly the capabilities that VGD firms try to integrate into the game development process in order to get the best out of the game play, the story, the graphics, and the audio elements. Education in

[9] Since one interviewee refused to name the firm's market knowledge network partners, the size of the firm sample for the market knowledge network is n=19 instead of n=20.

natural sciences, which refers stronger to the *know-why* than to the *know-how* mode of knowledge patterns, is relatively unimportant. Finally, at least every tenth employee having a university degree was educated in other subjects, such as business administration. VGD firms frequently integrate this sort of competences at the management level.

The dominance of certain recruitment sources is another indicator for the constellation of knowledge bases used in Hamburg's VGD sector. Table 3 includes a number of interesting findings concerning the VGD firms' most important recruitment sources for highly qualified labor.[10] First, raising the innovative potential by strengthening cross-sectoral labor mobility – which goes in line with the idea of *related variety* (Frenken et al. 2007; R. Boschma et al. 2009) – does obviously not belong to the core human resources strategies. In face of Hamburg's well-established media and software sectors surrounding the video game cluster, we might deduce that, so far, the VGD firms missed the opportunity to profit more from inter-sectoral exchange of embodied brain power with geographically and technologically neighbored industries.

Second, universities, even though half of the interviewed firms value them as "important" or "very important" recruitment sources, clearly play a minor role in comparison to universities of applied sciences. This finding fits to the interpretation of employees' educational level (Table 2): VGD studios in Hamburg generally prefer to recruit graduates showing strengths, above all, in the application of knowledge to solve a concrete, product-related problem. Universities of applied sciences offer the adequate learning environment to increase the corresponding know-how. Graduates from universities, who focused on the analytical and science-based range of expertise during their academic education, are ranked minor suggesting that the analytical knowledge base might be less important than the synthetic one.

Table 3. *Recruitment sources for VGD firms (n=19) in Hamburg*

Recruitment source	**"Very important"/ "important"** (percentage)	**Average importance[1]**		
		Regional	**National**	**International**
Universities of applied sciences[2]	73.7	3.6	3.3	1.9
Firms of the same sector	68.4	3.8	3.5	2.0
Universities	47.4	3.1	3.2	2.1
Firms of different sectors	0.0	2.2	2.0	1.4
Average		3.2	3.0	1.9

[1] 1 = not important, 5 = very important
[2] The German "Fachhochschulen" (engl. = universities of applied sciences) are comparable with technical colleges or polytechnics in other countries

[10] In this context, highly qualified labor is defined as specimen who graduated at the tertiary level of education.

Third, attracting talents from competitors, i.e. from other VGD firms, defines another major line of recruitment activities of the firms that participated in this study. Such a strategy helps them to learn (indirectly) from their competitors. Given the assumption that firms of the same industry are driven by, in general, similar knowledge base configurations (cf. Section 2), intra-sectoral labor pooling rather leads to a deepening of already existing knowledge base constellations than it results in altering them.

According to the spatial organization of labor pooling for highly talented people, a clear tendency can be found in a way that the shorter the distance to the respective recruitment source, the more do these sources play a role in the employment strategy of the typical VGD firm in Hamburg. The strong focus on local/regional and national labor market provokes two lines of explanation: Hamburg, and the rest of Germany, may provide sufficient talents and therefore it is not necessary to recruit staff from abroad. Another explanation may be that it is hard for German VGD firms to attract high potentials from abroad, due to the fact that Germany does not belong to the leading countries in VGD which can offer better career options.

In sum, the VGD firm's human resources and recruitment strategy particularly aims at acquiring embodied, applied, engineering and creativity based knowledge. This policy hints to a symbolic-synthetic knowledge base combination to be the crucial driver for innovation in Hamburg's VGD cluster.

4.3 Innovation patterns, R&D efforts, and external information sources

The analysis of the firm's innovation activities gives rise to further indicators for the knowledge mixture that drives the VGD cluster. Mentioned by 16 out of the 20 firms interviewed, the core of innovation efforts is the development of video games and related processes. These activities are mostly custom-tailored rather than standardized by nature. 11 firms highlight the design of the video game as belonging to their main activities to achieve competitiveness.[11] Marketing their own video games defines another crucial task for at least every second firm. These outcomes show that the central activities for staying competitive depend on a multitude of competences, mixing (high-) tech expertise with commercial know-how and abilities with reference to cultural interpretation.

Additional innovation and R&D-related indicators show: (i) The highest shares of the firms' turnovers result from both the sale of slightly changed games – reflecting the incremental path of innovation – and the sale of entirely new developed games – representing the radical mode of innovation. Whe-

[11] Design, as it is defined here, stands for the creativity-driven development of visually-based aesthetic values.

reas the incremental mode is typical for the synthetic knowledge base in action, the high relevance of radical innovations defines a characteristic feature of the analytical knowledge base. (ii) Furthermore, 17 out of 20 VGD studios indicated to employ R&D employees (i.e. personnel that is primarily occupied with the development of new video games), namely 27 (FTE) on average and 5 (FTE) as the median number, all of them organized in a distinct R&D department. Within the remaining 3 firms, which do not employ any full-time R&D staff, each worker dedicates nearly half of his/ her working time to R&D. However, the emphasis within *R&D* refers more to the *D-part* by highlighting the (software) engineering-based process of VGD. Usually, basic science-oriented or applied research (the *R-part*) does not belong to the core work of R&D employees in this sector. (iii) Finally, a view at the firms' patent statistics underlines the rather weak influence of the analytical knowledge base: The fact that none of the analyzed firms applied for a patent protection might be interpreted in a way that knowledge used to develop a video game is not patentable, because it is hardly codifiable.[12]

Apart from the previous results, the VGD firms were asked to evaluate different sources of information external to the firm. No matter if we refer to technological knowledge or to market knowledge, without exception all interviewees indicated the internet to be a crucial source of information. By using the internet, they get a fast overview of the newest game developments, or they receive direct feedback from user communities. In terms of technological issues, the internet is followed by the acquisition of licenses, machines and software which was indicated to be an "important" or "very important" information source by every second firm. Concerning market related knowledge, fairs, exhibitions and congresses rank directly behind the internet. At least nearly half of the firms rank specialized magazines and market surveys among the most important market information sources.

4.4 Knowledge exchange patterns: market and technological knowledge networks

The distinction between technological and market related knowledge (Section 4.1) provides a fine-grained picture of the VGD firms' knowledge exchange relations. The corresponding network analysis helps to find out with whom, and across what distances they share these different types of knowledge. At the same time, these insights provide a capable basis for determining the crucial knowledge base configuration that drives VGD within the cluster. Due to the focus on the *whole system* of knowledge linkages within and beyond the cluster's boundaries (Figures 2 and 3), the related data following hereafter is of an aggregated nature and does not necessarily reflect the knowledge network structure of one particular firm.

[12] Given that patenting video game software would be possible at all, many interviewees mentioned that protection mechanisms like these are rather seen as a no-go in the VGD community. Due to their opinion, patents would hamper the rapid development of the gaming industry for years.

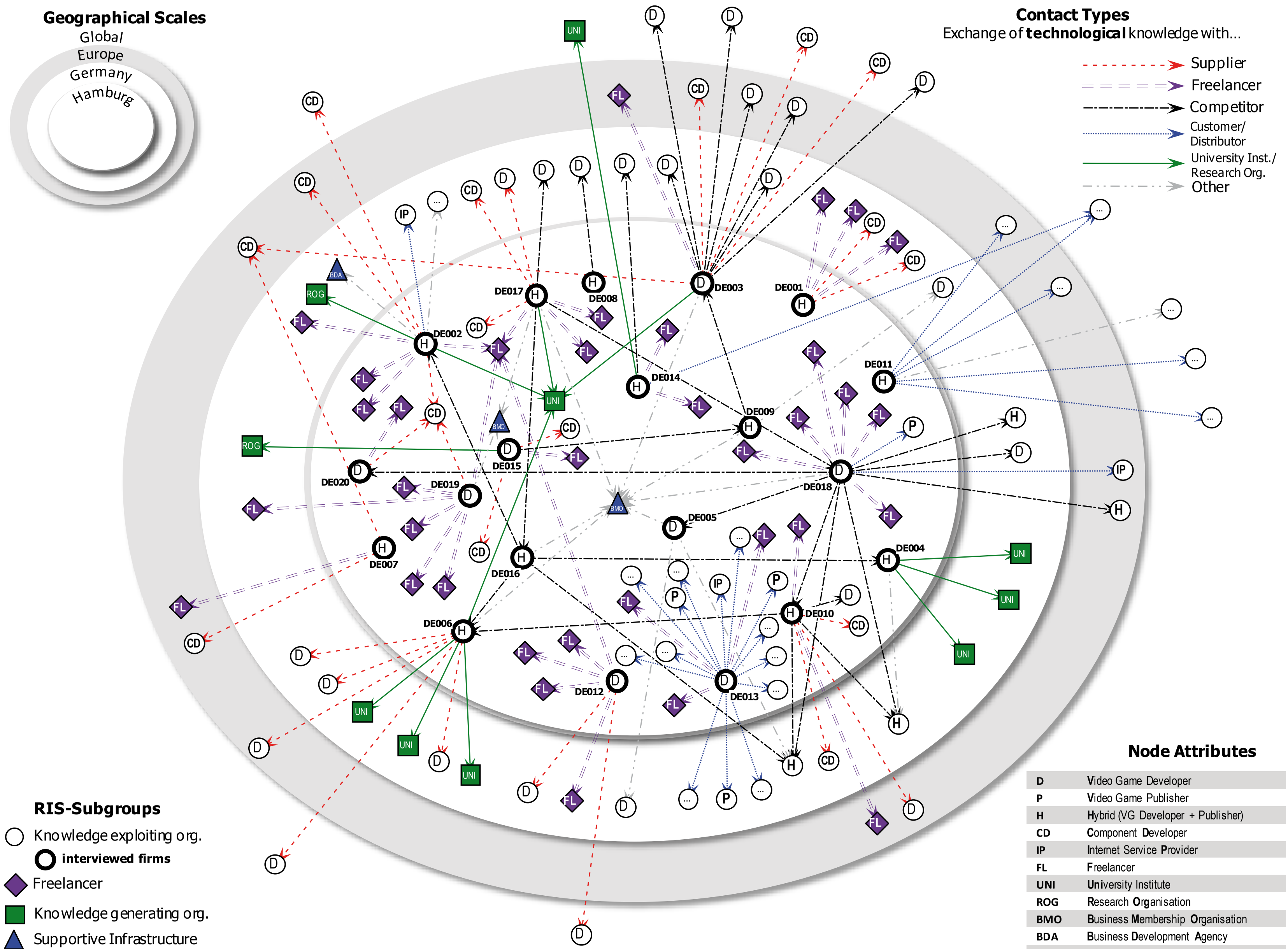

Figure 2. *Technological Knowledge Network of VGD firms (n=20) in Hamburg.*
Source: UCINET 6, elaborations based on own research data.

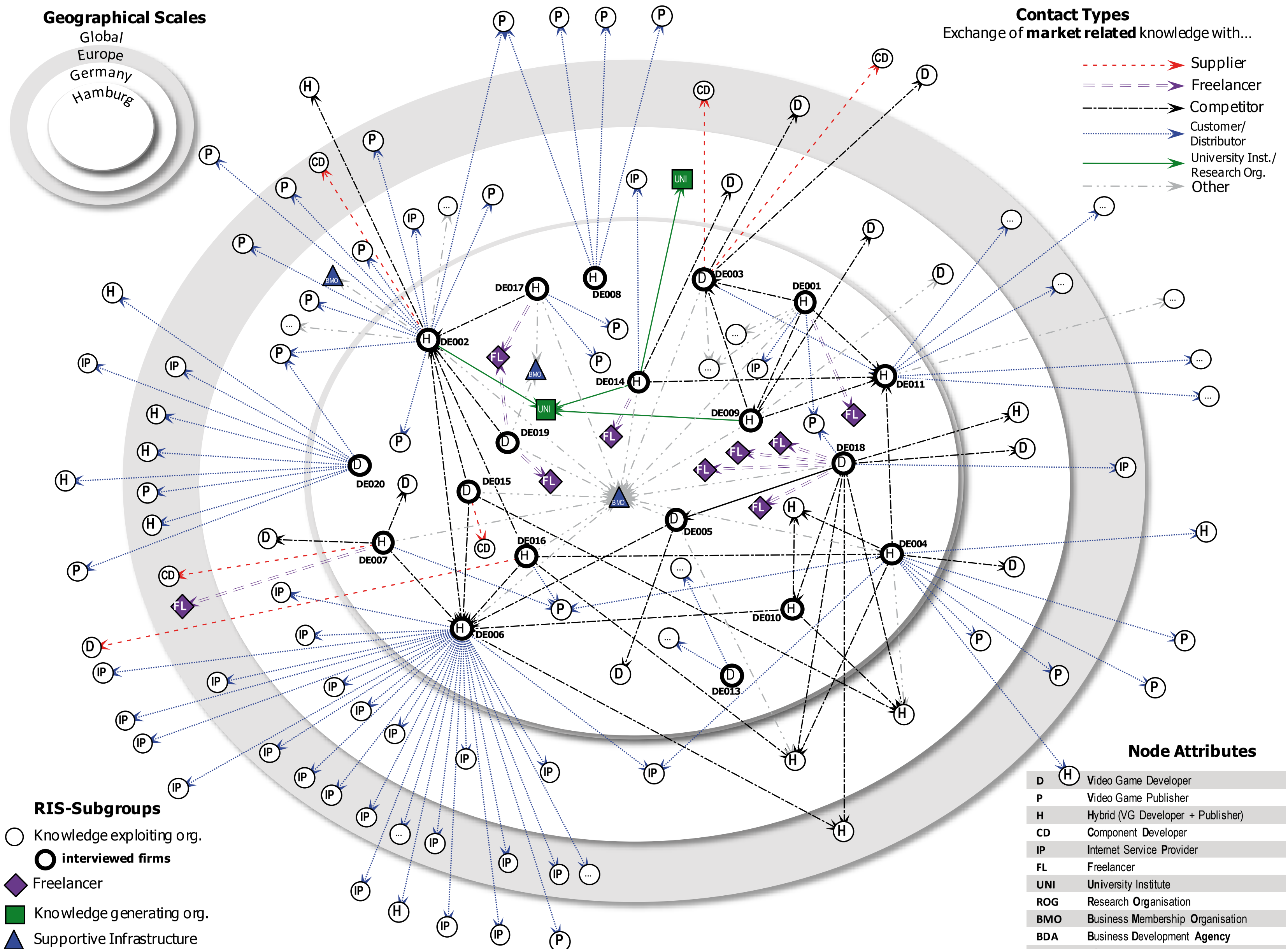

Figure 3. *Market Knowledge Network of VGD firms (n=19) in Hamburg.*
Source: UCINET 6, elaborations based on own research data.

Interactive learning between Hamburg's video game developers

Before we take a look at all the already mentioned contacts, Table 4 presents a range of *sociocentric* network indicators, concentrating on the knowledge flows identified between the 20 interviewed firms themselves.

The network *density* – calculated as a ratio between the actual number of ties and the potential maximum number of ties (Wasserman & Faust 1994) – is at least 0.0289 for the Technological Knowledge Network (TKN) (i.e., 2.9% of all potential inter-firm relationships between the interviewed firms are exploited), and 0.0614 (6.1%) for the Market Knowledge Network (MKN). In general, these figures prove that interactive learning between Hamburg's VGD firms takes place at a medium level. Especially with regard to the MKN, we can conclude that numerous potential *gatekeepers* (Giuliani & Bell 2005; Graf 2011) distribute relevant knowledge for innovation processes throughout the cluster. Tschang and Vang's (2008) ethnographic case studies of VGD projects might provide the appropriate explanation for the fact that the TKN is less dense than the MKN: The time-consuming projects (compared to other creative industries) require a longer period of constant interaction among team members. In combination with the need for secrecy, this form of work, the authors conclude, favors hierarchy-based governance modes and keeping technological knowledge in-house rather than sharing this knowledge with other VGD studios.

A glance at the number of network *components* reveals that the TKN connecting Hamburg's VGD studios is relatively fragmented, whereas the MKN is not: The TKN consists of 10 out of potentially 20 components, thereof one connecting 9 nodes, another one linking 3. The MKN consists of 4 of maximum 19 components, thereof a major one linking 16 firms.

Table 4. *Knowledge flows between 20 VGD firms for the TKN and 19 VGD firms for the MKN in Hamburg: summary of sociocentric network indicators*

Indicator	**TKN** (n=20)	**MKN** (n=19)
Number of ties	11	21
Density	0.0289	0.0614
Components	10	4
In-degree centralisation/ dicho	0.0803	0.2870
In-degree centralisation/ valued	0.0360	0.1643
Out-degree centralisation/ dicho	0.1357	0.1111
Out-degree centralisation/ valued	0.0914	0.0764
Hybrid reciprocity	11	21

The *centralization* index determines the extent of hierarchy within both networks. Except for the *in-degree centralization* measures concerning the MKN, both networks are relatively homogeneous in hierarchical structure.[13]

By combining the aforementioned network indicators we may conclude that for the exchange of technological knowledge the uniformity of network positions is situated on a modest level of interactive learning between the interviewed VGD firms. Market related knowledge circulates more intensely within this community, and the MKN is stronger geared to a few highly connected firms.

What can we now learn from these indicators in face of the underlying knowledge base? They show that knowledge sharing with more or less direct competitors constitutes a crucial strategy for a number of Hamburgian VGD studios. Spatially concentrated *communities of specialists*, as Cohendet and Simon (2007) call it, do exist within the cluster. This is typical for industries relying on the symbolic knowledge base. However, these specialists trade particularly market related information, whereas the exchange of knowledge targeting technological aspects is, so far, a little less intensive.

Nature of knowledge flows

From now on I turn to the *aggregated examination of the firms' entire egocentric knowledge networks* and with it leave the *sociocentric* perspective. The information given in Table 5 stresses that technology-oriented knowledge interactions are clearly oriented towards the applied and problem related dimension of knowledge used in VGD. Only very few firms in this sector cultivate relationships in order to absorb scientific expertise by, for example, integrating formal models. The concentration on sourcing for applied, practical-oriented knowledge, again, underlines the firm's dependency on synthetic and symbolic knowledge assets at the same time.

Table 5. *Characteristics of knowledge flows*

Knowledge Content	TKN	
	n	%
practical	138	93.2
scientific	3	2.0
both	7	4.7
Total	148	100.0

Notes: n = number of knowledge links, AvImp = average importance for firms' innovation performance (1 = not important, 5 = very important)

[13] Within the intra-regional MKN there are three firms, namely DE002, DE006 and DE011, which exhibit comparatively high in-degrees (see Figure 3).

Spatial organization of knowledge flows

Following Nachum and Keeble's (2003) call for broadening "the scope […] to explicitly acknowledge the variety of geographic scales at which these linkages take place", Table 6 distinguishes between locally/regionally bounded knowledge linkages and those transcending the national and the European boundaries. A central outcome is that easily most knowledge exchanges occur with network partners in close distance, which is typical for industries with predominantly synthetical and symbolic activities. Nearly every second knowledge flow stays within Hamburg itself, no matter if they refer to market or to technological aspects.

This finding goes in line with the assumption that knowledge creation processes of creative businesses are particularly anchored in local contexts which are capable to provide a buzz-like atmosphere (Bathelt et al. 2004) of creative ideas and knowledge spillovers. Hamburg's urban environment obviously serves this fertile ground (Scott 1997), guaranteeing the VGD firms to profit from the interaction in locally or regionally bounded professional communities (Cohendet & Simon 2007). Moreover, developing video games requires frequently repeated face-to-face-interactions to exchange ideas permanently and to negotiate further steps. Before publishing the game, the typical interactive steps of VGD are planning, scenario writing, developing graphics and sounds, programming, synthesizing graphics, sounds and programming, game testing, debugging, and beta testing (Oh 2007). Given a VGD firm does not stock all the knowledge ingredients needed in-house, it profits from the spatial proximity to co-operators, suppliers, customers and freelancers, facilitating the collaborative developing process.

Modern VGD requires sourcing for globally distributed knowledge as well, which is simplified through global virtual networks (Cairncross 1997). Due to the growing importance in this industry to widen marketing potentials, the need for knowledge sourcing on a global scale applies especially to the MKN. Although networking targeting in particular the technological dimension of the video game is, by quantity, notably vivid at the regional and national level of the TKN, the resulting knowledge flows rank lower in importance (concerning the firm's innovation performance) compared to international linkages. One explanation for this discrepancy between quality and quantity might be due to the inferior role of Germany within worldwide VGD (cf. Section 3). As a consequence, the firms are forced to source abroad to get access to the cutting-edge technological expertise they need. However, given that the *strength of weak ties* – paradox observed by Granovetter (1973) applies for this case study as well, the low rank of regional and national TKN contacts is not necessarily disadvantageous for the firms' innovative performances per se: According to Granovetter, weak ties often function as key mechanisms to mobilize ideas and information, in order to, for example, launch new products, or to solve a particular problem.

Table 6. *Geography of the TKN and MKN*

	TKN			MKN		
Geographical scale	**n**	**%**	**AvImp**	**n**	**%**	**AvImp**
Hamburg	73	49.3	2.9	68	41.5	2.8
Germany	45	30.4	3.1	36	22.0	3.3
Europe	17	11.5	3.9	28	17.1	2.6
Global	13	8.8	4.3	32	19.5	3.1
Total	148	100.0	3.2	164	100.0	2.9

Notes: n = number of knowledge links, AvImp = average importance for firms' innovation performance (1 = not important, 5 = very important)

Contact types

In addition to the geographical reach, every relation was further differentiated according to the type of contact (Table 7). The rationale behind this distinction is to determine the knowledge exchange partners which are crucial for the VGD process in order to gain a deeper insight into the particular knowledge base constellation driving this cluster.

To start with the exchange of technological knowledge, we observe that freelancers, specialized in different steps of the VGD process, are, by quantity and quality, the most important actors within the TKN of Hamburg's VGD firms (see also Figure 2).[14] These freelancers are highly mobile network actors (Lange & v. Streit 2011) which, in the Hamburg case, mostly work exclusively for a single VGD studio, yet on a temporary project basis (Grabher 2002a). As soon as these projects come to an end and new ones emerge, it is first of all the freelancers who change their position within the TKN, and new network constellations evolve. Hamburgian VGD studios potentially profit from such a sort of reconfiguring relationships: They accumulate knowledge through *learning by switching ties* (Grabher 2004a), albeit this process can be assumed to be less intense in the VGD industry compared to those creative industries being characterized by even shorter project periods (Tschang & Vang 2008). A precondition for this mode of learning is the *know-who* of potential collaborators to combine complementary, often highly tacit and embodied knowledge components in a productive way.

Competitors, composed of developers and hybrids in equal parts, constitute the second biggest group of knowledge exchange partners within the TKN of Hamburg's VGD firms. In combination with

[14] The group of freelancers in the video game sector includes, for example, game, graphic, and sound designers, software engineers, computer animators, or compositors.

the high share of interactions with freelancers, knowledge relations with competitors define the core of the community's network. The comparatively low average importance measure ascribed to competitors, however, points to a rather loose transfer of technology related information of rather low strategic impact. Interactive learning with suppliers, in particular component developers (i.e. firms specialized in delivering video game components, like enabling software, sound, animation, graphics, etc.), comprises nearly every fifth TKN contact, whereof less than every sixth relation refers to customers. In sum, the distribution of contact types within the VGD firms' TKN – reflecting the decisive role of freelancers, supplemented by knowledge transfers along the value chain – mirrors the typical knowledge exchange partners representing the symbolic knowledge base on the one hand and the synthetic knowledge base on the other hand. Due to the low percentage of TKN ties with university departments or other research organizations, the analytical knowledge base plays a minor role in this cluster.

Table 7. *Contact types within the TKN and MKN*

Contact type	TKN			MKN		
	n	%	AvImp	n	%	AvImp
Supplier	28	18.9	3.4	6	3.7	2.5
CoD	18	12.2	2.8	5	3.0	2.8
Dev	10	6.8	4.3	1	0.6	1.0
Freelancer	38	25.7	3.5	10	6.1	3.0
Competitor	30	20.3	2.5	41	25.0	2.7
Dev	16	10.8	3.4	11	6.7	2.8
Hyb	14	9.5	1.6	30	18.3	2.7
Customer/ distributor	23	15.5	3.5	77	47.0	2.9
Hyb	0	0.0	-	9	5.5	2.8
Pub	4	2.7	2.3	29	17.7	2.8
ISP	3	2.0	4.0	30	18.3	2.7
Other	16	10.8	3.7	9	5.5	4.1
University inst./ research orgs.	13	8.8	3.2	4	2.4	2.5
Other	16	10.8	3.2	26	15.9	3.6
BMO/BDA	10	6.8	2.6	17	10.4	3.2
Other	6	4.1	4.2	9	5.5	4.2
Total	148	100.0	3.2	164	100.0	2.9

Notes: n = number of knowledge links, AvImp = average importance for firms' innovation performance (1 = not important, 5 = very important), CoD = component developers, Dev = developers of video games, Hyb = firms that both develop and publish video games, Pub = publishers of video games, ISP = internet service providers, BMO/BDA = business membership organizations/ business development agencies

According to their share of all contact types, costumers are the dominating partners for Hamburg's VGD firms within the MKN. Nearly half of all knowledge transfers related to market aspects refer to this type of contact. A closer look at the data presented in Table 7 reveals that, within the group of customer contacts, it is mainly the publishers and internet service providers with whom the interviewed firms exchange strategic market information. Out of the VGDs' viewpoint these companies are closer to the market, predestined to deliver information in reference to, for example, latest market trends, consumer preferences, and competitor strategies. At least every fourth MKN contact refers to competitors, which is slightly more than the corresponding share mentioned for the TKN. Among the competitors it is particularly the hybrids which, due to their experience in publishing games, belong to the most interesting MKN partners. The low weight of supplier relations underlines the picture of a "centre of gravity" that, in comparison to the TKN, moves further to the customer side of the value chain. Finally, business membership organizations, first of all the local cluster initiative *gamecity:Hamburg* (cf. Section 3), belong to the most important providers of market knowledge. Alone *gamecity:Hamburg* bundles numerous MKN relations, functioning as the key knowledge broker throughout the network.[15] Particularly its quarterly organized business gathering provides a highly frequented networking opportunity, bringing creative heads together in a laid-back atmosphere of happening bars and club environments.

5. Conclusion, or getting back to the pizza

I have to confess that Mr. Iwatani and his famous slice of pizza are far away from present day video game developers in Hamburg with reference to time and space. However, after having presented and discussed a number of indicators in order to identify the knowledge base configuration which drives knowledge creation and innovation processes within Hamburg's VGD industry, Mr. Iwatani and his pizza, later called Pac-Man, suddenly, seem to be very close. This closeness, as already mentioned, does not refer to the location of named actors or the time they do or did something. The closeness refers to the ways different building blocks of information, skills and knowledge are to be linked in order to make a video game appear at nowadays computer, TV, or smart phone screens.

The central outcome of this paper is that it is both, the synthetic and the symbolic knowledge, and less the analytical one which drives VGD in Hamburg. Nevertheless, it is not easy to say just by numbers if there is one of the two dominating knowledge bases which is more important for the average Hamburgian VGD studio compared to the other. Therefore, we may ask "What kind of activities defines the competitive core of the VGD studio, and which one could be sourced out without giving away this core competence?"

A plausible answer could be the one that it is in fact the activities based on the symbolic knowledge assets that constitute this core competence. It is foremost the creativity of the game developer, and only to a lesser extent the computing skills, which influences the gameplay, the story, the sound and

[15] Assuming that the analysis of interactive learning between Hamburg's VGD firms themselves (see the first part of Section 4.4) includes gamecity:Hamburg as well, network indicators – especially those describing the MKN structure – would indicate an even higher density of knowledge flows within Hamburg's VGD industry.

the visualizations of the game the most. These are exactly the elements of the video game which cause the distinguishing feature, and thus influence the firm's competitiveness to the greatest extent. Others may comparatively simple reply that the creative horizons of the game are determined by the technological possibilities of soft- and hardware. Consequently, VGD firms always have to be up-to-date concerning new technologies und should not give this expertise away to another company.

From my point of view, answering the question "What is the core competence and what can be sourced out?" in a black and white manner does not give enough consideration to the complexity of the interaction between creativity and technology in modern VGD. The data I presented within this paper reflected quite well – to use Guérin's words – the "alchemy between technology and creativity" (2006, p.303) in Hamburg's VGD cluster. If policymakers want to fine-tune innovation policies according to the specific needs of this industry, they have to pay attention to the coactions of the symbolic and the synthetic knowledge base.

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8. Wissensbasen als Typisierung für eine maßgeschneiderte regionale Innovationspolitik von morgen?

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1. Die Notwendigkeit einer Typisierung nach Wissensbasen in der regionalen Innovationspolitik

Wenn es um Politik zur Förderung interaktiver Innovationsprozesse geht, gewinnt die regionale Ebene in vielen Industrieländern stark an Bedeutung (Cooke/Morgan 1998; Amin 1999; Koschatzky 2001; Asheim et al. 2003; Fritsch/Stephan 2005; Asheim et al. 2006). Zum Teil finanziert und stimuliert durch nationale und supranationale (europäische) Rahmenprogramme und beflügelt durch Erfolgsregionen wie Baden-Württemberg und Emilia-Romagna, haben viele Regionen in Industrieländern seit der zweiten Hälfte der 1980er Jahre Gründer- und Technologiezentren, Science Parks, Technopoles, Innovationsförderprogramme, Innovationsberatungsstellen und Clusterinitiativen ins Leben gerufen. Das Ziel dieser Maßnahmen ist es, durch die Förderung der Diffusion von neuen Technologien und von Wissen von Hochschulen und Forschungseinrichtungen zu kleinen und mittleren Unternehmen auf der einen Seite, und von Großbetrieben zu kleinen und mittleren Unternehmen, sowie zwischen kleinen und mittleren Unternehmen auf der anderen Seite, endogene Potenziale in Regionen zu entfalten. Der Bedeutungszuwachs der regionalen Ebene für Innovationsförderung kann als Ergebnis eines Zusammenwachsens von Regionalpolitik und Technologiepolitik betrachtet werden (Koschatzky 2001).

Beide Politikfelder weisen seit den 1980er Jahren eine konvergierende Tendenz in Richtung einer regionalen Innovationsförderung auf, da ihre Ziele, nämlich die Förderung der Innovationskraft und generell der Wettbewerbsfähigkeit von kleinen und mittleren Unternehmen, einander immer ähnlicher werden. Die Nähe zum spezifischen Bedarf der regionalen Akteure wird als eine der größten Stärken der Innovationsförderung auf regionaler Ebene gesehen. Nationale Ministerien können mit Allgemeinrezepten die spezifischen Wirtschaftsprobleme einzelner Regionen nur unzureichend lösen, während Entscheidungsträger auf regionaler Ebene aufgrund Ihrer Vertrautheit mit aktuellen Problemlagen in den jeweiligen Regionen Maßnahmen besser auf Probleme abstimmen können. Außerdem erhöht die Einbindung der regionalen Entscheidungsträger in die Umsetzung der Politikziele deren Motivation und Engagement, da sie „ihre eigenen“ Maßnahmen entwickeln und durchführen können. Schließlich steigt mit der Dezentralisierung auf regionaler Ebene die Chance einer größeren Vielfalt an stärker den regionalen Spezifika angepassten politischen Initiativen, wodurch interregionale Lerneffekte auftreten können. In Europa hat die regionale Innovationsförderung in den 1990er Jahren im Zuge der EU-Förderung durch Programme wie „Regionale Innovations- und Technologietransfer Strategien“ (RITTS) einen zusätzlichen Aufschwung erfahren.

Die regionale Innovationsförderung wurde sowohl durch ältere Theoriekonzepte, wie Industriedistrikte, als auch durch jüngere theoretische Ansätze, wie Regionale Innovationssysteme, die Lernende Region und Cluster beeinflusst. Diese so genannten territorialen Innovationsmodelle (Moulaert/Sekia 2003) wollten auf der einen Seite die Bedeutung der regionalen Ebene als Quelle für interaktives Lernen, Wissenstransfers und Innovationen betonen und auf der anderen Seite regionalpolitische Lehren aus Erfahrungen in Erfolgsregionen wie Baden-Württemberg und Emilia-Romagna ziehen (Cooke/Morgan 1998).

Zwar wurde mit der zunehmenden Regionalisierung von Innovationspolitik der Weg für eine weitere Ausdifferenzierung regionaler Förderinstrumente geebnet. Bislang jedoch hat die augenscheinliche Fokussierung der regionalen Innovationsförderung auf stets die gleichen Erfolgsregionen im Sinne von scheinbar nachahmenswerten Best-Practice-Beispielen sowie die Integration dieser in die Beratungspraxis eher zu einer Standardisierung der regionalen Innovationsförderung geführt, die in letzter Zeit kritisiert wird (Tödtling/Trippl 2005; Visser/Atzema 2008). Hassink und Ibert (2009: 167) dazu: „Noch problematischer dürfte allerdings die Gefahr sein, dass einige wenige Erfolgsregionen immer wieder den Referenzpunkt für politische Intervention bilden und damit zu einem politikstrategischen Passe-par-tout aufgebaut werden. Dem ist die Gefahr der Vereinheitlichung der Erfolgsrezepte inhärent, so dass jede Region tendenziell mit derselben Entwicklungsstrategie operiert, allerdings unter vollkommen unterschiedlichen Voraussetzungen und meist mit – im Vergleich zu den erfolgreichen Vorbildern – geschmälerten Erfolgsaussichten“.

Welche Lösungsansätze gibt es aber, um dieser Standardisierung entgegen zu wirken? Einige Ansätze gehen beispielsweise von einer Typisierung Regionaler Innovationssysteme aus, wie es Cooke (2004) mit den Graswurzel-, integrierten und dirigistischen Systemen getan hat, oder wie es Asheim und Coenen (2005) mit den Kategorien der territorial eingebetteten, den netzwerkartigen Regionalen Innovationssystemen und den regionalisierten Nationalen Innovationssystemen vorgeschlagen haben. Tödtling und Trippl (2005) schlagen vor, von typischen Innovationsbarrieren in unterschiedlich strukturierten Regionen auszugehen (Lock-Ins in altindustriellen Regionen, institutionelle Unterversorgung in peripheren Regionen und Fragmentierung in Großstadtregionen). Menzel und Fornahl (2009) haben die Phase des Clusters in seinem Lebenszyklus als Ausgangspunkt für eine verbesserte clusterbezogene Innovationsförderung vorgeschlagen.

Ein aktueller Versuch, regionale Innovationsstrategien stärker den regionalen Bedingungen anzupassen und damit erfolgreicher zu entwickeln, fußt schließlich auf der Berücksichtigung der offensichtlichen branchenspezifischen Unterschiede bei der Produktion, Anwendung und Weitergabe von Wissen. Dabei wird zwischen analytischen, synthetischen und symbolischen Wissensbasen (*industrial knowledge bases*) unterschieden. Diese Typisierung bildet den Kern unseres vorliegenden Beitrages.

Ziel unseres Beitrages zu diesem Sammelband ist es, diese neue Wissenstypkategorisierung vorzustellen und dabei darzulegen, in welchem Maße sie zu einer regionalen Innovationspolitik beitragen kann, die sich auf die jeweils spezifischen regionalen Wissensbasen bezieht. Der Beitrag basiert auf der aktuellen Arbeit der zwei Autoren in dem von der *European Science Foundation* geförderten europäischen Verbundprojekt „Constructing Regional Advantage (CRA): Towards State-of-the-Art Regional Innovation System Policies in Europe?“ Als theoretischer Rahmen dient dem Projekt eben jenes Konzept der Wissensbasen. Im Folgenden werden zuerst die verschiedenen Wissensbasen vergleichend gegenübergestellt. Anschließend erfolgt eine exaktere Betrachtung der jeweiligen Wissensbasen getrennt voneinander sowie eine beispielhafte Zuordnung verschiedener Wirtschaftszweige zu den Wissensbasen. Im letzten Abschnitt wird eine erste Einschätzung getätigt, inwiefern das Konzept der Wissensbasen genügend Potenzial aufweist, die Entwicklung in Richtung einer zukunftsfähigen (regionalen) Innovationspolitik weiter voranzutreiben. Weiterhin werden erste (regional-) innovationspolitische Handlungsempfehlungen entwickelt, die sich an den Besonderheiten der drei verschiedenen Wissensbasen ausrichten.

2. Wissensbasen im Vergleich

In Anlehnung an Asheim und Gertler (2005) argumentieren wir, dass Innovationsprozesse in verschiedenen Wirtschaftssektoren sehr unterschiedlich verlaufen und stark von der jeweils zugrundeliegenden Wissensbasis abhängen. Konkret lassen sich drei Wissensbasen unterscheiden: die analytische (wissenschaftsbasiert), synthetische (technisch/technologisch basiert) (Laestadius 1998) sowie die symbolische (kreative) Wissensbasis.[1] Die beschriebene Typisierung geht über die üblichen Diffe-

[1] Die Idee, zwischen den drei beschriebenen Wissensbasen zu unterscheiden, ging aus einer Diskussion zwischen Bjørn Asheim, Franz Tödtling, Gernot Grabher und Åge Mariussen im Jahr 2001 hervor (Asheim et al. 2007). Bereits 1998 unterschied Laestadius (Laestadius 1998) zwischen zwei der drei Wissensbasen: der synthetischen und der analytischen Wissensbasis.

renzierungen traditioneller Wissenstypologien, wie die des impliziten und expliziten Wissens, hinaus, indem sie ein vollständigeres Verständnis von dem Entstehen, der Anwendung sowie der Weitergabe von Wissen in unterschiedlichen Wirtschaftszweigen vermittelt. Die dreigliedrige Typologie hilft, die zentralen Merkmale der kritischen Wissenselemente zu erfassen, ohne die eine Innovationstätigkeit nicht stattfinden kann. In seiner ganzheitlichen und gleichzeitig differenzierenden Betrachtungsweise bildet die Unterscheidung der Wissensbasen – so die Annahme – eine Schlüsselvoraussetzung für die Weiterentwicklung maßgeschneiderter innovationspolitischer Instrumente, insbesondere auf regionaler Ebene.

Anhand von Tabelle 1 werden die zentralen Merkmale der analytischen, synthetischen sowie symbolischen Wissensbasen einander gegenüber gestellt. Die aufgelisteten Merkmale sind als idealtypische Beschreibung der jeweiligen Wissensbasis zu verstehen. Es geht darum, den Blick für die offensichtlichen Unterschiede zwischen den Lern-, Wissens- und Innovationsprozessen verschiedener Wirtschaftszweige zu schärfen. Um ihre Innovationsbemühungen voranzutreiben greifen die Organisationen verschiedener Wirtschaftszweige jeweils auf einen unterschiedlichen Mix aus Elementen verschiedener Wissensbasen zurück (vgl. Abbildung 1). So weisen Asheim, Boschma und Cooke (2007: 12) darauf hin, dass "the threefold distinction refers to ideal-types, most activities are in practice comprised of more than one knowledge base. The degree to which certain knowledge bases dominates, however, varies and is contingent on the characteristics of the firms and industries."

Jede der drei Wissensbasen besteht aus gewissen Kombinationen impliziten (stillen, personengebundenen) und expliziten (kodifizierten) Wissens (Polanyi 1966; Nelson/Winter 1982; Nonaka/Takeuchi 1995; Gertler 2003) sowie bestimmten Qualifikationen und Fähigkeiten, die von Organisationen in besonderem Maße nachgefragt werden. Weiterhin deutet das Theoriekonstrukt auf die Andersartigkeit der Innovationsherausforderungen und Muster des Wissensaustauschs im Vergleich der drei Wissensbasen hin. Diese Muster beeinflussen wiederum, in Kombination mit dem Grad der Kodifizierung des relevanten Wissens, die Sensitivität für räumliche Nähe zwischen den Wissensaustauschpartnern in interaktiven Lernprozessen (Amin/Cohendet 2004; Coenen et al. 2006; Asheim 2007). Außerdem spricht vieles dafür, dass das Ausmaß der Dominanz einer bestimmten Wissensbasis in Innovationsprozessen nicht nur vor dem Hintergrund branchenspezifischer Unterschiede zu betrachten ist. Die Tendenz zu einer bestimmten Wissensbasis hängt auch von der Phase ab, die den jeweiligen Entwicklungsstand innerhalb eines Innovationsprozesses beschreibt (Moodysson/Coenen/Asheim 2006).

Tabelle 1. *Idealtypische Merkmale der Wissensbasen im Vergleich*

Merkmal	Analytisch *science-based*	Synthetisch *engineering-based*	Symbolisch *creativity-based*
Eigenschaft des Wissens	Kodifiziertes Wissen in Patenten und wissenschaftlichen Publikationen et cetera	Personengebundenes, implizites Wissen durch anwendungsbezogenes *know how*, praktische Fähigkeiten	Personengebundenes, implizites Wissen, praktische Fähigkeiten
Generierung von Wissen	Deduktiv durch formale Modelle/ Wissenschaft licher Input (*know why*)	Induktiv, anwendungs- und problemorientiert (*know how*)	Interaktive, informelle und kreative Praxisorientierung (*know who*)
Charakter des Lernprozesses	Lernen durch Erforschen und Interagieren	Lernen durch Tun, Nutzen und Interagieren	Lernen durch Tun und Interagieren, Lernen von Jugend-/Straßenkultur
Austausch von Wissen	F&E-Zusammenarbeit mit Betrieben (F&E-Abteilungen) und Forschungseinrichtungen	Interaktiver Lernprozess mit Kunden und Zulieferern	Wissensaustausch innerhalb branchenspezifischer „communities“
Innovations-verständnis	Radikale Innovationen, Innovationen auf Grundlage neuen Wissens	Inkrementelle Innovationen, Innovationen durch Anwendung/ Kombination bestehenden Wissens	Innovationen durch kreative Verknüpfung bestehenden Wissens
Mitarbeiter-Qualifikation	Akademischer Studienabschluss/ Forschungserfahrung	Fachhochschulabschluss/ Berufsschulausbildung/„On-the-job-Training“	Kreativität, Vorstellungsvermögen und Interpretationsfähigkeiten
Bedeutung räumlicher Nähe	Gering bis mittel	Mittel bis hoch	Mittel bis hoch
Beispielhafte Tätigkeiten	Labor-basierte Forschung, wissenschaftlicher Diskurs	System-Design, Prototypenbau, Feinabstimmung, Prüfen und praktische Arbeit	Ideenfindung in Projektgruppen, Design, Imageaufbau

Quelle: Eigene Bearbeitung in Anlehnung an Asheim, Boschma und Cooke (2007: 12), Asheim (2007: 227), Asheim und Gertler (2005) und Moodysson, Coenen und Asheim (2006: 1047).

2.1 Die analytische Wissensbasis

Die analytische Wissensbasis geht auf den aristotelischen *episteme*-Begriff (griechisch für wissenschaftliche Erkenntnis) zurück und bezieht sich eher auf universelles und theoretisches Wissen, das dazu dient, die Eigenschaften der (natürlichen) Umwelt zu verstehen und zu erklären (*know why*) (Johnson/Lorenz/Lundvall 2002). Der Innovationsprozess innerhalb derjenigen Branchen, die in besonderem Maße Merkmale der analytischen Wissensbasis aufweisen, ist stark von wissenschaftlichem Input abhängig. Die Generierung von Wissen gründet häufig auf deduktiven, kognitiven und rationalen Prozessen oder auf formalen Modellen, was ausreichende Abstraktionsfähigkeiten der Arbeitskräfte voraussetzt.

Grundlagen- und angewandte Forschung sowie systematische Produkt- und Prozessentwicklung stellen Kernaktivitäten der Betriebe dar. Um erfolgreich Wissen in Innovationen umzuwandeln, unterhalten viele dieser Betriebe ihre eigenen Forschungs- und Entwicklungsabteilungen, stützen sich aber zusätzlich in beträchtlichem Maße auf Forschungsergebnisse von Universitäten und anderen Forschungseinrichtungen. Der erhebliche wissenschaftliche Einfluss spiegelt sich auch in intensiven akademischen Spin-off-Aktivitäten wider.

Die in den Innovationsprozess integrierten Wissens-In- und Outputs bestehen grundsätzlich aus einer Kombination impliziter und expliziter Bestandteile (Nonaka/Takeuchi 1995; Johnson/Lorenz/Lundvall 2002). Vereinfacht wird der Austausch beider Bestandteile durch Face-to-face-Kontakte. Trotzdem sind für den analytischen Fall Face-to-Face-Kontakte tendenziell unbedeutender als für den synthetischen Fall, weil Wissen häufiger kodifiziert und somit zwischen global verteilten Akteuren besser austauschbar ist (Asheim/Coenen/Vang 2007). Für den großen Anteil kodifizierten Wissens gibt es mehrere Gründe: (i) Neues Wissen basiert häufig auf der Analyse bereits existierender Studien (ii) oder der Anwendung wissenschaftlicher Prinzipien und Methoden. (iii) Innovationsprozesse sind eher formal organisiert (zum Beispiel in Forschungs- und Entwicklungsabteilungen) und (iv) Resultate werden meist in Berichten, elektronischen Dokumenten oder Patentbeschreibungen dokumentiert.

Obwohl räumliche Nähe zwischen den Wissensaustauschpartnern – aufgrund des relativ hohen Kodifizierungsgrades des Wissens – eine im Vergleich zu den beiden anderen Wissensbasen relativ geringe Rolle spielt, tendieren Industrien des analytischen Typs dazu, sich in der Nähe von Universitäten und sonstigen Forschungseinrichtungen anzusiedeln, die dem jeweiligen Betätigungsfeld entsprechend Forschung betreiben (Cooke 2005). Hier spielt der (persönliche) Zugang zu führenden Wissenschaftlern sowie Forschungs- und Entwicklungsinfrastrukturen eine wichtige Rolle für die Betriebe, um eigene Innovationsprozesse erfolgreich zu gestalten. Abgesehen davon tauschen viele Betriebe, die sich primär auf die analytische Wissensbasis stützen, (in der Regel kodifiziertes) Wissen im globalen Maßstab aus (Moodysson/Coenen/Asheim 2006).

Die oben genannten Aktivitäten erfordern spezielle Qualifikationen und Fähigkeiten der Arbeitskräfte. So sind neben dem bereits erwähnten Abstraktionsvermögen Kenntnisse zu Theoriebildung und -überprüfung und zur Dokumentation von Vorgehensweisen oder von Analyseergebnissen besonders gefragt. Den idealtypischen Anforderungsprofilen entsprechend verfügt der Kern der Arbeitskräfte über einen akademischen Studienabschluss und/oder Forschungserfahrung.

Die Anwendung von Wissen in Wirtschaftszweigen, die in besonderem Maße auf einer analytischen Wissensbasis fußen, mündet häufig in radikalen Produkt- und Prozessinnovationen. Derartige Innovationen bilden nicht selten den Ausgangspunkt für neue Start-Ups und Spin-Offs (Asheim/Coenen 2005; Asheim/Boschma/Cooke 2007; Asheim et al. 2007).

2.2 Die synthetische Wissensbasis

Die synthetische Wissensbasis leitet sich aus dem aristotelischen téchne-Begriff (griechisch für praktisches Können) ab. Folglich umfasst die synthetische Wissensbasis eher technisch oder technologisch basiertes, instrumentelles, kontextspezifisches und praktisches Wissen (*know how*). Das so geartete Wissen kommt vor allem in Innovationsprozessen in ingenieursorientierten Industrien und in der Mehrzahl unternehmensbezogener Dienstleistungen zur Anwendung und fließt zum Beispiel in die Konstruktion eines Produktes oder Prozesses, mit dem primären Ziel, eine bestimmte Funktion zu erfüllen ein (Johnson/Lorenz/Lundvall 2002; Strambach 2008). Es geht dabei um das Lösen einer konkreten Problemstellung. Der Prozess der Wissensentstehung läuft induktiv ab. Beispielhafte Tätigkeiten sind das (computerbasierte) Entwerfen komplexer technologischer Systeme, die Konstruktion von Prototypen, die Feinabstimmung und Überprüfung von Produkten sowie die praktische Arbeit im Allgemeinen. Fachhochschulen, Berufsschulen und „On-the-job-Training“ sind besonders wichtige Rekrutierungsquellen, da sie insofern eine angemessene Ausbildung gewährleisten, als dass sie auf das Erlernen anwendungsorientierter, konkreter handwerklicher und praktischer Fähigkeiten abzielen.

Die Forschungs- und Entwicklungsintensität ist grundsätzlich geringer einzustufen als es bei der analytischen Wissensbasis der Fall ist. “Overall, the accentuation within ‘R&D’ refers more to the ‘D-part’ in the form of product or process development” (Plum und Hassink 2011). Spielt Forschung eine Rolle, ist es meist angewandte Forschung (im Unterschied zu Grundlagenforschung), auch innerhalb interaktiver Lernprozesse zwischen Industrie und Universität. Der Wissensaustausch mit Universitäten und anderen Forschungseinrichtungen kann durchaus eine signifikante Rolle im Innovationsprozess der Betriebe spielen, obgleich der Schwerpunkt interorganisationaler Lernprozesse eher von inter-industriellen Verknüpfungen dominiert wird. Produkt- und Prozessinnovationen finden meist im Rahmen der Interaktion mit Kunden und Anbietern durch die Anwendung oder neue Kombination bereits bestehender Wissensbausteine statt.

Wissen, das in konkreten technischen Lösungen oder Arbeitsschritten verankert ist, kann zumindest teilweise in kodifizierter Form zugänglich sein (beispielsweise durch technische Zeichnungen). Da aber ein Großteil des Wissens häufig durch die am Arbeitsplatz erworbene (und damit personengebundene) Erfahrung sowie durch *learning by doing, using and interacting* entsteht, ist implizites Wissen in Bezug auf die synthetische Wissensbasis typischerweise wichtiger als dies für den analytischen Fall gilt (Nonaka/Takeuchi 1995; Johnson/Lorenz/Lundvall 2002). Die Übertragung von implizitem Wissen setzt fast immer voraus, dass sich Personen zur selben Zeit am selben Ort befinden (Audretsch 1998), weshalb für die synthetische Wissensbasis eine relativ stärkere Sensitivität gegenüber der räumlichen Nähe von Innovationspartnern charakteristisch ist.

Die Prozesse der Wissensgenerierung und -anwendung werden mit Blick auf die synthetische Wissensbasis insbesondere durch die Modifikation bestehender Produkte und Prozesse bestimmt. Häufig wird damit das Ziel verfolgt, die Effizienz wie Reliabilität neuer Lösungen zu erhöhen oder die praktische Anwendbarkeit und Nutzerfreundlichkeit aus Sicht der Konsumenten zu verbessern. Daher sind Innovationsprozesse in solchen Industrien meist inkrementeller Natur. Sie finden vorwiegend in bereits bestehenden Betrieben statt, aus denen relativ selten Spin-offs hervorgehen (Asheim/Coenen 2005; Asheim/Boschma/Cooke 2007; Asheim et al. 2007).

2.3 Die symbolische Wissensbasis

Mit zunehmender Bedeutung kreativ-kultureller Wirtschaftszweige, wie der Medienbranche (inklusive der Film- und Musikbranche, Printmedien, Internet), Werbe-, Design- oder Modebranche (Scott 1997; Scott 2007), hat sich neben der analytischen und synthetischen Wissensbasis ein dritter Wissensbasistyp herauskristallisiert: die symbolische Wissensbasis. Sie findet Ausdruck in der Ästhetik von Produkten, dem Design, dem Aufbau eines bestimmten Images im Zuge der Markenbildung von Produkten oder in der wirtschaftlichen Schaffung beziehungsweise Nutzung unterschiedlicher Formen kultureller Artefakte. Insofern zielen Innovationsprozesse typischerweise primär auf das Schaffen von symbolischen und damit immateriellen Werten (*sign-value*) ab und nur sekundär auf den Nutzwert (*use-value*) materieller Produkte.

Für kreativ-kulturelle Branchen, die durch die symbolische Wissensbasis geprägt sind, haben ästhetische Qualitäten einen höheren Stellenwert als kognitive Qualitäten. Insofern steht bei der Suche und Auswahl der Arbeitskräfte weniger deren Begabung im Vordergrund, Informationen besonders effizient aufnehmen und weiterverarbeiten zu können, sondern vielmehr deren Fähigkeit, symbolische Werte interpretieren und eigens kreieren zu können (Asheim et al. 2007). Kreativität, Vorstellungsvermögen und Interpretationsfähigkeiten sind die für diese Wissensbasis typischen Schlüsselqualifikationen. Allein ein universitärer Abschluss in einem Kultur-affinen Fach reicht damit nicht aus. Die Ausbildung in derart schöpferischen Wirtschaftszweigen versteht sich in erster Linie als ein Lernen im Sinne von *learning-by-doing*. Selbst Universitäten und Fachhochschulen fördern diesen Lernprozess, indem sie Wissen häufig auf Basis von Projektarbeiten vermitteln. Welche Bildungseinrichtungen allerdings besonders wichtig für die Entwicklung einer symbolischen Wissensbasis sind, hängt stark von dem jeweiligen regionalen und nationalen Kontext sowie der jeweilig betrachteten kreativen Branche ab (Asheim/Coenen/Vang 2007).

Das symbolische Wissen setzt ein tiefgründiges Verständnis von den Gewohnheiten und Normen derjenigen Gesellschaftsgruppen voraus, die im Fokus des jeweiligen (wirtschaftlichen) Interesses stehen. Asheim, Boschma und Cooke (2007) sprechen in diesem Zusammenhang auch von vertieften Einblicken in die *everyday culture* als wichtige Voraussetzung für das Erreichen bestimmter Ziele und Zielgruppen. Das kreative Wissen enthält eine vorwiegend implizite Komponente und ist stark kontextabhängig, da dessen Interpretation und Erzeugung erheblich von seiner kulturellen Einbettung abhängt. Aufgrund der Betonung persönlicher Fähigkeiten, Talente und Kreativitätsvermögen sind der Innovationsprozess und das eingesetzte Wissen in hohem Maße an Personen gebunden (Asheim et al. 2007). Diese tauschen sich häufig im Rahmen zeitlich begrenzter Projekte aus „in which knowledge is combined from a variety of sources to accomplish a specific task" (Grabher 2004: 1493). Stellt die Projektorientierung selbst kein differenzierendes Merkmal zur synthetischen und analytischen Wissensbasis dar, so lässt sich dies von dem spezifischen Charakter der Projektorganisation sehr wohl behaupten: Projekte, in deren Mittelpunkt Kreativität und das Schaffen symbolischer Werte stehen, weisen eher einen disruptiven Charakter auf. Während die Zusammensetzungen der Teams, die der synthetischen oder analytischen Logik entsprechen, in einer Folge von Projekten stärker auf Stabilität und Kumulation abzielen, sind die Akteurskonstellationen der symbolischen Wissensbasis über die Zeit betrachtet sehr viel instabiler. Hier können Menschen aus sehr unterschiedlichen beruflichen oder bildungsbezogenen Hintergründen aufeinandertreffen und in einer Atmosphäre produktiver Spannungen und Gegensätze neue Ideen und kreative Lösungen entwickeln. So folgern Asheim et al. (2007: 34): „Projects requiring a symbolic knowledge base […] are seen as arenas of productive tensions and creative confl icts that trigger innovation."

Stärker als dies bei der analytischen Wissensbasis der Fall ist, erfolgt der Wissenstransfer mit Blick auf die symbolische Wissensbasis vornehmlich über lokale informelle Informationskanäle, weshalb die räumliche Nähe beziehungsweise schnelle Erreichbarkeit zwischen den sich austauschenden Menschen besonders wichtig ist. Innovationsprozesse sind damit in besonderem Maße auf *local buzz* und Face-to-Face-Kommunikation zwischen potenziell kreativen Akteuren angewiesen. Bei local buzz ist es so, dass „actors are not deliberately ‚scanning' their environment in search of a specific piece of information but rather are surrounded by a concoction of rumours, impressions, recommendations, trade folklore and strategic information" (Grabher 2002: 209). Daher erscheint es nicht verwunderlich, dass das Gros der kreativ-kulturellen Wirtschaftszweige in den mit einer Vielzahl anregender und gut erreichbarer *hot spots* bespickten Städten und Metropolregionen zu finden ist (Asheim/Coenen/Vang 2007). Die starke Betonung von local buzz schließt jedoch eine überlokale, globale Verflechtung der Akteure keineswegs aus, schließlich setzen sich Projektteams häufig aus unterschiedlichen Kulturkreisen zusammen, so zum Beispiel am Filmset. Letztlich kommt es aber auch hier darauf an, dass die Menschen zumindest einen Teil der Projektlaufzeit an einem Ort zusammen kommen, um gemeinsam kreativ zu werden und ein kulturelles Produkt zu schaffen. Gerade Städte mit hohem kreativen Potenzial und einer ausgeprägten symbolischen Wissensbasis ziehen Kulturschaffende aus aller Welt an und bilden damit Knotenpunkte überlokal verbreiteten Wissens. Da symbolisches Wissen – wie geschildert – vor allem in personengebundener Kreativität Ausdruck findet und projektbezogen ausgetauscht und weiterentwickelt wird, ist eine genaue Kenntnis des Arbeitsmarktes nötig (*know who*), um Arbeitskräfte den Projektanforderungen entsprechend gezielt auswählen zu können. Abgesehen von der Entscheidung, welche Mitarbeiterin oder welcher Mitarbeiter eingestellt wird, ist das *know who* essentiell für den Projekterfolg, wenn es um die Suche nach unternehmensexternen Projektpartnern mit komplementären Fähigkeiten geht. Local buzz spielt auch hier eine wesentliche Rolle, wird die Zusammensetzung einer Projektgruppe doch nicht selten durch den eher informellen, teilweise zufälligen Austausch von Gerüchten und Informationen über potenzielle Projektteilnehmer beeinflusst. Die entsprechenden Voraussetzungen sind abermals in Städten und Metropolregionen zu finden, in denen nicht nur die Heterogenität der Wirtschafts- und Bildungsstruktur kreative Spannungen erzeugt, sondern auch ein grundsätzlich anregendes städtisches Umfeld anziehend auf kreative Individuen wirkt (Scott 1997). So weisen auch Asheim, Coenen und Vang (2007: 666) darauf hin, dass „the supply of ‘quality of life’ aspects, reflecting the dominant tastes of the employees in the industries with respect to bars, cafés, nightclubs, are crucial in attracting the creative workers”. Neben dem Vorhandensein derartiger Treffpunkte und der damit für viele Nutzer einhergehenden Steigerung der Lebensqualität sind Offenheit und Toleranz wichtige Standortkriterien für die Entwicklung einer symbolischen Wissensbasis.

3. Idealtypische Zuordnung verschiedener Wirtschaftszweige

Ein illustratives Beispiel für eine idealtypische Zuordnung verschiedener Wirtschaftszweige zu den drei zuvor beschriebenen Wissensbasen liefert Abbildung 1. Es wird deutlich, dass, wie in Absatz 2 angedeutet, Organisationen verschiedener Wirtschaftszweige bei Ihren Innovationsbemühungen auf jeweils unterschiedliche Kombinationen und Mischungsverhältnisse verschiedener Wissensbasen zurückgreifen. Folglich sind die einzelnen Branchen in der Abbildung nicht nur einer Ecke des Dreiecks zuzuordnen. Vielmehr „bewegen“ sich die Branchenmarkierungen in einem Kontinuum *zwischen* den drei Wissensbasis-Polen.

Der Entstehungsprozess eines Filmes beispielsweise ist sehr stark von der symbolischen Wissensbasis geprägt. Schauspieler werden schöpferisch tätig, indem sie Ihre Kreativität, Interpretationsfähigkeit und ihr Vorstellungsvermögen am Filmset einbringen. Damit fügen sie dem letztendlichen Produkt, dem Film, einen primär symbolischen und damit immateriellen Wert hinzu. Daneben spielt die Wahl des Drehortes eine Rolle, kann dieser doch ganz gezielt das ästhetische Empfinden des Zuschauers ansprechen und bestimmte Emotionen provozieren. Am Filmset sind aber auch technische Voraussetzungen, und damit technikbasiertes Wissen, unentbehrlich. Handlungen und Technologien, die sich mit der Belichtung, Kameratechnik oder Tonaufnahme in Verbindung bringen lassen, fußen erheblich auf der synthetischen Wissensbasis.

Die Biotechnologie hingegen fußt auf der analytischen Wissensbasis. Hier ist mit dem umfangreichen Input aus den Naturwissenschaften eine stark analytische Ausrichtung offensichtlich. Mit der konkreten Anwendung biotechnologischer Verfahren in der Pharmaindustrie, der Abfallwirtschaft oder auch in der Lebensmittelkontrolle nimmt die Fokussierung auf den Nutzwert des Endproduktes zu und damit der Anteil synthetischen Wissens.

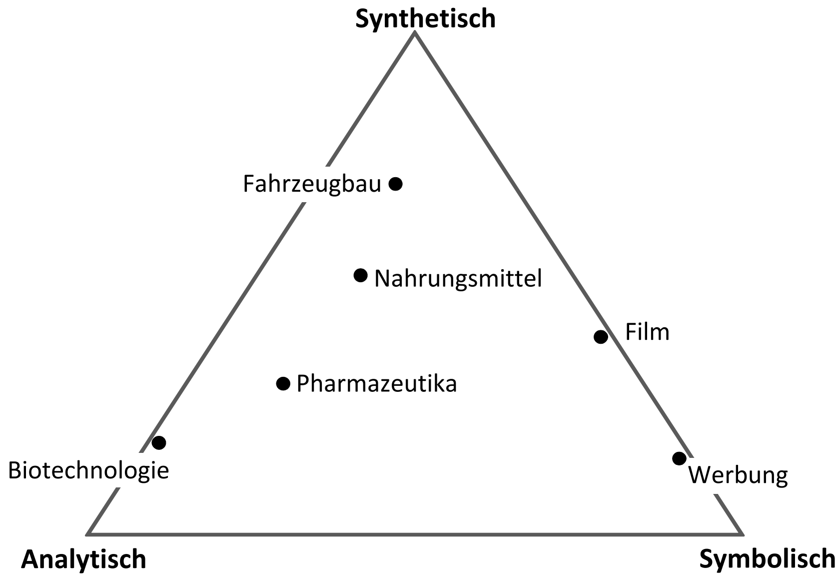

Abbildung 1. *Idealtypische Zuordnung verschiedener Wirtschaftszweige zu Wissensbasen.*

Quelle: Übersetzung nach Asheim (2007: 227).

Betrachten wir schließlich den Entstehungsprozess und die Vermarktung von Lebensmitteln, können wir tendenziell von einer stärkeren Durchmischung sämtlicher Wissensbasen ausgehen. Wie zuvor beschrieben, kann im Falle des Einsatzes biotechnologischer Verfahren bei der Kontrolle und Produktion von Nahrungsgütern analytisches Wissen von besonderer Bedeutung sein. Die hohe Relevanz der synthetischen Wissensbasis drückt sich zum Beispiel in der massiven Nutzung spezialisierter Werkzeugmaschinen aus. Der Einsatz anwendungsbezogenen Wissens und das Einbeziehen praktischer Erfahrungen im Umgang mit den Maschinen und dem Produkt selbst dominieren den Produktionsprozess und führen, sozusagen als Bei-Produkt, nicht selten zu inkrementellen Produkt- und Prozessverbesserungen. Symbolisches Wissen spielt letztlich auch eine Rolle, und zwar wenn Lebensmittel in Werbespots beworben werden, in denen dem Endverbraucher nicht nur der eigentliche Nutzwert des Produktes vermittelt werden soll. Vielmehr geht es um die Aufladung des Produktes mit intangiblen, symbolischen Werten, mit deren Hilfe dem Kunden ein bestimmtes Lebensgefühl, wie Vitalität, Genuss oder Gesundheit vermittelt werden soll.

4. Ansatzpunkte für eine nach Wissensbasen differenzierte regionale Innovationspolitik

Trägt die Differenzierung nach verschiedenen Wissensbasen dazu bei, regionale Innovationspolitik zukunftsfähig und maßgeschneidert zu gestalten? Aufgrund der Ausführungen würden wir diese Frage vorsichtig bejahen. Dies kann jedoch nur eine erste vorläufige Einschätzung der Möglichkeiten sein, die sich aus der Berücksichtigung der Wissensbasis-Typisierung bei der Formulierung einer regional angepassten Innovationspolitik ergeben. Empirische Untersuchungen, die zurzeit in Deutschland (Technologieregion Aachen, Südwestsachsen, Hamburg) und in weiteren acht europäischen Ländern durchgeführt werden, sollten zukünftig zu einer genaueren Vorstellung von der Beantwortung der Eingangsfrage führen. Auch ohne diese abschließende Bewertung ist es möglich, im Folgenden kurz einige wesentliche regionalpolitische Ziele anzuführen, die sich aus der Unterscheidung der analytischen, synthetischen und symbolischen Wissensbasis ergeben.

Eine hochwertige Wissensinfrastruktur (Universitäten, Fachhochschulen, öffentliche Forschungsinstitute), die die Produktion hochaktuellen Wissens an der Forschungsfront ermöglicht, sowie ein damit verbundenes Angebot an hochqualifizierten Arbeitskräften, sind wichtige Voraussetzungen für das Funktionieren eines Wirtschaftszweiges, der auf der *analytischen Wissensbasis* fußt (Asheim/Coenen 2005: 1186). Ein ausreichender Zugang zu wissenschaftlichen Wissensquellen (beispielsweise Labors) muss auch für kleine und mittlere Unternehmen sowie technologieorientierte Unternehmensgründungen gewährleistet sein. Dazu zählen weiterhin die Unterstützung intensiver Kooperationen zwischen Industrie und Wissenschaft, Technologietransfer-Agenturen, Beratungsangebote zu Patentstrategien oder zur Kommerzialisierung von Forschungsergebnissen sowie die Errichtung von Technologiezentren. Teile dieser Voraussetzungen werden eher durch das nationale Innovationssystem beeinflusst, aber auch auf regionaler Ebene können Maßnahmen eingeleitet werden, um die Vernetzung und Synergieeffekte zwischen den beschriebenen Akteuren zu stärken.

Obwohl Buzz und Face-to-Face-Kontakt bei der Weitergabe von Wissen im Vergleich zu den beiden anderen Wissensbasen etwas unbedeutender einzustufen sind und deswegen bei der Innovationsförderung weniger berücksichtigt werden müssen, kann die räumliche Nähe durchaus eine Rolle bei der Wahl des Wohnstandortes spielen, der sich vorzugsweise in der Nähe zu den Universitäten und Forschungsinstituten wiederfindet (Asheim/Coenen/Vang 2007). Die Anbindung an eine hochwertige Verkehrsinfrastruktur, wie etwa an einen international angebundenen Flughafen oder an den schienengebundenen Hochgeschwindigkeitsverkehr, sind wichtige Voraussetzungen für das Treffen von *Peers* aus der internationalen Scientific Community. Eine maßgeschneiderte Innovationspolitik auf regionaler Ebene, welche die Logik der *synthetischen Wissensbasis* in besonderem Maße berücksichtigt, sollte die folgenden Elemente enthalten. Ein wesentliches Ziel ist die Unterstützung von Lernprozessen in Verbindung mit zwischenbetrieblichen Kooperationen. Die Förderung sollte im Gegensatz zu der stärker angebotsorientierten Herangehensweise der analytischen Wissensbasis eher nachfrageorientiert ausgestaltet werden. So sollte geschaut werden, ob das Wissen, welches in der regionalen Wissensinfrastruktur (vor allem an den Fachhochschulen) generiert wird, genügend an die Bedürfnisse der industriellen Spezialisierung anschließt (Asheim/Coenen 2005: 1186). Face-to-Face-Kontakte sind zwar wichtig (und in jedem Fall deutlich wichtiger als Buzz), müssen aber nicht unbedingt an einem speziellen Standort mit besonderen Eigenschaften stattfinden. Auch bei diesem Wissenstyp gibt es im Allgemeinen keine besonderen Anforderungen an die Lebensqualität der Wohnorte. Für die interaktiven Lernprozesse, die bei der synthetischen Wissensbasis zentral sind und die zu neuen technologischen Kombinationen führen sollen, ist ein gemeinsamer sozialer und kultureller Kontext sehr förderlich (Asheim et al. 2007). Die regionale Innovationspolitik sollte auf der einen Seite existierende Spezialisierungen stärken und sie gleichzeitig durch neue Kombinationen erweitern.

Diejenigen Branchen, welche sich durch eine *symbolische Wissensbasis* auszeichnen, erfordern andere Schwerpunkte einer regionalen Innovationspolitik. Kenntnisse des spezifischen Arbeitsmarktes (know who) sind hier essentiell, ein städtisches Milieu daher sehr förderlich. Face-to-Face Kontakte und Buzz sind unabdingbar, um immer wieder aufs Neue kreative Talente für neue Projekte zu finden. Hier gilt es, dafür zu sorgen, dass es genügend innenstadtnahe Wohnungen in einem Umfeld mit genug Möglichkeiten des gegenseitigen Treffens gibt (Asheim/Coenen/Vang 2007). Laut Asheim et al. (2007: 40) ist "the policy challenge […] not so much focused on cluster-RIS relations as on the people climate of the region. This implies a need for broader urban policies promoting the people climate by being dedicated to the quality of place and to create an environment characterised by diversity and tolerance". Letzteres spielt offensichtlich auf Florida (2002) an, der jedoch urbane Diversität und Toleranz nicht nur als förderlich für Innovationsprozesse in kreativen Branchen ansieht, sondern damit auch die synthetische und die analytische Wissensarbeit einbezieht, die in seiner Vorstellung von der creative class (neben der symbolischen Wissensarbeit) gleichermaßen Berücksichtigung finden. Im Gegensatz zu Florida beziehen wir diese Empfehlung – attraktive, anregende Lebensräume im urbanen Raum zu schaffen – vor allem auf die Kreativen der Kulturökonomie im engeren Sinne.

Der Begriff einer „maßgeschneiderten" regionalen Innovationspolitik darf nicht suggerieren, Innovationsprozesse könnten vollends gezielten Politiken unterworfen werden, schließlich sind Innovationen stets das Ergebnis hochkomplexer Wissens- und Lernprozesse, in denen verschiedenste Akteure auf lokaler, regionaler wie globaler Ebene interagieren. Vorsicht ist im Übrigen immer dann geboten, wenn die regionale Innovationspolitik zu sehr auf eine dominante Wissensbasis ausgerichtet ist, die in der jeweiligen Region bereits weit entwickelt ist. In diesen Fällen droht Stagnation. Im Gegenteil belegen jüngere Untersuchungen beispielsweise in Bezug auf synthetisches Wissen: Regionale Industriecluster mit einer starken synthetischen Wissensbasis entgehen gerade dann Lock-Ins und damit dem drohenden wirtschaftlichen Niedergang, wenn sie gezielt eine Kombination mit symbolischem und/oder analytischem Wissen anstreben (Jeannerat/Crevoisier 2009).

In der Realität finden wir in Regionen eine Mischung verschiedener Industrien und Wissensbasen mit unterschiedlichen Schwerpunktbildungen. Hinzu kommt, dass Innovationsprozesse in einer Branche stets auf einen Mix aus verschiedenen Wissensbasen zurückgreifen. Diese Besonderheiten berücksichtigend, stellen wir mit den Worten von Asheim et al. (2007: 38) fest: „Even though most real cases of industrial innovation constitute a mix of all three, the main focus varies and motivates a classification with regard to dominant knowledge base requirements." Die Typisierung nach Wissensbasen könnte dazu beitragen, eine (besser als bislang) auf den jeweiligen Branchenmix der Region abgestimmte Innovationspolitik zu definieren und zielgerichtet weiterzuentwickeln.

In der Gesamtbetrachtung des Ansatzes der Wissensbasen und unter Berücksichtigung der damit verbundenen Besonderheiten und Einschränkungen deutet sich an, dass die Differenzierung nach Wissensbasen einen wichtigen Beitrag zu einer maßgeschneiderten regionalen Innovationspolitik liefern kann. In den insgesamt 24 Fallstudien, die wir im Rahmen des Projektes *Constructing Regional Advantage* zurzeit europaweit durchführen, werden wir zukünftig den Nutzen des Konzeptes genauer überprüfen und damit eine fundiertere Beantwortung der Titelfrage geben können.

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9. Conclusions and future research

The overall objective of the final chapter can be broken down into three sub-goals. One goal is to look back to what has been written so far; the second one is to expand these findings; and the third goal is to look forward by proposing future research steps. Accordingly, Chapter 9 summarizes the key findings of this book, both in theoretical as well as in empirical terms (Chapter 9.1). As with every research, my empirical studies have their limitations. These are addressed in Chapter 9.2. In addition, I scrutinize some potentials and limits of the KBC as a tool to advise policymakers (Chapter 9.3). After this, I highlight the key contributions of this dissertation to the existing literature in EG and related sub-disciplines which deals with knowledge, learning and innovation processes (Chapter 9.4). And lastly, on the basis of these sub-chapters, I deduce objectives for future research (Chapter 9.5).

9.1. Summary of main results

According to the overview of aims and research questions in Figure 1, the previous chapters strived to contribute to the theoretical clarification of the KBC (see, above all, Chapter 2) as well as to the emerging body of empirical research that is dedicated to this concept (Chapters 4 to 7). In the following, I will shortly summarize the key findings.

Theoretical findings

Chapter 2 represented the core of the theoretical discussion of the KBC within this dissertation. In detail, I elaborated the conceptual origin, the motivation, and the underlying assumption of the KBC (Chapter 2.1); I highlighted a multitude of conceptual inflows to the KBC and I stressed the key characteristics of each knowledge base (Chapter 2.2); and finally, these findings were conflated in Chapter 2.3 by presenting the overall theoretical embedding of this concept.

The differentiation between *analytical and synthetic activities* in economic sectors goes back to the findings by Laestadius (1998), which were further elaborated in a geographical context by Asheim and Gertler (2005). Later on, the *symbolic activities* were added (Asheim 2007) and, with it, completed the threefold categorization as we know it today. The central assumption is that industries differ substantially with regard to their specific knowledge base, of which three are to be distinguished: analytical (science based); synthetic (engineering based); and symbolic (creativity based) (cf. Chapters 2.1 and 2.2.3). The major motivation for differentiating industrial knowledge bases in EG and related fields of study, I argued, is to overcome the conceptual neglect of inter-industrial differences in *TIMs* (Chapter 2.1). These models remain on a relatively high level of abstraction at the expense of overlooking obvious differences between industries in the way they create knowledge and generate innovations.

Nevertheless, also TIMs played their role in the development of the KBC. I have argued that it is particularly the insights derived from *relational EG* in general, and *TIMs* in particular – complemented by and intertwined with related concepts on knowledge creation, learning and innovation processes – which inform the vertical dimension of the KBC table (cf. Table 1, and Chapter 2.2.1). The horizontal dimension of the KBC table, in turn, is essentially informed by conceptualizations of sector-specific patterns of innovation behavior and knowledge production. I highlighted in particular the *Pavitt's taxonomy* (Pavitt 1984), the *sectoral system of innovation* (SSI) (Malerba 2002), and the *DUI-STI duality* of innovation modes (Jensen et al. 2004) to be of substantial importance for the development of the threefold knowledge base taxonomy (cf. Chapter 2.2.2).

In sum, as concluded in Chapter 2.3, the KBC is not only a product of theoretical reasoning by economic geographers. Other sub-disciplines, first of all *economic sociology* and *evolutionary economics*, exhibit considerable impacts on related topics as well, though to a lesser extent with regard to the spatial dimension (cf. Figure 4). Finally, I emphasized the role of the empirical observations by *knowledge management*, *innovation*, *organizational*, and *sectoral studies* that inform (and link) both, the horizontal and the vertical dimension of the KBC architecture at the same time (see Figure 5).

Empirical findings

The central research question (cf. Figure 1) that guided my empirical analyses was: *Which knowledge base configuration (KBConfi) drives knowledge formation and innovation processes in selected regional industries in Germany?* This question has been answered for each of the three selected cases (Chapters 4, 5, and 7). In addition, a comparative paper was written that discussed part of the results of the first two case studies (Chapter 6). The whole body of empirical work was carried out by using a common methodological framework. Hence, the research design (Chapter 3.2) as well as the methods of data collection (Chapter 3.3) and analysis (Chapter 3.4) were the same for each case study. The dominating analytic technique that I used was *pattern matching* (cf. Chapter 3.2). In other words, I have 'pattern-matched' the observations on innovation and knowledge creation for each of the three regional industries with the different theoretical predictions that are related to the analytical, the synthetic, and the symbolic knowledge base. As a result, each case could be matched to a certain knowledge base, or to hybrid forms thereof.

In Chapter 4 I presented the case study results on the *biotechnology industry in the Aachen Technology Region* (BioAC). The main outcome was that the knowledge base that is crucial for innovation activities is primarily of analytical nature. Interactive learning of biotechnology firms within the region is clearly dominated by industry-university links, while for most firms the vertical dimension of co-operative innovation processes is rather shaped at national and global scales. Chapter 5 referred to the case of the *automotive industry in Southwest Saxony* (AutoSWS). I concluded that the regional industry heavily relies on the synthetic knowledge base, whereas the analytical knowledge base is comparatively weak. I finally argued that the firms' low performance in the analytical mode of knowledge creation holds the risk of losing the capacity to come up with highly innovative technical solutions in the future. The comparison of the results of Chapters 4 and 5 took center stage in Chapter 6, though with a focus on knowledge networking. With the help of the *BioAC case* on the one hand, and the *AutoSWS case* on the other hand, it was shown that firms which are foremost driven by the analytical knowledge base exhibit substantively different knowledge exchange and knowledge sourcing patterns in comparison to firms which primarily rely on the synthetic knowledge base. Chapter 7 completed my empirical contributions by challenging the assumption that learning, knowledge, and innovation processes within creative industries are predominantly shaped by the symbolic knowledge base. The central outcome was that, at least with regard to the *video game industry in Hamburg* (VgdHH), this is not entirely true. According to my analysis, both, the symbolic *and* the synthetic knowledge, and to a lesser extent the analytical knowledge, are the dominant elements that contribute to video game development in Hamburg.

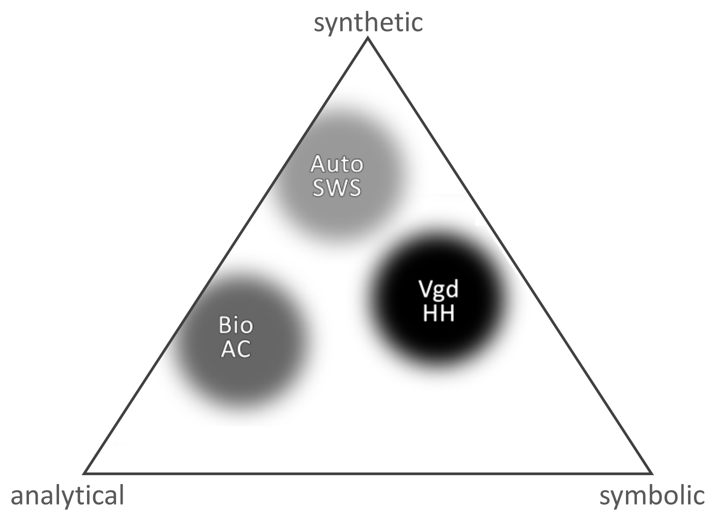

Figure 7. *Positioning of regional industries within the KBC triangle*

Source: Inspired by Asheim (2007, p.227)

Figure 7 unites the results of pattern matching. This qualitative illustration of the core outcomes clearly demonstrates that analyzing industrial knowledge bases does not mean to think in defined categories, but in a continuum of various KBConfis. As such, this finding apparently approves Asheim et al. (2011) who proposed that most economic activities in the 'real world' are driven by more than just one knowledge base, though the degree to which a particular knowledge base is dominant varies between industries.

9.2. Limitations of my empirical research and methodological reflections

In Chapter 3 I gave reasons for using the case study method within a research context like this (Chapter 3.1). I explained in detail the ways in which this method was adjusted to the purpose of my dissertation. This was done by emphasizing the underlying research design (Chapter 3.2), the data collection methods (Chapter 3.3), and the methods of data analysis (Chapter 3.4). Though the purpose of Chapter 3 was rather to substantiate my 'modus operandi' for the empirical papers, this subchapter addresses some limitations of my empirical research, and the way I tried to tackle them. Thereby, I concentrate on critical aspects concerning (i) the *limited explanatory power of quantitative data*, (ii) *constraints regarding my network analyses*; (iii) the *focus on firms*; (iv) the *bounded perspective of interviewees*; and (v) the *generalization problem of case study results*.

Limits of quantitative data

Due to the fact that a great deal of the data that could be derived from the standardized firm interviews was quantifiable, it was possible to generate descriptive statistical measures (cf. Chapter 3.3). However, there are particularly two limits with regard to quantitative data within a research context that does not only deal with 'hard facts' (e.g. patent numbers), but also points to the 'soft architecture' of the firm's knowledge bases (e.g. relations between actors). The first limitation refers to the data collection. In some of the firm interviews, it turned out to be problematic for the interviewees to adjust their answers to pre-defined response categories (cf. Reuber & Pfaffenbach 2005). This applied in particular to those questions which concerned knowledge creation, or knowledge exchange processes. Often, my impression was that the interviewees preferred to answer these questions in a more open and qualitative way, instead of squeezing their answers into, for example, five-point Likert-type scales.[51] In order to reduce the trouble that some firm representatives had with quantifying rather qualitative perceptions, I tried to carefully clarify the core of the question, as well as the meanings of the response categories (Lee 1999). Sometimes, it turned out to be helpful to

[51] An example for a Likert-type scale which can be found in the questionnaire (cf. Appendix 1) is related to the question of how important the exchange of technological knowledge with a particular network partner is with regard to the firms' innovation performance. The answers ranged from 1 = "not important" to 5 = "very important".

provide the participants with possible answers that served as an example. However, at the same time I tried to keep this potential source of influence on the interviewee's response behavior at a minimum.

The second limit of quantitative data relates to the identification of the type of knowledge that is critical for the firms' competitiveness and that constitutes the core of the industry's innovation efforts in a selected region (cf. RQ in Chapter 1.2). A high average value does not necessarily mean that a certain knowledge base is particularly pivotal for the individual firm, or the regional industry as a whole. Strictly speaking, the identification of the *crucial* type of knowledge requires from the researcher that he or she is able to segregate activities which constitute the firm's core competences from other activities which the firm may source out to suppliers. I tried to diminish this kind of 'interpretation problem' by complementing the quantitative data with qualitative information by industry experts (cf. Chapter 3.4).

Constraints of network analyses

My analyses of inter-organizational networks of knowledge flows (cf. Chapter 3.4) exhibit some constraints, too. Given that the interview partners were asked in an *open* question to mention preferably all the actors their firms exchange knowledge with, I generated data on *ego*-networks but not on so-called *complete* (or: *sociocentric*) networks. If I had collected data on *complete* networks by using, for example, the rather closed *roster-recall methodology*, I would have had the possibility to apply a richer body of SNA operations and related measures.[52] For all three case studies, *complete* networks could only be analyzed as long as the investigations referred to the relations between the interviewed firms themselves.

The more open questioning technique which targets the firms' *egocentric* knowledge networks, in turn, allowed me to consider the whole range of mentioned contacts, without any confinements in terms of pre-defined populations of potential network contacts. Provided that it is hardly possible to predefine *all* potential knowledge network partners particularly *outside* the selected region, the more 'footloose' *egocentric* networks are indispensable for analyses which target the spatial dimension of the KBC sufficiently.[53]

[52] According to Ter Wal and Boschma (2009, p.746), the roster-recall methodology "aims to collect full network data – as opposed to ego network data – on a pre-defined population of actors. In this methodology, each of the actors of the population is provided with a list of actors of the population. Preferably this roster includes all actors of the population, since listing just a selection might cause a bias of those firms being pre-indicated more often as a partner."

[53] Knox et al. (2006) as well as Comunian (2010) even state that every attempt to pre-define a group of potential network actors (as with the pure roster-recall method) conflicts with the network idea itself.

Another issue of limitation concerning the way that I made use of network analyses is the missing differentiation of the knowledge network relations according to their *degree of formalization*. Thus, it has to remain in the mist whether the examined regional industries are predominantly driven by formally organized knowledge interactions (e.g. in the form of contracted agreements of knowledge transfers), or whether these interactions are most often arranged in informal ways (e.g. in the form of loose conversations at networking events, trade fairs, or at conferences). The same applies to the explicit differentiation of *network governance modes*, distinguishing hierarchical from 'real' network, market, or project structures.

Finally, an information gap can be identified regarding the *reciprocity* of network relations. Whereas for the sociocentric part of my network analyses I was able to calculate hybrid reciprocity measures, this was not possible with regard to the whole body of inter-organizational links within the entire egocentric networks. Therefore, it is in the strict sense not traceable whether a given link constitutes a 'real' *exchange* of knowledge or whether it is in fact a *unidirectional* case of absorbing knowledge only by the interviewed firm. One last aspect of uncertainty concerning the firm's networks is due to the bounded perspective of the interviewees. I will come back to that point below.

Focus on firms

According to Markusen, "studying regions by studying firms" has been a "central and fruitful avenue of inquiry for regional planners, economists, and geographers for several decades" (1994, p.477). Similarly, one might claim that in particular the firms constitute the key actors within a regional industry, because they develop and produce goods and services; and goods and services constitute the central outcome of an industry, no matter if at the local, regional, or global level. Thus, it seems justifiable to collect exclusively data about firms in order to analyze the knowledge bases of the pre-defined industries in three German regions.

However, it is well-known among scholars that there is a multitude of additional actors that play a decisive role when it comes to the generation and exploitation of knowledge within each of the selected regional industries. These actors are, for example, university institutes and public research organizations (cf. Chapter 4), cluster management organizations (Chapters 4 to 7), or freelancers (cf. Chapter 7). Since all the *standardized* interviews were merely conducted with representatives of private companies, there is a risk of missing central actors which influence and make use of the underlying knowledge base of the regional industry to a great extent.

Two aspects concerning my research helped me to avoid a too strong bias on the private sector. The first aspect refers to the analyses of the firms' knowledge networks. Though the representatives of these (mainly non-private) organizations were not interviewed in a standardized way, the sheer fact that they were mentioned by the firms to belong to their knowledge network partners leads at least to an indirect way of collecting data about these actors. The second aspect refers to the semi-structured expert interviews. As can be seen in Table 4 (Chapter 3.4), this group included informants who represented cluster management organizations, state ministries, public research and education institutions, and the scientific community in EG and related fields of study. Given that some of the actors represent organizations which play not only an important role within the firm's knowledge networks, but also with regard to providing education and research services, or by supporting the regional industry's innovation efforts (financially or advisory), some of the qualitative interview data could be used as a kind of complementary source for the investigation of the knowledge base of each of the three regional industry cases.

Bounded perspective of interviewees

As with every attempt to ask individuals about the activities of the whole organization they manage or work for, the information the interviewer ultimately receives is always restricted to the bounded perspectives of the interviewees. This problem is closely connected to the issues of *validity* and *reliability*.

"[I]n an empirical setting [*validity*] refers to the degree to which gathered information actually measures the phenomena of interest" (Ahlqvist 2009, p.320). In my case studies, the so-called phenomena of interest were the *KBConfis that the pre-selected regional industries rely on*. This demarcation is consistent with the main unit of analysis, which was defined to be the industry within a region, whereas the firm was regarded as the sub-unit of analysis (cf. Chapter 3.2). Since I have not interviewed the firm as such (in the sense of interviewing *all* managers and employees of a firm), but only one or two representatives thereof, it has to be left open whether the aggregation of individual perspectives into the KBConfi of the overall regional industry is clearly justifiable. Though this conflict could not be entirely solved within this book, two methodological aspects helped me to considerably reduce the potential loss of validity. The first one refers to the validation of the interview results by triangulating different information sources, of which the expert interviews constituted the most helpful source (cf. Chapter 3.4). The second aspect refers to the interview partners themselves. Given that most of them belonged to the firm's executive staff, they can be assumed to provide a relatively high degree of in-depth and comprehensive information on the firm as a whole.

Reliability characterizes "the stability and consistency of the research instrument over repeated applications" (Ahlqvist 2009, p.320). Again, I want to highlight two aspects due to this condition. First, it is conceivable that posing the same standardized questions to *another* representative of the firm may result in different answers. However, since this has not been tested in terms of this research, it has to remain speculative. The second aspect of reliability concerns the temporary involvement of two other interviewees within the process of interviewing firms. With regard to the second case, 12 out of 58 interviews have been conducted by a student assistant; for the third case it was 1 out of 20 interviews which was done by another student assistant. In order to keep the stability and consistency of the research instrument at a preferably high level, it was indispensable to go jointly through the questionnaire step by step before applying it ("What is the precise meaning of each question?"; "How do we interpret the pre-defined response categories?"; "How should we introduce the topic of the interview?" etc.). In addition, I accompanied the prior mentioned assistant for the first two interviews to ensure that the differences in conducting the interviews could be reduced to an appropriate level.

Generalization problem

The problem of *generalizing* case study research is widely discussed in the literature (Markusen 1999; Martin & Sunley 2001; Rodríguez Pose 2001; Overman 2004; Flyvbjerg 2006; Essletzbichler 2009; Yin 2009, among others). In Chapter 3.1 I argued that the interrelation between the KBC and the three cases leads to an understanding of the extent to which the results can be generalized particularly. The dialog between theory and case-specific findings, however, can neither be understood as an attempt to make large-scale generalizations, nor to develop universal laws regarding industrial knowledge bases within regions. I would rather argue that the in-depth and context-oriented analysis of the particular KBConfi of very few pre-selected industrial settings awakened my research interest. Thus, this analysis fitted best to the underlying aims and research questions. If generalization is an issue within my dissertation, it refers more to the sensitization towards the sometimes hidden differences between (regional) industries in the way they generate and exploit knowledge and innovations (cf. Chapter 1.1).

All three case studies which I presented in Chapters 4 to 7 – the BioAC case, the AutoSWS case, and the VgdHH case – referred to specific constellations of *industry*, *geography*, and *time*. At the core of my investigation I discovered that *industries* differ substantially with regard to their knowledge base, which has been mentioned various times throughout this book. Moreover, due to the fact that all these case studies have been conducted in Germany, the corresponding findings can be assumed to be 'German-biased'. This assumption is due to the *national system of innovation* approach. Hence, each nation state exhibits specific sets of "elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge" (Lundvall 1992, p.2). For this reason, it is misleading to assume, for example, that knowledge creation and innovation processes within the biotechnology industry in the Aachen Technology region are driven by precisely the same KBConfi as the biotechnology industry in Boston, USA.

The same line of argument can be applied to the regional level, too. If we take the theory of *regional systems of innovation* (Cooke & Morgan 1998) seriously, we cannot automatically assume, for instance, that Southwest Saxony's automotive industry relies on the same (mixture of) knowledge bases as its counterpart in the region around Stuttgart does. Attempts to draw parallels between regional industries often bear the risk of 'comparing apples and oranges', because it is hardly achievable to isolate effects which rely on sectoral differences from regional effects (cf. Chapter 3.3).

Limiting effects on the transferability of results can also refer to the dimension of time; i.e. the question of *when* the case studies were carried out. For example, it can be imagined that the type of knowledge which constitutes the competitive core of one and the same video game development cluster changes over time. This may be due to shifting customer demands, or caused by the emergence of new technologies. These changes could, in turn, lead to new network structures, because some partners within the network may get less important (e.g. research organizations), whereas others may become more relevant (e.g. customers) for the success of the firm's innovation performance (cf. the proposed epistemological paradigm of EEG by Boschma & Frenken 2006; Boschma & Martin 2007). Therefore, researchers who want to carry out comparative studies on the knowledge bases of different clusters are well advised to compare regional industries which are positioned in the same stage of the *cluster life cycle* (Menzel & Fornahl 2009) in order to prevent confounding effects. Due to the fact that not all regional industry clusters that have been analyzed within this book relate to the same stage of development within the cluster life cycle, the cross-case comparison may, again, bear the risk of 'comparing apples and oranges'.[54]

9.3. Bridging theory and practice: potentials and limits of the KBC for policy use

The second *plea for a closer look* at the opening of this book asked for testing the KBC's *operationalizability* for the purpose of analysis and advising policymakers. Whereas Chapter 8 has already offered some preliminary policy recommendations in line with the theoretical propositions of the KBC, I complement these elaborations in the following, albeit with another focus. I refer primarily to the

[54] Assuming that the BioAC case and the VgdHH case define regional industries which find themselves in the emerging stage, the AutoSWS case has clearly left this phase and might rather be attributed to the declining, or to the renewal phase.

key potentials and limits of the insights that the KBC can offer in bridging industry-specific conceptualizations of knowledge creation (in a geographical perspective) and innovation policy formulation. Two aspects are emphasized in this respect. The first aspect targets the indispensable *preconditions for 'KBC-conform' public policy intervention* in a market economy. The second aspect concerns the demands on *an analysis tool* that aims to make the identification of KBConfis operable and accessible to a broader group of users engaged in policy formulation.

Preconditions for 'KBC-conform' policy intervention

It is obviously futile to implement public policy tools into an area, where these tools are not needed. With reference to the KBC and the regional industry respectively, this argument reads: Only if there is a *problem* concerning the regional industry's KBConfi which cannot be solved by the private economic actors themselves, policy intervention comes into question.[55] I propose the term *'knowledge base configuration problem' (KBCP)* in this respect, in order to capture in particular those problems that are caused by unfavorable knowledge base constellations, whereas 'unfavorable' refers to *KBConfis that hamper the regional industry's ability to innovate*.[56, 57]

In Chapter 5, for instance, I concluded that the low performance of AutoSWS firms in the analytical mode of knowledge formation holds the risk of losing the capacity to come up with highly innovative technical solutions. Hence, the underlying KBConfi is unfavorable due to a disproportion between synthetic and analytical knowledge among the respective firms. The decision to intervene, however, requires more than the mere assumption of a KBCP to exist. Accordingly, the initial questions are: How do we know that a KBCP does exist within a given regional industry at all? What are the indicators that we have to look for in order to identify the KBCP?

A promising way to approach these questions is to *compare KBConfis* of identical or, at least, similar industries in different regional settings.[58] The underlying hypothesis is: *The better a specific industry*

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[55] In line with Edquist (2008) I argue to use the term 'problem' instead of 'failure', because 'failure' connotes that an 'optimal' KBConfi exists. Though it may be advantageous to use the term 'failure' in traditional economics (cf. the notion of 'market failures' in Bator (1958)), it is not reasonable, if not impossible, to specify an optimal KBConfi. There is (so far) also no convincing argument to be found in the literature on the KBC which legitimates a definition of an ideal combination of the analytical, the synthetic, and the symbolic knowledge base.

[56] This definition of the KBCP implies one aspect which, however, cannot be solved within the limited space of this sub-chapter. It is the question if there is indeed a causal interrelation between the KBConfi and the regional industry's ability to innovate.

[57] It is also thinkable to broaden the rather narrow perspective on innovations towards the *competitiveness* of a regional industry in general. However, competitiveness is not only and not always connected to specific innovation strategies, but may be the result of other mechanisms, too.

[58] See also the contributions by Edquist (2008) who proposes to compare existing innovation systems in order to identify 'policy problems'.

performs in region A in comparison to the same industry in region B, the more favorable is its KBConfi in region A. In order to find out which of the two industries performs better, different indicators have to be taken into account. According to the previous definition of the KBCP, I propose to target especially those indicators which reveal the *innovative performance* of the firms. These indicators may range from R&D inputs, patent counts and patent citations to new product announcements (Hagedoorn & Cloodt 2003).[59] As such, they can be assumed to measure effectively the technical dimension of product and process innovations within industries which are driven by the analytical or the synthetic knowledge base.

However, numerous creative industries that primarily rely on the symbolic knowledge base target first and foremost the intangible, aesthetic attributes of a product, the creation of designs and images as well as the economic use of various forms of cultural artifacts (cf. Chapter 2.2.3). In such an industrial context, classical performance measures are not sufficient to capture the innovative performance of the regional industries. Hence, additional measures have to account for, for instance, different types of content creation or service innovations. Related indicators may refer to particular forms of property rights, such as trademarks and copyrights (Handke 2007).

As soon as a distinct industry in region B can be identified to perform worse in comparison to the innovative performance of a comparable industry in region A, a KBCP is existent in the case of B. Assuming that this problem cannot be solved by the private economic actors themselves, the precondition for 'KBC-conform' policy intervention is given.

Demands on a 'KBC-conform' analysis tool for regional innovation policy use

Guaranteed that the abovementioned hypothesis on 'favorable KBConfis' can be approved and that there is indeed a causal interrelation between the KBConfi and the regional industry's ability to innovate (cf. Fn 56), the next step, I argue, is to identify the underlying KBConfis. The simplified rationale is to adjust the weaker KBConfi for this industry in region A to the superior KBConfi of region B.[60] Thus, the next question about how to operationalize the KBC for the purpose of analysis and advising policymakers is: How can we identify the KBConfis of the regional industries in an *operable and accessible* manner so that it can be beneficial for policy formulation?

[59] Assuming that the KBCP is not restricted to the innovativeness, i.e. the focus is on the regional industry's *competitiveness* in general, additional indicators are available for the purpose of cross-regional comparisons. These may refer to employment trends, industrial production, or Gross Domestic Product.

[60] However, this practice naturally has its limits as soon as it turns out that the KBConfis are the same for each case.

In fact, my research on the BioAC, AutoSWS, and VgdHH cases primarily aimed to disentangle the underlying knowledge base(s) by operationalizing the KBC. As showed with reference to the interview questionnaire (cf. Table 2), there is a need to investigate a multitude of indicators in order to approximate the actual KBConfi (Chapter 3.3). These indicators rely on both, quantitative data as well as on qualitative perceptions, and face-to-face interviews turned out to facilitate the data collection process to a great extent. In addition, numerous supplementary sources of information were used in order to triangulate these outcomes (Chapter 3.4). As a résumé, I think that the procedure of data collection, analysis, and validation enabled me to offer well-considered answers to the pre-defined research questions.

I am convinced, however, that this relatively complex, time-consuming, labor-intensive, and thus cost-intensive process of identifying KBConfis is only to a limited extent suitable for the development of a standardized policy formulation tool which is thought to be operable and accessible to a broader group of users. Accordingly, there is a demand to (i) *reduce complexity* and to (ii) *shrink the room for misleading interpretations*. Simultaneously, of course, this tool must not lose in validity and reliability (cf. Chapter 9.2). Here, I aim to highlight some key aspects in a nutshell concerning the two demands, of which I believe they comprise the highest potential to push the development of 'KBC-conform' analysis tools for regional innovation policy use into an auspicious direction.

The first demand is to *reduce the complexity* of the tool. In order to do so, there is a need to ease data collection processes and to simplify the procedure of analyzing the data. A potentially effective way to ease the collection of data conspicuously is to increase the use of secondary information sources at the expense of conducting face-to-face interviews with representatives of firms which are exceedingly time- and labor-consuming (and therefore cost-intensive). This, however, presupposes a sufficiently high quality and quantity, and also a sufficiently depth of available data that enables the user of this analysis tool to identify the KBConfi of the particular regional industry.

Another issue with regard to the reduction of complexity concerns the definition of clear-cut thresholds which ideally lead to the unambiguous identification of the mix ratio of knowledge bases. Taken to extremes, a typical instruction might read: Given that the percentage value for criterion *X* exceeds *n*, knowledge base *C* can be said to heavily influence the industry's knowledge formation and innovation processes. Conversely, this example symbolizes the 'balancing act' between the use of 'hard numbers' and the risk to fail at depicting the most crucial knowledge base. Accordingly, in Chapter 9.2, I suggested that it is not always the highest value in a certain category which justifies that a certain knowledge base is seen to be the most essential for the regional industry as a whole.

Overall, however, this trade-off between the effort to reduce complexity by means of quantifiable outcomes and the goal to discover the actual KBConfi is clearly a problem that remains to be solved.

The latter is closely related to the second demand on a 'KBC-conform' analysis tool, which is to *shrink the room for misleading interpretations*. Although an effective solution to the issue of complexity calls for concentrating on *secondary* information sources (see above), there is no reason to reduce complexity at the expense of the validation of interpretations via triangulation (cf. Chapter 3.4). Based on my experiences throughout all three case studies, I argue that well-selected expert interviews remain to be an indispensable source of information in order to confine the risk of drawing misleading conclusions.

My considerations on the operationalizability of the KBC for the purpose of policy formulation do not claim to be exhaustive by any means, and the findings on some potentials and limits in this respect have to remain preliminary. Nevertheless, in combination with Chapter 3 in general, and with Chapter 9.2 in particular, I hope that this sub-chapter may at least provoke alternate lines of argument regarding the operationalizability of the KBC for policy purposes. In Chapter 9.5, I will complement these reflections by proposing some future research steps in order to expand the bridge between the concept's theoretical assumptions and its application in policy practices.

9.4. Key contributions to economic geography and related fields

Though in Chapter 9.1 I systematically summarized the main findings of the preceding sections, the precise answer to the question of what the *key contributions of this book* are is still missing. Therefore, I aim to provide an adequate response in the following paragraphs.

Consistent with the aims and research questions that I have defined in the introductory chapter, my dissertation contributes to the understanding of sector-specific processes of knowledge creation and innovation in a spatial perspective. My work is supposed to add some significant value to the corresponding theorizations and empirical analysis in EG and related fields of study. The term 'related fields' refers primarily to *evolutionary economics* and *economic sociology*, i.e. those academic areas which have played a distinctive role in the development of the KBC (cf. Chapter 3). Due to some overlaps of the subject matter, my research may also be interesting for some other fields of studies, namely: *regional sciences*; *cognitive sciences*; *knowledge management studies*; *organization studies*; or *science, technology, and innovation studies*. Nonetheless, the *core* of my contribution refers to the emerging body of literature in EG which focuses on the *KBC*.

There are two major contributions within this dissertation that I want to highlight below. The first one deals with my *field work* in particular, and the second contribution refers to the *systematic and comprehensive approach on integrating theory and practice*. The key *contributions of the KBC itself* – though they are necessarily inherent in the contributions of this book – will be explicitly highlighted thereafter.

Filling the empirical gap: disentangling knowledge bases

From my point of view, the book's title is a clear hint to its most striking contribution, namely the empirical insights it offers on the basis of the threefold knowledge base typology. Having carried out in-depth case study research on knowledge, learning, and innovation processes in three regional industries in Germany, I can fully approve the central argument of the 'founding fathers' of the KBC, that is, industries differ substantially with regard to their specific KBConfi. As such, this book clearly meets the first 'plea for a closer look', which means that it is necessary to have a closer look at the elementary but sometimes hidden differences between regional industries respecting the crucial knowledge that drives innovations and competitiveness of the corresponding firms (cf. Chapter 1.1). In view of the fact that the empirical research on industrial knowledge bases is still scarce, the identification of the underlying KBConfis of BioAC, AutoSWS, and VgdHH firms constitutes a substantial contribution to fill this gap.

Linking conception, evidence, and operationalization

The second major contribution of this book is the systematic and comprehensive way it combines the KBC's theoretical clarification, empirical evidence, and operationalization for public policy use. Here, again, the empirical building block plays a crucial role. Beyond its aforementioned 'gap-filling-function', it fulfills an 'integrating-function', that is, it constitutes the combining element between theory and practice. On the one hand, my empirical work adds value to the systematic testing of the KBC, and, therefore, contributes to the process of *explanation building* revolving around the concept itself (cf. Chapter 3.2). On the other hand, the methodological experiences in connection with my empirical investigations shaped the discussion on the concept's potential to be *operationalized*. The respective findings (Chapter 9.3) constitute a significant contribution to any attempt that aims at making the KBC operable and accessible for analysis as well as for public policy formulation.

Key contributions of the KBC

The most striking contribution of the KBC itself, I argue, goes beyond helping scholars to describe and to explain sector- and region-specific dynamics of knowledge formation. It is the *sensitization towards a more differentiated view* on the ways individual firms or whole industries generate and exploit knowledge, no matter if we refer to the local, regional, national, or global level of economic activity. As such, the KBC can be a useful tool to tackle the problem of disregarding inter-industrial differences in numerous conceptualizations of knowledge, learning, or innovation practices in a spatial context (e.g. TIMs, cf. Chapter 2). The concept of knowledge bases may be used as well in order to identify the key factors which affect the innovative performance and competitiveness of firms. This, in turn, could deliver valuable information for the development of new public policy implementations.

One could argue that using the KBC isolated from other approaches to the geography of knowledge, learning, and innovation bears the risk of 'missing a crucial part of the story'. However, since a great deal of the KBC is already informed by a number of concepts in EG and related disciplines in this realm (cf. Chapter 2), it seems reasonable to conclude that the risk of missing the point in the EG of knowledge, learning, and innovation is alleviated, at least in part. Thus, the contribution of the KBC is to a lesser extent the product of completely new knowledge in terms of a radical breakthrough in theorizing knowledge in EG; it is above all a result of the recombination of already existing knowledge in this field of study which is based on established theories and empirical evidence. From my point of view, this finding should not narrow the KBC's contribution to EG and related areas; it is, however, a matter of fact one should keep in mind when writing on the contribution of this concept.

9.5. Future research

I close this dissertation by raising some issues for future research on the KBC. I will distinguish two subject matters. On the one hand, I will examine some theoretical aspects. On the other hand, I will scrutinize a number of issues concerning methodological improvements, empirical research, and operationalizability. Nevertheless, both fields of future research are interrelated: The methods and empirical contributions rely on theoretical considerations; and the explanation building process concerning the development of the theoretical assumptions of the KBC is simultaneously informed by empirical work and methodological implementations.

Theoretical implications

A first aspect concerning future research steps refers to the potential expansion of the KBC. Until now, the conceptual basis of the KBC is the *threefold* differentiation of knowledge bases. As such, it needs to be distinguished between the analytical, the synthetic, and the symbolic mode of learning and knowledge creation. These modes, in turn, are argued to capture the whole range of industrial activities in the economy. Nevertheless, future research could challenge this argument by asking if there is a fourth (fifth, etc.) knowledge base that is *clearly distinct* from the already existing ones.

Since most of the case studies on KBConfis examine in particular the industries of the manufacturing sector, there might be a potential to find a new, *completely independent* knowledge base in the service sector.

In addition to such an *entirely new* knowledge base 'outside' the known classification, other studies could target the question whether there is empirical evidence for another knowledge base at the *intersection between two or three of the already existing knowledge bases*. At least for two cases – namely BioAC and AutoSWS – it was relatively obvious which of the three knowledge bases was the crucial one for learning, knowledge, and innovation processes. For the VgdHH case, however, the resulting picture was more complex. It turned out that it is both, the symbolic as well as the synthetic knowledge base, which are particularly important for the respective firms in order to bring their product – the video game – to the market successfully. Though the initiators of the KBC are well aware of the fact that many economic activities in the 'real world' are driven by more than just one single knowledge base, the question remains whether the three ideal-typical knowledge base categories suffice in order to discover the most crucial knowledge inputs *unambiguously*. Therefore, a future research objective could be to find out if there are groups of industries which legitimate the implementation of one additional knowledge base at the *intersection of two already existing knowledge bases*. However, no matter whether we refer to the potential discovery of a completely new and independent knowledge base, or whether we draw on the possible identification of another knowledge base at the intersection between existing ones, these considerations should also take into account that an increase in complexity may lead to a decrease in manageability, both, for analysis as well as for policy formulation purposes.

Another aspect concerning future research may target the interplay between the KBC and other conceptualizations of learning, knowledge, and innovation from a spatial perspective. I have argued in Chapter 2 that the theoretical construction of the KBC already roots in a number of further theories and concepts in EG and other academic fields. Hence, why could it be beneficial to intensify the dialog between distinct theory approaches in the upcoming years? In this respect, I will illustrate two examples.

A major strength of the KBC is certainly the systematic way it disentangles the complexity of economic action as well as underlying knowledge processes. Nevertheless, future research could challenge the question whether there is a need to add insights from additional theories and concepts in EG (or even from disciplines that, so far, seemed to be too far away). To give an example: Even if a dynamic perspective on knowledge processes is inherent in the KBC, it is *not explicitly* theorized therein. Thus, a fruitful future research objective could be to include – more explicitly – *evolutionary perspectives on economic action* in order to pay more attention to the fact that products, processes, technologies etc. change over time, and, coincidently, the knowledge inputs (i.e. the knowledge base(s)) that are needed. Here, the proposed epistemological paradigm of EEG (cf. Boschma & Frenken 2006; Boschma & Martin 2007) might serve as a fertile ground in order to pay more attention to these dynamics.

A much more visible way of linking the benefits of one concept to the strengths of another is to *merge* both concepts entirely. From my point of view, it could be an interesting task for future research to think about possible benefits if such a radical step would be undertaken with regard to the KBC. For example, one could discuss the benefits of matching the potential strengths of TIMs to those of the KBC. Such a radical form of interlinking might lead to constructions such as *engineering based* clusters, *science based* industrial districts, or *creativity based* innovation systems. Given that some TIMs are already playing an important role in regional development policy formulations (e.g. clusters, innovation systems), the merger of these models could contribute to further fine-tuning the corresponding public policy instruments.

Methodological improvements, empirical research, and operationalizability

Although my case studies contribute to fill parts of the research gap regarding the empirical testing of the KBC, the strong focus on the analysis of regional industries naturally comes along with missing other aspects. In the following section, I will refer to some of these limitations (see, above all, Chapter 9.2), but I also want to point out some disregarded aspects in the KBC literature in general. These shortcomings, in turn, constitute reference points in order to deduce some objectives for future research.

Some of these reference points for future research correlate with the definition of the (commonly used) unit of analysis in investigating knowledge bases so far. Most often – and that is also true for my research – empirical studies on industrial knowledge bases concentrate on a particular industry within a distinctive region (or metropolitan area). Albeit all of these studies unquestionably offer deep insights into the KBConfi of the respective regional industry, their scope of analysis is naturally restricted to a very limited piece of the 'real world'. Due to the fact that processes of learning and innovation – in reality – do not stop at sectoral or regional boundaries, it could be beneficial for future research to extend the scope of analysis on the functioning of knowledge bases. Despite the fact that the analysis of knowledge networks of firms within a particular regional industrial setting constitutes a good compromise to capture 'more' than merely the knowledge practices within a predefined region and sector (cf. Chapter 9.2), it cannot substitute research that is carried out at (i) a national or global level, or (ii) research which leaves the sectoral boundary. In other words, disentangling knowledge bases of, for instance, *global production networks* (Dicken 2007; Coe et al. 2008), or depicting KBConfis of the *regional system of innovation* (Cooke & Morgan 1998) as a whole, offers a promising future research field for studies which will target the KBC.

An additional aspect for future research deals with the limitations of *quantitative* data on the basis of *standardized* interviews (cf. Reuber & Pfaffenbach 2005; see also Chapter 9.2). Hence, future studies which aim at taking up my studies might gather more *qualitative* and thus *more open interview techniques* in order to complement my research which relies, first and foremost, on the results of standardized interviews with firm members. Due to the fact that research on KBConfis of defined regional industries targets not only the 'hard factors' of knowledge creation processes and innovation output, but also the 'soft architecture' of inter-organizational knowledge relations, qualitative research in the form of in-depth, semi-standardized interviews can be assumed to state a valuable, complementary source in order to gain even deeper insights into the functioning of knowledge bases.

Another potential field for future research concerns the dimension of time (cf. Chapter 9.2). Similar to the suggestion to integrate insights from more dynamic conceptions of economic action into the theoretical architecture of the KBC, there is clearly a research gap concerning the analysis of the development (and change?) of KBConfis over time (longitudinal studies vs. static view). Hence, it can be imagined that the KBConfi of a regional industry cluster in the emerging phase of the cluster life cycle differs substantially from the KBConfi of the same cluster while it is in the declining phase (cf. Menzel & Fornahl 2009).

Even if in the meantime some first exceptions have been published (see also the intended special issues which I referred to in Fn 2, Chapter 1.2), cross-*country*-comparisons of case studies on KBConfis of regional industries are still scarce. Especially research on the particularities of *national systems of innovation* (Lundvall 1992) might provide a fertile basis for future research projects. Accordingly, scholars could examine the influence of the country-specific institutional context on the underlying knowledge bases. The same counts for cross-*regional*-comparisons and the institutional context regarding the *regional system of innovation*. Albeit my work on three different industries within three German regions rather contributes to the latter body of research, there is much space left for future research on the *comparison of studies on different sector-spatial combinations*. This type of comparison research, in turn, would lead to a better relativization of results of single case studies.

Although I have presented some preliminary policy implications on the basis of the knowledge base typology in Chapter 8, and even if my considerations on the limits and potentials of the *operationalizability of this typology for policy use* (cf. Chapter 9.3) provided some initial ideas on how to bridge theory and practice, the field of study concerning public policy intervention is, so far, clearly underresearched.[61] Here, future research is needed in order to figure out which requirements an analysis tool has to meet in order to make the identification of KBConfis operable and accessible to a broader group of users who are engaged in policy formulations. This includes, for example, the definition of preconditions for 'KBC-conform' public policy intervention as well as research which targets the complexity vs. manageability problem. Some first proposals regarding this subject matter can be found in Chapter 9.3 of this book.

I would like to finish this dissertation by encouraging research on *two 'cause-and-effects-questions'*. First, there is a need to better understand how different KBConfis impact the competitiveness of firms in different industries, or regional industries as a whole. The corresponding question is whether there is indeed a causal interrelation between the KBConfi and the ability of a firm (or regional industry) to innovate successfully. Second and last, future research is needed to find out how effects of knowledge bases on knowledge creation and innovation processes can be isolated from effects of the specific regional context.

[61] One exception to this research gap, however, is the collaborative research project which I referred to in Fn 1, Chapter 1.1. This project aims at providing some first answers on how regional innovation policies can be fine-tuned according to the KBConfis of different regional and sectoral settings.

Epilogue

Looking back at what I have written between the first and the last page of this book, the empirical investigation of the knowledge base configuration of three regional industries in Germany definitely takes center stage in this book. Moreover, I tried to add to the understanding of the KBC from a theoretical point of view. While I was writing this theoretical part, I started to think that it could be interesting to explain the process in which the KBC was developed by making use of the threefold KBC itself. However, then I thought this digression would not fit into a 'streamlined' dissertation. What saves me is this short epilogue.

As I have mentioned in Chapter 9.4, the KBC is to a lesser extent the product of completely new knowledge in terms of a radical breakthrough in theorizing knowledge in EG. It is rather a result of the recombination of already existing knowledge in this field of study, based on well-established theories and empirical evidence. For this reason, we might conclude that the development of the KBC provides a prime example for an activity that heavily relies on the synthetic knowledge base. At the same time, however, it is obviously the outcome of scientific reasoning, and thus might be regarded as the result of a knowledge process which is driven by the analytical knowledge base. But does the attempt to bring new concepts to the cutting edge of a research field not also require a great deal of creativity that is in particular driven by the symbolic knowledge base?

Differentiating knowledge bases in order to identify the particular knowledge base configuration that drives the development of the KBC itself remains to be an exciting task, at least for someone who devotes a whole book to the KBC. However, before I raise another issue, I think I will better close this book and leave it at this.

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Appendix

Appendix 1: Questionnaire used for firm interviews

Identification number of interviewed firm: ________________
Name of the interviewed firm / organization: ________________
Street name: ________________
House number: ________________
Postal code: ________________
City: ________________
Function of the interviewee:

- ☐ Entrepreneur
- ☐ Head of technical department
- ☐ Head of commercial/ marketing department
- ☐ Other

If "other" please specify: ________________

Part I: Firm attributes

1.a) In what year was your firm established?

____

1.b) In case of merger or acquisition: Please indicate also the year in which the most recent merger or acquisition took place:

____

2.a) Is your firm owned by another organization? ☐ Yes ☐ No

2.b) If "yes": is this relevant in daily business and for choosing cooperation partners? ☐ Yes ☐ No

3.) Has your firm always been located in its current location? ☐ Yes ☐ No

If "No":
Where was it located before? ____________________________
When did your firm move? ____________________________

4.a) Could you please indicate how many employees (FTE) are working in your firm? ____________

4.b) What was this number 3 years ago? _____________

Part II: Personnel & Recruiting activities

5.) What is the educational level of the employees? Please indicate the share (%) of the following (in sum 100%):
Higher than or equal to Bachelor's degree: _______________%
Lower than Bachelor's degree: _______________%

6.) What is the educational background of the employees? Please indicate the share (%) of the following disciplines (in sum 100%):
Sciences _______________%
Technical studies like engineering _______________%
Artistic studies, like arts, media etc. _______________%
Other _______________%

7.) Please indicate from which of the following organizations you recruit your highly skilled employees. Please indicate their relative importance from 1 (not important) to 5 (very important).

Universities	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Technical institutes	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Firms (same sector)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Firms (other sectors)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

8.) Please indicate from which of the following three spatial levels (regional, national, international) you recruit your highly skilled employees. Please indicate their relative importance from 1 (not important) to 5 (very important):

Universities – Regional	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Universities – National	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Universities – International	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Technical institutes – Regional	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Technical institutes – National	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Technical institutes – International	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Firms (same sector) – Regional	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Firms (same sector) – National	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Firms (same sector) – International	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Firms (other sectors) – Regional	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Firms (other sectors) – National	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Firms (other sectors) – International	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

9.) Please name the three most important sectors you recruit from. Indicate their importance form 1 (relative low) to 5 (relative high)

Sector 1:	_______________	Importance:	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Sector 2:	_______________	Importance:	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Sector 3:	_______________	Importance:	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Part III: Knowledge exchange networks & knowledge sourcing

10.) Please indicate the share of (in sum 100%):
Knowledge acquired inside the company ______________%
Knowledge acquired outside the company ______________%

Part III.A: Market knowledge

This part of the interview deals with the exchange of market knowledge, e.g. knowledge concerning new market developments, market trends, market development, etc.

11) Please name organizations your firm is in contact with and exchanges market information for your innovation activities. These may be firms, universities, research organizations, and public agencies etc., no matter whether these are local or non-local organizations.

1.
a) Identification number of org.: _______________ Name of org.: _______________

b) Type of organization: ☐ Supplier ☐ Customer ☐ Competitor ☐ Other

If "Other", please specify: ______________________________

c) Please indicate the location of the organization (municipality): _________________________

d) Please indicate how important this relation is for your firm's innovation performance.
(1 not important to 5 very important)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

e) Please mention in which sector this organization is mainly active: ______________________

f) Please mention for this organization whether the market knowledge in your firm is similar to that of this organization.
(1 not similar to 5 very similar)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. …
3. …
… …

12.) Could you express the importance of the following sources of information for gathering market knowledge? Please indicate their relative importance from 1 (not important) to 5 (very important).

a) Fairs and exhibitions ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
b) Specialized magazines ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
c) Market surveys ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
d) Academic journals ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
e) Are there any other sources of market knowledge that are not mentioned above?
Source 1: _______________ Importance ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Source 2: _______________ Importance ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Source 3: _______________ Importance ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Part III.B: Technological knowledge

This part of the interview deals with the exchange of technological knowledge required as input in production, new product / process development, and technological improvements.

13.) Please name organizations your firm is in contact with and exchanges technological information for your innovation activities. These may be firms, universities, research organizations, and public agencies etc., no matter whether these are local or non-local organizations.

1.

a) Identification number of org.: _______________ Name of org.: _______________

b) Type of organization: ☐ Supplier ☐ Customer ☐ Competitor ☐ Other

If "Other", please specify: ______________________________

c) Please indicate the location of the organization (municipality): _________________________

d) Please indicate how important this relation is for your firm's innovation performance.
(1 not important to 5 very important)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

e) Please mention in which sector this organization is mainly active: ______________________

f) Please mention for this organization whether the technological knowledge in your firm is similar to that of this organization.

(1 not similar to 5 very similar)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

g) Please mention whether the technological knowledge exchanged is primarily practical or scientific based.

☐ Practical ☐ Scientific ☐ Both, practical and scientific

2. …
3. …
… …

14.) Could you express the importance of the following sources of information for gathering technological knowledge? Please indicate their relative importance from 1 (not important) to 5 (very important).

a) Fairs and exhibitions ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
b) Specialized magazines ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
c) Market surveys ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
d) Academic journals ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
e) Are there any other sources of technological knowledge that are not mentioned above?
Source 1: _______________ Importance: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Source 2: _______________ Importance: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Source 3: _______________ Importance: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Part IV: Innovation performance

15.) What are the main activities of your firm for achieving competitiveness (multiple selections possible)?

☐ Production of tailor made products / processes for individual customers
☐ Production of standardized products / processes
☐ Product / process development
☐ Design
☐ Marketing
☐ Other
If "other" please specify: ____

16.) Has the firm carried out the following changes in the last three years?

☐ Introduced new or significantly improved products / services on the market?
☐ If yes, are the products/services also new to the firm's market?
☐ Made use of new or significantly improved production processes, components or materials?
☐ Carried out new or significantly improved strategy?
☐ Carried out new or significantly improved organizational structures?
☐ Considerably improved market concept?

17.) Please indicate how much of the turnover of your firm (in sum 100%) is attributed to:

New, dramatically improved products/services introduced in the last 3 years? _______%
New, slightly improved products/services introduced in the last 3 years? _______%
Unaltered products/services the last three years? _______%

18.) Has the firm applied for patents during the last three years? ☐ Yes ☐ No

a) If yes, how many? ________
b) What is the percentage of co-patenting? _______%
c) If no, why not? ____

19.) Has the firm employees (full-time equivalents) that are occupied with the development of new products / services / solutions most of the time? ☐ Yes ☐ No

a) If yes, how many? ________
b) If yes, has the firm an R&D department? ☐ Yes ☐ No
c) How much of the time of the workers is dedicated to the development of new prod-ucts/services/solutions? ____

Appendix 2: Eidesstattliche Erklärung

Hiermit erkläre ich an Eides statt, dass die Abhandlung – abgesehen von der Beratung durch den Betreuer – nach Inhalt und Form die eigene Arbeit ist. Die Arbeit wurde bisher keiner anderen Stelle im Rahmen eines Prüfungsverfahrens vorgelegt. Einzelne Kapitel wurden bereits veröffentlicht bzw. sind zur Veröffentlichung bei den in der Arbeit angegebenen Fachzeitschriften eingereicht.

Im Einzelnen handelt es sich dabei um folgende Kapitel:

- Kapitel 4: veröffentlicht in der Zeitschrift *European Planning Studies*
- Kapitel 5: eingereicht und in Bearbeitung für die Zeitschrift *European Urban and Regional Studies*
- Kapitel 6: veröffentlicht in der Zeitschrift *Papers in Regional Science*
- Kapitel 7: eingereicht und in Bearbeitung für die Zeitschrift *Industry and Innovation*
- Kapitel 8: veröffentlicht als Buchkapitel in dem Sammelband *Räume der Wissensarbeit – Theoretische und methodische Fragen zur Rolle von Nähe und Distanz in der wissensbasierten Wirtschaft*.

Die Arbeit ist unter Einhaltung der Regeln guter wissenschaftlicher Praxis der Deutschen Forschungsgemeinschaft entstanden.

Kiel, 26. Juli 2011 ____________________________

Oliver Plum