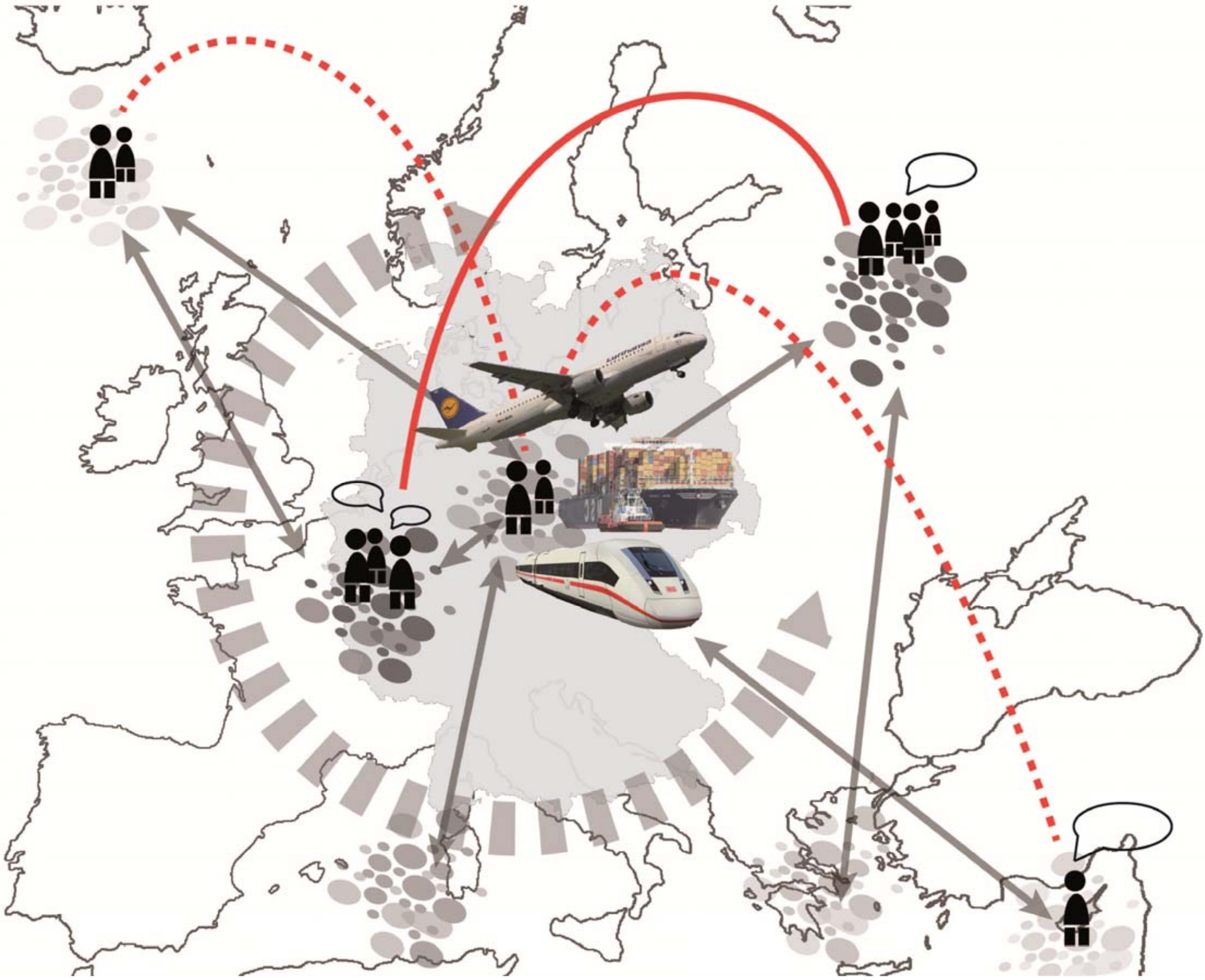
The multi-dimensional knowledge economy in Germany

Knowledge creation and spatial development

Michael Bentlage



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Michael Bentlage

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„O glücklich, wer noch hoffen kann,
aus diesem Meer des Irrtums aufzutauchen!
Was man nicht weiß, das eben brauchte man,
und was man weiß, kann man nicht brauchen."

Johann Wolfgang von Goethe: Faust, Vor dem Tor, 1064-1068.

Danksagung

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Description of the doctoral thesis

Spatial development is a multi-dimensional process in which knowledge creation plays a crucial role. Since knowledge production is an interactive process, the interplay between the dimensions of social interaction, spatial scales and time are central. Cities and regions strongly depend on the ability to absorb and reorganize knowledge bases in order to sustain competitive advantage. This dissertation assesses and quantifies the interplay of knowledge creation and spatial development by applying a relational perspective on knowledge networks, spatial accessibility and economic performance. Furthermore, it discusses different approaches of proximity and the dynamics within urban systems.

Beschreibung der Doktorarbeit

Räumliche Entwicklung und Wissensproduktion sind in einem mehrdimensionalen Prozess mit einander verwoben. Diese Dimensionen schließen räumliche Maßstäbe, soziale Strukturen und zeitliche Veränderungen mit ein. Die Entwicklung in Städten und Regionen ist maßgeblich davon abhängig wie Wissensströme aufgenommen und kombiniert werden können. Diese Arbeit quantifiziert und analysiert das Zusammenspiel zwischen Wissensproduktion, physischer Erreichbarkeit und räumlicher Entwicklung aus einer relationalen Perspektive. Dazu werden die Netzwerke von wissensintensiven Unternehmen betrachtet und im Zusammenhang mit verschiedenen Formen von Nähe diskutiert.

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List of abbreviations

FUA – Functional Urban Areas
NUTS - Nomenclature of territorial units for statistics or Nomenclature of unités territoriales statistiques
HHI – Herfindahl-Hirschman-Index
ESPON – European Spatial Planning and Observation Network
MCR – Mega-City Regions
USA – United States of America
EU – European Union
RZI – Relative Specialisation Index
RDI – Relative Diversity Index
IC – Interlock Connectivity
GaWC – Globalization and World Cities
BBSR – Bundesinstitut für Bau-, Stadt- und Raumforschung
BBR – Bundesamt für Bauwesen und Raumordnung
LQ – Localisation-quotient
APS – Advanced Producer Services
HT –High-tech
HQ – Head quarter
ICT – Information and communication technologies
OECD – Organization for Economic Cooperation and Development
R&D – Research and development
UMZ – Urban morphological zone
GDP – Gross domestic product

Preface

This dissertation is a result of my studies in geography, with a focus on economic development and quantitative methods. Furthermore, it displays my work at the Chair for Urban Development within the Faculty of Architecture at the Technische Universität München.

This is one of the first publication based dissertations at the Faculty of Architecture and at the Technische Universität München. The structure of this work and presentation of the papers is oriented on dissertations at other universities. The articles of this dissertation are in different stages of publication. Each article represents an own chapter and acts as an independent publication. Thus, some overlap between the articles might exist. In particular the theoretical parts refer to similar references in order to provide full understanding of the topics. The articles are included in the original publication form. In order to realise coherent citation and numbering, the following changes are made:

- Uniform citation
- Continuous numbering of chapters, figures and tables
- Graphical layout to fit the form of the dissertation
- Uniform style and numbering of headers

The work is separated in different articles; I will use the synonyms thesis, doctoral thesis or dissertation to refer to the entire work. Notwithstanding, British English and American English make a difference in the words ‘dissertation’ and ‘thesis’, within this work these expressions are used in the same meaning.

As I am the first author of the included articles, I developed the concepts and research questions of the different papers. This includes elaborating on the idea, formalising the theoretical and methodological concept and the interpretation of the topics. The co-authors helped me to discuss these topics and supported my ideas with intense discussions.

Munich, April 2014 Michael Bentlage

1 Introduction

1.1 Knowledge creation and spatial development

Spatial development is a multi-dimensional process in which knowledge creation plays a crucial role. Since knowledge production is an interactive process, the interplay between the dimensions of social interaction, spatial scales and time are central (Hautala and Jauhiainen 2014). Cities and regions strongly depend on the ability to absorb and reorganize knowledge bases in order to sustain competitive advantage (Florida 2007; Porter 1990; Camagni and Capello 2013). Thus, it is broadly accepted that knowledge is a resource which needs to be stored, managed and applied (Amin and Cohendet 2004: 14). The meaning of knowledge for economic processes is multifaceted (Cooke et al. 2007: 28). Knowledge, firstly, is a tradable good which is used as an input factor for production processes. Secondly, knowledge is an output factor which is generated within innovation and learning processes and applied in further production. Finally, knowledge represents power and an important strategic tool for creating future development paths of firms and regions (Simmie 2012; Cooke and Simmie 2005; Simmie et al. 2002).

Previous knowledge is considered key for the understanding and learning of further knowledge (Nooteboom 2000; Malmberg and Maskell 2006). The more you know the better accessible further knowledge will be. The learning actors are embedded in a process of incorporation of remote and possessed knowledge resources (Balland, Buchman and Franken 2014). These actors tend to be on the move from a familiar knowledge state to a new and unknown qualification level. The interplay of localized knowledge resources in geographical proximity and in remote places is crucial: “geographical proximity per se is neither a sufficient nor a necessary condition for learning and interactive innovation” (Boschma 2005: 62). Therefore, spatial accessibility and non-physical connectivity are important requirements for the expansion of knowledge bases.

A number of concepts have been developed to define this process of knowledge creation. The innovative milieu (Fromhold-Eisebith 2004; Crevoisier 2004; Maillat 1998, 1998; Harrison, Kelley and Gant 1996; Crevoisier 1993), the learning region (Rutten and Boekema 2012, 2007; Hassink 2001; Geenhuizen and Nijkamp 2000; Maillat and Kebir 1999; Florida 2007, 1995) or regional and national innovation systems (Brenner et al. 2011; Zabala-Iturriagagoitia et al. 2007; Koch and Stahlecker 2006; Edquist 2004; Lundvall 1992; Cooke 1992) provide insights in learning processes within a spatial and social context. Thus, there seems to be a shift from the view of knowledge as a commodity or object to the perspective in which “knowledge must be conceived of as activity and process” (Vissers and Dankbaar 2013: 702). In this regard, agglomeration economies assume that geographical proximity fosters this common activity of knowing by making knowledge spillovers more likely (Lambooy 2010; Trippl and Maier 2010; Capello 2009; Simmie 2004; Howells 2002; Simmie 2002).

The process of knowledge creation, however, does not end at the boundaries of a region. Therefore network economies (Graf 2006; Simmie 2004; Coe et al. 2004; Bentlage, Lüthi and Thierstein 2013) play a crucial role in the development of spaces. Regions are integrated in global systems of information flows and knowledge networks (Florida 2007: 63-67). Indeed, stepping beyond the delineation of a region opens up perspectives on supra-regional networks and urban systems. This dualism of naturally delineated regions on the one hand and supra-regional networks on the other is reflected in various studies. Among others, influential work has been done by Amin and Thrift (1992) on 'neo-Marshallian nodes in global networks', Bathelt, Malmberg and Maskell (2004) with their analysis of the 'local buzz and global pipelines, or by Harrison (2013), who outlines the difficulties in conceptualizing the global-local interface that a region yields (Harrison 2013). In this regard Thrift states:

> *"space is no longer seen as a nested hierarchy moving from 'global' to 'local'. This absurd scale-dependent notion is replaced by the notion that what counts is connectivity" (Thrift 2004: 59).*

Investigating spatial development from the process of knowledge creation requires an approach that considers the different dimensions of space, time and social structures (Jessop 2008). This leaves the question of causes and effects of spatial preconditions and knowledge networks open. "The privileged causal arrow in proximity studies has always been to explain knowledge networking from proximity" (Balland, Buchman and Franken 2014: 3). Hence, spatial preconditions such as proximity determine the ability to establish knowledge cooperation. However, there might by an inverse direction of causality. According to Padgett and Powell (2012): "in the short run, actors create relations, in the long run, relations create actors" (Padgett and Powell 2012: 2). Within this dissertation knowledge creation and spatial development are interlinked in three causal interrelations:

1. Space → knowledge

Knowledge production is dependent on spatial factors such as the level of qualification of the labour market, transportation infrastructure, universities or the urban quality. I refer to this as 'interrelation 1', where space and spatial attributes are the precondition for knowledge production.

2. Knowledge → space

Knowledge production drives spatial development by enabling innovation and fostering economic growth. This process is mainly triggered by firms and institutions which improve the qualification of the labour force, invest in infrastructure and demand for customized services and products. This I refer to as 'interrelation 2', where knowledge determines spatial development.

3. Space ←→ knowledge

'Interrelation 3' is a combination of these opposing causalities; it includes the time scale and suggests that spatial preconditions enable knowledge production, which in turn affects spatial development within the next temporal phase. This relationship might be a cumulative causation (Breschi, Malerba and Orsenigo 2000; Simmie 2003; Myrdal 1957) or an emerging system in which knowledge creation and spatial preconditions transform future development paths (Brenner and Mühlig 2013; Ter Wal 2013; Pagliara et al. 2012).

The multi-dimensional perspective on knowledge creation includes three main topics within five independent articles. The first main topic revolves around the interplay of network and agglomeration economies. Knowledge creation is involved in spatial accessibility, non-physical connectivity and economic performance. In this regard we assume a cumulative causation of knowledge and space. This topic is discussed in two articles:

Chapter 2: Knowledge creation in German agglomerations and accessibility – An approach involving non-physical connectivity

Chapter 3: Externalities of knowledge creation as interwoven constructs. Conceptualizing the interplay of networks, urbanization and localization externalities in Germany

The second main topic encompasses the functional and spatial differentiation of knowledge networks and the value-adding process. This approach focuses on spatial distribution of knowledge intensive activities and reveals relevant forms of proximity and functional differentiation. This topic is discussed in two articles:

Chapter 4: Knowledge Hubs: Poles of Physical Accessibility and Non-Physical Connectivity

Chapter 5: Revealing relevant proximities. Knowledge networks in the maritime economy in a spatial, functional and relational perspective

Finally, the third main topic applies a longitudinal analysis to the changes in centrality and connectivity of agglomerations in Southern Germany. This enables to better understand the causes and effects of knowledge production, changing urban hierarchies, spatial development and transportation infrastructure. This includes one paper:

Chapter 6: Von Zentralen Orten zu Zentralen Knoten. Über Zentralität, Konnektivität und Spezialisierung in den Metropolregionen München und Stuttgart

The remaining part of this introductory chapter provides, firstly, an overview of the doctoral thesis and, secondly, introduces the knowledge economy with regard to the process of knowledge creation and application. It also includes considerations of the importance of innovation as an interactive process for spatial development. Furthermore, it traces back the question of why knowledge has become so important for the economy and what makes it different from other resources, such as physical labour or machinery.

Thirdly, I present the relational perspective for spatial development. This includes the conceptualisation of space as absolute, relative and relational space. Subsequently, I review the research on urban systems starting with the work of Christaller (1968), who analyses the distribution of central places with regard to their functional meaning for surrounding market areas. Advances in theorizing and modelling interrelations of cities merge together in the paradigm of relational economic geography (Bathelt and Glückler 2002, 2011; Taylor 2004). This allows the understanding of cities from two perspectives: as territories in which endogenous developmental forces operate, and as nodes with links to exogenous changes (Bentlage, Lüthi and Thierstein 2013; Growe and Blotevogel 2011).

Fourthly, this section includes a compilation of concepts which deal with knowledge and space. This overview is aligned along three dimensions: the first dimension ranges from the employees to their social context, the second dimension includes the time scale, and the third dimension focuses on the spatial reach into which these concepts provide insights.

Finally, at the end of this chapter the five papers which form the parts of this publication based dissertation are introduced.

1.2 The emerging knowledge economy

The knowledge economy comprises multifaceted economic activities ranging from value added relations to a systemic perspective on interlinked business activities. Castells (2000) states that knowledge intensive activities are interlinked with the entire economy.

> *"Advanced services, including finance, insurance, real estate, consulting, legal services, advertising, design, marketing, public relations, security, information gathering, and management of information systems, but also R&D and scientific innovation, are at the core of all economic processes, be it in manufacturing, agriculture, energy, or services of different kinds." (Castells 2000: 409.*

However, the perception of the knowledge economy clearly varies. I will outline a framework for understanding the entire economic change towards knowledge and innovation. Detailed definitions and differentiations of the knowledge economy will be done in the following chapters separately. In particular chapter 5 assesses different knowledge types in a spatial and relation perspective.

While the "knowledge economy is not confined" to certain sectors (Cooke et al. 2007: 28), Cooke (2002) focuses on knowledge generation, since this is what makes the difference between knowledge intensive and non-knowledge intensive businesses. It is not only a matter of the use and application of knowledge, but about the "exploitation of new knowledge in order to create more new knowledge" (Cooke 2002: 4-5). According to Lüthi (2011: 20) this argument reflects the network approach of Castells' (2000) idea of the "rise of the network society". Castells (2000) puts emphasis on the interactive processes of knowledge generation. It is "the action of knowledge upon knowledge itself" that is key for economic performance and productivity (Castells 2000: 17). Thus, the difference between both knowledge intensive and the non-knowledge-intensive businesses is based on the treatment of knowledge, whether it only involves input for value addition, or is input and output of value creation.

Cooke and Leydesdorff (2006) point out that the term 'knowledge economy' derives from an understanding of knowledge as an input factor within the production process (Cooke and Leydesdorff 2006: 7). This perception originates in the work of Schumpeter, who states that innovation is strongly driven by "new combinations of knowledge" (Schumpeter 1934: 57). The term 'knowledge-based economy', however, reflects a broader system, in which institutions, governments and economic actors are involved (Cooke and Leydesdorff 2006: 7). This systemic approach focuses on technological trajectories and regimes in which common language, understanding and property rights are forms of capital to be ensured and exploited (Nelson and Winter 1982).

The systemic character of the knowledge economy is also outlined by Lüthi (2011) and Lüthi, Thierstein and Bentlage (2011):

> *''the knowledge economy is that part of the economy in which highly specialized knowledge and skills are strategically combined from different parts of the value chain in order to create innovations and to sustain competitive advantage'' (Lüthi, Thierstein and Bentlage 2011: 162-163).*

There is an ongoing debate as to whether the economy has evolved to one in which knowledge as a resource evokes a radically new way of theorizing and modelling economic interrelationships between actors, institutions and space (Amin and Cohendet 2004: 14). Gibbons et al. (1994) propose that "knowledge production is carried out in the context of application" (Gibbons et al. 1994: 3) and leads to non-hierarchical, transdisciplinary, socially accountable and reflexive systems of production (Gibbons et al. 1994: 3). This is the mode 2 model of knowledge production (Hessels and Lente van 2008: 741-742).

In contrast, the former mode 1 model of knowledge creation was mainly applied in universities and scientific institutions, where knowledge was isolated from the practical economic system. The new model of knowledge production strongly reflects the interests and strategies of the business actors and governments funding such activities.

> *"Knowledge is always produced under an aspect of continuous negotiation and will not be produced unless and until the interests of the various actors are included" (Gibbons et al. 1994: 4).*

Knowledge production thus includes more than market transactions and "commercial considerations" (Gibbons et al. 1994: 4) it is also a socially situated phenomenon and, as such, distributed throughout the whole of society. Therefore, the emergence of the knowledge economy is an extension of knowledge oriented activities in which cross-sectional and heterogeneous relationships reach beyond business operations.

Even more focused on the interplay between business actors, universities and institutions the 'Triple Helix' approach suggests that transactional costs might be reduced by establishing non-linear processes of innovations (Leydesdorff 2000; Etzkowitz and Leydesdorff 2000). This implies that knowledge transfer enables increased co-learning and shared experiences within ongoing research and application. The routines of knowledge are not formalized in advance, but are observable and imitable while learning on the job. However, science and its attempts to synthesize and codify knowledge into formulas and models is not obsolete. Moreover, Etzkowitz and Leydesdorff (2000) highlight the interwoven nature of mode 1 and mode 2 models and suggest that knowledge transfer rests upon the possibility of its being remotely communicated or imitated while working in close proximity:

> *"When one opens the black-box one finds Mode 1 within Mode 2, and Mode 2 within Mode 1. The system is neither integrated nor completely differentiated, but it performs on the edges of fractional differentiations and local integrations." (Etzkowitz and Leydesdorff 2000: 119)*

These local integrations depend on the type of knowledge involved (see chapter 5 for a detailed discussion).

However, there are still very advanced economic activities which contain a profound knowledge base but are not included in the knowledge economy. A recent OECD study points out that "Vocational qualifications are as important as educational attainment in Germany's labor market" (Bloem and Lalancette 2013).

The extension of knowledge intensive activities or the share of labour force within the knowledge economy reflects the learning process of the entire economy. Given that the economy in Germany is gradually evolving into knowledge intensive activities, the question arises about the velocity of change. According to Breschi, Malerba and Orsenigo (2000) two opposing scenarios exist: creative destruction and creative accumulation (Breschi, Malerba and Orsenigo 2000: 389). Creative destruction occurs due to crises or the decline of key players in the economy and gives rise to totally new business actors. Creative accumulation, on the other hand, could be understood as a constant learning process in which the economic system changes only moderately. These different modes of innovation draw on the theory of economic change (Schumpeter 2006).

The emergence of the knowledge economy "has to do with a continuing transformation towards more knowledge-intensive activities rather than a radical change and rupture of economies and societies" (Cooke et al. 2007: 26). Knowledge has always played a crucial role within business operations. From this perspective, we could identify the first agents of the knowledge economy as those who built the pyramids in Egypt or the first vessels which crossed the Atlantic Ocean. This view implies that it is not the economy itself which transforms into another economy, but rather it is the activities within these economies which become more knowledge intensive and change the rules of the entire economy.

Dicken (2011) suggests regarding the world as being in a constant state of flux (Dicken 2011: 14). We have to assume that knowledge intensive firms constantly reorganize their intra-firms and extra-firm networks in order to achieve the best conditions for learning and reduction of production costs. In this regard, the functional logic of the knowledge economy is a key driver for spatial development (Lüthi 2011: 26-41). This approach will be discussed in detail in chapter 2 and 4.

This idea of a constantly changing economy due to learning and recombination of knowledge and production processes introduces the concept of emerging systemic changes and relational geographies. Castells (2000) explains the dominance of the space of flows over the space of places:

> *"Flows are not just one element of the social organisation: they are the expression of processes dominating our economic, political, and symbolic life" (Castells 2000: 442).*

In this regard it is relations that shape spatial development and not the actors themselves:

> *"To understand the genesis of objects, we argue, requires a relational and historical turn of mind. On longer time frames, transformational relations come first, and actors congeal out of iterations of such constitutive relations." (Padgett and Powell 2012: 2)*

This relational perspective on development process and emerging structures has a long tradition in economic geography. The next chapter elaborates this perspective with regard to urban systems and structural economic change towards knowledge and innovation.

1.3 Towards a relational perspective

Urban systems have always been part of spatial planning and development processes. The term ‘metropolis’ originates from the ancient Greek definition of settlements, which provide services and administrative functions for a hinterland. Accordingly, the Romans used cities in order to imperialize a territory and to establish organisational structures led by Roman governors. During the Middle Ages in Europe, cities received rights to build market places in which traders from outside the cities sold their commodities. Interestingly, these examples shed light on the interrelation of cities and their hinterland as well between each city. This inter-city relationship forms an urban system (Taylor 2013; Wallerstein 1986). The emergence and change of such urban systems in the context of Germany will be discussed in the chapters 5 and 6.

Thus, while it may be seen that these urban systems are not an invention of the 20th century, in which innovation in transportation and telecommunication took place, the perception of urban systems has changed fundamentally due to these new technologies. This evolution results in an up-scaling process and has produced a systemic rethinking of cities and their development (Bettencourt 2013; Bettencourt et al. 2007; Batty 2013a, 2013b). See chapter 3 for further discussion. The remaining section aims to elaborate a systemic approach to cities with a focus on the rise of systemic thinking in 20th century. I introduce the concept of relational space in contrast to absolute and relative spatial perceptions. Following this, I transpose the relational approach to urban systems and spatial development.

1.3.1 Concepts of space

The perception of space differs according to the objects of research. Scientists and philosophers have contributed to this discourse from classical times onwards (Weichhart 2008: 78). To understand the development of cities within the context of knowledge production, I will present three perspectives on space: absolute space, relative space and relational space. The level of complexity increases in this sequence from absolute to relational space.

The formation of absolute space refers to the work of Newton, Descartes and Kant. In these absolute terms “space is a fixed and unchanging grid” (Harvey 2006: xix). Space is perceived as an absolute object, which is defined by geographical coordinates and represents a part of the global sphere. This spatial concept is independent of the objects and the processes in it. Therefore, space is a unit on its own and used to describe where things are (Blotevogel 2005: 831). The expression ‘space as a container’ builds upon such an idea of space. In this regard, space has content, such as mountains, employees or infrastructure. Traditional location theories such as the ‘land use theory’ (von Thünen 1826), central place theory (Christaller 1968) or the theory of market areas (Lösch 1962) apply this perspective on space to their analyses (Weichhart 2008: 78).

Relative space is defined by the potential movement of objects and is “neither fixed nor Euclidean” (Harvey 2006: xix). This refers to Einstein’s theory of relativity. Space is given by dislocation of place A and place B expressed by physical distance, time or costs. Thus, to describe place A, the relative distance to place B is needed. This spatial expression became relevant due to improvements in transportation and telecommunication technologies. The results of these advances is defined as space-time compression (Dicken 2011: 81), which means that higher accessibility causes the shrinking of distances. In this context, hub airports or any other network node become “shifting topological spaces” (Harvey 2006: xix) which shape the accessibility between two places and, therefore, induce changes in their relative distances. Space-time models (Wegener 2009; ESPON 2009; Axhausen 2008) employ such a relative perspective. However, it is not only physical accessibility that leads to space-time shrinkage, but also non-physical connectivity that interconnects regions. This approach is outlined in detail in chapter 2 and 3.

Finally the relational perspective on space goes back to the work of Leibniz. This conceptualization assumes that material objects and human beings are structured by their relations to one another (Weichhart 2008: 79). In this regard space is not a ‘real’ object as such, but defined by the relations between the objects in space (Werlen 1999: 169). For example, it is not the existence of two neighbours living next door to each other that defines space, but the relation given by their neighbourhood. This allows us to ask after the quality of these relations and which spaces result from these interrelations. These considerations on relational space have provoked discussion in the context of relational economic geography (Bathelt and Glückler 2011, 2003, 2002; Boggs and Rantisi 2003), which incorporates the ideas of evolutionary and process based approaches (Buchman and Martin 2010).

This dissertation conceives spatial development as a multi-dimensional process involving time, space, and social structures. Different concepts of space are therefore necessary to arrive at a sufficient understanding of knowledge production. See Witlox (2010) for bridging traditional location theory and relational approaches to economic decision making. Absolute space, for example, allows localisation of the assets of knowledge generation, such as the amount of highly-qualified labour force or universities. Relative space introduces the idea of how these assets are accessible in terms of commuting distances or transportation costs. Relational space focuses on the processes that take place and in which these highly qualified employees and the universities are involved. These processes of knowledge creation depend strongly on spatial accessibility and connectivity and thus incorporate relative space as well. Therefore, relational space represents the most complex concept and combines the aforementioned approaches.

1.3.2 A relational approach to urban systems

Cities function as nodes in which supply of and demand for certain functions such as political power, trade, or labour force meet. Jacobs hypothesises that even the oldest cities such as ‘Catal Hüyük’ hosted the origins of spatial development. Cities are not the final step in a sequence from rural settlements to urbanized and dense agglomerations. Moreover, rural development depends strongly on the development of cities or as Jacobs (1969) puts it: “Cities first – rural development later” (Jacobs 1969: 3-7). Jacobs refers to the renewal of work:

> *“It is one thing to notice that equipment to change and improve the productivity of already existing rural work arises in cities” (Jacobs 1969: 11).*

Consequently, new ideas and innovations are born mainly in cities and are transplanted to rural areas where new forms of production evolve. This already implies the interrelation of a city and its hinterland and the co-existence of the diversified cities and specialized production sites (Duranton and Puga 2000). See chapter 6 for a longitudinal analysis of this interplay.

The interrelation between places and their territories is conceptualized extensively in Christaller's 'Central Place Theory', which defines interrelatedness of cities according to their degree of centrality (Christaller 1968). The more central a place, the bigger its hinterland and the higher its rank within the urban hierarchy. Centrality is strongly driven by the size of the population and a proxy for interaction which is represented by the density of telephone lines. This approach could be considered as a first formalisation of an urban system.

Since the 1980s an intense debate started in which economic action is perceived in its context where it takes place (Bathelt and Glückler 2011: 5). Influential work has been done by Emirbayer and Goodwin (1994), Storper (1997), Emirbayer (1997), Dicken and Malmberg (2001), Henderson et al. (2002) and Yeung (2005). According to the aforementioned relational space, economic agency is not independent from the setting in which it is carried out and is involved in an evolutionary process. Key elements of this relational context are organisation, interaction, innovation and evolution (Bathelt and Glückler 2002: 36-40). Furthermore, Bathelt and Glückler (2011) define the relational perspective as an approach that focuses "on a relational understanding of economic action which is analysed in spatial perspective" (Bathelt and Glückler 2011: 6). Having a look at urban systems requires a perspective on these economic agents, their agency and how these activities are linked to one another. Consequently, economic decisions and development processes are not atomistic units, but rather situated in context.

The emergence of theorising and conceptualising of the relational perspective on urban systems cannot be detached from a structural approach to spatial development. Taylor, Hoyler and Verbruggen (2010) argue that contemporary urban systems are best described by complementing Central Place Theory with Central Flow Theory. Thus, to completely understand the dynamics and shape of the urban system, one needs to explore territorial developments and the integration in non-local networks at the same time (Thrift 2004, Boschma 2005). This dual perception of spatial development adds the relational perspective to economic and urban geography. Nevertheless, it is not clear yet whether it is relations or spatial characteristics that have a higher impact on economic performance. Bathelt and Glücker (2005) state, that spatial development is a result of relational and substantive conditions. Boggs and Rantinsi (2003) as well Padgett and Powell (2012) argue that the importance of agency exceeds the underlying structure. See chapter 3 for an intense discussion.

A comparison between Munich and London with regard to their national context illuminates this dualism. Munich, for example, is one of the most productive places in Europe since it has a strong and highly qualified high-tech sector combined with advanced producer services (Goebel, Thierstein and Lüthi 2007). Nevertheless, its global significance is relatively low. Munich is lacking in critical mass and therefore in the network links that would make it a global city. This situation is clearly determined by the polycentric structure of the federal states in Germany, where there is no primary city (Hoyler 2011: 225-226). London, however, has strong global integration and is defined as a global city (Sassen 2001). Britain's centralized nation state causes a strong concentration of economic forces in the city. A high share of the labour force is employed in a globally acting financial sector. As a consequence of this global integration, the city was hit hard by the financial crisis in the years 2008 and 2009 (Cassis 2010: 293-294). Consequently, we have a territorial spatial perspective, which influences the structure or substantive side of the picture, and a relational side which is represented by network integration. Both are needed to understand urban development.

Harrison (2013) calls for a multi-dimensional approach to spatial development processes, which takes networks and territorial characteristics of spaces into account. In this regard, space consists of the dimensions of territory, place, scale and networks (Jessop 2008). Thus, a discussion on knowledge creation and spatial development needs to involve different approaches and dimensions. By the same token, time and social structures are also relevant to this process.

1.4 Approaching space, social structures and time in knowledge production

Economic agency and decision making are situated in social structures and in a historical context. Considering spatial development from such a perspective, the elements of organisation, interaction, innovation and evolution link space, time and social structure (Bathelt and Glückler 2002: 36-40). Various concepts are applicable to the generation of knowledge and resulting spatial patterns. This chapter aims to explain in which way social structures, time and space are relevant to knowledge production and knowledge possession, and how these dimensions are reflected in the literature. I do not offer a detailed description of theoretical concepts, but rather a discussion of the relationship between society, time and space. This approach, for example, shows how concepts such as 'technological regimes', 'clusters' and 'communities of practice' yield communalities and overlaps but differ in terms of emphasis on space, time or social structures. Figure 1.1 shows these dimensions in three axes: space, time and social structure.

The diagram has the following reading rules:

- The concepts in the diagram are located in vicinity when they are similar and on the opposite when they complement one another. The concepts were selected in accordance with their relevance to each of the three dimensions. The diagram displays the emphasis attaching to the concepts, i.e. their main focus.
- There are two shapes to illustrate these concepts: firstly, concepts that link different dimensions are represent by circles or parts of circles. Secondly, concepts that reach along different scales are illustrated by a circle sector. Some concepts contain both a combination of different dimensions and different scales.
- The spatial dimension is aligned on the vertical axis, since this dimension is the most important one for this dissertation. On this basis the dimensions of social structure and time represent complements to spatial approaches. The concept of the 'innovative milieu' for example derives from the concept of 'industrial districts' and the co-location of similar firms. Since it includes the aspect of social inclusion of actors in the milieu it incorporates assumptions on social structure.
- The axes indicate an increase of scale from the centre to the periphery of the graph; the smallest unit is located in the centre. Moving along the axis of social structure means that the emphasis will be put on supra structures such as networks, communities or even the society. The same holds true for the time scale. Concepts located in the centre of the diagram reflect rather short-term changes. The further these are located outside the graph, the longer the time scale. Finally, the axis of space ranges from the individual to the macro levels such as nation sates or the whole world.

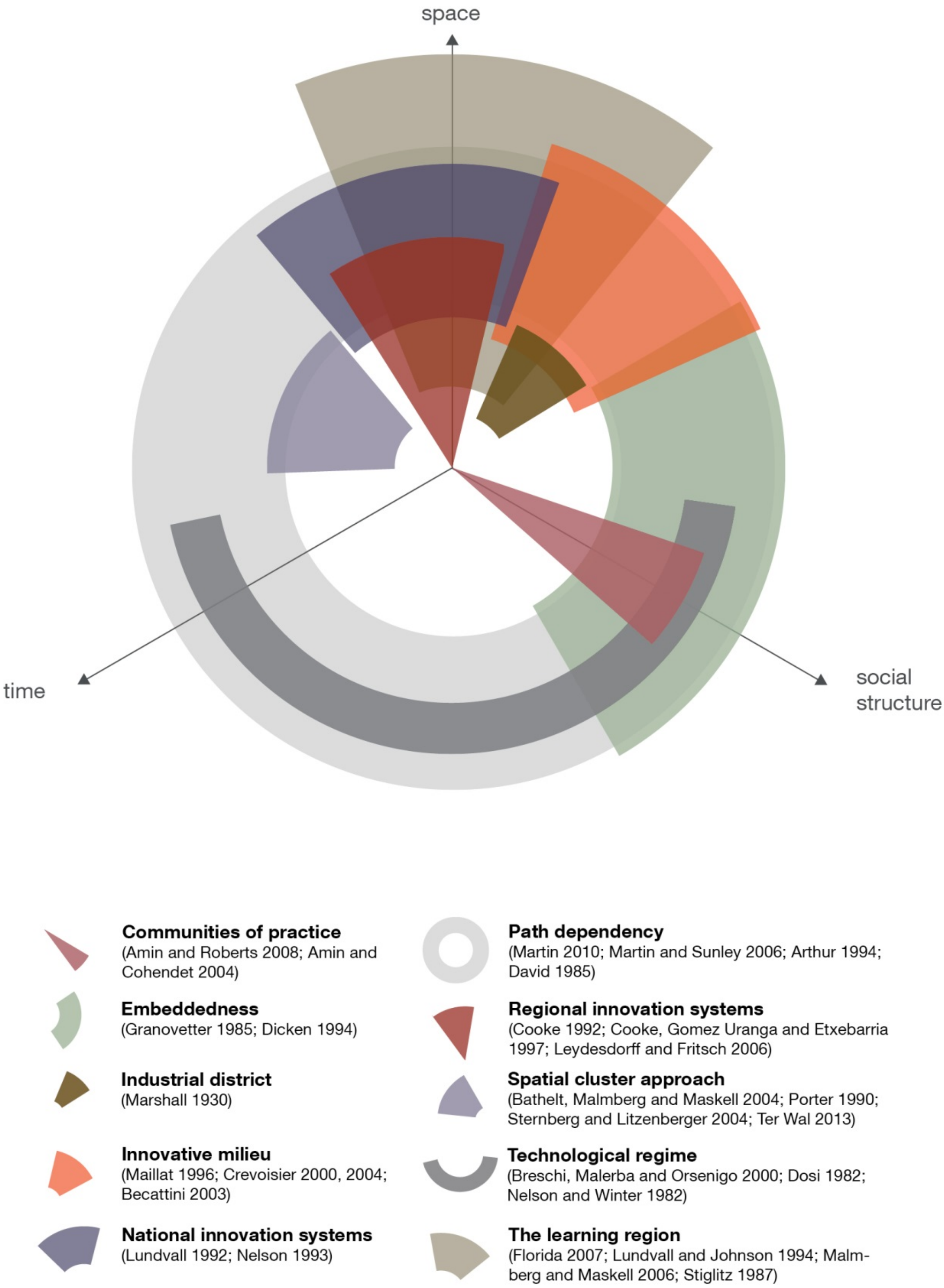

Figure 1.1: the knowledge economy and its reflection in space, social structure and time

This diagram represents a stylized overview of different approaches to knowledge creation and spatial development and acts as a toolkit indicating which concepts might be useful for such a multi-dimensional approach. An example might help to clarify this: consider the interrelation of spatial long-term development and knowledge creation. This interrelation is illustrated at the periphery of the axis of time in the diagram. It indicates that one might refer to the ideas of ‘technological regimes’ and the accumulation of knowledge (Breschi, Malerba and Orsenigo 2000; Castellacci and Zheng 2010). Taking such an evolutionary perspective, ‘path dependency’ seems to be relevant as well. This concept refers to each of the three dimensions, since it induces long-term persistence of spatial and societal structures. Thus, the concept extends into the periphery of the map and enables us to understand the creation of new development paths or the persistence of old ones (Martin 2010; Simmie 2012). In addition, national innovation systems allow investigation of the interplay of institutions of education, vocational training and private actors of innovation within a national economy (Lundvall 1992; Moulaert and Sekia 2003). Accordingly, these basic concepts provide a starting point for the long-term perspective on spatial development and knowledge creation. The following subsections explain the alignment of these concepts along the axes.

1.4.1 Space

The first dimension concerns aspects of knowledge generation and application from different spatial perspectives and is focussed on the ideas of agglomeration economies (for an overview see Neffke (2009). The world economy has changed fundamentally, moving in the direction of a flexible and decentralized production system (Dicken 2011). From a functional perspective, regions provide certain qualities and specificities which act as ‘*entrance cards*’ to a global system of interrelated knowledge resources and value added activities. Primarily, it is an interplay of infrastructure, institutions and their exploitation by individuals and firms which causes spatial disparities and consequently differences for regional development paths. There are three main strands of literature discussing these interrelations. The first is the interplay of geographical and relational proximity, the second aims to explain the co-location of knowledge actors and how this results in productivity gains and the third includes institutions and formalizes the ideas of innovation systems.

Knowledge has a tacit dimension, which is not transferable over distances (Polanyi 1966). It is this which is addressed in the first strand of literature, where geographical and relational proximity are considered constituent parts of knowledge transfer (Boschma 2005). The outcome of this dialectical approach is mainly the awareness that closeness is very case specific and the decision as to what is close and what is not depends on the discussed processes (Gertler 2003). Furthermore, being too close in terms of cognitive proximity might mean that information is not new enough to result in development (Nooteboom 2000).

Gertler (2003), for example, argues that tacit knowledge, firstly, is difficult to exchange over long distances (Gertler 2003). Secondly, it is context specific and, thirdly, learning becomes increasingly a social activity which causes the embeddedness of actors (Gertler 2003: 79). The focus here is on the dichotomy between a local or regional sphere and a non-local/global range of knowledge relations (Amin and Thrift 1992; Gertler 2008; Bathelt, Malmberg and Maskell 2004). Thus, spatial and relational proximity are counterbalanced in order to complement existing knowledge bases aiming to perfect innovations. In the context of globalisation this interplay builds a main pillar of the 'learning region':

> *"regions are becoming focal points for knowledge creation and learning in the new, global, knowledge-intensive, capitalism. In effect they are becoming learning regions" (Florida 1995: 19).*

Hence knowledge creation seems to build on three principles, geographical closeness, access to global knowledge and infrastructure that facilitates that knowledge generation (Florida 2007; Lundvall and Johnson 1994; Malmberg and Maskell 2006; Stiglitz 1987). Geographical proximity evokes agglomerative forces in a certain spatial scale: the region. These regions are defined as "natural economic zones" (Ohmae 2004: 78-79) and delineated by processes of knowing, learning or innovating. A seminal work on regions in the context of globalisation is provided by Storper (1995, 1997) who states that "untraded interdependencies generate region-specific material and non-material assets in production" (Storper 1995: 192). These untraded interdependencies are informal rules, communication and learning that lower transaction costs and enable learning processes within the region.

In the second strand of literature, interactive knowledge generation is perceived as a location-based phenomenon. The discussion on co-location is very prominent in economic geography. Prominent concepts are 'industrial districts' (Marshall 1947), 'clusters' (Bathelt, Malmberg and Maskell 2004; Porter 1990; Sternberg and Litzenberger 2004; Ter Wal 2013; Buchman and Fornahl 2011; Martin and Sunley 2001) and 'innovative milieus' (Maillat 1996; Crevoisier 2000, 2004; Becattini 2003). The latter approach builds on the ideas of Marshall, but differs in terms of the assumption that supra-local knowledge flows contribute to the development of the milieu (Maillat 1998: 3). This difference is illustrated in the diagram. Furthermore, the idea of the milieu puts strong emphasis on a social component. This compilation of concepts demonstrates that the perception of space has changed fundamentally. Former concepts, such as industrial districts, applied a perception of absolute space other concepts such as the learning region tend to focus on the relational space.

The spatial dimension of the cluster approach becomes clear by tracing it back to the work of Marshall on industrial districts, which attributes a firm's success to industrial co-location within a spatially confined area (Marshall 1947). Subsequently, these findings were refined and further developed within the field of agglomeration economies (Neffke 2009). A number of authors have outlined a differentiated approach, where local buzz and global pipelines are complementary (Bathelt, Malmberg and Maskell 2004; Buchman 2005).

Although this is a very extensive field of research, definitions and perceptions of clusters have in common that they "stress the importance of local processes of collective learning, based on a high degree of spatial embeddedness, in combination with the tacit nature of knowledge" (Ter Wal and Buchman 2011: 920). Spatial proximity in this regard makes knowledge spillovers more likely to happen (Torre and Rallet 2005; Trippl and Maier 2010; Basile, Capello and Caragliu 2012). The presence of a localized network, which is per definition a-spatial, is conceived as a further contributor to accessing knowledge bases in clusters (Maggioni, Nosvelli and Uberti 2007; Simmie 2004). If defined spatially, it constitutes an additional dimension of innovation networks in contrast to 'technological regimes' and 'communities of practice'. Furthermore the emergence and development of clusters refers to the time scale. The life cycle of clusters with regard to 'path dependency' is discussed broadly (Martin and Sunley 2011; Ingstrup and Damgaard 2013; Koschatzky and Stahlecker 2012; Karlsen 2011; Tichy 2001).

Finally, the third strand of literature discusses the importance of institutions and infrastructures in the context of innovation and regional development (Nelson 1993; Braczyk, Cooke and Heidenreich 1998; Bergman and Feser 2001; Foray and Lundvall 1996; Lundvall 1992). This analysis of regional and national innovation systems is driven by the fundamental finding that competitive advantage and innovation capabilities are mutually reinforced by public actors.

> *"This institutional set-up, which varies from country to county and from region to region, is said to constitute the location-specific supply base of technological and knowledge externalities that firms draw upon for their competitiveness" (Amin and Cohendet 2004: 88).*

The difference of national and regional innovation systems is mainly that regions are considered 'natural economic zones', whereas national innovation systems depend stronger on a territorial perception (Asheim and Isaksen 1997; Storper 1997).

1.4.2 Social structure

The second dimension is named 'social structure' and reaches from the individual to the joint or communal application of competencies (Lawson 1999). Knowledge is possessed by individuals within social structures (Amin and Roberts 2008; Vissers and Dankbaar 2013). These social structures could be represented by firms or scientific communities who provide research equipment, machinery or the opportunity to communicate and discuss knowledge. Knowledge is in a constant process of transformation in which proximity is realized by learning processes (Balland, Buchman and Franken 2014; Buchman 2005). Since knowledge production is increasingly carried out in a division of labour where comparative cost advantages are realized, knowledge itself is shared between people and communities. Isolating these individuals from their social structures could mean that knowledge is no longer available (Meusburger 2000).

The concepts differ in terms of accounting for the social context. Whereas the concept of 'embeddedness' captures the behaviour of individuals and institutions in a socially constrained situation and, thus, introduces a social component to economic agency (Granovetter 1985; Boekema and Rutten 2004). Although, Dicken (1994) introduced this social approach to geography, its emphasis is primarily a social one. Thus I consider embeddedness on a high scale of the social dimension.

'Communities of practice' concentrate on individuals and their involvement in 'knowing in action' (Amin and Roberts 2008: 365). Furthermore, actors in communities of practice are informally bound together by shared experience, expertise and commitment to a joint enterprise (Lave and Wenger 1991; Wenger 1998) and therefore are more likely to interact for the purpose of innovation.

Within economic geography, the interrelation of social structures and the concept of the firm are discussed broadly. This gives rise to the questions of where the firm ends and whether the firm acts as a collective body in which individuals fulfil sovereign but joint tasks (Taylor and Asheim 2001; Dicken and Malmberg 2001). Dicken and Malmberg (2001) make clear that the firm is more than a legal entity and its activities reach beyond the market space:

> *"This involves recognizing the nature of firms not only as legally bounded entities and owners of proprietary assets (both tangible and intangible) but also as institutions with permeable and highly blurred boundaries—in other words, conceptualizing them as "networks within networks" or "systems within systems."" (Dicken and Malmberg 2001: 346).*

Therefore, individuals might have social relations with partners outside of the firm. The firm, accordingly, is not just an aggregate of individual behaviour. Nevertheless, the ongoing reorganisation of knowledge resources displays an important approach for the analysis of knowledge creation.

Castellaci and Zheng (2010) stress the differences between industries when carrying out innovation activities (Castellacci and Zheng 2010: 11). The 'technological regime' roots social values and behaviour, which vary between these industries. This concept was introduced by Nelson and Winter (1977 and 1982) as an "intellectual framework" for interpreting the variety of innovative processes observed across industrial sectors (Nelson and Winter 1977; Nelson and Winter 1982). This tells us a great deal about future development options. For example: innovation in the German automobile sector is strongly driven by the biggest car producers, which demand customised components or modules from their suppliers (Rentmeister 2001). The literature on technological regimes refers this pattern to Schumpeter Mark II (Nelson and Winter 1982). This kind of regime is structured by oligopolistic markets in which bigger firms make use of their resources and power. Car producers tend to gather their suppliers locally in order to minimise delay in the production processes (Thierstein et al. 2011).

Contrastingly, within a Mark I regime, entrance barriers are rather low and innovation activities are distributed equally between firms (Breschi, Malerba and Orsenigo 2000). Consequently, transferring knowledge from one industry to another requires not only cognitive proximity between the actors involved (Buchman and Iammarino 2009), but also a common perception of how innovation is carried out and organized. The concept of technological regimes herein reaches beyond the economic dimension and captures cultural differences between innovating industries.

1.4.3 Time

Including time in the consideration of knowledge refers to processes of creation, application and accumulation of knowledge (Hautala and Jauhiainen 2014). It is closely linked to the activities of learning and memorizing. The ideas of knowledge accumulation suggest that economic systems act as long-term memories and display the evolution of such a system (Barabási 2009). 'Evolutionary economic geography' and its adaptation of 'path dependency' to regional development illustrates that the process of acquiring new knowledge is conditioned by the knowledge base which already exists (Simmie 2012; Neffke, Henning and Buchman 2011; Martin 2010; Garud, Kumaraswamy and Karnøe 2010; Martin and Sunley 2006). Thus, "history reverberates" (Martin and Sunley 2006: 401) in regional development and knowledge creation is an extension of the existing knowledge base. This concept of path dependency refers to all three dimensions and excludes the lower scales in the centre of the diagram since:

> *“most institutions are composite entities, made up of numerous microlevel institutions: organizational elements, structural arrangements, sociocultural norms, and individual rules and procedures. Furthermore, it is possible for many of these components to change without necessarily requiring a change of all the remaining components” (Martin 2010: 13).*

Hence whereas the social or spatial setting remains in path dependency, individuals might change their trajectories relatively easily.

In this context, ‘technological regimes’ seem to address the question of time implicitly. Individuals, firms and communities have common rules and perspectives. Technological regimes frame the trajectories a firm or a technology might take within a period of time (Dosi 1982; Nelson and Winter 1982; Castellacci and Zheng 2010; Breschi 2000; Breschi, Malerba and Orsenigo 2000). Thus, technological change as a result of knowledge accumulation and innovation takes place within the boundaries such a regime implies.

> *“Regimes are defined by the combination of factors including the level of technological opportunity for established firms, the ease of access to new technological opportunity by entrant firms, and the cumulativeness of learning” (Marsili 1999: 2).*

Accordingly, a technological regime can be considered to be the long-term memory of an industry, which can hamper and propel innovation by past innovation and learning processes and the resultant accumulation of knowledge. Moreover, it constitutes a reasonably stable social system over time and thus stretches along in the diagram on higher scales with reference to the dimensions of social structure and time.

This overview of concepts of knowledge creation shows that knowledge creation and spatial development are complex processes. That is why a multi-dimensional approach is required, meaning one which takes social structures, spatial relations and change over time into account. This overview therefore provides background information for the different articles that follow in chapter 2 to 6.

1.5 Research questions and structure of the thesis

The thesis is organized into five different articles revolving around the process of knowledge creation and spatial development. Figure 1.2 shows the structure of the thesis with its main topics and included articles. The remainder of this section briefly introduces these papers.

The multi-dimensional knowledge economy in Germany. Knowledge creation and spatial development

introduction	- the knowledge economy - relational perspective of urban systems - a multi-dimensional approach to knowledge creation
Part I The interplay of Network and Agglomeration economies. Knowledge creation involved in spatial accessibility, connectivity and economic performance.	Knowledge creation in German agglomerations and accessibility – An approach involving non-physical connectivity
	Externalities of knowledge creation as interwoven constructs. Conceptualizing the interplay of networks, urbanization and localisation externalities in Germany
Part II Functional and spatial differentiation of knowledge networks and the value-adding process	Knowledge Hubs: Poles of Physical Accessibility and Non-Physical Connectivity
	Revealing relevant proximities. Knowledge networks in the maritime economy in a spatial, functional and relational perspective
Part III Changing hierarchies. Centrality, connectivity and specialisation	Von Zentralen Orten zu Zentralen Knoten. Über Zentralität, Konnektivität und Spezialisierung in den Metropolregionen München und Stuttgart
conclusion	- key findings - beyond the multidimensional approach - outlook on future development research

Figure 1.2: structure of the thesis (own illustration)

Chapter 2 deals with the questions regarding how physical networks (i.e. those concerning accessibility via air, road and rail traffic), and non-physical connectivity (i.e. interlocking firm networks of multi-branch and multi-location companies), impact economic performance in functional urban areas (FUAs) in Germany. Correlation and regression analyses are employed in order to quantify and compare the physical and non-physical impacts.

Chapter 3 aims to scrutinize the interrelation of network externalities and agglomeration externalities, and their impact on productivity in Germany. Therefore, we apply principal component analysis in order to statistically differentiate between urbanization, localization and network externalities. Then we estimate a series of regression models, which take into account the interrelation of those types of externalities.

Chapter 4 focuses on the spatial distribution of value chains and knowledge networks. This functional perspective provides insights in the co-existence of diversified and specialised regions. Moreover, economies of localisation and urbanisation seem to complement one another. The spatial distribution of both these environments of economic processes reveals a strong spatial interrelation.

Chapter 5 deals with the maritime economy in Germany as a case study which transcends the economic sectors of services, manufacturing and transportation. The maritime economy is a heterogeneous cluster in which knowledge-intensive activities are interwoven with production and trading of goods. Based on a data set of corporate knowledge networks, we are able to analyse the maritime economy from three different perspectives: the functions of the actors involved, their types of knowledge relations with each other, and the spatial configuration of these sub-networks.

Chapter 6 responds to Central Place Theory by scrutinising the change in the functional urban hierarchy in Southern Germany. Christaller provides an explanation for the size and the distribution of central places. He focuses on their importance for the supply of essential goods and services. Due to globalization, decreasing transportation cost, and liberalization of trade, central places are increasingly interlinked with global sources. Specialized skills and knowledge play a crucial role, and undermine Central Place Theory by putting emphasis on uniqueness and locally situated knowledge resources. Cities become more and more complementary, which triggers dynamics within the urban hierarchy. This is mainly driven by localization economies. Urbanization economies, in contrast, tend to stabilize the urban hierarchy.

The conclusion, finally, recapitulates the main findings of each chapter and discusses the multi-dimensional approach. Furthermore, it provides an outlook at future development options of the German urban system in the context of economic structural change, the provision of comparable living conditions in Germany and economic crisis from 2007 onwards.

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2 Knowledge creation in German agglomerations and accessibility

An approach involving non-physical connectivity

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Abstract

Knowledge production is a complex process in which implicit and explicit knowledge are interwoven. Therefore, knowledge-intensive firms require access to information and the ability to acquire experienced-based knowledge through face-to-face contacts. Network economies and agglomeration economies form a strong theoretical background which explains the externalities within knowledge production. Although relations between networks of cities and agglomeration effects are widely discussed, physical infrastructure and spatial accessibility are still not adequately integrated into the concept of externalities within knowledge production. Nevertheless, physical interaction fosters knowledge creation by making labour forces, greater market areas and remote locations more accessible. This paper introduces a combined framework of physical and non-physical accessibility. Interaction between firms – connectivity – is calculated using the Interlocking Network Model. Physical accessibility is defined by the potential to reach as much of the population as possible within a certain area by air, rail and road transportation. Thus, we quantitatively assess the interrelatedness of modes of transport and the non-physical connectivity of firms. This quantitative framework shows that physical infrastructure, spatial accessibility and the ability of firms to form networks are mutually reinforcing. First results indicate that on the regional scale, access by rail and road are far more important than air access, which in turn is the dominant mode of access for business activities on the global scale. Nevertheless, when taking account of the impact on regional added value, critical mass of population and employment outweighs accessibility and connectivity.

Keywords:

Knowledge economy, Knowledge creation, Germany, Interlocking firm network, Connectivity, Accessibility, Economic performance

My contribution:

- Conceptualisation of the article and research question
- Data calculation and statistical analysis
- Interpretation of the results

2.1 Introduction

The production of knowledge takes part in complex networks of firms and individuals. Recent decades have witnessed a period of fundamental change in worldwide economic activities (Dicken 2011). During this period, the use and supply of information and communication technology (ICT) has broadened and transportation costs have fallen steeply, thus further accelerating the process of globalisation. This development has prompted some authors to declare ‘‘The Death of Distance’’ (Cairncross 1997) and that ‘‘The World Is Flat’’ (Friedman 2005). These assumptions about the impact of globalisation suggest that face-to-face contacts and geographical proximity no longer matter in the creation of knowledge.

Although ICT has the potential to spread information wherever there is access to these technologies, knowledge and the knowledge economy tends to be concentrated in global nodes such as global cities (Castells 2000; Sassen 1991). Dicken (2011) verifies this finding and points out that Advanced Business Services in particular ‘‘continue to be extremely strongly concentrated geographically’’ (Dicken 2011: 390). Only those industries that are based on highly localised raw materials tend to concentrate to this extent. Thus, the world is likely to become more and more spiky because population, patents, and a number of scientific citations are located in several urban centres in North America, Europe and South-East Asia (Florida 2005). Richard Florida uses these variables as indicators of economic activity and knowledge-based assets, and hypothesises that globalisation has clearly changed competition but does not level the ‘‘playing field’’. Indeed, within knowledge creation and application, spatial proximity and faceto-face contacts still play a crucial role (Storper and Venables 2004). In particular, tacit knowledge, which is mainly based on experience, can only be transferred in learning processes. A new division of labour has resulted from this complex process of knowledge creation and application and has led to a new spatial logic (Sokol, van Egeraat and Williams 2008: 1143).

Knowledge creation in firms depends on various factors, which can be divided into internal and external factors. Internalities, such as the qualification of human capital or investment in research and development, are conditions that can be influenced by the firm individually. Externalities are advantages from which firms benefit at no cost to themselves, or disadvantages which they have to pay for, but for which they are not responsible. In our analysis we will focus on the positive externalities of network economies and agglomeration economies. Network economies highlight the effects of strategic links between hubs of knowledge. Agglomeration economies enable knowledge spill-overs between individuals. Therefore, knowledge-intensive firms require an environment with two main conditions: access to networks for receiving information, and critical mass to realise knowledge spill-overs. For both conditions, spatial accessibility and the non-physical connectivity provided by firm networks play a crucial role and foster the economic performance of a region (de Bok and van Oort 2011). Exploiting these economies raises the question of how can firms or other players access these externalities in both ways, i.e. physically and non-physically.

From a spatial perspective, the effects of accessibility are made clear by the example of airports. Droß and Thierstein (2011) as well as Thierstein, Goebel, and Lüthi (2007) showed that airport access affects economic performance. Airports attract knowledge-intensive firms, which in turn drive spatial development (Button and Taylor 2000; Droß and Thierstein 2011; Goebel, Thierstein and Lüthi 2007; Haas and Wallisch 2008; Kramar and Suitner 2008; Schaafsma 2009, 2008; Schaafsma, Amkreutz and Güller 2008). Such firms demand diverse pools of labour, which are to be found in agglomerations on the one hand, and in high access to global markets provided by airports and strategic links between firms on the other. Although these effects are assumed to be relevant for economic performance and indeed for the locational behaviour of knowledge-intensive firms, empirical evidence on how strong they are has not yet been produced (Behnen 2004: 284).

In this paper we assess the knowledge production process by highlighting the importance of accessibility. We combine the concept of spatial accessibility with the theoretical approaches of network economies and agglomeration economies that show how firms exploit these externalities. In addition we differentiate accessibility according to mode (air, rail or road) and dimension (physical and non-physical), with the potential to either establish links within a network or to access parts of agglomerations. Furthermore, we show that the location-related decision-making by firms in the Advanced Producer Services (APSs) and high-tech sectors correlates quite strongly with the accessibility of spatial entities, although differences between both sectors are still evident. We therefore analyse the locational behaviour of firms, their intra-firm networks and the role of physical accessibility, and consider this in relation to the economic performance of Functional Urban Areas (FUAs) in Germany. Accessibility is understood as the foundation for entering and establishing networks of knowledge creation and impacts on economic performance to a large extent. The question arises how firms access externalities to create knowledge.

This paper is structured as follows: ''Externalities of knowledge creation – networks, agglomerations and accessibility'' defines the knowledge economy and discusses externalities of knowledge production; ''Accessibility: an approach with non-physical connectivity'' introduces a concept of spatial accessibility including non-physical connectivity; ''The interplay between physical accessibility and non-physical connectivity'' illustrates the interplay between physical accessibility and non-physical connectivity; ''Effects of Accessibility on the Economic Performance'' gives first analytical results of the effects of accessibility on economic performance. ''Conclusion'' concludes the discussion.

2.2 Externalities of knowledge creation – networks, agglomerations and accessibility

2.2.1 The knowledge economy and knowledge production

The process of knowledge creation requires a dynamic interplay between tacit and explicit forms of knowledge as well as a strong interaction between people both within organisations and between them. Therefore physical accessibility plays an important role (Thierstein, Goebel and Lüthi 2007: 88). Since codified and tacit knowledge are interwoven (Polanyi 1966), accessibility works in a nonphysical and a physical dimension. Physical accessibility enables the movement of people and establishes face-to-face contacts; non-physical accessibility facilitates the exchange of information. In general, accessibility is an externality that enables firms to reduce costs (de Bok and van Oort 2011: 9) and enlarge their market coverage and, therefore, to realise economies of scale and economies of scope, which in turn generate economic growth (Axhausen 2008: 7-10). Hence, a circular cumulative causation is initiated as the gains from economic growth will be reinvested in infrastructure and human capital, which lead to further improvement of accessibility in both the physical and non-physical dimensions.

Although knowledge is held to be the fundamental resource within the process of innovation, there is no commonly accepted definition of what the knowledge economy is. We therefore apply the following definition of the knowledge economy:

> *"the knowledge economy is that part of the economy in which highly specialized knowledge and skills are strategically combined from different parts of the value chain in order to create innovations and to sustain competitive advantage" (Lüthi, Thierstein and Bentlage 2011: 162-163).*

This definition is based on two key features: Firstly, it is not only the use of knowledge that is important for defining the knowledge economy, but also the knowledge creation process (Cooke et al. 2007: 27)). Secondly, it takes account of the strategic importance of knowledge in the innovation process. The profit imperative is an important logical principle shared by all knowledge-intensive firms. It is not only the creation of new knowledge that preoccupies their managers, but also the appropriation of surplus value (Sokol, van Egeraat and Williams 2008: 1143).

Furthermore, the definition underlines the relational character of the knowledge economy. Since highly specialised knowledge and skills are based on a combination of scientific knowledge and practical experience, the knowledge economy establishes strategic links between firms and other organisations as a way to acquire specialised knowledge from different parts of the value chain (Lüthi, Thierstein and Bentlage 2011: 163). In terms of economic sectors, the knowledge economy can be understood as an interdependent system of APS and high-tech firms. APS can be defined as

> *"a cluster of activities that provide specialised services, embodying professional knowledge and processing specialised information, to other service sectors" (Hall and Pain 2006: 4).*

The essential common characteristic of these sectors is that they generate, analyse, exchange and trade information, making them spearheads and key intermediaries in the knowledge economy (Sassen 2001: 90). However, APS are not the only determining element in the process of structural change towards the knowledge economy. In order to understand the geography of globalisation, one has to account for both the APS and high-tech sectors simultaneously (Castells 2000).

Both kinds of knowledge – explicit and tacit knowledge – work differently in the way people have to interact (Polanyi 1966). Since the transfer of tacit knowledge requires direct face-to-face interactions, the findings of Polanyi (1966) are not only important for firms but also for regions. Innovative activities have been shown to be highly concentrated in a minority of urban regions (Simmie 2003). The main reason why these regions play an important role in the supply of knowledge is that firm networks benefit from geographical proximity and local knowledge spill-overs. Malecki (2000) describes this as the ‘‘local nature of knowledge’’ and highlights the necessity to accept knowledge as a spatial factor in competition:

> *‘‘If knowledge is not found everywhere, then where it is located becomes a particularly significant issue. While codified knowledge is easily replicated, assembled and aggregated (. . .), other knowledge is dependent on the context and is difficult to communicate to others. Tacit knowledge is localised in particular places and contexts (. . .)’’ (Malecki 2000: 110).*

The distribution and transfer of explicit and tacit knowledge as well as the interplay between geographical and relational proximity forms a key basis for the development of regions. On the one hand, the concentration of knowledge resources in particular regions influences the roles those regions may play in the global economy. On the other hand, the dynamics of knowledge exchange within and between regions contribute to either the maintenance or modification of those roles within the functional urban hierarchy. This raises questions about the spatial reach of knowledge spill-overs and the relative importance of regional versus international knowledge spill-overs. Simmie (2003) shows that knowledge- intensive firms combine a strong local knowledge capital base with high levels of connectivity to similar regions in the international economy. In this way they are able to combine and decode both codified and tacit knowledge originating from multiple regional, national and international sources (Simmie 2003).

2.2.2 Exploiting agglomeration economies

Agglomeration economies are generic geographical processes mapping the microeconomic logic of knowledge creation and business organisation in space. Early theories on agglomeration economies are strongly inspired by Marshall (1920), who argued that spatial concentration could confer external economies on firms as they concentrate in particular cities (Marshall 1920). Marshall’s concept was taken up by Hoover (1937), who grouped the sources of agglomeration advantages into internal returns of scale, localisation and urbanisation economies. Localisation economies reflect the tendency for firms in closely related industries to locate in the same place; urbanisation economies, on the other hand, arise from the diversity and the more general characteristics of a city (Hoover 1937). Based on these early agglomeration theories, a second wave of agglomeration models was developed in the 1980s onwards to explain why local space is still important for newlydeveloping production firms. For example: the new industrial district (Becattini 1991), the innovative milieu (Maillat, Quévit and Senn 1993, 1993) or the regional innovation system (Cooke 1992).

The commonality of these approaches is that they acknowledge geographical proximity as an important determinant for the innovation activities of knowledge-intensive firms. A number of authors have demonstrated through econometric methods that knowledge spill-overs are closely related to spatial proximity (Bottazzi and Peri 2002; Breschi and Lissoni 2009; Jaffe, Trajtenberg and Henderson 1993). The importance of face-to-face contacts in communication and the tacit nature of much of this communication mean that geographical proximity is still a crucial factor in knowledge creation. Short distances bring people together and enable them to exchange tacit knowledge. This leads to the development of localised knowledge pools, which are in turn characterised by personal contacts and informal information flows, both within and between firms of the knowledge economy. The spatial concentration of these information flows influences scanning and learning patterns, as well as the sharing of localised knowledge and the innovation capabilities of knowledge-intensive firms (Howells 2000: 58).

2.2.3 Exploiting network economies

Codified knowledge can be applied, expressed and standardized. Hence, it is a marketable good that can easily be distributed over time and space. New information and communication technologies offer the opportunity to increasingly codify and commodify knowledge and make it tradable across long distances, which means that codified knowledge becomes more and more de-territorialised. This enables companies to source activities and inputs globally and to benefit from relational proximity and international knowledge spill-overs. Tacit knowledge, in contrast, refers to knowledge that cannot be easily transferred. It comprises skills based on interactions and experiences. Tacit knowledge and personal experience are necessary in order to make use of codified knowledge in creative and innovative processes (Schamp 2003: 181).

The functional logic of the knowledge economy has a significant impact not only on agglomeration economies, but also on global network economies. Although there is strong evidence that knowledge is highly concentrated in a minority of city-regions, it is unlikely that all the knowledge required by a firm for innovation can be found within a single region. Companies have to spread activities globally to source inputs and to gain access to new markets. High-tech industries, for example, use global sourcing to improve existing assets or to create new technological assets by locating R&D facilities abroad (OECD 2008: 10). In order to realise global sourcing strategies successfully, relational proximity – especially organisational and time proximity – is important. Organisational proximity is needed to control uncertainty and opportunism in the knowledge creation process (Boschma 2005: 65). It creates a sense of belonging, which facilitates interaction and offers a powerful mechanism for long-distance coordination (Torre and Rallet 2005: 54). Time proximity, on the other hand, is supported by a rich and diversified infrastructure of global travel and communication, such as rapid and frequent trains and flights, and easy access to interactive communication facilities. It covers important aspects of ‘being there’, but it does not demand enduring co-location and local embedding (Amin and Cohendet 2004: 105).

All in all, the spatio-economic behaviour of knowledge-intensive firms has led to the emergence of a globalised city network. Two major world city network approaches are of particular importance for this paper. The first approach is Friedmann's (1986) 'world city' concept, which focuses on the decision-making activities and power of TNCs in the context of the international division of labour. He argues that ''key cities throughout the world are. . . 'basing points' in the spatial organisation and articulation of production and markets'' (Friedmann 1986: 71).

The second approach is Saskia Sassen's 'Global City' concept (Sassen 2001), which associates cities with their propensity to engage with the internationalisation and concentration of APS firms in the world economy (Sassen 2001: 90). Sassen (1994) defines global cities as ''strategic sites in the global economy because of their concentration of command functions and high-level producer- services firms oriented to world markets'' (Sassen 1994: 145).

In order to brook this shortcoming, the empirical part of this paper applies Taylor's 'world city network' approach to an analysis of global connectivity (Taylor 2004). This approach provides an empirical instrument for analysing inter-city relations in terms of the organisational structure of knowledge-intensive firms and complements the physical accessibility approach.

2.3 Accessibility: an approach with non-physical connectivity

As mentioned above, accessibility is considered in a physical and non-physical dimension. Physical accessibility is determined by the potential to reach a population via air, rail or road traffic. Non-physical accessibility is defined by the Interlocking Network Model (Taylor 2004). This model conceptualises hypothetical information flows between cities and reflects the degree of integration in global information flows, which is also referred to as the connectivity of a city. Furthermore, physical accessibility can be associated with network economies and agglomeration economies. Whereas rail and road accessibility work on the scale of agglomerations, accessibility by air provides network links to worldwide locations. A comparison of physical accessibility and non-physical interaction was undertaken by several authors. For example, Tranos (2011) shows the relations between Internet backbones and aviation networks. Derudder and Witlox (2005) analyse aspects of the World City Network offered by the Interlocking Network Model and its interrelation with air travel.

2.3.1 Physical accessibility

Data on physical accessibility was originally calculated by the European Spatial Planning and Observation Network (ESPON) for NUTS[1] 3 level. Here, accessibility is defined by ‘‘how easily people in one region can reach people in another region’’ (ESPON 2009a: 4). This calculation indicates the potential for activities and enterprises in the region to access markets and activities in other regions. It was obtained by calculating the population in all other European regions, weighted by the travel time (ESPON 2009a: 7). The formula is in two parts: the activity function, which represents the activities or opportunities to be reached and the impedance function, which represents the effort, time, distance or cost needed to reach them (ESPON 2004a: 276). The equation is defined as:

$$A_i = \sum_j W_j^{\alpha} \exp(-\beta c_{ij}) \qquad (1)$$

where Ai is the accessibility of area i, Wj is the activity, here the size of population,W, to be reached in area j. This term is weighted by an exponent α which takes agglomeration effects into account and shows that larger facilities may be disproportionately more attractive than smaller ones. The negative exponent βc_{ij} is the generalised cost of reaching area j from area i. It indicates that nearby places have higher weights than remote ones.

This is known as the potential measure and was introduced by Hansen to indicate opportunities for interaction (Hansen 1959). The potential measure is considered useful for exploiting network and agglomeration externalities since ‘‘the greater the number of attractive destinations in areas j, and the more accessible areas j are from area i, the greater the accessibility of area i’’ (ESPON 2004b: 276). Geurs and van Eck (2001) compiled a detailed catalogue of further accessibility measures, which also take account of the production functions of consumers and activity-based approaches.

The accessibility values used here are indices calculated for 27 members of the European Union. A value below 100 indicates an accessibility factor lower than the European average.

[1] Nomenclature of unités territoriales statistiques

In contrast, values above 100 represent accessibility above the European average. These data from NUTS 3 regions were converted to the spatial units of Functional Urban Areas (FUAs) to enable them to be combined with data from intra-firm networks. Hence, the accessibility data of FUAs reflect an area-weighted average of data from NUTS 3 regions. FUAs are agglomerations defined by an average commuting time of 60 min around a defined centre (ESPON 2004).

Fig. 2.1 shows a comparison of multimodal accessibility of NUTS 3 entities on the left-hand side and FUAs on the right-hand side. Multimodal accessibility includes potential accessibility by road, rail and air traffic. The regions with highest accessibility are concentrated around metropolitan areas and reach values of 150 and more. Regions with low accessibility can be found in the area between Berlin, Hamburg, and Hannover, as well as next to the national borders in the east and north. However, these regions still yield values that are only slightly below the European average. Whereas rail and road tend to be ubiquitous within Germany and neighbouring agglomerations, airports are concentrated in metropolitan regions. The question thus arises as to which mode of access affects the non-physical interaction in which way.

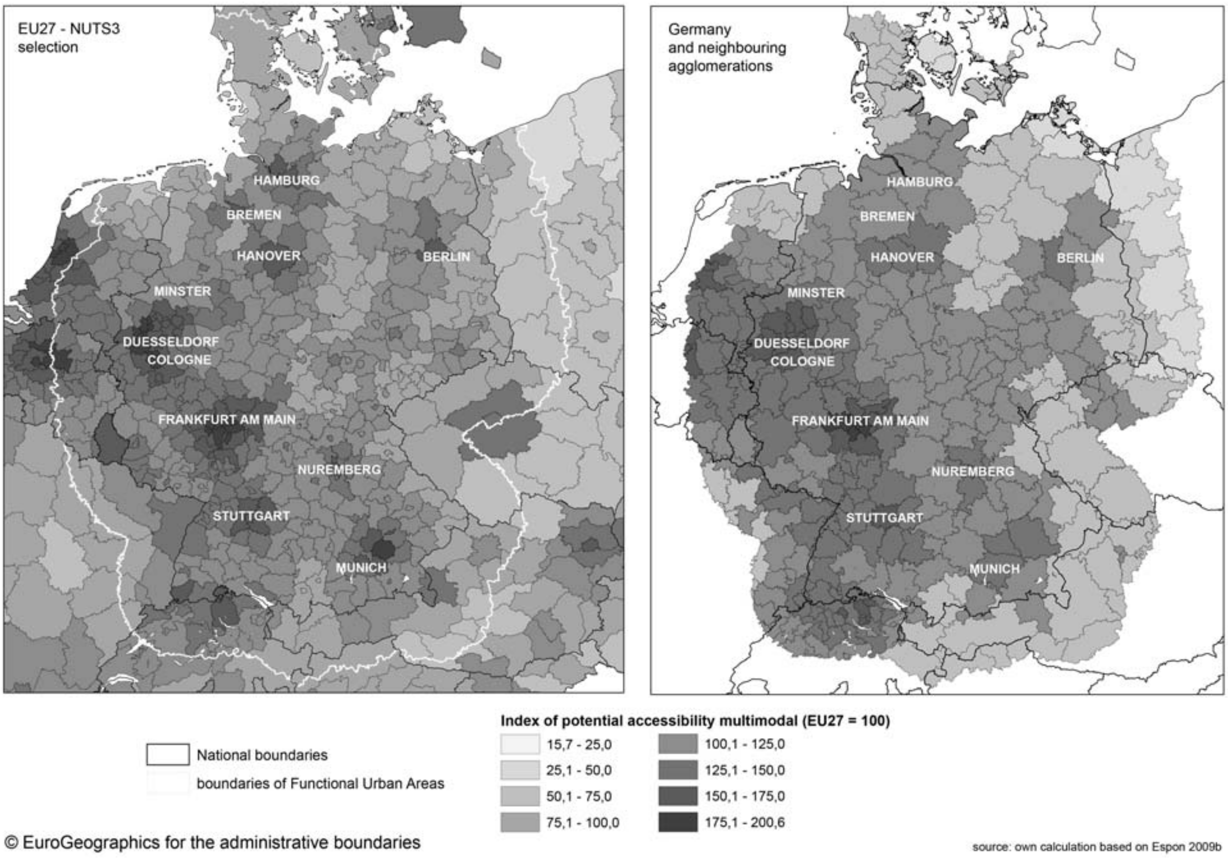

Figure 2.1: Calculation of accessibility for Functional Urban Areas (own calculation based on ESPON (2009b)

It can be assumed that Germany, due to its dense population distribution, is well served with physical infrastructure on the one hand and provides good access to several modes of transport on the other. Whereas road and rail offer a ubiquitous supply and tend to improve accessibility on the regional scale, airports and their accessibility are concentrated in metropolitan areas in the western part of Germany.

2.3.2 Defining non-physical connectivity

The analysis of intra-firm networks is based on the methodology of the Globalisation and World Cities Study Group (GaWC) at Loughborough University. This approach estimates city connectivities from the office networks of multi-city enterprises. Intra-firm networks are spatially distributed branches of one individual corporation. The basic premise of this method is that the more important the office, the greater the flow of information from it to other office locations. The empirical work was undertaken in three stages. In the first stage, we created a reliable company database by identifying the biggest APS and high-tech firms[2] which operate in Germany and collected information from their websites about the importance of their locations within the worldwide network of firms – the service values of a location. The result of this process was a basic set of 270 APS firms and 210 high-tech enterprises.

In the second stage, we developed what is known as the 'service activity matrix'. This matrix is defined by FUAs along structured lines on a regional, national, European and global scale, with knowledge-intensive firms in the columns. Each cell in the matrix shows a service value (v_{ij}) that indicates the importance of a FUA (i) to a firm (j). The importance is defined by the size of an office location and its function. All office locations are rated on a scale of 0–5 by analysing the firms' websites. The standard value for a cell in the matrix is 0 (no presence) or 2 (presence). If there is a clear indication that a location has a special relevance within the firm network (e.g. regional headquarters, supra-office functions) its value is upgraded to 3 or, in the case of even greater importance, to 4. The enterprise headquarters is valued at 5. If the overall importance of a location in the firm network is very low (e.g. small agency in a small town) the value is downgraded to 1.

In the third stage, we used Taylor's Interlocking Network Model to estimate the connectivities of FUAs (Taylor 2004). Network connectivities are the primary output from the interlocking network analysis. The measure is an estimation of how well-connected a city is within the overall intra-firm network. There are different kinds of connectivity values. The connectivity between two FUAs (a, b) of a certain firm (j) is analysed by multiplying their service values (v) representing what is known as the elemental interlock (r_{abj}) between two FUAs for one firm:

$$\mathrm{r_{abj}} = \mathrm{v_{aj}} \times \mathrm{v_{bj}} \qquad (2)$$

To calculate the total connectivity between two FUAs, the elemental interlock for all firms located in these two FUAs is summarised. This leads to the city interlock (r_{ab}):

$$\mathrm{r_{ab}} = \sum \mathrm{r_{abj}} \qquad (3)$$

[2] APS is defined by the following sectors: accounting; insurance; banking & finance; management & IT consulting; law; logistics (3p & 4p); design, architecture & engineering; advertising & media; information and communication services.Hightech is defined by the following sectors: chemistry & pharmacy; machinery; electronics; computer hardware; telecommunications; medical & optical instruments; vehicle construction.These sectors employ a high proportion of highly-skilled labour and carry out intensive research and development activities. See Legler and Frietsch (2006).

Aggregating the city interlocks for a single FUA produces the interlock connectivity (N_a). This describes the importance of the FUA within the overall intra-firm network

$$N_a = \sum r_{ai} \;\; (a \neq i) \qquad (4)$$

From this calculation we obtain an indicator of integration within several networks. Fig. 2.2 shows the connectivity with surrounding neighbours on the one hand and with global locations on the other, to give the oppositional orientation into global or regional networks. Surrounding neighbours are defined by the Rook Contiguity[3] of first and second order. The values shown here are the city interlocks normed to highest values on each scale and sector with either the surrounding neighbours or locations outside Europe on the global scale.

[3] Rook contiguity: this method defines spatial entities as neighboured by sharing a common border. In contrast to queen contiguity this also accepts neighbourhood when spatial entities share a common single point.

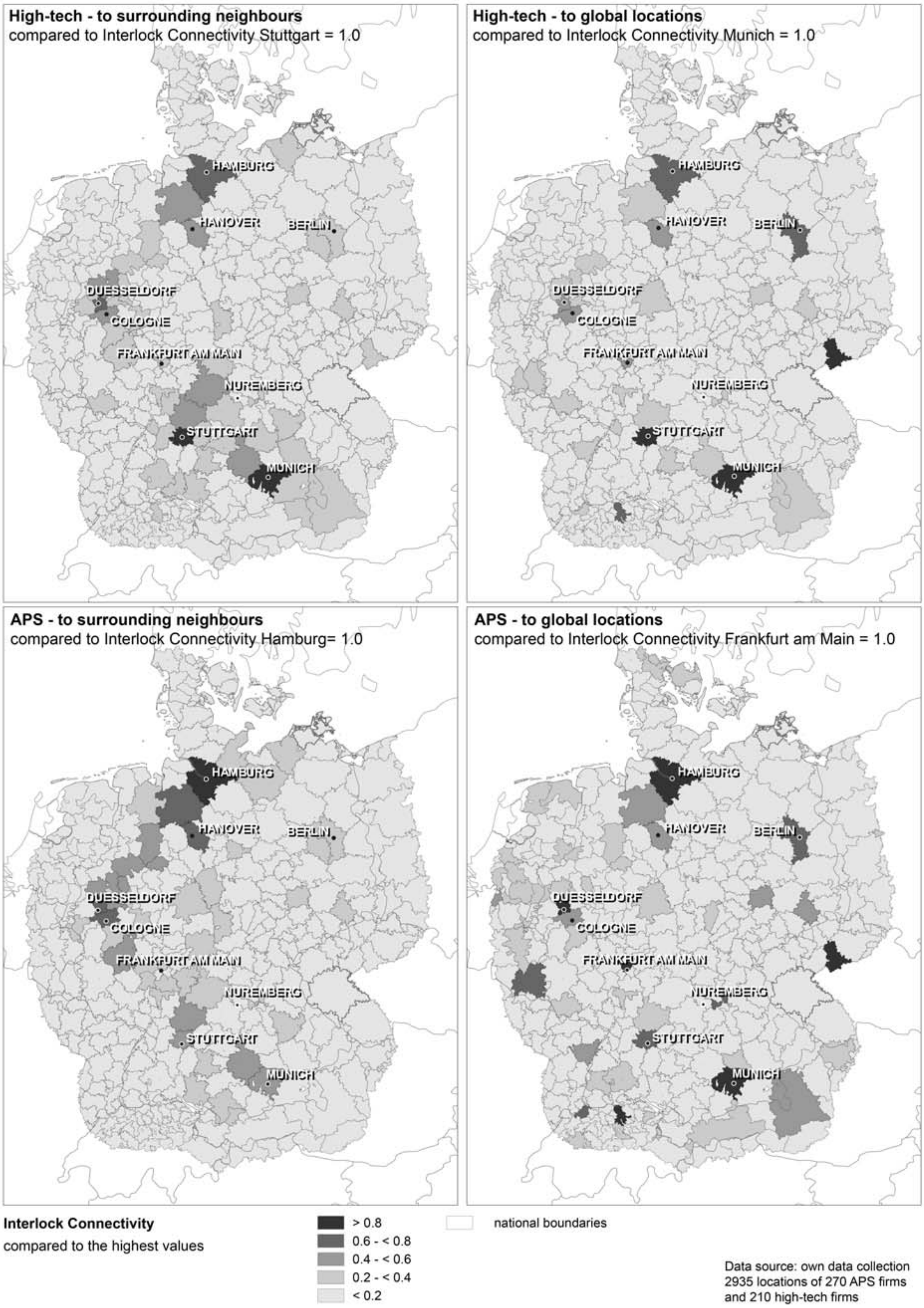

Figure 2.2: Interlock connectivity of APS and high-tech enterprises on the regional and global scale (own calculation).

Values for some FUAs such as Hamburg, Munich and Stuttgart are always high on both scales and in both the APS and high-tech sectors. APS firms tend to be organised in an area-wide distribution. For example, banks offer services even in the smallest FUAs, which lead to high connectivities on the regional scale such as in the area between Hamburg, Duesseldorf and Frankfurt. Nevertheless, global activities are concentrated in a small number of centres.

When considering high-tech by itself, such regional/global opposition is not evident. Regions which have intensive interaction with neighbouring agglomerations also show strong connections with global locations. Some exceptions can be detected in the southern parts of Germany. In particular, regions between Stuttgart, Nuremberg, and Munich have high values on the regional but not on the global scale. This might be explained by a high concentration of suppliers close to plants in the automotive sector in the southern part of Germany.

2.4 The interplay between physical accessibility and non-physical

As mentioned in ‘‘Externalities of knowledge creation – networks, agglomerations and accessibility’’, knowledge creation depends on the interplay between codified and tacit knowledge, because people require experienced-based knowledge to understand and adapt codified knowledge. Accordingly, there is also an interplay between the physical movement of people and the non-physical exchange of information (Beaverstock et al. 2010). To examine the strength of this interplay an exploratory correlation analysis is carried out. Fig. 2.3 illustrates the set of variables used. All the variables are grouped thematically. Population and employment are indicators of agglomeration. Road, rail, and air access indicate the potential link-up in physical networks. Finally, the group of variables in non-physical networks represents the intra-firm networks on different scales. The regional scale is defined by the interlock connectivity to surrounding neighbours. The national scale is defined by the boundaries of Germany. The European scale contains all the countries of the European continent and the global scale is all other locations. In stage one, we employed a bivariate Pearson correlation. In stage two a partial correlation was applied to check for covariances between the explanatory variables.

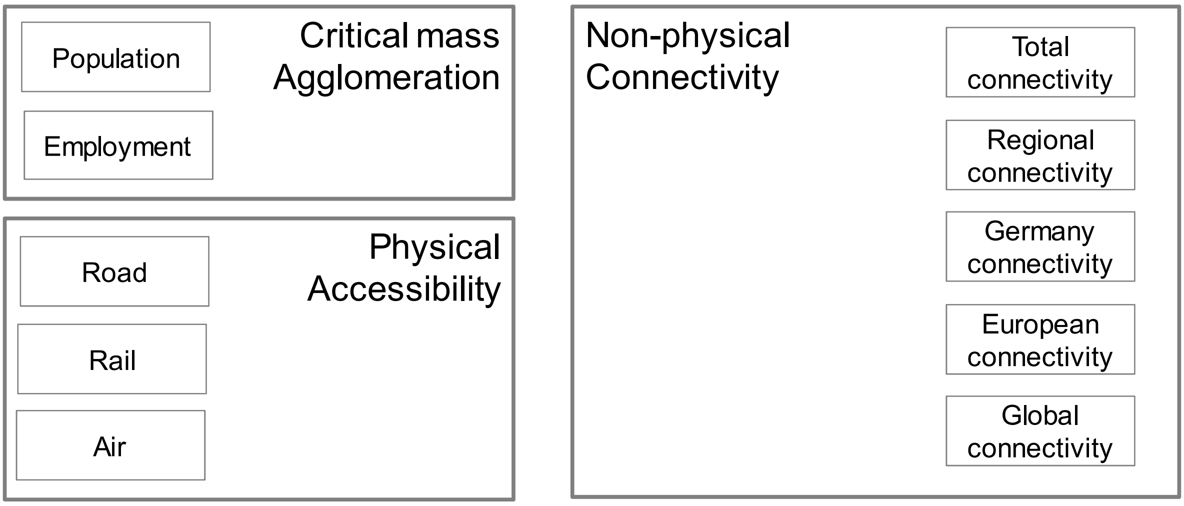

Figure 2.3: Set of variables and methodological procedure.

There is a strong interdependence between critical mass and integration in networks, which is investigated in the first stage.

Put simply, the bigger a region the more companies it hosts. Fig. 2.4 therefore shows a comparison of correlations between interlock connectivity, accessibility and population, as well as employment and population. When calculating the correlations to the latter variables, we excluded all FUAs that are not in Germany, because homogenous data for employment is not available. Correlations between non-physical interaction and accessibility data are calculated for the whole of Germany and neighbouring agglomerations. Most importantly, correlations are listed when they exhibit significance at or above 95%.

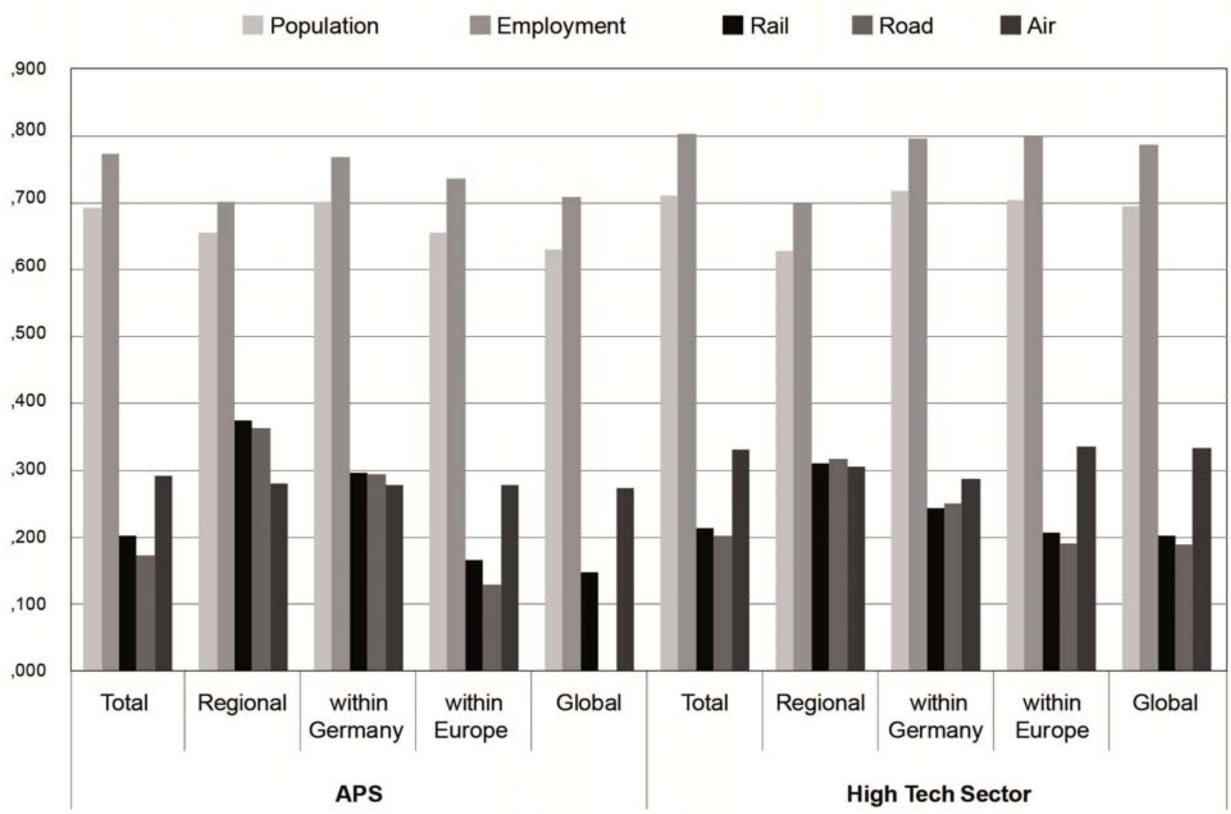

Figure 2.4: Correlation between interlock connectivity on different scales, accessibility by different modes, population, and employment (own calculation)

This analysis is carried out on different spatial scales, from the regional to the global scale. These scales do not overlap. As previously mentioned, the strongest correlations are exhibited with population and employment. These results provide a reference to the correlations with accessibility modes. With regard to listed spatial scales and their dependency, firstly, the greater the accessibility via rail and road, the stronger the connections to surrounding neighbours. This result is attributable to the high interlock connectivity values within metropolitan regions.Wehave seen that the Rhine-Ruhr possesses a dense network of rail and road. Above all, especially in hightech, this area as a whole shows dense non-physical interaction.

Secondly, as expected, correlation coefficients with road and rail decline steadily as the distance increases from the regional to the global scale in both the high-tech and APS sectors. In particular, APS correlations lose importance as the extent of intra-firm networks widens. Similarly, the high-tech sector confirms this trend, but still shows significant interrelations with rail and road access on the global scale, which might be explained by the high concentration of physical infrastructure, such as motorways and railway lines for logistics around production plants, rather than by the actual use of these transport modes for global activities. Basically, firms within this sector operate globally, which corresponds to the transport infrastructure, and therefore correlation coefficients might be higher on that scale.

Thirdly, correlations with air access do not differ between the various scales. Undoubtedly they are significant, but do not confirm the expected impact of growing air access on the European and global scale.

In summary, the hypothesis that air access remains the most important factor, and that air access is a more relevant factor for interactions outside Germany, requires clarification. In the case of APS, its influence on connectivity does not change along the spatial scales. In contrast, correlations with road and rail decrease uniformly. Hence the relative importance of air access compared to other modes of accessibility increases the wider the scale. Critical mass is also slightly less important. To evaluate this finding, partial correlation analyses are used in a second stage to test the influence of air accessibility as such by excluding covariances with all other modes of access and agglomeration indicators. Results are shown in Fig. 2.5.

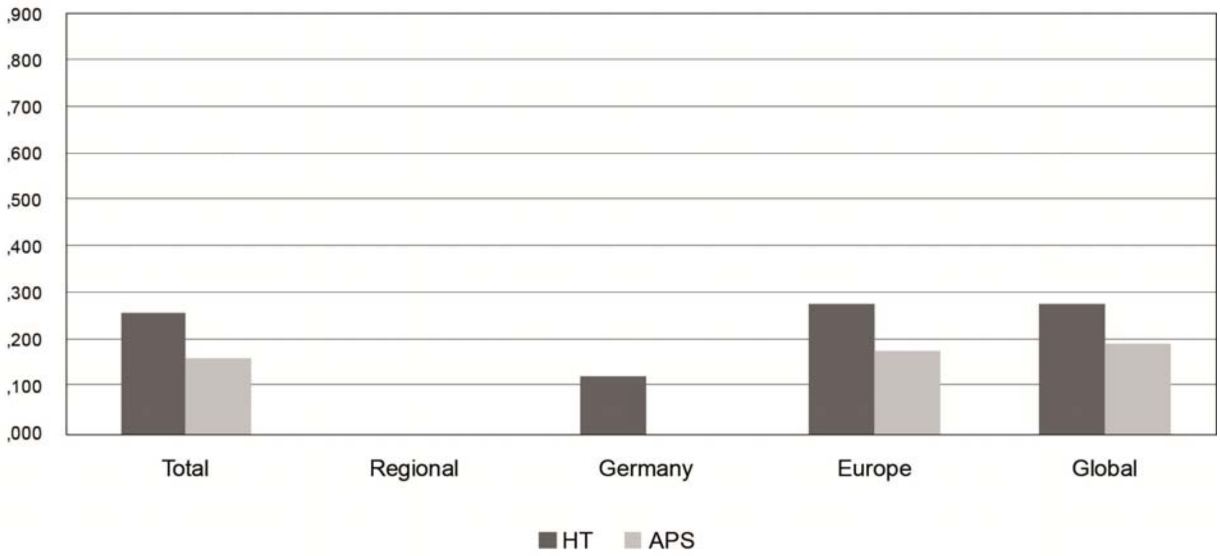

Figure 2.5: Partial correlation between interlock connectivity on different scales and accessibility by air (own calculation).

After excluding these interrelated effects of air, road, and rail access as well as population and employment by partial correlation, we obtain the single impact of air access on non-physical interaction. Similarly to the previous analysis, the impact of accessibility by air increases when the connectivity to locations abroad also increases. Again, all correlations are significant at the level of 95% or above and thus may be considered reliable. High-tech values sit slightly above those of APS. Moving from the national to the global scale this difference decreases, but on all levels shown in this figure, accessibility by air seems to be more important for high-tech firms than for APS firms. As mentioned above, this might be influenced by a certain concentration of high-tech in global centres like Shanghai and Singapore while APS firms focus more on Europe and within Germany. The majority of all interactions within the high-tech sector occur predominantly outside Germany, whereas APS interactions are localised within German borders (Lüthi, Thierstein and Bentlage 2011). Foreign firms also tend to locate closer to hub airports than domestic firms (Thierstein, Goebel and Lüthi 2007: 49). To assess the effects of the aforementioned externalities of agglomeration economics and network economies, we applied a multiple linear regression analysis with the aim of explaining its interrelation with the economic performance.

2.5 Effects of accessibility on the economic performance

The economic performance of a region depends on the ability of firms to exploit externalities of agglomeration and network effects. To evaluate these externalities and to compare their impacts with the size of population and employment, we applied a multiple linear regression analysis. This approach is rather simplistic and a very first step which aims to provide insights into the interplay of physical and non-physical relations between regions. The dependent variable is the Gross Domestic Product per employee in the Functional Urban Areas within Germany. This variable indicates an output factor, which is influenced by the externalities. To make socio-economic data useable for FUAs, data from NUTS-3 areas were disaggregated to urban morphological zones (UMZ), which are located within those areas, and then aggregated again to the FUAs. Data for UMZs is provided by the CORINE land cover project; they are defined as ‘‘A set of urban areas lying less than 200 m apart’’ (European Environment Agency 2011). The bigger the urban zones, the more employment, population and value creation are expected to be located there. This method is based on the assumption that socio-economic values are mainly generated or located in urban areas. Table 2.1 illustrates the variables used, their data source and how they were calculated for the FUA. Detailed procedures for this method of data management are described in Gallego and Peedell (2001) and Milego and Ramos (2011).

Variable	**Data Source**	**Processing for FUA level**	**Year**
Gross Domestic Product	Eurostat 2011	Weighting by area of urban morphological zones	2008
Total Employment	Bundesagentur für Arbeit 2010	Weighting by area of urban morphological zones	2008
Employment in Knowledge Economy	Bundesagentur für Arbeit 2010	Weighting by area of urban morphological zones	2008
Physical Accessibility	ESPON 2009b	Area weighted average	2006
Urban Morphological Zones	European Environment Agency 2011		2006

Table 2.1: Variables, data sources and calculation for FUAs (Bundesagentur für Arbeit 2010; Eurostat 2011; ESPON 2009a; ESPON 2009b)

Although these influences are significant, the causalities are interwoven and mutual. As mentioned above, it is a cumulative causation rather than a direct impact model in which accessibility, network economies, agglomeration economies, knowledge production and economic output relate to each other.

Fig. 2.6 shows the results of GDP per employee. The highest valueis located in the FUA of Fürth, which might be a misleading result caused by the disaggregation and aggregation procedure shown above. When comparing with other FUAs we assume that the total GDP was drawn correctly from NUTS 3 areas but the employment figures are way too low, which leads to the highest ratio. Owing to this, we have excluded Fürth from further analysis.

Nevertheless, an adjustment with exact population numbers for FUAs showed reasonable results.

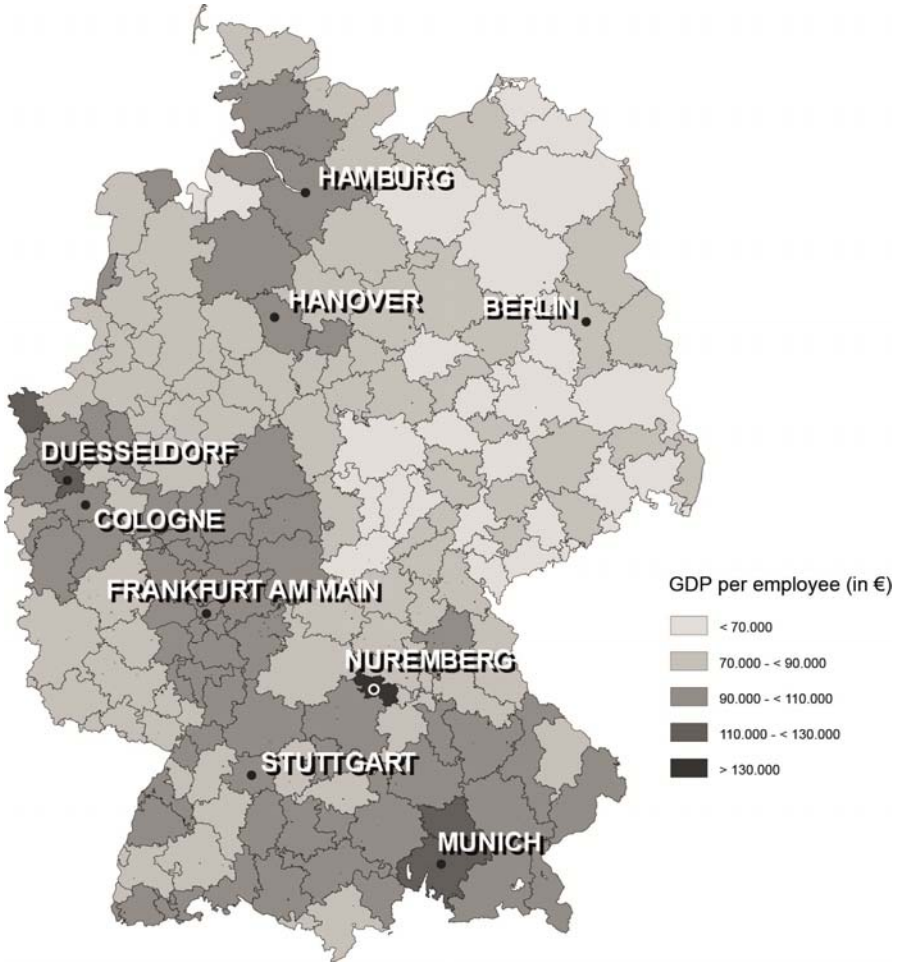

Figure 2.6: Gross Domestic Product (GDP) per employee in €. Source: Eurosta (2011)

Further variables were derived from NUTS 3 areas by using the urban morphological zones. These variables are grouped into the aforementioned externalities. Table 2.2 shows an overview of these externalities and their indicators.

Externalities	**Indicators**
Network externalities	Physical accessibility • Access via air Non-physical networks • Interlock connectivity of APS and high-tech
Agglomeration externalities	• Hirschman-Herfindahl Index (knowledge economy) • Total employment • Shares of knowledge-intensive employment • Access via rail and road

Table 2.2: Externalities and associated indicators

The basis for the regression analysis is formed by the bivariate correlation analysis in ‘‘The interplay between physical accessibility and non-physical connectivity’’. A detailed compilation of correlation coefficients between selected variables is also shown in ‘‘Appendix’’. A multiple linear regression model was developed based on these findings. This model explains the GDP per employee by the total interlock connectivity (APS and high-tech), multimodal accessibility (index) and the Hirschman–Herfindahl Index (HHI) of knowledge-intensive sectors. Whereas interlock connectivity and multimodal accessibility represent the potential of a region to be integrated into non-physical and physical networks, the HHI is considered an indicator of agglomeration advantages. The HHI ranges between 0 and 1. Value 1 indicates that knowledge-intensive employment is concentrated in one sector and the region is strongly specialised. The opposite is a diversified region, which is indicated by values close to 0. Thus the HHI is used as an indicator of localisation economies (values close to 1) and urbanisation economies (values close to 0) (Beaudry and Schiffauerova 2009: 321).

The variables were included stepwise in the model in order to observe how they influence each other. The R2 of the final model shown in Table 2.3 reaches a value of 0.41, which means that the model does not fit well enough to explain the majority of the variance of the GDP per employee. Nevertheless, the variables included and the model itself – according to the F-statistics – are significant and allow the impacts of externality indicators on the economic performance of a FUA to be quantified. The proportion of knowledge-intensive employment could not be included, because its high correlation to non-physical connectivity reduces the significance of the latter variable.

Model	R2	Adjusted R2	Standard Error of the Estimate	F	Sig.
1	.086	.079	.01060	12.981	.000a
2	.365	.355	.00887	39.296	.000b
3	.410	.397	.00858	31.521	.000c

a. Predictors: (Constant), Interlock Connectivity (APS+HT)
b. Predictors: (Constant), Interlock Connectivity (APS+HT), Accessibility Multimodal (Index)
c. Predictors: (Constant), Interlock Connectivity (APS+HT), Accessibility Multimodal (Index), Hirschman-Herfindahl Index (knowledge economy)
d. Dependent Variable: Gross Domestic Product per employee

Table 2.3: Summary of the regression model

Table 2.4 shows the results of the regression equations. The strongest interrelation is measured between GDP per employee and the physical multimodal accessibility. The standardised regression coefficient reaches the value of 0.562 and indicates a positive dependency between both variables. The coefficients of non physical connectivity and the HHI are clearly not as strong. Non-physical access reaches a value of 0.157 and HHI a value of 0.217. Therefore, the higher the integration into information networks, the better the FUA performs economically. However, the positive interrelation between GDP per employee and HHI indicates that the more specialised a FUA is, the better it performs. This is demonstrated by high concentrations of the high-tech sector in specialised automotive regions such as Wolfsburg or Ingolstadt with a high GDP per employee.

Model		**Unstandardised Coefficients**		**Standardised Coefficients**	**t**	**Significance**	**Collinearity Statistics**	
		B	Standard Error	Beta			Tolerance	VIF
1	(Constant)	.085	.001		69.331	.000		
	Interlock Connectivity (APS+HT)	.000	.000	.293	3.603	.000	1.000	1.000
2	(Constant)	.052	.004		12.140	.000		
	Interlock Connectivity (APS+HT)	.000	.000	.118	1.650	.101	.901	1.110
	Accessibility Multimodal (Index)	.000	.000	.556	7.750	.000	.901	1.110
3	(Constant)	.046	.005		10.202	.000		
	Interlock Connectivity (APS+HT)	.000	.000	.157	2.230	.027	.875	1.142
	Accessibility Multimodal (Index)	.000	.000	.562	8.098	.000	.900	1.110
	Hirschman-Herfindahl-Index (knowledge economy)	.036	.011	.217	3.243	.001	.965	1.037
Dependent Variable: Gross Domestic Product per employee								

Table 2.4: Regression coefficients and Collinearity statistics

To sum up, the regression analysis provides a simple first step in assessing the interdependence between economic performance and the externalities of agglomerations and networks. A more sophisticated analysis needs to take error distributions and spatial lag patterns into account. Although ICT provides the potential for the ubiquitous distribution of information, access to the localised transportation infrastructure remains important for economic performance because it enables geographical and relational proximity. This in turn leads to different preconditions between regions. As Törnqvist (1968) noted, the ‘‘most important contacts [...] demand direct personal contacts between personnel, and thus passenger movement’’ (Törnqvist 1968: 101). Other modes of interaction, such as telecommunications, are no substitute for face-to-face contacts.

2.6 Conclusion

The process of knowledge production occurs within a close interplay between physical and non-physical interaction, combining tacit and explicit knowledge. APS firms on the whole tend to concentrate and operate intensively on the national scale. In particular, banks and insurance firms are distributed throughout an area to supply their services. Nevertheless, there are a lot of APS firms which only interact abroad and use airports as a hub to access affiliates around the globe quickly. Airport cities emerge as a functional spatial configuration from this development (Schaafsma, Amkreutz and Güller 2008).

Both APS and high-tech firms also operate on a global scale to combine the advantages of agglomeration and network economies. Nevertheless, differences between both sectors are observable. High-tech firms on the whole are not restricted to the national markets to offer daily supplies in the way APS firms often are. They optimise value chains that have high stakes in production worldwide because the proportion of physical labour within the production process is supposed to be higher than in APS. Production is often therefore carried out in locations with lower wages and the coexistence of a highly qualified workforce, such as in India or South-East Asia. Taking the dimension of time into account, hightech firms display strong global relationships by requiring fixed capital. The result of these worldwide operations is ‘‘footloose’’ industries, such as the automotive industry (Sturgeon, van Biesebroeck and Gereffi 2008: 318). Standardised elements of value chains, which equate to codified knowledge, are outsourced. Thus, for example, production plants are built wherever machinery and real estate is low-cost.

The regression analysis applied here aims to provide preliminary results about the interplay between integration into global networks and the physical transportation infrastructure. In this context, spatial effects might be assessed with spatial lag or spatial error models, since the outreach of transportation infrastructure goes beyond the boundaries of the spatial entity where it is located. Furthermore, this approach focuses on one point in time and is therefore not able to assess the causality between the supply of transport infrastructure and the economic development triggered. Therefore as a preliminary measure we assume it might be a cumulative causation. Further investigation with time series might reveal clarity on the reciprocal impacts. The sensitivity of the analysis also needs to be assessed accordingly. Focusing on the residuals of the regression analysis might offer information on methodological shortcomings.

Reflecting Richard Florida’s hypothesis that the world is spiky, our results offer an indication of how strongly physical infrastructure influences business operations in the knowledge economy. Indeed, an uneven supply of physical infrastructure, such as airports or other modes of transportation, initiates a cumulative causation. Higher accessibility leads to wider market coverage by firms and fosters economic performance, which in turn enables further investment in physical infrastructure. Furthermore, the direction of causation is mutual, because wider market areas in knowledge- intensive business activities also require the physical presence of knowledge workers. However, we have to bear in mind that accessibility serves as a necessary but not sufficient condition – without a minimum of market opportunities, accessibility alone will not achieve the desired effect.

Appendix

Tabelle A1

Bivariate Pearson Correlation between selected variables. Correlation coefficients greater than 0.5 or lower -0.5 are shown in bold.

		Gross Domestic Product per employee	**Hirschman-Herfindahl Index (knowledge economy)**	**Proportion of employment in**		**Non-physical connectivity**			**Physical accessibility (Index)**			
				APS	HT	Total (APS+HT)	APS	HT	Multi-modal	Rail	Road	Air
Gross Domestic Product per employee		1	.150	.493**	.325**	.304**	.288**	.316**	**.596****	.481**	.387**	**.603****
Hirschman-Herfindahl Index (knowledge economy)		.150	1	-.169*	**.765****	-0.146	-.171*	-0.092	-0.022	.023	0.051	-.036
Proportion of em-ployment in	APS	.493**	-.169*	1	-.092	**.739****	**.755****	**.667****	**.614****	.453**	.300**	**.643****
	HT	.325**	**.765****	-.092	1	-0.058	-0.109	0.034	0.147	.144	.177*	.159*
Non-physical connectivity	Total (APS+HT)	.304**	-0.146	**.739****	-.058	1	**.988****	**.963****	.347**	.185*	.119	.387**
	APS	.288**	-.171*	**.755****	-.109	**.988****	1	**.912****	.341**	.178*	.113	.383**
	HT	.316**	-.092	**.667****	.034	**.963****	**.912****	1	.337**	.186*	.124	.373**
Physical accessibility (Index)	Multi-modal	**.596****	-.022	**.614****	.147	.347**	.341**	.337**	1	**.880****	**.770****	**.966****
	Rail	.481**	.023	.453**	.144	.185*	.178*	.186*	**.880****	1	**.899****	**.744****
	Road	.387**	.051	.300**	.177*	0.119	0.113	0.124	**.770****	**.899****	1	**.630****
	Air	**.603****	-.036	**.643****	.159*	.387**	.383**	.373**	**.966****	**.744****	**.630****	1
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												

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3 Externalities of knowledge creation as interwoven constructs

Conceptualizing the interplay of networks, urbanization and localization externalities in Germany

Submitted to Regional Studies:

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Abstract:

The interdependence of knowledge creation and agglomeration and network externalities not finally defined. This might be due to the fact that these externalities are more strongly interwoven than previously assumed. The assessment of these externalities on productivity needs to consider these interrelations. We use a unique data set for Germany functional urban areas (FUA) containing interlocking firm networks, air passenger movement, spatial accessibility and employment structure. By means of factor analysis, we firstly operationalise externalities. Secondly, we employ regression analysis to assess their impact on productivity. The regression analysis includes interaction terms. This paper shows that network externalities interact strongly with urbanisation while sharing the aspect of size, and to localisation by linking specific knowledge bases to global networks.

Keywords

Knowledge production, network economies, agglomeration economies, productivity, factor analysis, regression analysis, Germany

My contribution:

- Conceptualisation of the article and defining the research question
- Data collection and processing
- Statistical analysis
- Interpretation and discussion of the results

3.1 Introduction

The discussion of spatial development and economic performance is a controversial one. It is not clear whether diversification or specialization lead to higher economic performance (Beaudry and Schiffauerova 2009), nor whether external network activities or internal knowledge spillovers within the agglomeration contribute more to the economic development of regions. A dualism thus exists which both acknowledges network integration and intense agglomeration advantages at the same time: 'geographical proximity per se is neither a sufficient nor a necessary condition for learning and interactive innovation' (Boschma 2005: 62). Consequently, the agglomerative force of geographical proximity needs to be completed by relational proximity to external knowledge resources. Hence, in order to improve economic performance, spatial planning has to face a multitude of potential approaches.

This dualism of networks and agglomerations includes approaches such as the 'neo Marshallian nodes in global networks' (Amin and Thrift 1992) or the 'local buzz in global pipelines' (Bathelt, Malmberg and Maskell 2004. Although, various scholars have addressed this dualism (Amin and Thrift 1992; Bathelt, Malmberg and Maskell 2004; Taylor 2007; Harrison 2013; Dicken and Malmberg 2001; Dicken 2000), empirical evidence for the impact on productivity and a quantitative evaluation has not yet been clearly provided (Bentlage, Lüthi and Thierstein 2013: 48). Consequently, the main challenge for such an exercise might be that agglomeration and network externalities are even more interwoven than researchers have assumed. Assessing the impact on productivity calls for an analysis of the interrelations between those externalities. Therefore, the question in this article is not how strongly each externality might influence productivity, but how these externalities are interrelated and how these interrelations ultimately affect productivity. Based on an own data set we are able to assess network externalities and agglomeration externalities at the same time.

Germany as the biggest economy in Europe is an interesting case for this study because of its interurban networks and competition among these. The German urban system forms a strongly polycentric structure, reinforced by the federal constitution of the nation state (Growe and Blotevogel 2011; Münter and Volgmann 2014; Münter 2011; Lüthi, Thierstein and Bentlage 2013; Lüthi 2011). Each federal state, or 'Bundesland', has its own capital city and authority over education and research policies. Thus, Germany features a spatially decentralised, highly qualified labour force and research institutions in almost every Bundesland (BMBF 2012). In contrast to more centralised states such as France and Great Britain, Germany lacks the urban primacy of a single 'world city'. Of the German cities, only Frankfurt as the German financial centre, shows prominence in world city research, while the biggest cities in Germany, Berlin, Hamburg and Munich, tend to be more peripheral in this network (Hoyler 2011; Derudder et al. 2010).

Furthermore, Lüthi, Thierstein and Bentlage (2013) show that the position of a city within the functional-urban hierarchy in Germany is not automatically a result of its size. Berlin as the German capital and the biggest city in the country, for example, displays a deficit of network linkages considering its sheer size. The same holds true for Cologne. This city has a higher population than the neighbouring city of Düsseldorf. In terms of size Cologne is less intensely integrated in networks of knowledge intensive firms than Düsseldorf. This might be due to the fact that Germany's third biggest airport is located in Düsseldorf. Hamburg hosts a strong, globally extended logistics sector. Therefore, the city has the highest interlocking connectivity for APS firms, whereas Munich is the leading high-tech centre in Germany (Lüthi, Thierstein and Bentlage 2013: 48). The demographic changes and population shrinkage cause relative disadvantages in rural and peripheral areas such as in the north-east of Germany and between the cities of Leipzig, Nuremberg and Hanover, where population density and accessibility are relatively low (BBSR 2011). Furthermore, Germany is still shaped by its East-West divide, which is observable more than 20 years after the reunion (Bickenbach and Bode 2013). These examples illustrate that in the German context, we expect network externalities to play an important role in regional variations in economic performance.

This paper is structured as follows: Section 2 discusses the interplay of agglomeration and network economies and the concept of externalities. Section 3 introduces the conceptual approach to externalities. Section 4 defines the data and introduces the methodology. Section 5 presents the results of the factor analysis and assess the impact of these externalities on productivity given by GDP per employee in Functional Urban Areas. Section 6 concludes with the results and questions for further research.

3.2 Disentangling Agglomeration and Network Externalities

Knowledge generation and spatial structure are interlinked within a complex system. This section will provide an insight into this complexity by assessing the relevance of proximity, functional integration of economic activities, and spatial preconditions for knowledge creation. Agglomeration and network economies and their conceptualisation of externalities provide a profound approach to this analysis. We firstly outline the characteristics for both these concepts with a focus on the operationalisation of externalities and, secondly, we look at the interplay of agglomeration and network economies. This section does not aim to present an exhaustive review of theoretical explanation, but rather a starting point for an empirical approach.

3.2.1 Characteristics of Agglomeration and Network Economies

Agglomeration economies and network economies contain both internalities and externalities. 'Internalities, such as investment in research and development or equipment, are conditions which can be influenced by the firm individually. Externalities are advantages from which firms benefit at no cost to themselves, or disadvantages which they have to pay for but for which they are not responsible' (Bentlage, Thierstein and Lüthi 2014: 32). Parr (2002) provides an overview of this interplay of internalities and externalities with regard to agglomeration economies (Parr 2002: 718). Firms might benefit from external resources such as labour force, provision of infrastructure or access to transportation and information networks.

The concept of a*gglomeration economies* stems from the period of industrialization. This theoretical framework deals with the question of why economic activities concentrate in space. Marshall (1930) elaborates the concept of 'industrial districts' that provides firms in the same sector with knowledge spillovers. This approach assumes that cognitive proximity works as a binding link between individuals and so enables knowledge transfer (Marshall 1930). The basic idea of Marshall's industrial districts is based on the division of labour conceptualized by Adam Smith (Groenewegen 2007). Smith (1776) argues that dividing labour into different and specialised parts interrelates with the necessity to trade and exchange (Smith 1776: 1.2.1). The specialisation of employees enables increasing returns due to lowering production costs by improving skills and experience (Smith 1776: 1.4.1). Moreover, this specialisation requires exchange with others. Thus, the early conceptualisation of agglomeration economies incorporates the idea of network economies by including exchange of commodities. Therefore, we have to assume that both forms of economy mutually reinforce.

Hoover (1948) elaborates on the ideas of Marshall and introduces a differentiation between 'Internal returns of scale', 'localization economies' and 'urbanization economies' (Hoover 1948). These categories have sparked a vibrant discussion on agglomeration economies (Glaeser et al. 1992; Beaudry and Schiffauerova 2009). Whereas localisation economies draw on externalities of specialisation (Glaeser et al. 1992), urbanisation economies refer to Jacobs' externalities of diversity. Jacobs (1969) defines the benefits of diversity as follows: 'the greater the sheer number of and variety of division of labour, the greater the economy's inherent capacity for adding still more kinds of goods and services' (Jacobs 1969: 59). Buchman and Lambooy (1999) link the characteristics of agglomeration economies to the ideas of evolutionary economic geography and path dependent development (Buchman and Lambooy 1999: 417-418). In that sense, increasing returns induce path dependency while using one technology to hinder the change to other technologies.

Apart from the distinction between urbanisation and localisation economies mentioned above, Parr (2002) distinguishes three main types of external agglomeration economies. He explicitly mentions ‘activity complex’ externalities as a third type. These activity complex externalities are derived from ‘economies of coordination’ and the input-output structure of individual firms (Parr 2002: 718). As such, these crucially revolve around communication channels and the flows of commodities, capital and labour, which are equally captured with the network perspective to the degree in which they are supra local.

Network economies became prominent during the era of intense globalisation induced by lowering transport cots and the liberalisation of labour, capital and trade (Dicken 2011). Network economies are a result of considerations of how information, goods, capital and people move and how this affects the knowledge basis of an economy. Depending on these factors, the focus on networks differs. The word-city network analyses information flows within firms (Taylor 2013, 2013, 2004; Derudder et al. 2014). Global production networks assess the global-local interface of trade and connectivity (Hesse 2010; Coe, Dicken and Hess 2008; Cooke 2013; Kelly 2011). The movement of air passengers and its relational to world cities combines the physical exchange with the non-physical flow of information (Neal 2012; Neal 2011; Neal 2010; Liu, Derudder and García 2013; Short 2004). Other approaches include foreign direct investment (Bronzini 2007; Van der Waal 2012, in press; Zhao and Zhang 2007) or the interrelation of shipping commodities and firm networks (Ducruet and Zaidi 2013; Ducruet and Notteboom 2012; Jacobs 2009; Hesse 2013).

Since this article focuses on the generation of knowledge in the context of agglomerations and networks, the nature of knowledge plays a crucial role. Knowledge is codified or tacit in nature. Codified knowledge can be applied, expressed and standardised. Hence, it is a marketable good that can be distributed over time and space to some extent (Gertler 2008; Jensen et al. 2007). New information and communication technologies offer the opportunity to increasingly codify and commodify knowledge and make it tradable across long distances. This enables companies to source activities and inputs globally and to benefit from relational proximity and international knowledge spillovers. Codified knowledge might become de-territorialised, whereas tacit knowledge remains contextualised (Bathelt and Glückler 2002: 215). Tacit knowledge, therefore, refers to knowledge, that cannot be easily transferred (Gertler 2003). It comprises skills based on interactions and experiences. Tacit knowledge and personal experience are necessary in order to make use of codified knowledge in creative and innovative processes (Schamp 2003: 181).

Our approach of network externalities focuses on intra-firm and extra-firm linkages as well on air passenger traffic. Therefore, we employ the strategic decision making of firms in choosing locations and partners. The spatio-economic behaviour of knowledge-intensive firms has led to the emergence of a globalised city network (Castells 2000; Taylor et al. 2011; Lüthi 2011). Friedmann’s (1986) ‘world city’ concept focuses on the decision-making activities and power of transnational corporations (TNCs) in the context of the international division of labour. These cities are ‘basing points’ in the spatial distribution of production and markets (Friedmann 1986: 71). Sassen’s ‘Global City’ concept (2001) associates cities with their propensity to engage with the internationalisation and concentration of firms in the world economy (Sassen 2001: 90). Sassen (1994) defines global cities as ‘strategic sites in the global economy because of their concentration of command functions and high-level producer-services firms oriented to world markets' (Sassen 1994: 145).

However, the interplay of network economies and agglomeration economies is still under-researched in the sense that empirical work linking both concepts is missing (Rozenblat 2010: 2842). Moreover, the causal interrelation of networking and the proximity to actors lacks detailed exploration: 'The privileged causal arrow in proximity studies has always been to explain knowledge networking from proximity' (Balland, Buchman and Franken 2014: 3). Therefore, the authors suggest applying a dynamic perspective to the coevolution of network activities and conditions of proximity including the interplay of geographical and relational proximity.

3.2.2 The interplay of Agglomeration and Network externalities

Agglomeration economies and network economies are interwoven mechanisms of spatial development. Scholars have challenged this interplay. New forms of information and telecommunication technologies have the potential to spread out economic activities to a certain degree, but economic centres nevertheless persist (Castells 2000). However, these network effects will change spatial structure: '[t]his is not the persistence of old forms but the occurrence of new forms, precisely fed by the globalization and dispersal of economic activity that such telecommunication capabilities make feasible' (Sassen 2001: 34-35).

Indeed, we must work on the basic assumption that agglomerations transform gradually into networked agglomerations. Thus, the spatial configuration of agglomerations gradually incorporates network economies and transforms into a new system of 'increasing interwoven-ness of agglomeration and network economies'. The relevance of regions in the context of globalisation is provided by Storper (1997) who states that the interplay of organisation, technologies and territory provoke advantages of geographical proximity that persist in the era of intense globalisation (Storper 1997).

An example might help to illustrate this idea of an increasing interwoven-ness of agglomeration and network economies: the interrelation of sea ports and cities. Hoyle (1989) describes this relationship in five developmental stages. The first is the early cityport in a medieval era where the city and the port have strong functional and spatial interdependence. In the second stage, during industrialization the ports begin to expand beyond their former limits. This growth of network economies and functional separation is enabled by railway connections and technological advances allowing access to the hinterland. This growth regime continues during the third stage of a Modern Society. Ports undergo further spatial and functional expansion with an increasing involvement of industrial manufacturing such as refineries, which induce specialisation of ports due to economies of scale. The subsequent fourth era represents a period in which retreat from the waterfront of cities takes place. The port functions tend to localise at new port facilities and industrial sites for which new areas were needed. The fifth stage represents renewal of the city and its waterfront. (Hoyle 1989: 431-432). This induces re-concentration of economic activities revolving around the maritime economy (Wiese and Thierstein 2014; Hein et al. 2013; Hall and Jacobs 2012). This process comes along with structural change and branching in the maritime economy, which includes functions such as research and development in ship construction or off-shore wind energy (Fornahl et al. 2012; Buchman and Franken 2011; Brandt, Dickow and Drangmeister 2010). The growth of ports as anchors of network links is strongly involved in the evolution of cities and induces localisation and urbanisation economies (Hall and Jacobs 2012: 190).

Different approaches exist that address the coevolution of agglomeration and network economies. Amin and Thrift (1992) conceptualise this dualism as 'Neo-Marshallian nodes in global networks' and support the idea that economies of scale induced by specialisation go hand in hand with the integration into the world economy and global connectivity. Cities as places of agglomeration and centres of network activities play a crucial role in this context: 'Thus the world economy may have become more decentralized, but it is not necessarily becoming decentred. Centres are still needed in a world of indirect communication, for three reasons […] representation, interaction and innovation' (Amin and Thrift 1992: 576).

Another seminal work on the dualism of agglomeration and network is provided by Bathelt, Malmberg and Maskell (2004). In this regard, firms benefit from the local buzz, which represents knowledge circulation within a cluster (Bathelt, Malmberg and Maskell 2004: 38). Global pipelines enrich this local component of knowledge creation by drawing translocal information links and access to remote markets (Bathelt, Malmberg and Maskell 2004: 41). The interplay between both these elements of knowledge creation becomes clear in the following hypothesis: 'that both local buzz and global pipelines offer particular, albeit different, advantages for firms engaged in innovation and knowledge creation' (Bathelt, Malmberg and Maskell 2004: 41). Although both components of knowledge creation differ in the way knowledge could be transferred, both are still required for agglomerations to sustain competitive advantage.

The argument of Bathelt, Malmberg and Maskell (2004) builds upon the advances of the GREMI School and the innovative milieu in particular (Crevoisier 2004; Maillat 1998; Camagni 1991; Maillat 1996; Maillat, Quévit and Senn 1993). Maillat (1997) states that the innovative milieu is a collective and cognitive structure, which bridges global technological development with localised production systems (Maillat 1998: 3). It combines openness to global changes while focusing on local resources of knowledge spillover (Maillat 1998: 6).

Taylor (2007) takes the perspective on cities as processing units. Cities combine activities revolving around the network integration and servicing of a hinterland. Taylor calls this the city-ness and town-ness which are inherent in the development of cities. Whereas, 'city-ness' represents the degree to which a city is 'net-working', 'town-ness' refers to the 'hinter-work' of that city in servicing the surrounding area (Taylor 2007: 292).

However, local and regional resources of spatial development face the process of up-scaling of metropolitan regions. Although the dualism of agglomeration and network implies a dichotomy between local and global and, thus, might leave us 'caught between network and territory' (Harrison 2013), other spatial configurations and scales show relevance, too. Predominantly, emerging polycentric Mega-city regions (MCRs) provide a further spatial scale that incorporates agglomerative forces and interconnectedness between those agglomerations (Hall and Pain 2006). The concepts of 'decentralized centralization' (Pain 2008: 1163) and 'borrowed size' (Alonso 1973; Meijers and Burger 2010: 1384) consider this interconnectedness on the scale of MCR as a horizontal integration of division of labour and functions.

While operationalising network and agglomeration externalities, the following challenges have to be faced: firstly, the employment size of an agglomeration affects urbanisation and network activities. Batty (2013a) states that the growth of cities determines the number of connections, density patterns, and functional differentiation (Batty 2013a: 38-40). Secondly, urbanisation and localisation are not contradictory concepts at all. Agglomerations might be diversified across different branches and specialised within at least one branch simultaneously (Parr 2002). Therefore, separate indicators for urbanisation and localisation which do not contradict each other are required. Thirdly, the spatial range of externalities is not confined to the boundaries of agglomeration and might differ by means of these externalities (Audretsch 2003). Thus, the impact of different externalities might reach beyond these boundaries.

3.3 Conceptual Approach to Network and Agglomeration Externalities

Externalities of urbanisation, localisation, and networks show interwoven patterns. In this section we firstly introduce our approach of operationalisation. We then define variables according to the aforementioned externalities.

The definition of variables for the analysis is based on several contributions within this field of research. Indicators for agglomeration externalities include variables of specific employment shares, spatial accessibility as a measurement for the provision and functioning of transportation infrastructure, urban structure given by density, the performance of the labour market such as unemployment rates, indices for localisation of economic activities, and finally the degree of specialisation or diversification in regions (van Oort, Oud and Raspe 2009; Sternberg and Arndt 2001; Duranton and Puga 2000; Storper 2010; Bentlage, Lüthi and Thierstein 2013; Audretsch 2003; Ciccone 2002; Meijers and Burger 2010). Network externalities include intra-firm and extra-firm linkages as well the accessibility via air traffic and passenger movement at airports. Figure 3.1 gives an ex-ante overview of these groups and their reference to the aforementioned externalities.

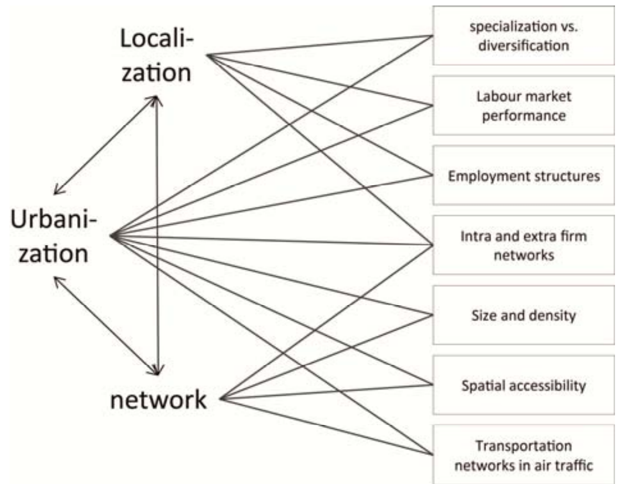

Figure 3.1: potential indicators of urbanisation, localisation and network externalities (own illustration)

These variables are grouped thematically. Initially, we define seven different groups of variables according to the aforementioned linkages between the thematic groups of variables and the externalities. The outcome is a unique data set for Germany from the years 2009 and 2010, which includes 40 different variables. These are shown in the appendix 2 including descriptive statistics.

3.3.1 Urbanisation externalities

Urbanisation externalities are associated with diversification and density of different activities within the agglomeration. We include the ‘absolute number of employment’ and the ‘employment density’ within a region. Furthermore, the ‘ratio of unemployed foreigners compared to overall employment' indicates the integration of migrants. A labour market with a low ratio might perform better in terms of absorbing immigrants and thereby demonstrate a high degree of diversity.

Data on physical accessibility represents the provision of transportation by rail, road and air in a region. These measures were originally calculated by the European Spatial Planning and Observation Network (ESPON) for NUTS[4] 3 level. Here, accessibility is defined by 'how easily people in one region can reach people in another region' (ESPON 2009, p. 4). This calculation indicates the potential for people and enterprises in the region to access markets and activities in other regions. It is obtained by calculating the population in all other European regions, weighted by the travel time (ESPON 2009, p 7).

Another group of variables is given by the employment shares in 16 different branches for each region. The observed sectors reveal a high share of highly qualified personal and broad activities in research and development[5]. A clear definition of these sectors including NACE codes is shown in Appendix 1.

The aforementioned employment shares provide a profound insight into the degree of specialisation or diversification within a region. In methodological terms, this approach aims to consider diversification not as the opposite of specialisation. Therefore, some authors use the inverse Hirshman-Herfindal Index (HHI), which captures the dominance of a particular sector in a region (Beaudry and Schiffauerova 2009; Kluge and Lehmann 2012; Glaeser et al. 1992; Feldman and Audretsch 1999; Blien, Südekum and Wolf 2006; Duranton and Puga 2000; Combes 2000). Based on the HHI Duranton and Puga (2000) present the relative diversity index (RDI) that controls for the employment shares of the involved sectors on a superior scale, such as nationwide (Duranton and Puga 2000: 535). We take the employment structure in 16 branches of knowledge intensive activities in 179 FUAs into account and compare this to the overall employment structure of Germany. The RDI is given by:

$$RDI = \left| \frac{1}{\frac{empl_{r,s}}{empl_r} - \frac{empl_s}{empl}} \right| \qquad (1)$$

With $empl_{r,s}$ as the employment in the industry s (s = 1,…,S) in region r (r = 1,…,R). Thus, this index has high values for regions that show the same employment structure as Germany and low values for regions that differ from the German average (Duranton and Puga 2000: 535).

3.3.2 Localisation externalities

The effects of localisation externalities are captured with the quotient of specialisation (Duranton and Puga 2000; Glaeser et al. 1992). This relative specialisation index (RZI) also takes the entire economy into account and displays the level of specialisation for a region relative to the overall employment structure. This measure is defined by:

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[4] Nomenclature of unités territoriales statistiques

[5] APS is defined by the following sectors: accounting; insurance; banking & finance; management & IT consulting; law; logistics (3p & 4p); design, architecture & engineering; advertising & media; information and communication services. High-tech is defined by the following sectors: chemistry & pharmacy; machinery; electronics; computer hardware; telecommunications; medical & optical instruments; vehicle construction. These sectors employ a high proportion of highly-skilled labour and carry out intensive research and development activities. See Legler and Frietsch (2006)

$$RZI = \sum_{S=1}^{S} \frac{\frac{empl_{S,r}}{empl_r}}{\frac{empl_S}{empl}} \qquad (2)$$

With $empl_{r,s}$ as the regional share of an industry relative to the share of that industry in the whole country. Values above 1 indicate that the region has a higher share in a sector compared to the overall share in Germany. A value below 1 indicates that the share of sector is below the national average (Glaeser et al. 1992: 1141).

Both these indicators show strong interdependence with the size of a regional economy. A region might show a high RZI for two reasons. On the one hand, the region might really be specialised since one sector overshadows other sectors, on the other hand, the same region might reveal specialisation in one sector just because other sectors are completely missing. The same holds true for the RDI urbanisation. Whenever the total number of employment in all sectors is low but in relative terms shows the same pattern as for Germany as a whole, a region might be considered divers. Thus, these indicators neglect the quality of diversity or specialisation when size and functional composition of the regional economy are not taken into account.

3.3.3 Network externalities

Network externalities in this paper involve information flows within firms and between firms. This non-physical approach is enriched by air passenger flows. Intra-firm networks are calculated by the 'Interlock Connectivity (IC)' based on the methodology of the Globalisation and World Cities Study Group (GaWC) (Taylor 2004). This approach estimates city connectivity from the transnational office networks of enterprises. Intra-firm networks are spatially distributed branches of one individual corporation. The basic premise of this method is that the more important the office, the greater the flow of information from it to other office locations. Our own database contains a basic set of 270 APS firms and 210 high-tech enterprises at 2,735 locations worldwide. See Lüthi (2011) for a detailed explanation of the data (Lüthi 2011). We employ the 'absolute interlock connectivity' and the 'interlock connectivity relative to the number of firm locations within a region' in order to obtain a relative network measure which is independent of size effects. Finally, the data set contains shares of interlock connectivity within Germany and to global locations. The latter excludes the European scale.

This database also provides different service values for each firm location. We include the 'total number of headquarters' and the 'share of headquarters in all observed firm locations' in our analysis. These measures are differentiated for APS and high-tech firms and provide an indication of power with regard to command and control functions of a firm location within the FUAs.

Inter-firm linkages express a further network externality based on a value chain approach (Lüthi 2011: 37-41). The data of inter-firm networks stems from our own online questionnaire of knowledge intensive firms. In this web survey, 331 firms indicated where their most important partners are located along a stylized value chain. This value chain contains the stylized elements 'research & development', 'processing', 'financing', 'marketing', 'sales & distribution' and 'customers'. The participants in the survey could name their three most important partners. The questionnaire does not specify what their importance might be. In this regard the participants evaluated for themselves whether these collaborations mean financial support, new ideas or access to joint projects. Using this data base, we are able to draw 1,346 links in the value-creation process across the global (Lüthi 2011: 136-139).

Flight networks are obtained from STATISTISCHES BUNDESAMT (2009). These include the ‘number of origin/destination travels’ and the ‘amount of passengers changing planes at an airport’. The variables indicate the significance of hub airports, such as Frankfurt or Munich (Statistisches Bundesamt 2009).

3.4 Methodological approach

This section presents the spatial entities of the analysis and the data preparation. Furthermore it introduces the technique of factor analysis and regression modelling.

3.4.1 FUAs as spatial entities of analysis

Most socio-economic data in Germany is available on administrative levels such as districts or planning regions. In order to avoid the occurrence of the modifiable area unit problem (Menon 2012; Madelin et al. 2009; Openshaw and Taylor 1981; Openshaw 1984), we consider functional urban areas (FUAs). FUAs are defined by an average commuting time of 60 minutes around a predefined centre (ESPON 2004). These spatial building blocks yield a natural limitation to daily economic activities. Other functional approaches include ‘real’ commuting flows to delineate labour markets. See Kropp and Schwengler (2011, 2008) for an overview.

To make socio-economic data useable for FUAs, data from NUTS-3 areas were disaggregated by an area weighted approach to urban morphological zones (UMZ), which are located within those areas, and then aggregated again to the FUAs. The CORINE land cover project provides and defines UMZ as ‘A set of contiguous urban areas lying less than 200m apart’ (European Environment Agency, 2011). Our assumption is: the bigger a UMZ, the more employment and value creation are expected to be located there. Detailed procedures for this method of data management are described in Gallego and Peedell (2001) and Milego and Ramos (2011).

3.4.2 Variable transformation

The variables of our data set are relatively strongly skewed to the right and contain a lot of small values and a few cases with very high values. These outliers fundamentally affect the factor analysis. Regions with a strong specialisation in certain industries, for example in chemicals, drive loadings in one factor, which in turn is rather a representation of single regions with their specific data than a real continuum from low to high values. In that sense the assumptions of normally distributed variables are violated. Therefore, the variable transformation reduces the effects of strong outliers. In order to enable the factor analysis and regression modelling, we control for the normal distribution in the data and apply a logarithmic transformation to the input variables (Auer and Rottmann 2011: 491). The transformation formulas are shown in the appendix 3. Furthermore, factor analysis and regression analysis assume linear relationships between the input and output variables. However, the relation of city size and its connectivity is described by a power law (Batty 2013a, 2013b; Bettencourt 2013; Bettencourt et al. 2007). Our logarithmic transformation takes these considerations into account.

In most cases this transformation results in normally distributed variables, which are relatively independent from outliers in the data. A note ‘no transformation’ shows that even the transformation could not determine the normal distribution. Due to the transformation procedure, the variables ‘accessibility per road’, ‘employment share in non-knowledge intensive sectors’ and ‘share of IC global in high-tech’ changed their signs to a negative scale. These variables were re-transformed by a multiplication with -1 to provide an intuitive interpretation of the factor analysis.

3.4.3 Method

Factor analysis provides a powerful technique for assessing the interrelation across variables. This method assumes that certain observable variables share the same source of causality for their appearance (Backhaus et al. 2003: 266 and 291-293). In this regard a factor is considered a commonality which inheres in a set of variables. Ultimately a factor represents a latent foundation which cannot be measured directly. The resulting factors, accordingly, display a starting point for further consideration on the causes and effects of externalities that finally manifest in forms of network, urbanisation or localisation. In contrast to principal components analysis, factor analysis enables an assessment of the processes evoking the outcome of the set of variables.

Principal factor analysis (PFA) is used to reduce the number of dimensions within a set of variables and enables detection of 'super variables', which cannot be observed in reality or by experiment. Thus, a factor represents a regression of variables sharing a common meaning and provides the advantage of eliminating multi-collinearity since these factors are uncorrelated (Unkel and Trendafilov 2010; Scott and Mantegna 2009; Clark, Davies and Johnston 1974; van Oort, Oud and Raspe 2009).

Regression analysis enables evaluation of the impact of an independent variable on a dependent variable. The analysis includes an ordinary least squares regression (Auer and Rottmann 2011; Burt, Barber and Rigby 2009; Backhaus et al. 2003; Greene 1993; Johnston 1985). This additive model will be extended with interaction terms which calculate the coefficient of the interplay of several variables. This approach allows a search for the complementary or substitutive effects of coexisting variables within a region (Brambor, Clark and Golder 2006; Kluge and Lehmann 2012; Tauchmann et al. 2008; Aiken and West 1991; Norton, Wang and Ai 2004; Wright 1976). A hypothesis will help to clarify this technique: 'An increase in X is associated with an increase in Y when condition Z is met, but not when condition Z is absent' (Brambor, Clark and Golder 2006: 65). Thus, for example, as soon as network effects encounter other externalities, such as a specialised work force or highly developed infrastructure, their impact becomes significant. Thus, having high scores in network externalities and at the same time in localisation externalities leads to an additional interactive effect.

This approach encompasses a broad range of the different externalities. However, such an holistic approach might neglect the form of the relations between the observed variables and the factors. Although, the variable transformation takes non-linear relationship into account, more elaboration on these multiple relationships might reveal other forms of dependency, which might not be transferable to linear slopes (McCann and Acs 2011: 23). Furthermore, this approach represents an analysis for a single point in time. Since our data set was collected by empirical investigation for one point in time, we are not able to assess cause and effects by employing time series. This, in particular, would provide deeper insights into causal relations (Balland, Buchman and Franken 2014).

3.5 Results

The analysis is structured in two stages. Firstly, we employ a factor analysis in order to define the aforementioned externalities of agglomeration and networks. Secondly, we include the factors in a different regression analysis. The dependent variable is ‘GDP per employee’. The models include multiple linear regression with interaction terms.

3.5.1 Results of the factor analysis

The factor analysis extracts 8 different factors with an eigenvalue higher than 1. A further transformation by orthogonal varimax rotation secures statistical independency of the factors and improves their interpretation. Therewith, it eliminates the multi-collinearity of our variables. Table 3.1 shows the factor loadings with a value of 0.2 and higher. These loadings represent correlation coefficients between the input variables and the factors. Thus, the higher a factor loading, the stronger the interrelation of an observed variable and a calculated factor. The KMO statistics with an value of 0.85 indicate an overall explanation of the variables (Backhaus et al. 2003: 276). Both the RDI and RZI are not included in the factor analysis because of the aforementioned interaction with employment size and functional composition. Thus, these measures are introduced into the regression analysis separately.

The last column in the table shows the uniqueness of each variable. This measure reflects that part of variance which is not reproduced by the factor analysis and, thus, remains as a residual of each variable. Thus, the meaning of a variable reaches beyond the analysis and represents the share which is specific. A clear definition of an acceptable uniqueness is not given. The specificity of a variable depends on the purpose of each factor analysis (BACKHAUS: 290). Thus, we consider a value of more than 0.6 to be relatively high. This holds true for the variables of the ‘share of headquarters in all observed firm locations’ in both APS and high-tech. Furthermore, the employment shares in ‘telecommunication’ ‘engineering’, ‘chemistry & pharmacy’, ‘3p/4p logistics’ and ‘computer industry’ still have high unique parts. These specific parts result from high concentrations in just a few locations and represent specific location patterns of employment.

Variable	F1 – size, APS employment, machinery and connectivity	F2 – accessibility and density	F3 – global APS networks	F4 – APS, entrepreneurship and high employment	F5 – APS HQ and flight networks	F6 – technical industries and high-tech HQ	F7 – global high-tech networks	F8 - specialised car industry	uniqueness
physical infrastructure									
accessibility per rail		0,929							0,089
accessibility per road		0,895							0,155
accessibility per air	0,301	0,754							0,241
volume of origin-destination air traffic	0,280				0,889				0,104
volume of changing passengers in air traffic					0,895				0,166
Employment size, density and entrepreneurship									
employment density	0,559	0,523					0,262		0,289
employment (BA)	0,733		0,297						0,287
unemployed per employed				-0,671		-0,261		-0,290	0,335
share of foreign unemployed persons	-0,336	-0,575		-0,498			-0,231		0,165
ratio of established firms in total number of firms				0,646					0,479
employment shares in:									
Machinery	-0,311			0,362		0,531			0,393
Electronics						0,686			0,413
Telecommunication				-0,202					0,872
Medical & optical instruments						0,546		-0,204	0,615
Vehicle construction								0,636	0,549
Banking & Financing	0,403	0,367		0,676					0,191
Insurances	0,720								0,411
Information and Communication Services	0,655	0,218							0,416
Advertising & Media	0,679	0,275		0,298					0,356
Management- & IT-Consulting	0,595	0,500					0,247		0,276
Design, Architecture & Engineering	0,447								0,659
Law	0,685			0,302				-0,308	0,284
Accounting	0,524			0,547					0,326
Chemicals & Pharmacy		0,387							0,835
Logistics (3p & 4p)			0,240			-0,287			0,805
Computer & Hardware	0,227					0,362			0,714
non-knowledge intensive	-0,259	-0,427		-0,314		-0,305	-0,293	-0,567	0,127
firm networks									
share of Headquarters of high-Tech firms						0,420			0,761
share of Headquarters of APS firms	0,455	0,255							0,676
number of Headquarters of high-Tech firms	0,661					0,371		0,327	0,298
number of Headquarters of APS firms	0,780				0,433				0,151
Interlock connectivity in high-tech	0,634		0,328				0,447		0,199
Interlock connectivity in APS	0,677		0,529						0,176
IC high-tech relative to number of locations							0,589		0,604
IC APS relative to number of locations			0,764	0,237					0,329
high-tech share of IC global							0,730		0,393
APS share of IC global	0,397		0,826						0,126
high-tech share of IC within Germany								-0,559	0,650
APS share of IC within Germany	-0,371		-0,870						0,068
external firm linkages normed maximum	0,687				0,246				0,382

Table 3.1: Factor loadings greater 0.2 and uniqueness (own calculation)

The main finding of this exercise is that factor analysis is not able to clearly separate the externalities from one another. This, in particular, holds true for network and urbanisation externalities as well to a lower degree for localisation and networks. In this regard, we obtain the evidence that our spatial externalities are synergistically interwoven. ‘Factor 1 – employment size, APS employment and connectivity’ displays the interplay of an urban environment with correlations to size of employment, the network integration and high employment shares in Advanced Producer services (figure 3.2). This factor has high loadings in the variables ‘total employment’, ‘interlock connectivity in high-tech and APS’ and a relative high correlation to ‘O/D air passenger traffic’. Thus, this factor represents the service centres and main cities such as Berlin, Munich or Hamburg.

‘Factor 2 - accessibility and density’ reveals a highly urbanised spatial pattern of density and accessibility along the Rhine River. This factor has a strong spatial autocorrelation and scores very highly in areas with dense transportation networks such as the Rhine-Ruhr area and along the Rhine River towards the south of Germany as wells as to Nuremberg and Hanover. Munich, Berlin and Hamburg seem to be peripheral to this corridor of density. Besides these urban characteristics the chemicals sector correlates with this factor, since the firms BASF in Ludwigshafen and Bayer in Leverkusen are located within this dense corridor.

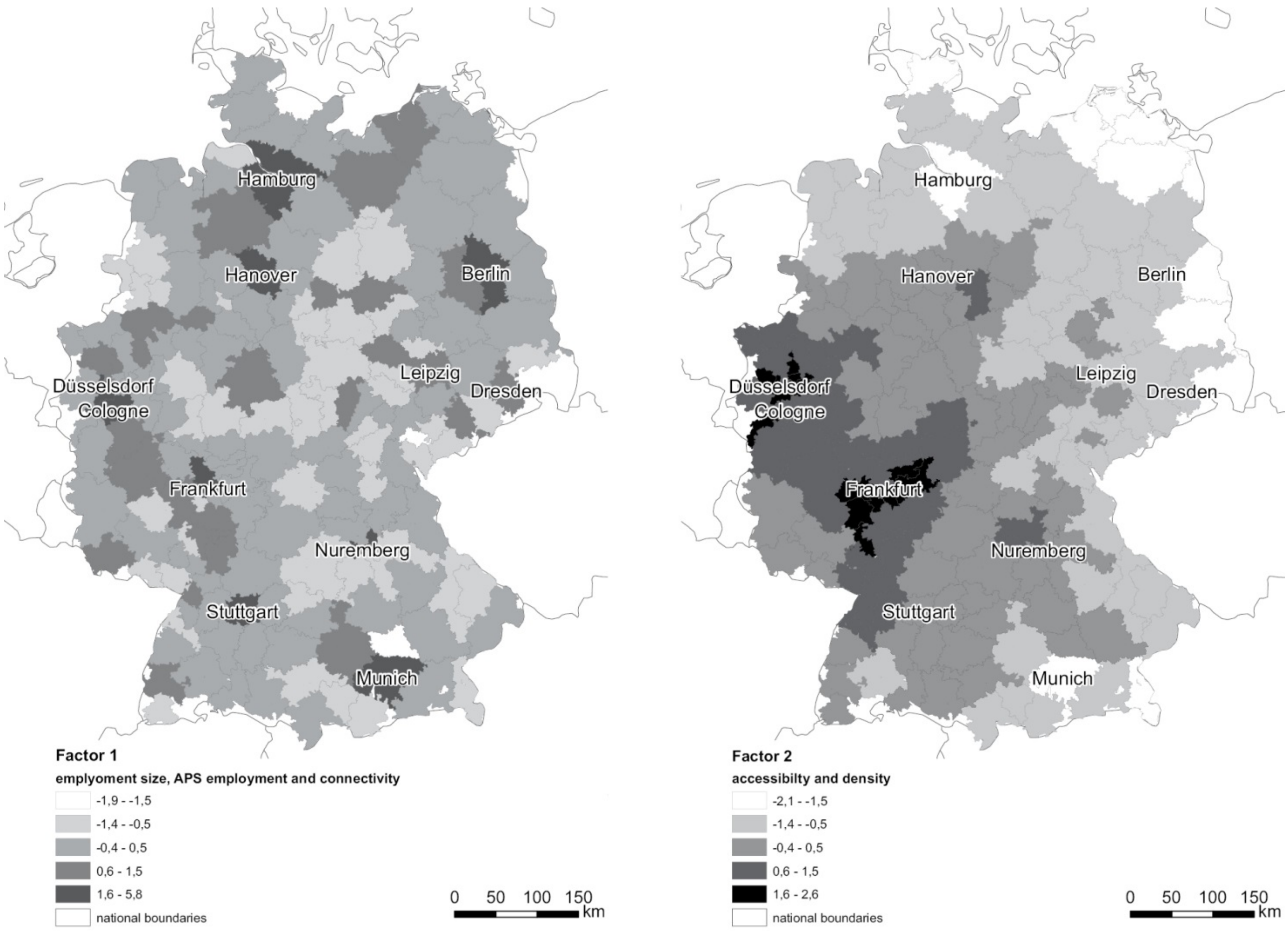
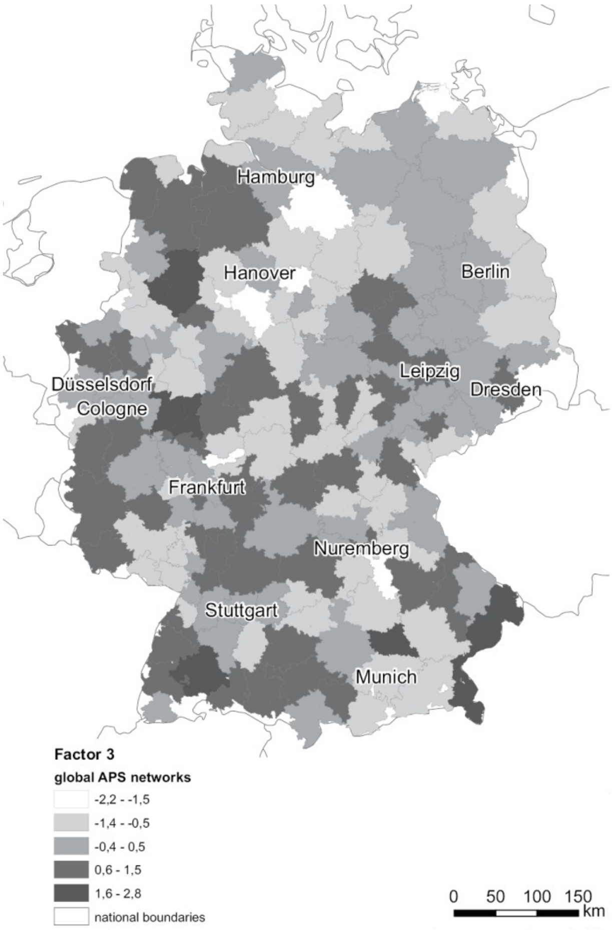


Figure 3.2 and 3.3: Factor 1 – employment size, APS employment and connectivity and Factor 2 - accessibility and density

‘Factor 3 – global APS networks’ represents a measure for access to ‘global pipelines’ via intra-firm network within APS. This factor has high correlations with the absolute ‘Interlock connectivity in APS’, ‘IC APS relative to number of locations’, and ‘APS share of IC global’. Furthermore, the ‘APS share of IC Germany’ has a negative relationship to that factor. Therefore, high values are observable close to hub airports such as Frankfurt and Freising, and remote areas with subsidiaries of globally active corporations and low density. The north west of Germany, for example, hosts several maritime services (Brandt, Dickow and Drangmeister 2010). Saarbrücken as a bordering FUA to France is home to big logistic enterprises.

Another striking result is the sector specific distribution of factor loadings. ‘Factor 4 - APS, entrepreneurship and high employment’ correlates highly with the employment shares of ‘banking’, ‘accounting’ and the ‘ratio of established firms’. Hence, regions with high scores perform well in terms of entrepreneurship and service activities such as retail banking and law consultancy. These values are lower in the eastern part of Germany, in which entrepreneurship is less prominent. This factor, consequently, indicates a clear east west divide within Germany.



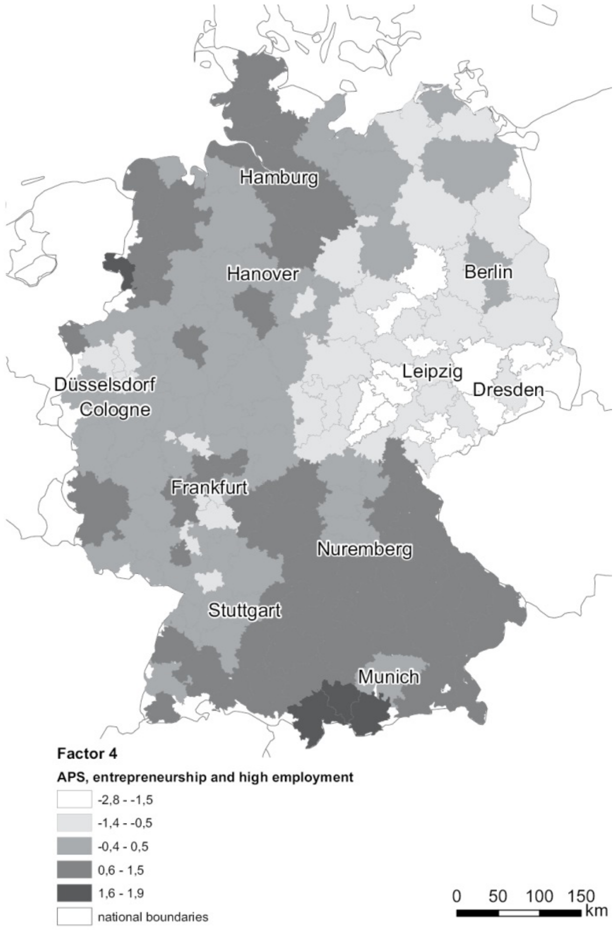


Figure 3.4 and 3.5: Factor 3 – global APS networks and Factor 4 - APS, entrepreneurship and high employment

‘Factor 5 - APS HQ and flight networks’ represents a high correlation between the number of transferring passengers, origin-destination travellers, and the headquarters functions of APS firms. Big cities, such as those with an international airport, i.e. Frankfurt, Hamburg or Berlin, score highly on that factor. Frankfurt, with the most important hub airport in Germany, ranks in first place. Since Munich airport is not located in the FUA of Munich but in the neighbouring FUA of Freising, the data reveal a specific situation. The city of Munich and the airport in Freising become substitutive locations for global APS firms (Thierstein, Goebel and Lüthi 2007). Therefore, we conclude in general that globally operating APS firms tend to locate at these hub airports in order to provide high global accessibility for business travel and face-to-face meetings, since the sectors of banking and law are considered the strategic players in the global economy (Taylor et al. 2013; Taylor, Hoyler and Pain 2013). In this regard, a hub airport represents a nucleus for 'net-working' activities. Other research focusing on the importance of air travel and business activities conducted by Neal (2012) and Liu, Derudder and García (2013) support this finding.

'Factor 6 - technical industries and HT HQ' score highly in the sectors of machinery, medical equipment, and electronics. These industries are strongly concentrated in the southern part of Germany and draw on intense interlinkages to the automotive industries. The results may also indicate a connection to a value creation system besides automotive engineering. Munich reaches a very high value for this factor, which is surprising for a larger city, since it is APS functions which tend to locate here. It is one of the advantages of the city of Munich that it has a balanced mixture of APS, employment size, and highly specialized high-tech activities. Thus, the Munich case represents exception compared to other regions, in that it hosts localisation tendencies within an urbanised environment (Pen, Dorenbos and Hoogerbrugge 2012).

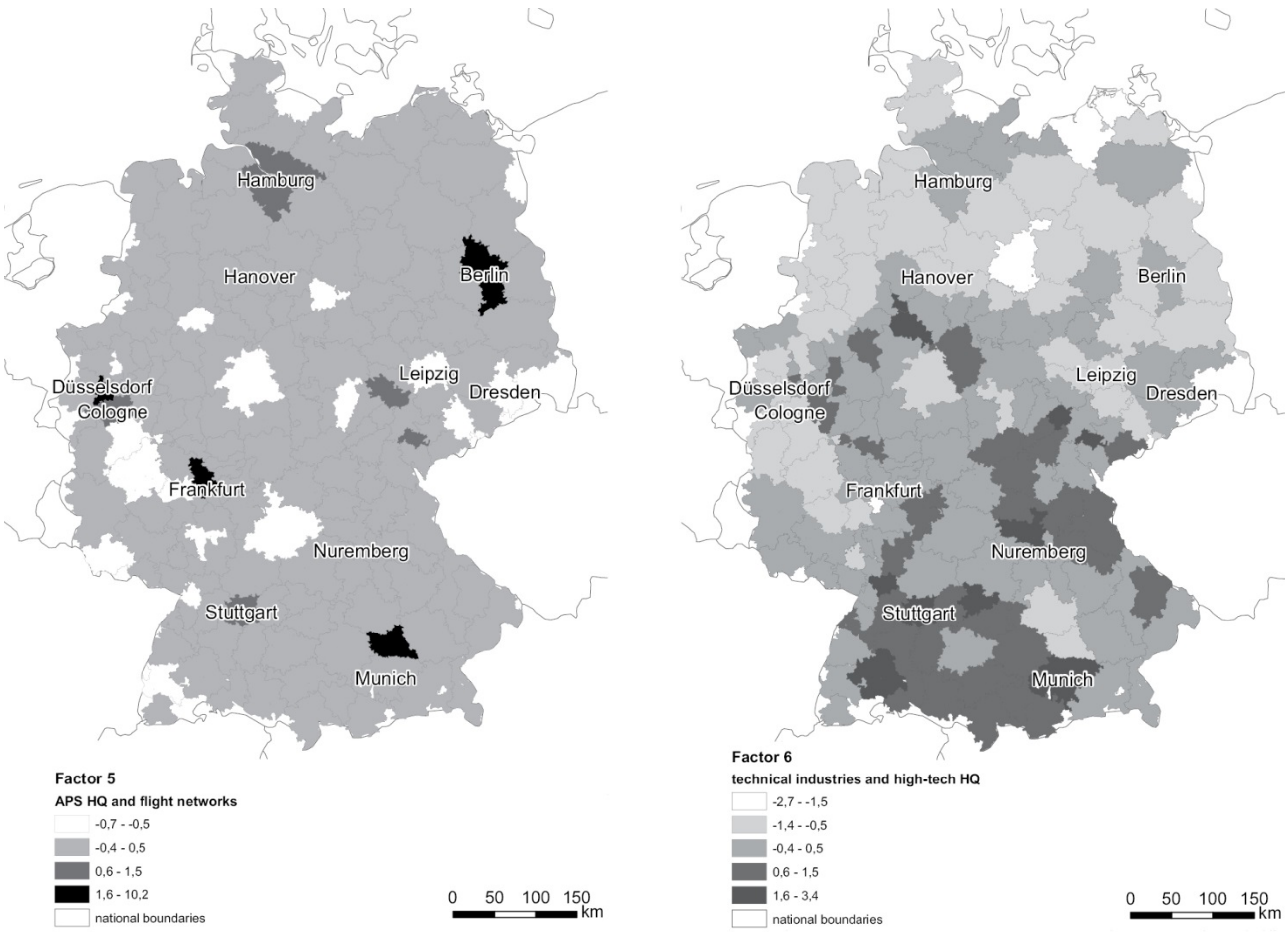


Figure 3.6 and 3.7: Figure 3.6: Factor 5 - APS HQ and flight networks and Factor 6 - technical industries and high-tech HQ

The ‘Factor 7 – global high-tech networks’ reflects networks of high-tech firms. These patterns tend to occur in remote areas with low density. These regions are dominated by a few firms with large intra-firm networks. Examples are the VW corporation in Wolfsburg, with more than 50,000 employees, BASF SE (111,201 employees) in the FUA of Ludwigshafen, and AlzChem AG (1,300 employees) and PharmaZell (500 employees) in Rosenheim, which have a high employment share and extensive networks all around the globe (Bisnode 2014). The FUA Salzburg in the south-west is actually an Austrian cross-border agglomeration, which extends into German territory. It scores highly in both network externalities, due to large chemical plants in Burghausen and localised APS activities in the centre of Salzburg. The rest of the agglomeration is rural and therefore lacks the sufficient size that might lower the accountability of network measures.

Finally, the car industry is represented in ‘Factor 8 - specialised car industry’. This reveals a highly specialised environment to be found in the Regions of Wolfsburg, with the VW Corporation, and Ingolstadt, with Audi, where it scores exceptionally highly. A strong concentration of activities in the automotive sector is located between Munich, Regensburg and Ingolstadt. Firms in the latter region have strong linkages to other firms in Munich. Therefore, Munich provides advanced product services to this specialised hinterland (Thierstein et al. 2011). The Ems region in the north west of the country also scores highly due to extensive ship building, which is also included in the sector of vehicle construction.

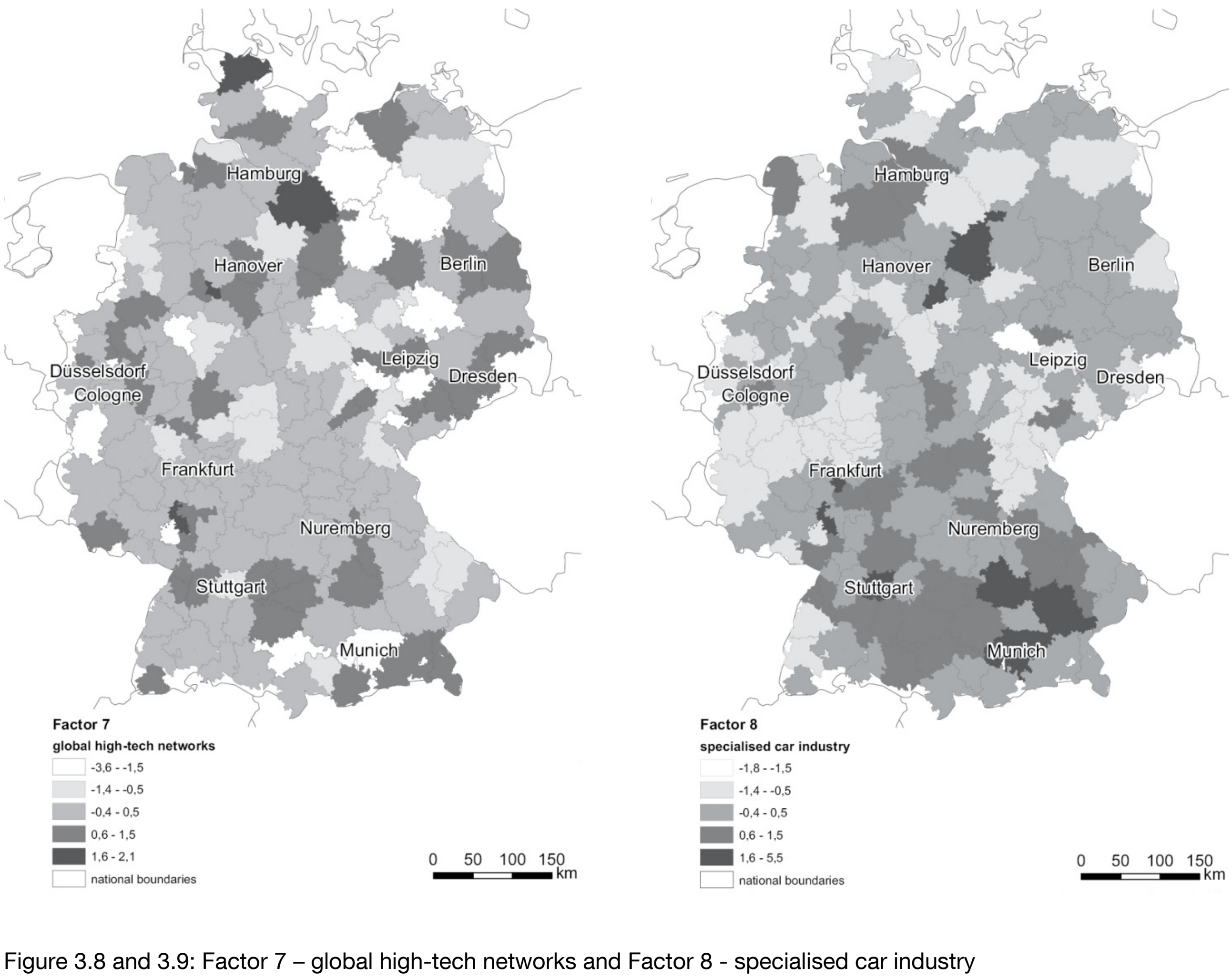


Figure 3.8 and 3.9: Factor 7 – global high-tech networks and Factor 8 - specialised car industry

Following from our analysis, we contest a clear separation of externalities. Basically, factor analysis considers variables as factors when they stem from the same source of causality. This becomes especially clear when looking at the variables 'interlocking connectivity in APS and high-tech' and 'total number of employment'. These observations stem from a commonality in employment size represented by factor 1. Both variables of interlock connectivity appear again in other factors and have a stronger relation to sector specific activities. The interrelations are strongest for the pairs urbanisation and networks and localisation and networks. Urbanisation and localisation have per definition a weak overlap, since these are different environments for economic processes.

This result, finally, supports the initial hypothesis that network externalities represent a form of operational business's activities, which come with externalities or localisation and urbanisation. The overlap between urbanisation and networks is a result of size and transportation infrastructure and therefore a rather general interrelation. With regard to localisation and networks, this intersection is due to certain globally operating firms in less dense regions. In the German case, network externalities indeed seem to function simultaneously as an evolution of and a contribution to the different environments of urbanisation and localisation.

3.5.2 The impact of externalities on productivity

Regression analysis enables us to test the impact of the extracted factors on GDP per employee. This section elaborates a series of regression analyses beginning with an ordinary least squares (OLS) regression (Auer and Rottmann 2011; Burt, Barber and Rigby 2009; Backhaus et al. 2003). This additive model will be extended with interaction terms, which calculate the coefficient of the interplay of several variables (Wright 1976; Aiken and West 1991; Norton, Wang and Ai 2004).

The application of a multiple linear regression model assumes that the dependent and independent variables have a linear relationship. The dependent variable, GDP per employee, is transformed with a logarithm. The form of the multiple OLS regression is given by:

$$\ln(y) = \beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n + \varepsilon \qquad (3)$$

With ln(y) as the dependent variable transformed with a natural logarithm, β represents the regression coefficients of the independent variable x. The error term is formalized by ε. Since, the factors that are included as independent variables are standardised, the regression coefficients can be interpreted easily without taking different scales into account.

The results of the elementary OLS regression are shown in table 3.2. The models 1-5 show stepwise estimations based on an additive approach. Models 1 and 3 represent the basic stepwise OLS regression. Model 1 includes the aforementioned factors. These 8 variables already account for a coefficient of determination R^2 of 78.2 %. All factors have a positive impact on productivity and are significant except 'Factor 6 –technical industries and high-tech HQ'. These industries also have a high share of employment which is not knowledge intensive and rather production oriented. Thus, machinery in particular includes activities which might be high-tech per definition but involve low tech manufacturing in broad production series as well. Therefore, its impact on productivity might increase when other indicators such as specialisation or other production are met. The variables 'Factor 2 - accessibility and density', 'Factor 4 - APS, entrepreneurship and high employment' and 'Factor 8 - specialised car industry' have the highest impact on productivity. The network effects given by 'Factor 3 – global APS networks' and 'Factor 7 – global high-tech networks' are clearly less strong.

Model 2 introduces the indicators RDI and RZI, which are significant as well. The correlation between these variables is rather low and accounts for -0.14. The RDI displays a negative sign, which might be due to neglecting the quality of the diversification level. Furthermore, a dummy variable 'west' is included. This reveals a very high impact on productivity and overshadows the 'Factor 4 - APS, entrepreneurship and high employment', since eastern Germany has a less vibrant culture of entrepreneurship.

These mutual impacts of the variables need further elucidation. Therefore, we implement an interaction term, which is given by:

$$\ln(y) = \beta_0 + \beta_1 x_1 + \ldots + \beta_i x_i + \beta_n (x_1 * x_2) + \varepsilon \qquad (4)$$

The coefficient β_n of the interaction of ($x_1 * x_2$) indicates complementary effects with a positive sign and substitutive effects with negative signs. The models 3 to 5 represent these interactive models. Model 3 investigates the interplay of urbanisation, localisation and network externalities. Model 4 deepens the interrelation within localisation economies. Model 5 represents the most significant interaction terms and introduces further control variables. In this regard, we assume to reveal complementary effects in the following nine interactions:

Model 3:

- size, services and diversity
- size, APS networks and flight networks
- size, accessibility and APS networks
- machinery, car production and specialisation
- size and high-tech networks
- size, accessibility, APS and high-tech networks

Model 4:

- machinery and specialisation
- car production and specialisation
- machinery, car production, high-tech networks and specialisation

Model 5 includes significant interaction terms and additional control variables.

The inclusion of interaction slightly improves the coefficient of determination for the models. Model 3 shows interesting results in terms of the interplay of the externalities. The isolated diversity index RDI has a negative sign across all models. However, this impact turns positive when RDI interacts with 'Factor 1 - size, APS employment and connectivity' and 'Factor4 - APS, entrepreneurship and high employment'. Consequently, this measure of diversity only has a positive impact on productivity when it encounters different service activities and sufficient size of the economy. This might be another argument for the interwoven pattern of urbanisation, critical mass and network activities given by the absolute interlock connectivity.

independent variable			**model1**	**model2**	**model3**	**model4**	**model5**
F1 - size, APS employment, machinery and connectivity		beta	.0498598***	.0450787***	.0487162***	.0446316***	.0443618***
		se	0.0000	0.0000	0.0000	0.0000	0.0000
F2 - accessibility and density		beta	.0773245***	.0490148***	.0766607***	.0748608***	.0576558***
		se	0.0000	0.0000	0.0000	0.0000	0.0000
F3 - global APS networks		beta	.0103875*	.0071607	.0147363**	.0135088**	.0111026*
		se	0.0403	0.1282	0.0023	0.0080	0.0162
F4 - APS, entrepreneurship and high employment		beta	.0515876***	.0115816	.066711***	.0538271***	.032483**
		se	0.0000	0.2124	0.0000	0.0000	0.0018
F5 - APS HQ and flight networks		beta	.0193556***	.0205194***	.0126647*	.0177132***	.0154526**
		se	0.0002	0.0000	0.0183	0.0006	0.0015
F6 - technical industries and high-tech HQ		beta	.0090238	.0012022	.0019377	.0050914	-.0027722
		se	0.1036	0.8209	0.7282	0.3654	0.6217
F7 - global high-tech networks		beta	.0231193***	.0124468*	.0225753***	.0220049***	.0152006**
		se	0.0000	0.0223	0.0000	0.0001	0.0042
F8 - specialised car industry		beta	.0510887***	.0335072***	.0360533***	.039662***	.0284346***
		se	0.0000	0.0000	0.0000	0.0000	0.0000
ln(RDI)		beta		-.1493846*	-.1370336	-.0826924	-.1788221**
		se		0.0249	0.0533	0.2334	0.0056
ln(RZI)		beta		.0144297*	.0135164*	.0145768*	.0128341*
		se		0.0157	0.0270	0.0266	0.0257
interaction terms							
size, services and diversity:	F1 - size, APS employment, machinery and connectivity * F4 - APS, entrepreneurship and high employment * ln(RDI)	beta			.0077611**		.0066024**
		se			0.0023		0.0031
size, APS networks and flight networks:	F1 - size, APS employment, machinery and connectivity * F2 - accessibility and density * F3 - APS networks * F4 - APS, entrepreneurship and high employment * F5 - APS HQ and flight networks	beta			-.0002053		
		se			0.9849		
size, accessibility and APS networks:	F1 - size, APS employment, machinery and connectivity * F2 - accessibility and density * F3 - global APS networks	beta			-.0004604		
		se			0.9604		
machinery, car production and specialisation:	F6 - technical industries and high-tech HQ * F8 - specialized car industry and machinery * ln(RZI)	beta			.0128362**		.0092987*
		se			0.0053		0.0355
size and high-tech networks:	F1 - size, APS employment, machinery and connectivity * F2 - accessibility and density * F7 - global high-tech networks	beta			.0154323*		.0125448**
		se			0.0319		0.0011
machinery and specialisation:	F6 - technical industries and high-tech HQ * ln(RZI)	beta				.006067	
		se				0.4209	
car production and specialisation:	F8 - specialized car industry and machinery * ln(RZI)	beta				.0104752	
		se				0.1312	
machinery, car production, high-tech networks and specialisation:	F6 - technical industries and high-tech HQ * F8 - specialized car industry and machinery * F7 - global high-tech networks * ln(RZI)	beta				.0164284*	
		se				0.0216	
control variables							
west (dummy: west = 1, east = 0)		beta		.1279125***			.0999986***
		se		0.0000			0.0001
FUA is located at the boundaries of Germany		beta					.0019624
		se					0.8666
intercept			10.93695***	11.33263***	11.38931***	11.20976***	11.44909***
			0.0000	0.0000	0.0000	0.0000	0.0000
r2			.7818673	.8189973	.8226398	.7988556	.8390784
N			179	179	179	179	179
aic			-458.768	-486.1679	-481.8068	-463.2814	-499.2172

Table 3.2 result of the regression analysis (own calculation)

In our case all independent variables have positive effects on productivity, except ‘Factor 6 – technical industries and high-tech HQ’. This variable even shows a negative sign in model 5. Interestingly, when this variable interacts with ‘Factor 8 - specialised car industry’ and RZI it reveals a positive impact on productivity. This result might indicate that machinery influences productivity when it is linked to car manufacturing within a specialised environment. We might conclude that this forms a localised production system, since ‘Factor 8 - specialised car industry’ also correlates to the amount of inter-firm cooperation.

Assessing the impact of specialisation and networking in more detail, model 4 separately calculates the interactive effects of ‘Factor 6 – technical industries and high-tech HQ’ and RZI, Factor 8 - specialised car industry’ and RZI and conjointly with ‘Factor 7 – global high tech networks does not show a significant impact on productivity. This again supports the aforementioned finding of a localised and globally integrated production system revolving around machinery and mobility.

Finally, the interaction of ‘Factor 1 - size, APS employment and connectivity’, ‘Factor 2 - accessibility and density, ‘Factor 3 - APS networks’ and ‘Factor 7 – global HT networks’ indicates that network activities tend to have an additional positive effect on productivity when these are combined with sufficient size, spatial integration given by accessibility, and other service activities.

Although, productivity is highly spatially autocorrelated (Fischer and Varga 2003; Lagendijk 2001), tests with spatial lag models did not improve the estimation. ‘Factor 2 - accessibility and density’ compensates for the spatial association between the predictor variables and productivity.

The German case with its polycentric structure and a globalised economy seems to be an interesting starting point for the interplay of networks, urban centres and specialised economies. However, the automotive sector and its strong concentration in the south of Germany dominates the production system and the emergence of localisation economies. Consequently, this approach incorporates a strong German specificity in the distribution of economic activities. Other industries, such as chemicals or biotechnology, might show strongly specialised tendencies as well, but could not be assessed on this macro-analytical level.

3.6 Conclusion

The impacts of externalities on productivity provide interesting insights into interwoven patterns of urbanisation, localisation and network activities and their complementary effects. Testing the factor analysis with different regression analyses shows clearly that the factors contain a broad spectrum of the externalities and interact in the productivity. The conclusion can be drawn that the interaction terms improve the OLS regression slightly. Accordingly, network and agglomeration externalities show some reinforcing effects on one another.

The Munich case shows a striking interrelation of the networks, specialisation and urbanisation in a wider context of a Mega-City region that includes the cities Regensburg, Ingolstadt and Augsburg. In this regard a 'decentralised concentration' emerges, which drives the polycentric structure within that region. The city of Munich hosts many APS activities which service the hinterland of highly specialised activities in the mobility sector. Net-working activities are strongly concentrated at the airport of Freising. Thus, the airport acts as the global gateway to the Mega-City region. This airport appears to have a front and a back side. Whereas specialised activities are located in the 'Hinter-land' between Regensburg, Freising and Ingolstadt, Munich captures the symbolic significance of the airport, hosting the more urbanised APS firms, and represents the 'Vorder-land' of the airport. Frankfurt airport shows a totally different pattern in these externalities. In the context of the Mega-City region with a higher degree of ploycentricity, the effects of urbanisation, localisation and networks seem to superimpose.

Our assumption of an 'increasing interwoven-ness of agglomeration and network economies' seems to be supported by these findings. However, it suggests much more reflection on the path dependent development of spatial structure and the emergence of externalities is needed. This further implies the hypothesis that agglomeration externalities represent a temporary spatial configuration which is optimal for the localized production systems. Once these benefits of agglomeration economies disappear, the agglomeration of economic activity devolves and other forms emerge. In this regard, the transformation of agglomerations complemented by network activities might capture different spatial manifestations. Both processes work simultaneously and foster the integration of agglomerative forces in supra-regional developments.

Further research might be directed towards several objectives. The form of the interrelation between theses externalities and productivity should be investigated in more detail. Although our approach already incorporates logarithmic transformation, other forms that have no linear correspondence, such as U-shaped interrelations might exist. Therefore, externalities might have minima or maxima that affect productivity. Finally, longitudinal analysis and time series might allow further deciphering the causes and effects of agglomeration and networks.

Appendices

Appendix 1: Knowledge intensive sectors (Lüthi 2011 based on Legler and Frietsch (2006)

Advanced Producer Services (APS)	**High-Tech**
Banking & Finance: 6511, 6512, 6521, 6522, 6523, 6711, 6712, 6713, 7011, 7012 **Advertising & Media:** 7440, 2211, 2212, 2213, 2214, 2215, 9211, 9220, 9240 **Information and Communication Services:** 6430, 7221, 7230, 7240, 7250, 7260 **Insurance:** 6601, 6602, 6603 **Logistics (3p & 4p):** 6030, 6110, 6220, 6230, 6340 **Management- & IT-Consulting:** 7210, 7222, 7413, 7414, 7415 **Design, Architecture & Engineering:** 7420, 7430 **Law:** 7411 **Accounting:** 7412	**Chemistry & Pharmacy:** 2330, 2413, 2414, 2416, 2417, 2420, 2441, 2442, 2451, 2461, 2463, 2464, 2466, 2511, 2513, 2615 **Machinery:** 2911, 2912, 2913, 2914, 2924, 2931, 2932, 2941, 2942, 2943, 2952, 2953, 2954, 2955, 2956, 2960 **Electronics:** 3110, 3120, 3140, 3150, 3161, 3162, 3210, 3320, 3330 **Computer & Hardware:** 3001, 300 **Telecommunication:** 3220, 3230 **Medical & optical instruments:** 3310, 3340 **Vehicle construction:** 3410, 3430, 3511, 3520, 3530

variable	unit	mean	min	max	data source
physical infrastructure					
accessibility per rail	Index (EU 27)	160,20	93,38	227,37	own calculation based on ESPON (2009)
accessibility per road	Index (EU 27)	174,67	100,93	222,03	
accessibility per air	Index (EU 27)	113,74	59,98	194,80	
volume of origin-destination air traffic	count passengers in million	985	-	50.574	Statistisches Bundesamt (2009)
volume of changing passengers in air traffic	count passengers	129	-	14.166	
Employment size, performance and entrepreneurship					
employment density	employee/per km²	163,28	20,69	1.759,91	own calculation based Federal Employment Agency (2009)
employment	count	142.975,26	11.924,76	1.154.372,96	
unemployed per employed	unemployed person/employee	8,82	3,44	20,33	(Statistisches Bundesamt 2010)
share of foreign unemployed persons	foreign unemployed/employee	15,71	2,66	73,49	
ratio of established firms in total number of firms		0,08	-0,02	0,25	
RDI		8.286863	2.07	18.19	Own calculation based on (Bundesagentur für Arbeit 2010)
RDI		1.03	0.00	18.40	
employment shares in:					
Chemistry & Pharmacy		1,61	0,01	28,70	Bundesagentur für Arbeit (2010)
Machinery		3,48	0,32	13,73	
Electronics		2,70	0,02	17,28	
Telecommunication		0,29	-	3,98	
Medical & optical instruments		0,69	0,14	5,57	
Vehicle construction		2,64	0,01	36,58	
Banking & Financing		2,20	0,71	12,74	
Insurances		0,38	0,00	4,56	
Information and Communication Services		0,53	0,06	2,73	
Advertising & Media		0,81	0,14	7,09	
Logistics (3p & 4p)		1,83	0,50	5,79	
Management- & IT-Consulting		1,83	0,37	9,36	
Design, Architecture & Engineering		1,27	0,63	3,62	
Law		0,42	0,19	1,64	
Accounting		0,79	0,44	1,70	
Computer & Hardware		0,13	-	3,80	
non-knowledge intensive		78,40	52,64	90,53	
firm networks					
share of HQ in high-tech in all locations	percentage	0.88	0	20.00	Own data collection
share of HQ in APS in all locations	percentage	1.13	0	23.00	
number of HQ in high-tech		0.08	0	1.00	
number of HQ in APS		0.28	0	0.25	
Interlock connectivity in high-tech		5.752,70	-	47.853,00	
Interlock connectivity in APS		10.178,24	1.118,00	68.819,00	
IC high-tech relative to number of locations		483,36	-	1.542,00	
IC APS relative to number of locations		485,79	186,30	1.030,00	
high-tech share of IC global	percentage	39,32	-	100,00	
APS share of IC global	percentage	20,28	2,99	50,38	
external firm linkages normed maximum		0,05	-	1,00	own data survey
N=179					

Appendix 2: included variables, descriptive statistics (own calculation)

Appendix 3

A p-value close to 0 that the data is not normally distributed. High positive skewedness indicates that the variable is skewed to the right. The equations were calculated with Stata by using the function lnskew0.

variable label	mean	sd	skewness	p (original)	transformation	P transform
Physical infrastructure						
accessibility per rail	159,86	32,21	0,08	0,04	ln(x + 694.9933)	0,05
accessibility per road	174,44	27,44	-0,54	0,00	ln(-x + 273.9235)	0,08
accessibility per air	113,41	24,93	0,68	0,00	ln(x - 13.61678)	0,94
volume of origin-destination air traffic	996476,60	5075882,00	7,25	0,00	no transformation	
volume of changing passengers in air traffic	130330,10	1177093,00	10,61	0,00	no transformation	
Employment size, performance and entrepreneurship						
employment density	156,85	189,29	3,15	0,00	ln(x - 19.96261)	0,00
Employment	144572,80	157574,90	3,86	0,00	ln(x - 7884.905)	0,11
unemployed per employed	8,87	4,11	1,00	0,00	ln(x - 2.202668)	0,03
share of foreign unemployed persons	15,82	17,43	1,68	0,00	ln(x - 1.501913)	0,00
ratio of established firms in total number of firms	0,08	0,05	0,21	0,29	ln(x + .5948706)	0,50
RDI		2.30	0.41	0.01	ln(RDI+18.09331)	0.10
RZI		1.55	8.21	0.00	ln(RZI+.0480983)	0.07
Employment shares in:						
Chemistry & Pharmacy	0,02	0,02	8,21	0,00	ln(x + .0007577)	0,11
Machinery	0,03	0,02	1,49	0,00	ln(x + .008069)	0,80
Electronics	0,03	0,02	2,45	0,00	ln(x + .0035211)	0,62
Telecommunication engineering	0,00	0,00	4,48	0,00	ln(x + .0001118)	0,77
Medical & optical instruments	0,01	0,01	4,44	0,00	ln(x - .0013177)	0,01
Vehicle construction	0,03	0,04	4,27	0,00	ln(x + .0001985)	0,82
Banking & Financing	0,02	0,01	5,01	0,00	ln(x - .0043719)	0,00
Insurances	0,00	0,01	3,46	0,00	ln(x - 2.18e-06)	0,02
Information and Communication Services	0,01	0,00	2,10	0,00	ln(x - .0002232)	0,87
Advertising & Media	0,01	0,01	4,07	0,00	ln(x - .0011178)	0,07
Logistics (3p & 4p)	0,02	0,01	1,75	0,00	ln(x - .0005057)	0,04
Management- & IT-Consulting	0,02	0,01	1,96	0,00	ln(x - .0023228)	0,50
Design, Architecture & Engineering	0,01	0,01	1,61	0,00	ln(x - .005242)	0,64
Law	0,00	0,00	2,51	0,00	ln(x - .0013881)	0,12
Accounting	0,01	0,00	1,24	0,00	ln(x - .0019283)	0,25
Computer & Hardware	0,00	0,00	7,57	0,00	ln(x + .0000192)	0,07
non-knowledge intensive	78,47	7,17	-0,84	0,00	ln(-x + 100.1436)	0,67
Firm networks						
share of HQ in high-tech in all locations	0,08	0,16	3,86	0,00	no transformation	
share of HQ in APS in all locations	0,03	0,05	1,94	0,00	no transformation	
number of HQ in high-tech	0,88	2,03	6,17	0,00	no transformation	
number of HQ in APS	1,13	3,23	4,50	0,00	no transformation	
Interlock connectivity in high-tech	5816,98	7350,28	2,97	0,00	ln(x + 406.0742)	0,59
Interlock connectivity in APS	10291,97	12878,81	2,78	0,00	ln(x - 980.6182)	0,09
IC high-tech relative to number of locations	482,90	209,96	1,22	0,00	ln(x + 822.5225)	0,00
IC APS relative to number of locations	484,84	154,25	1,05	0,00	ln(x - 54.15877)	0,74
high-tech share of IC global	39,36	13,54	-0,45	0,00	ln(-x + 301.9213)	0,00
APS share of IC global	20,12	9,95	0,36	0,00	ln(x + 23.53156)	0,00
high-tech share of IC Germany	24,03	13,51	2,27	0,00	ln(x + 14.06509)	0,00
APS share of IC Germany	53,43	18,40	0,00	0,00	ln(x + 958.2226)	0,00
external firm linkages normed by maximum	0,05	0,13	5,30	0,00	ln(x + .0000898)	0,00
N = 179						

Appendix 3: variables, descriptive statistics and transformation to normal distribution (our calculation)

3.7 References

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4 Knowledge Hubs

Poles of Physical Accessibility and Non-Physical Connectivity

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Abstract:

Hub cities combine the spatial accessibility and non-physical connectivity. Thus these cities provide spatial proximity to local partners and relational proximity to global knowledge resources. Firms tend to optimize their value chains according to the provision of these externalities. The result of this decision making process of choosing locations is an urban system in which specialisation and diversification is interdependent. The production of knowledge incorporates both economies of scale realised by specialisation and economies of scope given by a diversified environment. By means of intra-firm and extra-frim networks we are able to visualise and analyse these interrelations along a stylised value chain. We show that the interplay of diversified and specialised cities grounds on a spatial distribution of the division of labour and that the coexistence of these environments inheres a spatial logic.

Keyword: knowledge production, hub cities, diversification, specialisation, division of labour

Own contribution

- Conceputalization of the article and ddfining reserach question
- Data analylsis and interpretataion
- Assessing the interplay of diversification and specialisation

4.1 Introduction

The production of knowledge takes part in complex networks of firms and individuals (Kujath and Schmidt 2010). Recent decades have witnessed a period of fundamental change in world-wide economic activities (Dicken 2011). During this period, the use and supply of information and communication technology (ICT) has broadened and transportation costs have declined steeply, thus further accelerating the process of globalization. However, this process evoked a concentration of knowledge and the knowledge economy in global nodes such as global cities(Sassen 1991; Castells 2000; Taylor 2004). Dicken (2011) points out that Advanced Business Services in particular 'continue to be extremely strongly concentrated geographically' (Dicken 2011: 390). Thus, the world is likely to become more and more spiky because population, patents, and a number of scientific citations are located in several urban centres in Northern America, Europe and South-East Asia (Florida 2005). Richard Florida uses these variables as indicators of economic activity and assets of knowledge and hypothesizes that globalization has clearly changed competition, but does not level the 'playing field' (Friedman 2005). Indeed, within knowledge creation and application, spatial proximity and face-to-face contacts still play a crucial role (Storper and Venables 2004). In particular, tacit knowledge, which is mainly based on experience, can only be transferred in learning processes. A new division of labour has resulted from this complex process of knowledge creation and application and has led to a new spatial logic (Sokol, van Egeraat and Williams 2008: 1143). A system of interconnected world cities has emerged and a few cities are held to be central places in which those connections converge: the knowledge hubs (for a more detailed specification, see Neal, this volume). According to the concept of the space of places and space of flows (Castells 2000) we consider knowledge hubs as urban areas with vertical integration and vibrancy in a horizontal, that is regional, dimension. Therefore a knowledge hub is an urban area, which is simultaneously vertically integrated into functional networks that reach beyond the metropolitan scale and which generates territorial spill-overs within its urban area (Castells 2000; Bathelt, Malmberg and Maskell 2004; Growe and Blotevogel 2011).

Knowledge is created in a process where implicit and explicit knowledge are interwoven. This process depends on various factors which can be divided into internal and external factors. Internalities, such as investment in research and development or equipment, are conditions which can be influenced by the firm individually. Externalities are advantages from which firms benefit at no cost to themselves, or disadvantages which they have to pay for but for which they are not responsible. In our analysis we will focus on the positive externalities of network economies and agglomeration economies. Network economies highlight the effects of strategic links between hubs of knowledge. Agglomeration economies enable knowledge spill-overs between individuals. Therefore, knowledge intensive firms require an environment in which two main conditions inhere: access to networks to receive information and critical mass to realize knowledge spill-overs. For both conditions, spatial accessibility and the non-physical connectivity, which is provided by firm networks and which is a proxy for hypothetical information flows (Taylor 2004: 61, Lüthi 2011: 106), play a crucial role and foster the economic performance of a region (de Bok and van Oort 2011). Exploiting these economies raises the question of how firms or actors can access these externalities in both ways, i.e. the physical and non-physical.

In this paper we assess the emergence of knowledge hubs in Germany by highlighting the interplay of physical and non-physical accessibility within knowledge production. We combine the concept of spatial accessibility with the theoretical approaches of network economies and agglomeration economies that show how firms exploit these externalities. In addition we differentiate accessibility according to mode (air, rail or road) and dimension (physical and non-physical) (see Knowles (2006)), which provide the potential to either establish links within a network or to access parts of agglomerations. Physical accessibility enables the movement of goods or people and establishes face-to-face contacts; non-physical accessibility facilitates the exchange of information. Furthermore, we show that decision-making in choosing locations of firms in Advanced Producer Services (APS) and high-tech sectors correlates quite strongly with the accessibility of spatial entities. Nevertheless, differences between both sectors are observable. We therefore analyse the locational behaviour of firms, their intra-firm and extrafirm networks and the role of physical accessibility and consider this in relation to the economic performance of Functional Urban Areas (FUA) in Germany. Accessibility is understood as the foundation for entering and establishing networks of knowledge creation and impacts economic performance to a large extent. The question arises how firms access externalities to create knowledge.

This paper is structured as follows: section two defines the knowledge economy and discusses externalities of knowledge production. In section three considers the emergence of knowledge hubs in a process of cumulative causation of knowledge production. Section four introduces a concept of spatial accessibility including non physical connectivity; in section five the interplay between physical accessibility and non-physical connectivity is illustrated; section six focuses on the relatedness of diversified and non-diversified hubs and their functional importance. Section seven concludes the discussion.

4.2 Externalities of Knowledge Creation – Networks, Agglomerations and Accessibility

This section provides an insight into the process of knowledge production and how accessibility enables firms to exploit externalities of agglomerations and networks in order to create knowledge. Knowledge production is based on two key features: Firstly, it is carried out in a complex process where people and firms interact (Cooke et al. 2007: 27). Secondly, knowledge is not only a fundamental resource in the innovation process but also a strategic property fostering the development of firms.

4.2.1 The Knowledge Economy and Knowledge Production

The profit imperative is an important logical principle shared by all knowledgeintensive firms. It is not only the creation of new knowledge that preoccupies their managers, but also the appropriation of surplus value (Sokol, van Egeraat and Williams 2008: 1143). Furthermore, these features underline the relational character of the knowledge economy. Since, highly specialized knowledge and skills are based on the combination of scientific knowledge and operating experiences, the knowledge economy establishes strategic links between firms and other organizations as a way to acquire specialized knowledge from different parts of the value chain (Lüthi, Thierstein and Bentlage 2011: 163). In terms of economic sectors, the knowledge economy can be understood as an interdependent system of Advanced Producer Services (APS) and high-tech firms. APS can be defined as 'a cluster of activities that provide specialized services, embodying professional knowledge and processing specialized information to other service sectors' (Hall and Pain 2006: 4). The essential common characteristic of these sectors is that they generate, analyze, exchange and trade information, making them spearheads and key intermediaries in the knowledge economy (Sassen 2001: 90). However, APS are not the only determining element in the process of structural change towards the knowledgeeconomy. In order to understand the geography of globalization, one has to account simultaneously for both APS- and high-tech sectors (Castells 2000). Nevertheless, there is no commonly accepted definition of what the knowledge economy is. Therefore we apply the following definition of the knowledge economy:

> *"the knowledge economy is that part of the economy in which highly specialized knowledge and skills are strategically combined from different parts of the value chain in order to create innovations and to sustain competitive advantage." (Lüthi, Thierstein and Bentlage 2011: 162–163)*

We can distinguish between different definitions of knowledge. Depending on the processes researchers focus on, we can concentrate on either the modes in which knowledge can be transferred or communicated to others or the bases on which knowledge is founded. Asheim et al. (2007) distinguish three different knowledge bases: analytical, synthetic and symbolic. This takes the increasing complexity of knowledge into account and makes clear that different economic activities draw from different knowledge bases. For instance activities in high-tech sectors such as biotechnology tend to draw their knowledge from scientific work and use the analytic knowledge base, whereas design or architecture draw from the symbolic knowledge base, where aesthetic considerations have a higher importance.

A broader distinction was developed by Polanyi (1966) in his seminal work 'The tacit dimension'. He focuses on the modes in which knowledge can be communicated and argues that 'we can know more than we can tell' (Polanyi 1966: 4). Therefore, knowledge consists of a tacit and an explicit dimension. Both kinds of knowledge work differently in the way people have to interact. Within the process of knowledge creation a dynamic interplay between tacit and explicit forms of knowledge is required. Regarding accessibility, explicit knowledge can be transferred in a nonphysical way via ICT, while implicit knowledge requires strong interaction between people and organizations (Bathelt, Malmberg and Maskell 2004: 32). Therefore physical accessibility plays an important role (Thierstein, Goebel and Lüthi 2007: 88).

Since the transfer of tacit knowledge requires direct face-to-face interactions, the findings of Polanyi (1966) are not only important for firms but also for regions. Innovative activities have been shown to be highly concentrated in a minority of urban regions (Simmie 2003). The main reason why these regions play an important role in the supply of knowledge is that firm networks benefit from geographical proximity and local knowledge spill-overs. Malecki (2000) describes this as the 'local nature of knowledge' and highlights the necessity to accept knowledge as a spatial factor in competition:

> *"If knowledge is not found everywhere, then where it is located becomes a particularly significant issue. While codified knowledge is easily replicated, assembled and aggregated […], other knowledge is dependent on the context and is difficult to communicate to others. Tacit knowledge is localised in particular places and contexts […]." (Malecki 2000: 110)*

The distribution and transfer of explicit and tacit knowledge as well as the interplay between geographical and relational proximity forms a key basis for the development of regions. On the one hand, the concentration of knowledge resources in particular regions influences the roles that they may play in the global economy. On the other hand, the dynamics of knowledge exchange within and between regions contribute to either the maintenance or change in those roles within the functional urban hierarchy. Simmie (2003) shows that knowledge intensive firms combine a strong local knowledge capital base with high levels of connectivity to similar regions in the international economy. In this way they are able to combine and decode both codified and tacit knowledge originating from multiple regional, national and international sources (Simmie 2003) and, therefore, they are considered as hubs.

4.2.2 Exploiting Agglomeration Economies

Agglomeration economies are generic geographical processes mapping the microeconomic logic of knowledge creation and business organization in space. Early theories on agglomeration economies are strongly inspired by Alfred Marshall (1920), who argued that spatial concentration could confer external economies on firms as they concentrate in particular cities (Marshall 1920). Marshall's concept was taken up by Hoover (1937), who grouped the sources of agglomeration advantages into internal returns of scale, localization and urbanization economies. Localization economies reflect the tendency for firms in closely related industries to locate in the same place; urbanization economies, on the other hand, arise from the diversity and the more general characteristics of a city (Hoover 1937). Based on these early agglomeration theories, a second wave of agglomeration models was developed in the 1980s onwards to explain why local space is still important for newly-developing firms of production. For example: the new industrial district (Becattini 1991), the innovative milieu (Maillat, Quévit and Senn 1993) or the regional innovation system (Cooke 1992).

According to recent publications there is no mutual consensus whether specialization or diversification foster spatial development. These contrary opinions can be ascribed to (Marshall 1920), who stated that specialization and therefore localization economies drive innovations, and Jacobs (1969), who adopts the attitude that diversification enables economic growth. Empirical evidence can be found for both strands of theory (Beaudry and Schiffauerova 2009). However, Duranton and Puga (2000: 534 and 553) state that a coexistence of diversified and specialized cities bring out a sufficient condition for successful economies. This coexistence is embedded in a process of spatial division of labour and specialized cities emerge in the shadow of diversified knowledge hubs. Therefore, Boschma and Iammarino (2009) developed the approach of related varieties and define these as ‘sectors that are related in terms of shared or complementary competences’ (Boschma and Iammarino 2009: 292–293). An individual city may be assessed as specialized to a high extent but considering the entire network in which it is integrated a balanced diversity is generated by establishing links to those parts of the value chain, which are not located in that city. In other words, a high degree of specialization comes along with intensive network processes in both ways the physical and non-physical and, hence, knowledge hubs emerge where those networks converge again.

The commonality of these approaches is that they acknowledge geographical proximity as an important determinant for the innovation activities of knowledgeintensive firms. A number of authors have demonstrated through econometric methods that knowledge spill-overs are closely related to spatial proximity (Jaffe, Trajtenberg and Henderson 1993; Bottazzi and Peri 2002; Breschi and Lissoni 2009). The importance of face-to-face contacts in communication and the tacit nature of much of this communication still make geographical proximity a crucial factor in knowledge creation. Short distances bring people together and enable them to exchange tacit knowledge. This leads to the development of localized knowledge pools, which are in turn characterized by personal contacts and informal information flows, both within and between firms of the knowledge economy. The spatial concentration of these information-flows influences scanning and learning patterns, as well as the sharing of localized knowledge and the innovation capabilities of knowledgeintensive firms (Howells 2000: 58).

4.2.3 Exploiting Network Economies

Codified knowledge can be applied, expressed and standardized. Hence, it is a marketable good that can easily be distributed over time and space. New information and communication technologies offer the opportunity to increasingly codify and commodify knowledge and make it tradable across long distances, which means that codified knowledge becomes more and more de-territorialized. This enables companies to source activities and inputs globally and to benefit from relational proximity and international knowledge spill-overs. Tacit knowledge, in contrast, refers to knowledge, that cannot be easily transferred. It comprises skills based on interactions and experiences. Tacit knowledge and personal experience are necessary in order to make use of codified knowledge in creative and innovative processes (Schamp 2003: 181).

The functional logic of the knowledge economy not only has a significant impact on agglomeration economies, but also on global network economies. Although there is strong evidence that knowledge is highly concentrated in a minority of city-regions, it is unlikely that all the knowledge required by a firm for innovation can be found within a single region. Companies have to spread activities globally to source inputs and to gain access to new markets. Hightech industries, for example, use global sourcing to improve existing assets or to create new technological assets by locating R&D facilities abroad (OECD 2008: 10). In order to realize global sourcing strategies successfully, relational proximity – especially organizational and time proximity – is important. Organizational proximity is needed to control uncertainty and opportunism in the knowledge creation process (Boschma 2005: 65). It creates a sense of belonging, which facilitates interaction and offers a powerful mechanism for long-distance coordination (Torre and Rallet 2005: 54). Therefore trust plays a crucial role (Amin and Roberts 2008). Time proximity, on the other hand, is supported by a rich and diversified infrastructure of global travel and communication, such as rapid and frequent trains and flights, and easy access to interactive communication facilities. It covers important aspects of 'being there', but it does not demand enduring co-location and local embedding (Amin and Cohendet 2004: 105).

All in all, the spatio-economic behaviour of knowledge intensive firms has led to the emergence of a globalised city network. Two major world city network approaches are of particular importance for this paper. The first approach is John Friedmann's (1986) ‘world city’ concept, which focuses on the decision-making activities aergnd power of TNCs in the context of the international division of labour. He argues that ‘key cities throughout the world are […] ‘basing points’ in the spatial organization and articulation of production and markets’ (Friedmann 1986: 71).

The second approach is Saskia Sassen’s ‘Global City’ concept, which associates cities with their propensity to engage with the internationalization and concentration of APS firms in the world economy (Sassen 2001: 90). Sassen (1994) defines global cities as ‘strategic sites in the global economy because of their concentration of command functions and high-level producer-services firms oriented to world markets' (Sassen 1994: 145).

The empirical part of this book chapter applies Taylor’s ‘world city network’ approach to analyse global connectivity (Taylor 2004). This approach provides an empirical instrument for analysing inter-city relations in terms of the organizational structure of knowledge-intensive firms and complements the approach of physical accessibility.

4.3 Knowledge hubs: Result of or Precondition for Knowledge Creation?

As shown above the process of knowledge creation is a key driver for innovation and economic development. However, knowledge is generated in networks where people and organizations interact. Castells (2000: 442) argues “that our society is constructed around flows” and these “Flows are not just one element of the social organization: they are the expression of processes dominating our economic, political, and symbolic life [...].” According to this statement, knowledge hubs emerge from the process of knowledge creation by a convergence of global flows of information and regional knowledge spill-overs. Thus, knowledge hubs are considered as a precondition for accessing information and partners along the value chain and, therefore, enable knowledge production. In general, accessibility is an externality that enables firms to reduce costs (de Bok and van Oort 2011: 9) and enlarge their market areas and, therefore, to realize economies of scale and economies of scope, which in turn generate economic growth (Axhausen 2008: 7‑10). Specifically, accessibility enables firms to source knowledge from different parts of the world and from the urban area they are located in. Hence, a circular cumulative causation (Myrdal 1957; Hirschman 1958) is initialized because the gains from economic growth usually are reinvested in technological infrastructure, human capital and the knowledge base, which lead to further improvement of accessibility in both the physical and non-physical dimensions.

To conclude, we define knowledge hubs as urban areas with a vertical integration in functional networks. At the same time they have vibrancy in a horizontal dimension, which we refer to as the regional dimension. Therefore a knowledge hub is an urban area, which is simultaneously vertically integrated into functional networks that reach beyond the metropolitan scale and generates territorial spill-overs within its urban area (Castells 2000; Bathelt, Malmberg and Maskell 2004; Growe and Blotevogel 2011).

The notion of hubs derives from transportation and network analysis. Whereas O’Kelly (1998) analyses the hub-and-spoke system of transportation networks, Barabási and Albert (1999) develop the analytical-mathematical approach. They showed that networks such as the World Wide Web tend to have a few actors with a large number of connections. Based on this finding these actors were defined as hubs (Barabási and Albert 1999). Derived from this method publications in urban geography treated cities as hubs to understand their position and importance within a system (Schmidt 2005; Hesse 2010; Growe and Blotevogel 2011; Redondi, Malighetti and Paleari 2011). Two main strands exist in considering cities as hubs: first, the integration in networks of physical and, second, non-physical interactions. The physical interactions are given by passenger travel or trade of goods, the non-physical connections are enabled by ICT or internal and external firm networks.

Since studies of relations between world cities were carried out, the interrelation between physical and non-physical has become evident. Derudder (2006) stressed this interplay with a comparison of infrastructural and organizational approaches to assess the world city network. On the global scale of world cities much effort was made to investigate the network structures of airline passengers (O'Connor 2003; Mahutga et al. 2010). Derudder and Witlox (2005) have shown that these data are prime source in order to figure out the central cities within a network. In a further analysis Derudder et al. (2007) state that the network structure of air connections reflects the patterns of the world city system according to the studies of Taylor (2004), however, the strategic thinking of airlines might lead to a change of this system (Derudder and Witlox 2008). Therefore, the 'hub-and-spoke model as a whole may become somewhat dissociated from the major origin/destination nodes in the network, hence the appropriate designation of these hubs as 'new network cities'' (Derudder, Devriendt and Witlox 2007: 318). This finding raises the question to which extent passenger travel will affect the regional economy.

Droß and Thierstein (2011) as well as Goebel et al. (2007) discussed these effects of airline networks. Airports attract knowledge intensive firms, which in turn drive spatial development (Button and Taylor 2000; Goebel, Thierstein and Lüthi 2007; Haas and Wallisch 2008; Kramar and Suitner 2008; Schaafsma 2009, 2008; Schaafsma, Amkreutz and Güller 2008; Droß and Thierstein 2011; Conventz and Thierstein 2014). Such firms demand both diverse pools of labour, which are to be found in agglomerations, and high access to global markets provided by airports and strategic links between firms on the other hand. Beyond these analyses, which indicate a strong interrelation between network structures and the effects on spatial development, they further imply that there is a strong dependency between the physical and the non-physical interrelations. For example, Tranos (2011) shows that there is a strong relation between Internet backbones and aviation networks (Tranos and Gillespie 2011). Derudder and Witlox (2005) analyse aspects of the World City Network given by the Interlocking Network Model and its interrelation with air travel - although the direction of causality remains somewhat open (Tranos and Gillespie 2011; Tranos 2011). Nevertheless, network economies and agglomeration economies give a strong theoretical background for this relationship since both concepts provide elements for cumulative causation.

4.4 Accessibility: An Approach with Non-physical Connectivity

As mentioned above, accessibility plays a crucial role for the exploitation of externalities and is considered in a physical and non-physical dimension. Physical accessibility is given by the potential to reach a population via air, rail or road traffic. Non-physical accessibility is defined by the Interlocking Network Model (Taylor 2004). This model conceptualizes hypothetical information flows between cities and reflects the degree of integration in global information flows, which is also referred to as the connectivity of a city. Furthermore, physical accessibility can be associated with network economies and agglomeration economies. Whereas rail and road accessibility work on the scale of agglomerations, accessibility by air enables network links to worldwide locations.

4.4.1 Physical Accessibility

Data on physical accessibility was originally calculated by the European Spatial Planning and Observation Network (ESPON) for NUTS 3 level. Here, accessibility is defined by ‘how easily people in one region can reach people in another region’ (ESPON 2009: 4). This calculation indicates the potential for activities and enterprises in the region to access markets and activities in other regions. It was calculated by reckoning the population in all other European Regions, weighted by the travel time (ESPON 2009: 7). This so called potential measure was introduced by Hansen to indicate opportunities for interaction (Hansen 1959). The potential measure is considered useful for exploiting network and agglomeration externalities. Geurs and van Eck (2001) compiled a detailed catalogue of further accessibility measures, which also take production functions of consumers and activity based approaches into account

The accessibility values used here are indexes calculated for 27 members of the European Union. A value below 100 indicates an accessibility factor which is lower than the European average. In contrast, values above 100 represent accessibility above the European average. These data from NUTS 3 regions were converted to the spatial units of Functional Urban Areas (FUA) to combine them with data from intra-firm networks. Hence, accessibility data of FUAs reflect an area weighted average of data from NUTS 3 regions. FUAs are agglomerations, which are defined by an average commuting time of 60 min around a defined centre (ESPON 2004).

Figure 4.1 shows a comparison of multimodal accessibility of NUTS 3 entities on the left hand side and FUAs on the right hand side. Multimodal accessibility includes potential accessibility by road, rail and air traffic. The regions with highest accessibility are concentrated around metropolitan areas and reach values of 150 and more. Regions with low accessibility can be found in the region between Berlin, Hamburg, and Hanover, as well as next to the national borders in the east and north. However, these regions still yield values that are just slightly below the European average.

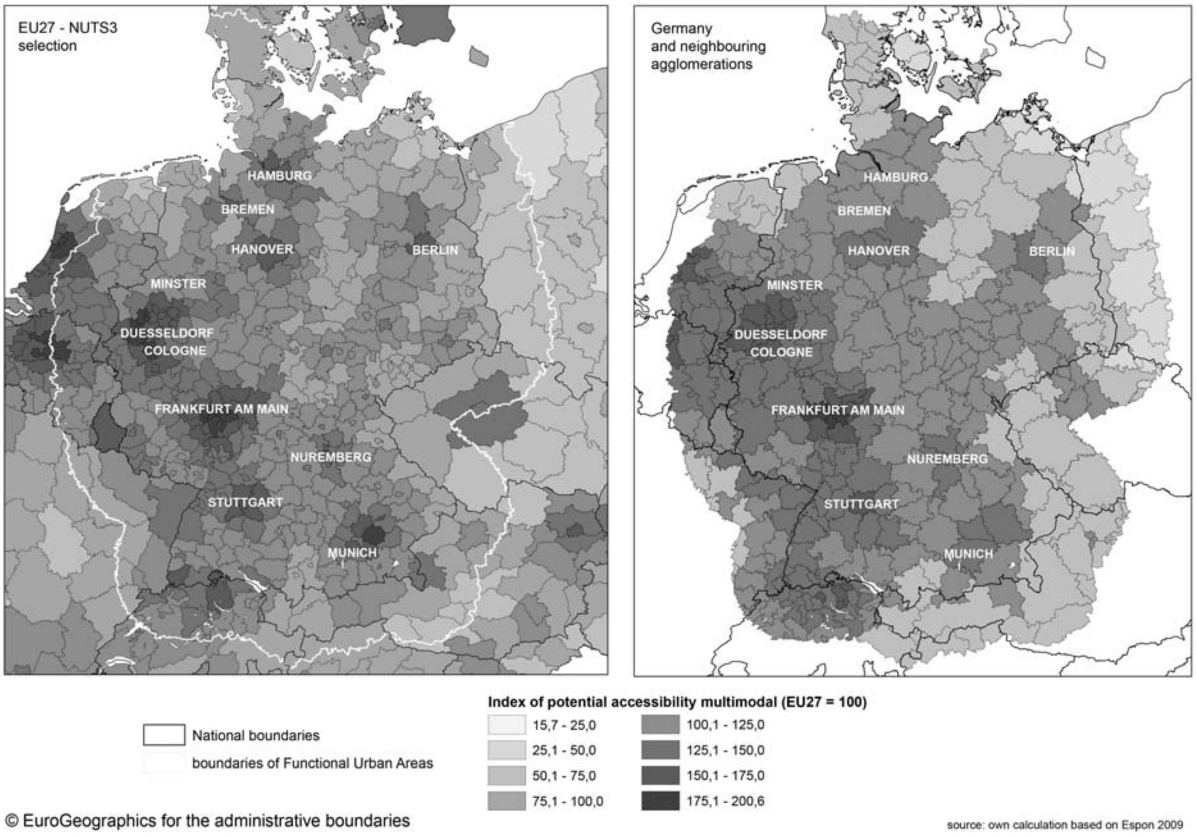

Figure 4.1 Calculation of accessibility for Functional Urban Areas (Source: own calculation based on ESPON (2009))

It can be assumed that Germany, due to its dense population distribution, is well served with physical infrastructure on the one hand and provides good access to several modes of traffic on the other. Whereas road and rail offer a ubiquitous supply and tend to improve accessibility on the regional scale. Data on rail access include regional and supra regional connections. Therefore this mode seems to be ubiquitous. Taking the development of high speed rail in recent years into account might evoke greater regional disparities. Airports and their accessibility are concentrated in metropolitan areas in the western part of Germany. In order to define hubs of physical accessibility air access plays a crucial role, because it is a unique selling position.

4.4.2 Defining Non-physical Connectivity

The analysis of intra-firm networks is based on the methodology of the Globalisation and World Cities Study Group (GaWC) at Loughborough University (Taylor 2004). This approach estimates city connectivities from the office networks of multi-city enterprises. Intra-firm networks are spatially distributed branches of one individual corporation. The basic premise of this method is that the more important the office, the greater its flow of information to other office locations. The empirical work comprises three steps. In the first stage of the empirical work, we had to create a reliable company database in identifying the biggest APS and high-tech firms which operate in Germany and collected information about the importance of their locations worldwide within the firm network from the websites, the so called service values which a location has. The result of this process was a basic set of 270 APS firms and 210 high-tech enterprises.

In the second stage, we developed a so called ‘service activity matrix’. This matrix is defined by FUAs in the lines structured along the regional, national, European and global scale, and knowledge-intensive firms in the columns. Each cell in the matrix shows a service value (v_{ij}) that indicates the importance of a FUA (i) to a firm (j). The importance is defined by the size of an office location and its function. By analysing the firms' websites, all office locations are rated on a scale of 0 to 5. The standard value for a cell in the matrix is 0 (no presence) or 2 (presence). If there is a clear indication that a location has a special relevance within the firm network (e.g. regional headquarter, supra-office functions) its value is upgraded t 3 or, in the case of even greater importance, to 4. The enterprise headquarters was valued at 5. If the overall importance of a location in the firm-network is very low (e.g. small agency in a small town) the value is downgraded to 1.

In the third stage, we used Taylor's interlocking network model to estimate connectivities of FUAs (Taylor 2004). Network connectivities are the primary output from the interlocking network analysis. The measure is an estimation of how well connected a city is within the overall intra-firm network. There are different kinds of connectivity values. The connectivity between two FUAs (a, b) of a certain firm (j) is analysed by multiplying their service values (v) representing the so called elemental interlock (r_{abj}) between two FUAs for one firm:

$$\mathrm{r_{abj}} = \mathrm{v_{aj}} \times \mathrm{v_{bj}} \qquad (1)$$

To calculate the total connectivity between two FUAs, the elemental interlock for all firms located in these two FUAs is summarized. This leads to the city interlock (r_{ab}):

$$\mathrm{r_{ab}} = \sum \mathrm{r_{abj}} \qquad (2)$$

Aggregating the city interlocks for a single FUA produces the interlock connectivity (N_a). This describes the importance of a FUA within the overall intra-firm network.

$$\mathrm{N_a} = \sum \mathrm{r_{ai}} \;\; (a \neq i) \qquad (3)$$

From this calculation we obtain an indicator of integration within several networks. Figure 4.2 shows the connectivity to surrounding neighbours and to global locations. Surrounding neighbours are defined by the Rook Contiguity of first and second order. Given a certain FUA, rook contiguity includes the first order neighbours by sharing a common border with the given FUA. The second order neighbours are those, which border to these FUAs of first order. The values shown here are the city interlocks normed to highest values on each scale and sector to either the surrounding neighbours or locations outside Europe on the global scale.

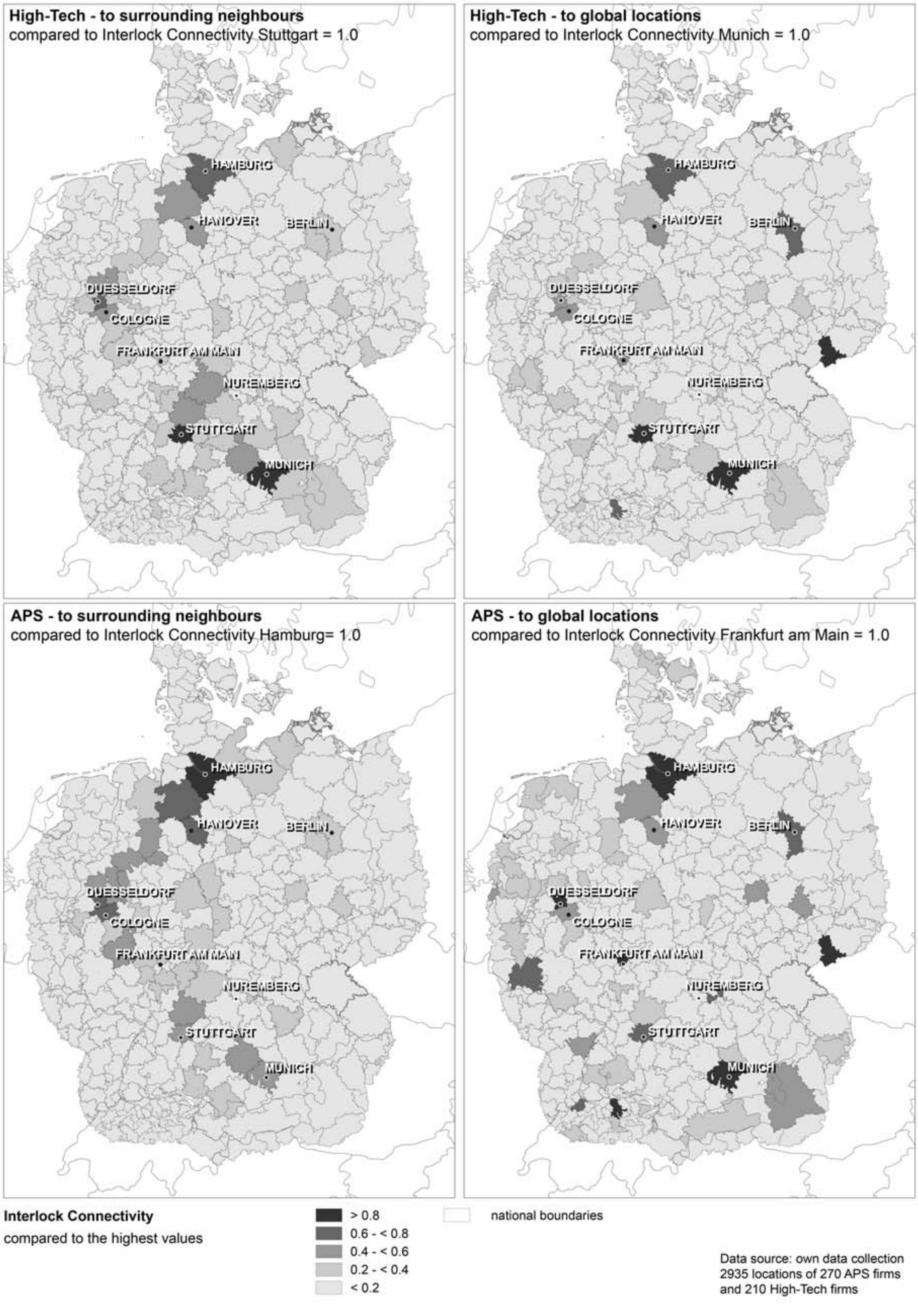

Figure 4.2 Interlock connectivity of APS and high-tech sectors on the regional and global scale (own calculation)

Values for some FUAs such as Hamburg, Munich and Stuttgart are always high on both scales and in both the APS and high-tech sectors. APS-firms tend to organize an area-wide distribution. For example banks offer services even in the smallest FUAs, which lead to high connectivities on the regional scale such as in the area between Hamburg, Düsseldorf and Frankfurt. Nevertheless, global activities are concentrated in a small number of centres.

When considering high-tech by itself, such regional/global opposition is not evident. Regions, which have intensive interaction with neighbouring agglomerations also show strong connections to global locations. Some exceptions can be detected in the southern parts of Germany. In particular, regions between Stuttgart, Nuremberg, and Munich have high values on the regional but not on the global scale. This might be explained by a high concentration of suppliers close to automotive sector plants in the southern part of Germany. All in all, hubs for non-physical connectivity for APS are Hamburg, Frankfurt, Munich, Düsseldorf, Stuttgart and Berlin. For high-tech these are Munich, Stuttgart, Hamburg and Berlin.

4.5 The Interplay between Physical Accessibility and Non-physical Connectivity

As mentioned above we define knowledge hubs as urban areas at the intersection of physical and non-physical networks, because knowledge creation depends on the interplay between codified and tacit knowledge, since people require experienced based knowledge to understand and adapt codified knowledge. Accordingly, there is also an interplay between physical movement of people and the non-physical exchange of information (Beaverstock et al. 2010). To assess this interplay a correlation analysis is carried out. Figure 4.3 illustrates the set of variables which are used. All variables are grouped thematically. Population and employment are indicators of agglomeration. Road, rail, and air access indicate the potential link-up in physical networks. Finally the group of variables of nonphysical networks represents the intra-firm networks on different scales. The regional scale is defined by the interlock connectivity to surrounding neighbours. The national scale is given by the boundaries of Germany. The European scale contains all countries of the European continent and the global scales are all other locations. Since the variables are nearly normally distributed, we employed a bivariate Pearson correlation in order to evaluate interrelations between variables.

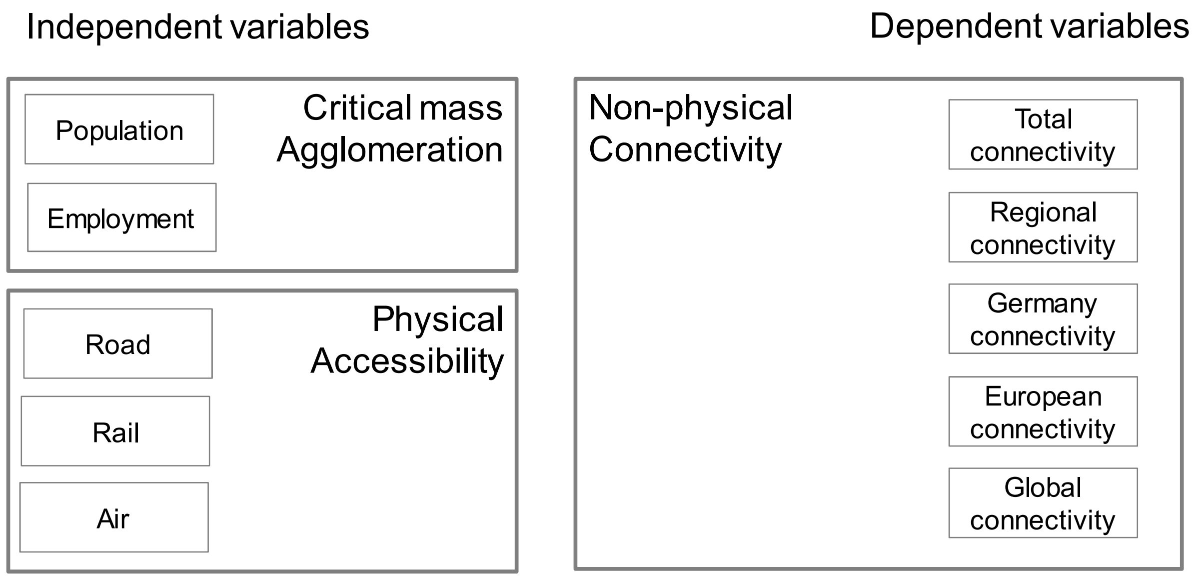

Figure 4.3 Set of variables and methodological proceeding

There is a strong interdependence between critical mass and integration in networks. This is investigated in the first stage. Simply put, the bigger a region the more companies it hosts. Therefore Figure 4.4 shows a comparison of correlations between interlock connectivity, accessibility, and population as well as employment and population. When calculating the correlations to the latter variables, we excluded all FUAs which are not in Germany because homogenous data for employment is not accessible. Correlation between non-physical interaction and accessibility data are calculated for the whole of Germany and neighbouring agglomerations. Most importantly, correlations are listed when they exhibit significance at or above 95 per cent.

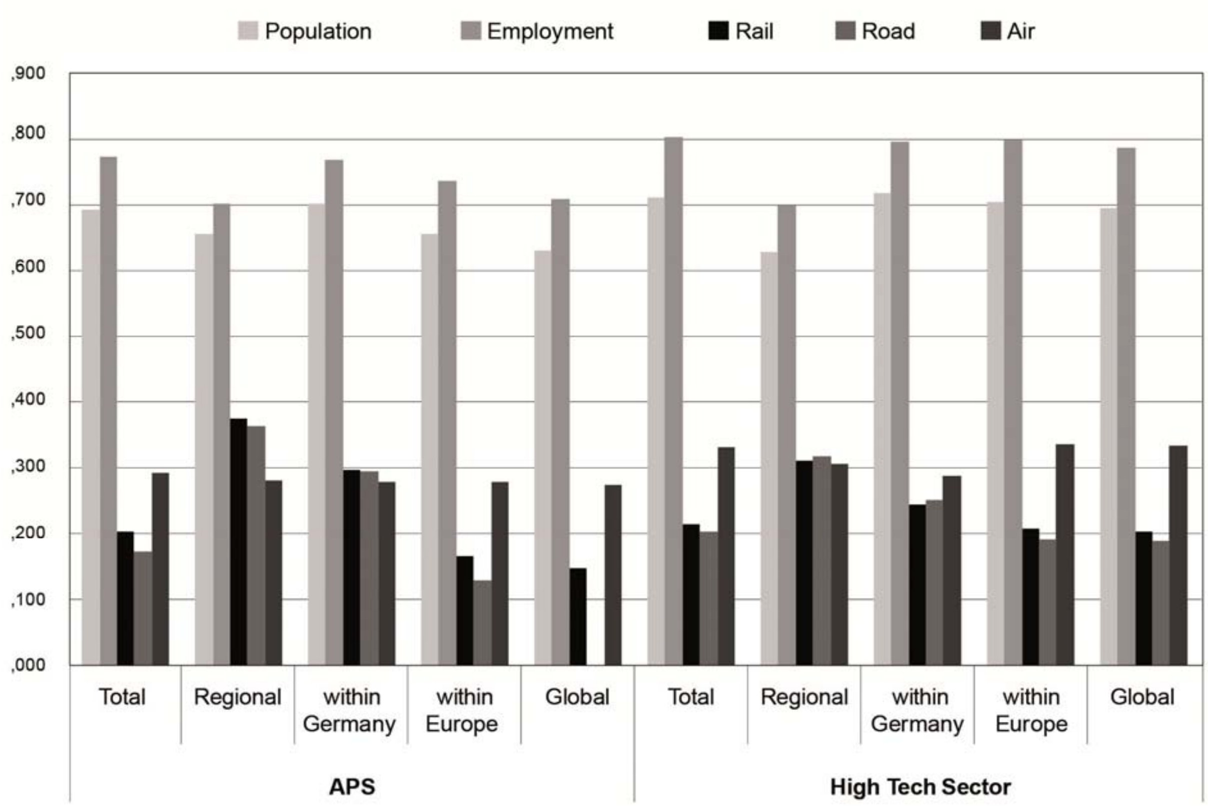

Figure 4.4.: Correlation between interlock connectivity on different scales, accessibility by different modes, population, and employment (own calculation)

This analysis is carried out on different spatial scales, from the regional to the global scale. These scales do not overlap. As previously mentioned, the strongest correlations are exhibited with population and employment. These results give a reference to the correlations with accessibility modes. With regard to listed spatial scales and their dependency, firstly, the higher accessibility via rail and road, the stronger connections to surrounding neighbours are. This result is attributable to the high values of interlock connectivity within metropolitan regions. We have seen that the Rhine-Ruhr possesses a dense network of rail and road. Above all, especially in high-tech, this area as a whole shows dense non-physical interaction.

Secondly, as expected, correlation coefficients with road and rail decline steadily with increasing distance from the regional to the global scale in both high-tech and APS. In particular, APS correlations lose importance the wider intrafirm networks extend. Similarly, high-tech confirms this trend, but still shows significant interrelations with rail and road access on the global scale, which might be explained by rather high concentration of physical infrastructure such as motorways and railway lines for logistics around production plants than by the actual use of these transport modes for global activities. Basically, firms within this sector operate globally, which collocates with transport infrastructure, and therefore correlation coefficients might be higher on that scale.

Thirdly, correlations to air access do not differ between the several scales. Undoubtedly they are significant but do not confirm the expected impact of growing air access on the European and global scale.

In summary, although ICT have the potential for ubiquitous access to information, localized transportation infrastructure remains important for economic performance because it enables geographical and relational proximity. This in turn leads to different preconditions between regions. As Törnqvist (1968) noted, the ‘most important contacts [...] demand direct personal contacts between personal, and thus passenger movement’ (Törnqvist 1968: 101). Other modes of interaction, such as telecommunication, are no substitute for face-to-face contacts. The hypothesis that air access remains the most important factor and that air access is a more relevant factor for interactions outside Germany requires clarification. In the case of APS, its influence on connectivity does not change along the spatial scales. Contrastingly, correlations to road and rail decrease uniformly. Hence the relative importance of air access compared to other modes of accessibility increases the wider the scale is. Furthermore, critical mass is slightly less important.

4.6 The Spatial Complementary in Knowledge Production

Since physical and non-physical network links converge in knowledge hubs these cities also capture a functional position within this system. Therefore, we analyse, firstly, the coexistence of diversified and specialized FUAs and, secondly, the relations between firms and their external partners along a stylized value chain. Figure 4.5 shows the Hirschman-Herfindahl-Index (HHI) of knowledge intensive branches. The HHI ranges between 0 and 1. Value 1 indicates that knowledge intensive employment is concentrated in one branch and the region is strongly specialized. The opposite is a diversified region, which is indicated by values close to 0. Thus, the HHI is used as an indicator of localization economies (values close to 1) and urbanization economies (values close to 0) ((Beaudry and Schiffauerova 2009: 321). According to the HHI the FUAs of Wolfsburg and Ludwigshafen are the most specialized ones in our data sample. Wolfsburg reaches, due to its high concentration of automotive related firms, a value of 0.59 and Ludwigshafen, famous for production in chemistry and pharmaceuticals, has a value of 0.45. The lowest values and, therefore, the most diversified employment are to be found in the FUAs of Munich, Hamburg, Hannover, Dusseldorf and Cologne. At the same time these FUAs have the highest interlock connectivities (see Figure 4.2). Furthermore the specialized FUAs of Ingolstadt, which is located north of Munich, and Wolfsburg located east of Hanover are located quite close to the diversified FUAs of Munich and Hanover. Because of this geographical proximity between specialized and diversified regions we assume that there is a distinct inter-relation between them (Brandt et al. 2008; Thierstein et al. 2011).

A similar investigation was carried out by (Growe 2010) who showed that agglomerations can have either a surplus or deficit of ‘functional importance’ in employment in advanced producer services, which implies that there might be a spatial division of labour between those agglomerations, which show a surplus and those, which have a deficit in order to complement the value chain of knowledge production (Growe 2010: 12‐15). To ground the assumption we compare our analysis of employment with the distribution of the elements of a standardized value chain.

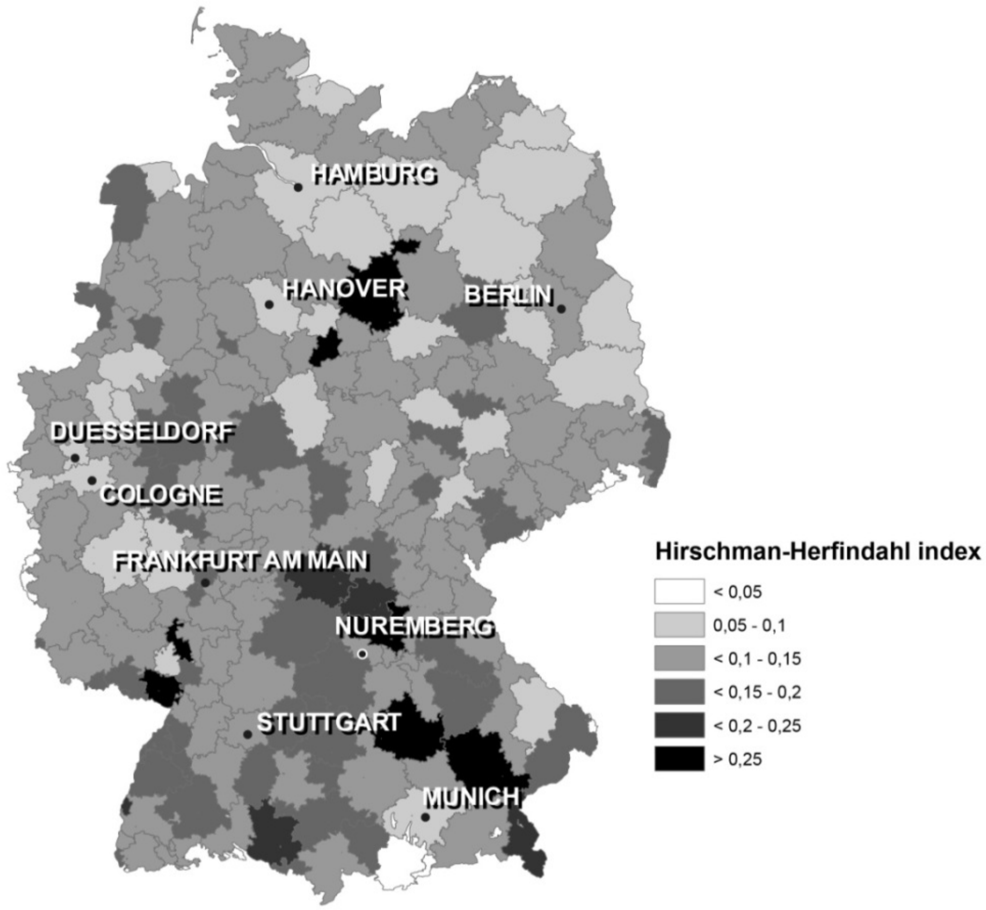

Figure 4.5: Hirschman-Herfindahl-Index of knowledge intensive employment (Source Bundesagentur für Arbeit 2010)

To investigate this assumption we present the results of the web survey in which knowledge intensive firms were asked where their partners are located along a stylized value chain with the elements 'research & development', 'processing', 'financing', 'marketing', 'sales & distribution' and 'customers' (Lüthi, Thierstein and Bentlage 2013). The complete analysis was published in (Lüthi 2011: 136‑139). All in all, 331 firms indicated 1346 value-adding activities. In Figure 4.6, a value chain element is mapped only if it reaches the highest LQ within the FUA and ‑ at the same time ‑ if it received at least 4 references in the questionnaire. Hence, the map shows a selection of the questionnaire and it contains the relative functional specialization in the German space economy, with Munich, Stuttgart, Frankfurt and Hamburg having outstanding intensities of high value-added activities such as R&D, financing and marketing. In Nuremberg, Dresden and Mainz, there is a relative concentration of processing, while customers of knowledge-intensive companies are mainly located in Berlin, Hanover and in the Rhine-Ruhr region.

Figure 4.6: Map of value-adding activities in the FUAs of Germany (own calculation)

Summing up, we showed that there is a coexistence of specialized and diversified FUAs in Germany. First, the coexistence of diversified and specialized FUAs in a geographical proximity implies a relatedness of those regions. Referring to Duranton and Puga (2000) specialization and diversification are elements of a mutual process. Therefore, knowledge hubs emerge through the relations between those FUAs. Secondly, the analysis of the value chain verifies this finding. We assume that the entire production of goods and services has to combine all elements of the value chain. Since these are distributed unequally in space, firms tend to complement their value chain by interacting with partners.

4.7 Conclusion

When taking the non-physical dimension into account there are only a few FUAs in Germany, which can be called a hub. For APS these are Hamburg, Frankfurt, Munich, Dusseldorf, Stuttgart and Berlin and for high-tech these are Munich, Stuttgart, Hamburg and Berlin. Since the process of knowledge production takes part in a strong interplay between physical and non-physical interaction in order to combine tacit and explicit knowledge. Taking the physical accessibility into account the access by air traffic plays a crucial role for knowledge hubs. Therefore FUAs such as Frankfurt and Munich appear as hubs. Airport cities emerge as a functional spatial configuration from this development (Schaafsma, Amkreutz and Güller 2008). Nevertheless, APS firms on the whole tend to concentrate and operate intensively on the national scale. In particular, banks and insurance firms are distributed areawide to supply their services.

Both APS and high-tech firms operate on a global scale to combine the advantages of agglomeration and network economies. Nevertheless, differences between both sectors are observable. High-tech firms on the whole are not fixed to the national markets to offer daily supplies in the way APS firms often do. Our results show that there is relatedness between specialization and diversification of FUAs. The degree of diversification is higher in strongly connected FUAs such as Munich, Hamburg or Dusseldorf, where also a large number of advanced producer services firms are located. Specialization is mainly to be found in less connected FUAs with high employment in high-tech firms. So, high-tech firms and their economic activities concentrate in certain FUAs such as Wolfsburg and Ludwigshafen. Although these FUAs are not equipped with high accessibility by air and, furthermore, they do not capture strong non-physical connectivity, they still assume an important position in a functional and spatial division of labour. Therefore those specialized FUAs obtain a hub-like significance. Both processes ‐ specialization and diversification ‐ seem to complement each other. From a theoretical point of view these findings suggest that urbanized economies benefit from a process of urbanization economies and localization economies.

However, high-tech firms also optimize value chains that have high stakes in production worldwide because the share of physical labour within the production process is supposed to be higher than in APS. Therefore, production is often carried out in locations with lower wages and the co-existence of a highly qualified workforce, such as in India or South-East Asia, and therefore the correlation of air access and interlock connectivity show significant values.

Reflecting Richard Florida's hypothesis that the world is spiky, our results offer an indication of how strongly physical infrastructure influences business operations in the knowledge economy. Indeed, an uneven supply of physical infrastructure, such as airports or other modes of transportation, initializes a cumulative causation. Higher accessibility leads to wider market areas of firms and fosters economic performance, which in turn enables further investment in physical infrastructure. Furthermore, the direction of causation is mutual, because wider market areas in knowledge intensive business activities also require the physical presence of knowledge workers.

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5 Revealing relevant proximities

Knowledge networks in the maritime economy in a spatial, functional and relational perspective

Forthcoming:

Bentlage; Michael, Wiese, Anne, Brandt, Arno, Thierstein, Alain and Frank Witlox (2014, forthcoming): Relevant proximities. Knowledge networks in the maritime economy in a spatial, functional and relational perspective. In: Raumforschung und Raumordnung

Abstract

The maritime economy as a heterogeneous innovation system has ongoing relevance to the successful spatial and functional development of regions in Europe. A strong technological knowledge base underpins the competitiveness of maritime economy which is grounded in distinct spatial structures and proximities. The simultaneous relevance of global and local knowledge is particularly pronounced in the maritime economy through its inherent relevance to globalization and structural change. Conventional classifications of the maritime economy embedded in the discussion of the spatialization of knowledge intensive activities and global value chains, however, limit the analysis to certain parts of the maritime cluster. This paper looks at the applicability of various discourses on interactive knowledge generation and application as a process, based on a comprehensive dataset derived from cooperative links within the maritime economy of northern Germany. It suggests a framework for analysis, which is activity based and focused on the concurrent presence of different dimensions of proximity across value creating systems. We explore spatial patterns by means of social network analysis, which are industry-specific and have the potential to inform efforts to increase functional as well as physical connectivity in region. The empirical analysis sets out from the individual firm as an actor seeking to optimize its location for the purpose competitiveness. It proposes an approach, which is routed in the ongoing discussion on spatial and functional dispositions for innovation activity and bridges the dichotomy of knowledge intensive services and manufacturing activities in the maritime economy.

Keywords:

Maritime Economy, Knowledge Networks, Spatial Development, Proximity, Urban System, Germany

My contribution:

- Conceptualizing the article and defining the research question
- Discussing the theoretical background
- Statistical analysis and interpretation

Die Relevanz von Nähe: Wissensvernetzung in der maritimen Wirtschaft aus räumlicher, funktionaler und relationaler Perspektive

Die maritime Wirtschaft als ein heterogenes Innovationssystem hat großen Einfluss auf die räumliche und funktionale Entwicklung von Regionen. Die stetige Weiterentwicklung der Wissensbasis in der maritimen Wirtschaft steht in enger Verbindung mit räumlichen Strukturen und deren Verflechtung. Dabei ergänzen sich Wissensressourcen auf verschiedenen Maßstäben von lokal bis zu global gegenseitig. Konventionelle Klassifizierungen der maritimen Wirtschaft auf Grundlage der Wirtschaftsbereiche reichen dazu nicht aus, um die ‚Verräumlichung' von Wissen zu verstehen. Eine relationale Perspektive auf Wissensnetzwerke im Zusammenhang mit dem realen Austausch von Gütern ist eher in der Lage, dieses Verständnis zu fördern. Dieser Beitrag versteht die Wissensproduktion als interaktiven Prozess, der eng mit der Produktion von Gütern verflochten ist, und untersucht die Anwendbarkeit verschiedener Wissenskonzepte auf die Kooperationsnetzwerke in der maritimen Wirtschaft in Deutschland. Dabei erarbeiten wir Herangehensweise, die sich mit den Funktionen und Tätigkeiten der Unternehmen und Forschungseinrichtungen auseinandersetzt und dabei Zusammenhänge von räumlicher und relationaler Nähe analysiert. Wir wenden dabei die Soziale Netzwerkanalyse im räumlichen Kontext an. Dadurch wird ersichtlich, dass das Netzwerk der maritimen Wirtschaft hauptsächlich von Dienstleistern, Schiffsbauern und Forschungseinrichtungen zusammen gehalten wird. Die Städte in Norddeutschland formen dadurch im Ansatz ein hierarchisches Netzwerk, in dem Hamburg die höchste Bedeutung hat und als Gatekeeper funktioniert. Jenseits dieser hierarchischen Netzwerkstruktur etablieren sich spezialisierte Standorte entlang der Ems-Achse.

Keywords:

Maritime Wirtschaft, Wissensvernetzung, Raumentwicklung, Nähe, urbane Systeme, Deutschland

5.1 Introduction

The spatial organization of industrial activities has undergone dramatic change in the past 50 years (Dicken 2011). Globalization and the rise of information and communication technologies (ICT) have propelled the restructuring of value chains and knowledge networks (Derudder and Witlox 2010; Brown et al. 2010). The maritime economy has been instrumental to economic change and the formation of the urban system in Germany by producing knowledge and innovations for centuries. Recently, structural change has propelled the integration of specialized services that facilitate the flow of information and goods. The locational behavior and the importance of these for the maritime economy have been explored by Jacobs, Koster and Hall (2010) and Jacobs, Ducruet and De Langen (2010). This development process concurs with the restructuring of port activities and the rise of port city-regions (Notteboom and Rodrigue 2005) as relevant units, marking a process of *up-scaling* and phenomenological alignment with emerging Mega-City Regions (Hall 2007b: 5-8). The spatial configurations, which drive and are being driven by changes in the industrial organization of the maritime economy, could reveal relevant interdependencies for the future development of port cities and their hinterland.

The term ‘maritime economy’ encompasses economic and research activities such as ship building, logistics and ports, off-shore energy supply, shipping companies, education and specialized services. This economic field is one of the growth engines for a country such as Germany, in which exports and trade are fundamental for economic success. Historically, the maritime economy in Germany traces back to the networks of the Hanse, which reached across the Baltic Sea and to Scandinavia. This network enabled to secure shipping and trading commodities between port cities such as Hamburg, Bremen, Danzig in Poland or Bergen in Norway. The end of the 19th century and the beginning of the 20th represented one of the most successful periods for shipping and trading activities so far. After World War II the German production of aircrafts and ships were closed down. In the year 1951 ship building in Germany was liberalized again (Verband Deutscher Reeder 2007). The reconstruction of Germany, increasing trade with locations abroad and the strengthening of the shipping industry were closely linked to one another. The containerization of trade fostered the position of Hamburg as one of the biggest ports in the world. Accordingly, German ship owners became powerful while managing ship fleets all around the world (Brandt 2011: 33-36). The German ports nowadays are involved in a distinct division of labor. Besides Hamburg the ports in Bremen and the JadeWeserPort in Wilhelmshaven are specialized in container shipping and act as main hubs for the German hinterland. These ports of the Northern Sea account for 80 percent of the German commodity exchange. The ports in Emden and Cuxhaven are specialized in shipping of cars (Brandt 2011: 98).

By means of its logistic service, the maritime economy is the “plumbing” of globalization, as 90 percent of goods are traded by ships (Rodrigue 2013: 160). On an aggregated level, the maritime economy, which is heterogeneous in terms of its knowledge bases, represents a complex innovation system in which physical flows of goods are interwoven with a non-physical dimension of knowledge in transfer. Therefore, the maritime economy provides a unique opportunity to assess the spatiality of knowledge networks, which reach beyond the facilities of ports (Hesse 2010; Brandt, Dickow and Drangmeister 2010: 241). On the one hand, the literature suggests that knowledge spillovers require face-to-face contacts for economic success. This understanding was established in the field of agglomeration economies (Eriksson 2011) and evolutionary economics (Buchman and Martin 2010). However, it has been argued elsewhere that a further differentiation in accordance to knowledge types is needed to explain the spatial organization of economic activities (Growe 2012; Zillmer 2010). Therefore, an industrial process-based approach is more applicable (Bryson and Daniels 2010; Amin and Cohendet 2004). Besides the instrumental involvement of the maritime economy in the process of globalization, this economic cluster includes a broad variety of knowledge-intensive activities and therewith affects spatial development in Germany from three different perspectives: spatial, functional and relational.

From a spatial perspective, the maritime economy shapes the interrelation of cities and ports. Innovations and new technologies have fundamentally re-structured this relationship. The ongoing extension of commodity chains has led to a further increased integration of ports in global production networks (Hall and Jacobs 2012, 2010). At the same time, global trade demands accessibility of large vessels and new port facilities, re-shaping coastlines. This process comes along with an expansion of the hinterland of a port (Hall and Jacobs 2012) to underpin the ports functionality. The recent urban transformation at the waterfront of cities such as Hamburg and Bremen is mainly driven by the reorganization of port activities and the rise of service activities. However, the physical presence of the maritime economy not only revolves around port facilities but also includes activities in financial centers or places remote to coastal areas where further actors such as research institutions or logistic partners are located (Brandt, Dickow and Drangmeister 2010: 238). Thus, the multiplicity of the maritime economy affects spatial development by a number of parallel processes and historical events.

The functional perspective considers the maritime economy a heterogeneous innovation system that transcends the sectors around transport, services and manufacturing as well private and public actors. Furthermore, the maritime economy is strongly affected by structural change, which fosters the importance of advanced producer services as intermediates in the production process, the relocation of labor intensive parts and new development paths such as the wind energy (Fornahl et al. 2012). These developments affect the functional interfaces within the maritime economy fundamentally.

The relational perspective puts emphasis on the knowledge networks of the actors of the maritime economy and considers knowledge creation as an interactive process. Since the value chains of this part of the economy reach from low-tech manufacturing to knowledge intensive industries, where knowledge production is a complex process that is strongly interlinked with the transformation and exchange of goods (Hall and Hesse 2013; Hesse 2013). Moreover, the nature of knowledge calls for a differentiated approach which takes into account that proximity is key for the transfer, application and generation of knowledge (Vissers and Dankbaar 2013). The more knowledge is based on experience and learning by doing, the more likely that actors seek for personal contacts and geographical closeness. Relational proximity is then used to complement this geographically bounded knowledge resources. In this regard geographic and relational proximity are counterbalanced in order to sustain learning processes and influx of new information (Malmberg and Maskell 2006: 8-9).

Transferring this process of knowledge creation in the maritime economy to spatial development, the question arises how different types of knowledge evolve indifferent patterns of proximity between urban centers in northern Germany.

By studying the activities contained within the maritime economy, we aim to improve the understanding of the ongoing differentiation of spaces initiated by the creation of knowledge in a highly complex economic field, which is deeply engrained in the identity of port cities. The question, therefore, arises how the different types of knowledge networks involve cities and regions in northern Germany into an urban system and ultimately affect spatial development in places even beyond port cities. Transformation of port cities, waterfront regeneration, logistic poles, port expansion, infrastructure planning and urban expansion leave a disparate image of European port cities in terms of economic success (Schubert 2009; Hein 2011; Hall 2007c). This research requires an analytical approach, which takes the heterogeneity of the maritime economy into account and further reflects innovation oriented cooperation on value-added relations. We apply a closer and inductive look at the composition and relationships within the maritime economy in order to evaluate the role of knowledge transfer for spatial development, the interdependence of activity fields and in between of spatial co-location and distant collaboration.

Thus, our research approaches the question of the spatial organization of the maritime economy from a spatial, functional and relational perspective. Firstly, we analyze the entire network of the maritime industry and how it devolves into certain sub-networks, which rely on sectorial composition and spatial qualities on a regional scale. Secondly, we investigate the functional engagement of the actors and how the different fields of activities are interrelated within the maritime economy. Thirdly, due to the fact that knowledge production is interlinked with the exchange and transformation of material goods we include value added characteristics in order to investigate the spatial range of the knowledge relations.

To gain insight into the character of activities and relationships within the maritime economy the second section elaborates the theoretical background of the analysis, discusses knowledge generation with regard to differences in the nature of knowledge and patterns of proximity and introduces the research hypothesis. Section three sketches the relationships among the activity fields involved in the maritime economy and introduces the set-up of analysis and the used data. Section four presents the empirical findings which demonstrate the validity of this differentiated approach by applying network analysis in order to study how knowledge interaction and spatial proximity are interrelated. The fifth section discusses the approach and methods used. Finally, the conclusion in section seven summarizes our findings with regard to the urban system in northern Germany.

5.2 Theoretical background: Knowledge creation and proximity

Our understanding of the maritime economy, in which knowledge production is interwoven with the trade and production of goods, and its relevance for spatial development processes is based on three constituent parts: firstly, the nature of its knowledge base and the catalytic effect of spatial and relational proximity. Secondly, the social process of knowledge creation, as it is interwoven with the production and trade of material goods. Thirdly, innovation as the valorization of generated knowledge in the form of a tradable product or service, driving economic development. This process of interactive knowledge generation evokes a complex interplay between spatial and relational proximity on different scale levels. The innovation system contains “the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge” (Lundvall 1992: 2). Therefore, we derive at an understanding in which the intersection of manufacturing, research and development and advanced services is emphasized.

5.2.1 The nature of knowledge

Knowledge is a production factor for both the input and the output side of value added (Amin and Cohendet 2004: 15). In order to transform knowledge into value, firms or people apply specific competencies. Knowledge as an output is provided for instance by scientific research. In order to study the spatial consequences of knowledge application and creation as well as collective learning further differentiation is required.

Since Polanyi (1966) published his work ‘The tacit dimension’ (Polanyi 1966), it is acknowledged that knowledge has a strong spatial relation, and that codified and tacit knowledge are mutually dependend (Kujath and Schmidt 2010). Whereas codified knowledge might be transmitted via ICT without any friction losses, tacit knowledge is considered as geographically located or socially embedded (Amin and Roberts 2008. Gertler (2003) provides three arguments for the spatial foundation of tacit knowledge: firstly, tacit knowledge is difficult to exchange over long distances since it is rooted in experiences one makes in learning processes. Secondly, it is context specific in terms of language, shared values or culture. Finally, the innovation process turns into social action in which learning structures become relevant and, thus, it involves institutions and organizations enabling access to learning (Gertler 2003: 78-79).

Gertler (2008) suggests a further distinction between analytic, synthetic and symbolic knowledge to capture the systematic differences in knowledge bases and innovation processes across industries. Analytical knowledge predominates in those industries where scientific knowledge derived from deductive models is highly important. This includes activities such as engineering and research. This type of knowledge tends to be codifiable and therefore less dependent on physical proximity for its exchange. Synthetic knowledge however, dominates in sectors where innovation originates from the application and re-combination of existing knowledge. This knowledge type is for example present in consulting activities, where services are individually customized based on previous experiences. It tends to be driven by specific problems, which arise from the interaction with clients and suppliers. The dependence on a particular context, set of routines and practical skills makes it less codifiable and more dependent on the tacit dimension. Hence, spatial proximity is considered a necessary prerequisite for the exchange of synthetic knowledge. Symbolic knowledge, which is applied in activities in media and advertising, is characterized by its strong semiotic and affective nature. It is highly context specific and its economic value arises precisely from its intangible character (Asheim, Coenen and Vang 2007), making it difficult to transfer across space. Due to its nature and association with the creative industries we consider it as not relevant for the maritime industries as defined by our sample.

5.2.2 Relevant proximities for knowledge creation

The literature on knowledge generation and innovation is closely related to Schumpeter's work on economic development (Schumpeter 1934). From a spatial perspective, the ability to produce and absorb knowledge is considered key to innovation and sustainable economic success. Moreover, the 'right' configuration of spatial and relational proximity is crucial for firm success (Nooteboom 2000; de Jong and Freel 2010; Schamp, Rentmeister and Lo 2004). As knowledge can take various forms and types, knowledge transaction depends on a variety of factors. Most critically, tacit knowledge transfer is catalyzed by proximity between actors (Buchman 2005). Physical proximity is given by short geographical distance and considered to catalyze knowledge transfer by increasing the likelihood of interaction (Eriksson 2011; Storper and Venables 2004), other forms of proximity such as cognitive, institutional and organizational proximity are based on the relations of actors and consider to broaden the bandwidth of communication by sharing (Gertler 1995; Torre and Rallet 2005; Buchman 2005). Cognitive proximity exists when actors share the same knowledge or technological base. Institutional proximity is realized by being a formal member of a club or association and finally organizational proximity is defined by being part of an overarching framework following same rules or strategies such as the subsidiaries within a company (Buchman 2005). Hall and Jacobs (2010) employed these different forms of proximity to the global system of ports and observed a shift in cognitive and organizational proximity between seaports. Their conclusion makes clear that the increase of external linkages of seaports is counterbalanced by strengthening the importance of proximity to institutions and other partner within the local environment (Hall and Jacobs 2010: 1113). However, revealing the relevance of proximity is not a dichotomy of local and global resources, but a multi-scalar perspective in which knowledge intensive firms and institutions make use of different forms of proximity to increase their knowledge base. With regard to the maritime economy we consider knowledge a multiplex subject including both advanced skills and standardized procedures with strong interrelation to physical goods and transportation. This perception overlaps with the definition of innovation that is realizing economic growth by new products, new processes or the exploitation of new markets.

Relational proximity by means of organizational, institutional and cognitive proximity is complementary to physical proximity in that it reduces the barriers to the exchange of knowledge within a shared value creation process, knowledge base and competitive and regulatory environment (Pavitt 1984; Malerba 2005). Furthermore, the continuous interaction in the value added process, potentially creates a shared understanding and common interpretative schemes (Lam 2005) as well as knowledge sources, which are complementary for the actors involved (Broekel and Buchman 2010). Furthermore, these different forms of proximity catalyze the exchange of knowledge, by providing an environment of trust and reciprocity (Granovetter 1985), which facilitates innovation in a heterogeneous field of specialized actors. Knowledge transfer between firms can be distinguished from transfer within firms as it bears particular potential in the context of industrial change, which is highly relevant to the maritime industry. Moreover, industrial dynamics and globalization have spurred the dependence of trans-organizational collaboration and new forms of integration in the maritime economy. Hence, complementarity in innovation capability can be described as the temporary alignment of economic interest or the completion of a previously existing knowledge in the form of a product in order to gain competitive advantage and increased returns. The multitude of interactions between private actors, institutions and public authorities constitutes the innovation system of the maritime economy.

The concept of related variety further refines the meaning of cognitive proximity in the context of knowledge creation. Related variety is defined by „sectors that are related in terms of shared or complementary competences“ (Buchman and Iammarino 2009: 292-293). Therefore, cognitive proximity between those sectors plays a crucial role. „Information is useless if it is not new, but it is also useless if it is so new that it cannot be understood” (Nooteboom 2000: 72). However, absorptive capacity is also constantly in flux. The number of employees and their knowledge base heavily affect a firm’s capability to broker knowledge (Cohen and Levinthal 1990). Primarily, the concept of related variety focuses on technological development within manufacturing sectors. Service sectors are not explicitly taken into account in this concept. However, they are relevant in the maritime economy due to their constitution, in which shipping companies are a prime example for an actor linking the sector of transport and logistics, manufacturing and high tech, by commissioning the construction of vessels to a certain specification and inserting those direct or indirectly in the system of maritime transportation. Moreover, this parallel activity within two value chains makes the shipping companies and their trade organizations a centre of gravity for related services such as insurance, the acquisition of labour, standards and rules, which manifest the cognitive proximity between manufacturing and service sectors.

5.3 Knowledge in interaction and value added relations

Conceiving knowledge creation as a process implies interwoven and co-inciding patterns of development, production and application thereof in products and services. The synthesis is an evolving innovation system which, in the case of the maritime economy, is affected by technological change and restructuring of value chains.

To analyze this innovation system we focus on the patterns of proximity between the actors of the maritime economy and their functional role in the process of innovation. Zillmer (2010) suggests an approach, which enables the analysis of knowledge in transfer. In her comprehensive analysis of different service activities she concludes on four different types of generic activity related to industrial clusters: high-tech, transformation services, transaction services and media/information services (Zillmer 2010: 113-122). Her approach focuses on the relations between single actors as the active parts in the network rather than the inherent knowledge stock or the aggregated level of technological regimes. It assumes a non arbitrary selection of partners and distinguishes product and process related services, making it particularly useful for the analysis of the Maritime Economy (table 5.1). Furthermore, it considers services and manufacturing activities as complementary in the value production (Bryson and Daniels 2010: 83-85). This approach is intrinsically relational since it centres around collaboration between actors for the purpose of knowledge generation.

Transaction services are defined as actors delivering input into the value chain process, which revolves around the amalgamation of different knowledge spheres. It focuses on the organization and management of economic transaction (Kujath and Schmidt 2010: 46) and includes advanced producer services such as insurances, financing or law, which are the backbone of the global economy.

Transformation services are provided by those actors, which deliver their non-material input into material focused parts of the industry and thereby shape the product as such. This includes research and development facilities as much as consultants delivering input into for instance the high-tech industry. The focus is on the transformation of existing knowledge into new knowledge for the benefit of a different economic application (Kujath and Schmidt 2010: 46). The refinement of materials such as metal is strongly dependent on the research carried out by engineers. For example, the shape and consistency of ship hulls has been developed significantly due to new production processes in metal works and new materials. The results are plans or templates for wider series of production.

As a functional group high-tech actors are concerned with the production of material goods. The value added to the system is firmly resting thereon. As opposed to the former two groups the material input is valued at cost rather than in conjunction with non-material components. It revolves around the production of knowledge intensive material goods by integrating new knowledge in products and processes (Kujath and Schmidt 2010: 45). A typical high-tech product is the computer chip, which enables complex control techniques within maritime navigation or supply chain management. Since high-tech activities are defined by the invention of new products, transformation processes tend to refine these materials accordingly.

	Boat building	Port corporation	Port logistics	Maritime services	Maritime education and professional development	Maritime science	Marine engineering	Marine engineering science	Shipping companies	Shipbuilding	Shipping supplier	Other economic actors	Other science actors
Boat building													
Port corporation													
Port logistics													
Maritime services													
Maritime education and professional development													
Maritime science													
Marine engineering													
Marine engineering science													
Shipping companies													
Shipbuilding													
Shipping supplier													
Other economic actors	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Other science actors													
Legend	*transformation*		*transaction*		*information*		*high-tech*						

Table 5.1: the fields of activity in the maritime economy and types of knowledge in transfer (based on Zillmer 2010)

Finally, relations based on media and information services contain activities, which transform knowledge in standardized knowledge good. These are predominantly educational relations where guidance and instructions for action are provided. This type of knowledge is considered as a preparation for future experiences. For example masters and skippers of ships train their skills in simulators before employing in reality.

These four roles are embedded in the value chain relations of the maritime economy and inherent to the innovation system. In order to explore distinct patterns of spatial organization, we formulate three hypotheses based on the theoretical insight on the interdependence of relevant geographic and relational proximities. To inform our empirical network analysis we use the following three hypotheses.

Hypothesis 1:

While transformation processes are based on explicit knowledge, transaction processes revolve around implicit knowledge sources. We expect that the spatial range of networks in the maritime economy is clearly differentiated according to the relevance of spatial and relational proximity. We then surmise that spatial proximity is more important for experience based knowledge interaction albeit in potentially remote locations. Therefore, transaction based exchange is concentrated in geographic proximity.

Hypothesis 2:

Cognitive proximity is a binding link for all actors within the maritime economy. We therefore expect cognitive proximity to shape the sub-divisions of the maritime economy by means of underlying knowledge bases.

Hypothesis 3:

The complementary nature of geographical and relational proximity forms an urban system. Whereas transformation links yield a higher proportion of explicit knowledge networks of this knowledge type tend to spread out further spatially. Transaction links, however, tend to concentrate at certain locations within an urbanized environment. We therefore expect distinct patterns of spatial organization of networks including this type of knowledge.

5.4 Methodology

5.4.1 The Maritime Economy as conglomerate of sectors

The concept of the maritime economy combines the production, delivery, servicing and trading of maritime vessels and components in one input-output system. A general definition of this field does not exist in the literature. Approaches differ clearly in terms of what the research subject is. Several studies focus on the exchange of commodities, the role of logistic firms and the organization of ports (Ducruet and Zaidi 2013; Hall and Jacobs 2010; Lee and Song 2010). The shipbuilding industry as the high-tech part within the maritime economy is subject to studies concerned with inter-industrial exchange of information flows and innovation capabilities (Fei 2011; Fornahl et al. 2012). The bearing of the maritime economy on spatial development is discussed within the context of the renewal of cities and ports. Hall and Jacobs (2012) show clearly that the reorganization of port activities affects urban development intensively. Actually, the biggest ports in the world coincide with populous agglomeration (Hall and Jacobs 2012: 190). Equally, headquarter functions of global firms and specialized services tend to locate in urban environment, whereas logistics remain at the port facilities. Finally, the maritime economy contains specialized service activities, which reveal distinct locational patterns different from other advanced producer services (Jacobs, Koster and Hall 2010). The review of these studies reiterates the heterogeneous character of the maritime economy, which includes manufacturing, services, transportation and energy, with their individual location strategies. This results in a multitude of drivers influencing spatial development in places where the maritime economy retains a strong economic position.

For the purpose of this study, our definition of the maritime economy transcends the economic sectors of Manufacturing (NACE Section C), Professional, Scientific and Technical Activities (NACE Section M), Transportation and Storage (NACE Section H), Education (NACE Section P), Administrative and Support Service Activities (NACE Section N). Other sectors, which might be of relevance in certain activity fields are Construction (NACE Section F) and Financial and Insurance Activities (NACE Section K). The NACE classification draws on economic activities by using common resources: "capital goods, labor, manufacturing techniques or intermediary products are combined to produce specific goods or services" (Eurostat 2008: 15). Thus, it is a framework focusing on input-output relations and a commonly used production base.

As a heterogeneous cluster of activities, the inner logic of cooperation and innovation is critically affected by the flow of knowledge within and across activity fields (Brandt, Dickow and Drangmeister 2010). According to these considerations we have defined 13 different activity fields that are part of the maritime economy. These are: boat building, port corporations, port logistics, maritime services, maritime education and professional development, maritime science, marine engineering, marine engineering science, shipping companies, shipbuilding, shipping supplier and other economic and science actors. The knowledge intensity varies across and within these activities. Therefore, we adopt a definition which is applicable to cross sectorial activities and different functional profiles. Hall (2007a) considers all those activities as knowledge intensive, whose ratio of highly qualified personnel is above the average of all services (Hall 2007a: 49). More specifically, Legler and Frietsch (2006: 22) define shipbuilding and shipping as knowledge intensive branches.

However, what is more important for the assessment of knowledge flows is the interrelation of the aforementioned activities and the inter-linkage with non-market relations within the industrial cluster. In regards to innovation activity the exchange of knowledge is not only critical for the development of new products and services but also for the brokering of uncertainty involved in such a process. Podolny (2001) argues that in order to successfully develop and place an innovation, firms draw on resources and information from their network but also need to gain visibility, which enables them to find or be found by exchange partners (Podolny 2001: 41-42). We argue that this dichotomy of transformation and transaction based activities is of particular relevance to the maritime economy.

5.4.2 Set-up of the analysis

A multifaceted methodology is required in order to assess the heterogeneity in the maritime economy. This approach explores the composition and relationships within the maritime economy. We evaluate the relevance of different forms of proximity for knowledge transfer and its effects on spatial development in this specific context of the maritime economy of Northern Germany. Furthermore, we analyze the functional interdependence of activity fields in relation to their spatial configuration, which varies from geographically distant to close.

Figure 5.1 shows the set-up of the analysis as layered applications of a spatial, functional and relational perspective. The geographical distribution of actors of the maritime economy forms the starting point of the analysis. We investigate the interrelations of actors of different fields of activity and focus on their functional means. Secondly, we show that the entire network of the maritime industry devolves into certain sub-networks, which relate to sectorial patterns and different types of knowledge, suggesting that cognitive proximities are of importance. Thirdly, due to the fact that knowledge production is interlinked with the exchange and transformation of material goods in this sample we include value added characteristics in order to investigate the spatial range of actors in terms of organizational proximities. Thereby, the characteristics of value-added relations are being attributed to the network links. In other words, we consider the cooperation as being interlinked either with the transformation of goods or services, the transaction or the production and development of high-tech products.

The dataset used here results from large scale surveys in the maritime economy carried out by the Norddeutsche Landesbank – Regionalwirtschaft (Brandt, Dickow and Drangmeister 2010: 241-242). Data access was exclusively provided by the project leaders of studies in the field of the maritime economy in Germany at Norddeutsche Landesbank – Regionalwirtschaft. Detailed reports on this analysis are provided by (Nord/LB 2009a, 2009b).

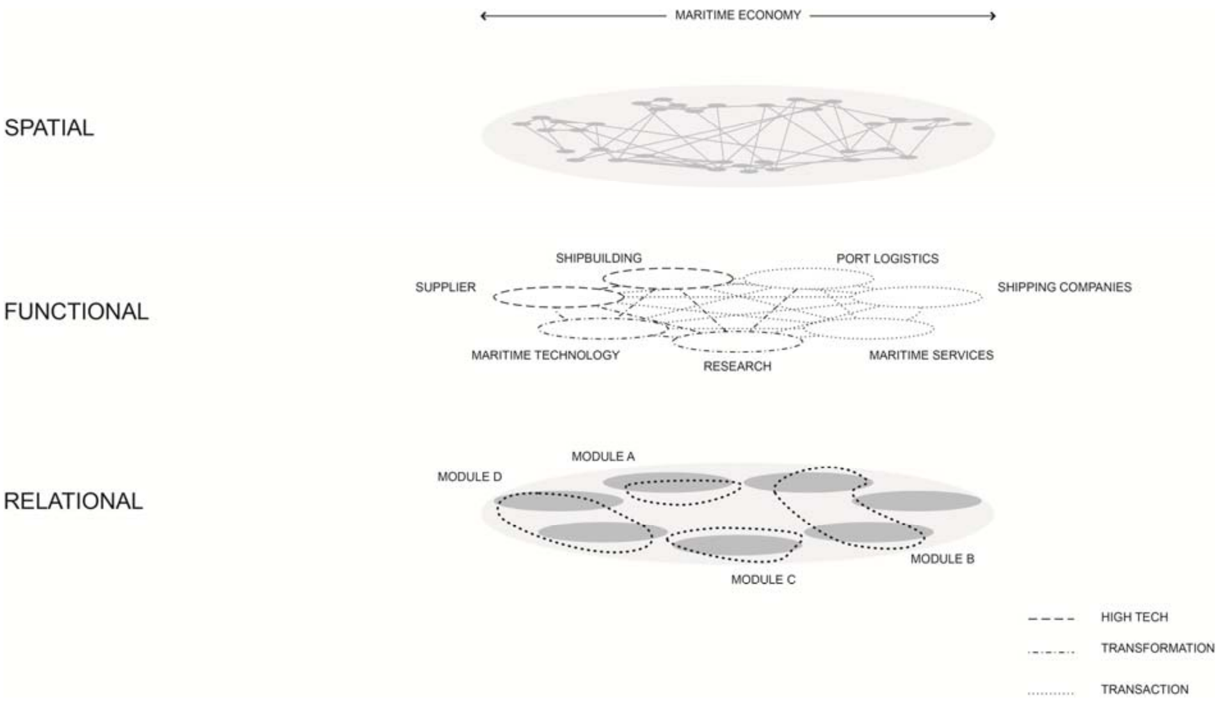

Figure 5.1: set-up of the analysis as layered applications (own illustration)

In an initial phase the database was built by gathering information from commercial resources, associations and networks, business directories as well as the Internet. In a second step the actors were asked to name their partners, which they cooperate with for the purpose of (1) education and qualification, (2) temporal co-working on innovation oriented projects and (3) long-term strategic cooperation. In addition, the data contains structural indicators such as the firm size, employment, turnover, innovation activities and expenditures and ambitions in research and development. All in all, the network contains 1,873 actors and 4,174 network links. The data base provides insight into the ties between individual firms and organization, which sustain their capability to innovate.

We apply social network analysis to assess the relations between different functions and knowledge types within the maritime economy. Social Network Analysis allows us to assess the importance and relations of individual actors with regard to their functions and activity fields. This bundle of methods is framed by a perception that "The structure of relations among actors and the location of individual actors in the network have important behavioral, perceptual, and attitudinal consequences both for the individual units and for the system as a whole" (Knoke and Kuklinski 1982: 13). With regard to economic geography and spatial development, Ter Wal and Buchman (2009: 740) suggest that "networks are an appropriate conceptualization of inter-organizational interaction and knowledge flows.") This paper applies this relational approach in the context of knowledge networks in the maritime economy.

The multi-facetted set-up of the analysis involving visualization and quantitative methods of network analysis enables us to understand the heterogeneous cluster of the maritime economy. To be successful, network analysis requires a clear definition of the boundaries of the system. Although our approach is promising in the sense that the actors of the maritime economy are captured by scanning the aforementioned registers of business circles and public associations, the involved actors might have links to other economic fields, too. For example, producers of pistons might supply ship builders and car producers at the same time. Therefore, this company might be part of the maritime economy and the mobility sector. Hence, the data of our analysis represents only a part of the economy and the reference to urban systems is not complete, as other economic parts might reveal different network structures.

5.5 Results

The maritime economy displays an innovation system that inheres a strong link of knowledge flows and the production and exchange of material goods. In this section we explore the maritime economy from a spatial, functional approach.

5.5.1 The maritime economy as an innovation system

The network of the maritime economy revolves around a limited number of actors as central nodes. Figure 5.2 shows the distribution of weighted degree centrality. This measure is calculated by the sum of links of an actor multiplied with the weights of its network links (Freeman 1979). In our data these weights differ between 1 and 3. Hence one actor with one triple weighted link is as important as an actor with three single linkages. Thus high values of weighted degree centrality could either be the result of a high number of low rated links or a lower number of highly classified connections.

The actors are ranked according to their weighted degree centrality. The slope begins at the value of 393 and decreases steeply. The second most connected actor has a weighted degree centrality of 272 followed by 266. Therefore, the slope is similar to a power decay function and may provide a scale-free network (Barabási 2009: 412), which indicates that the network structure is independent form its size.

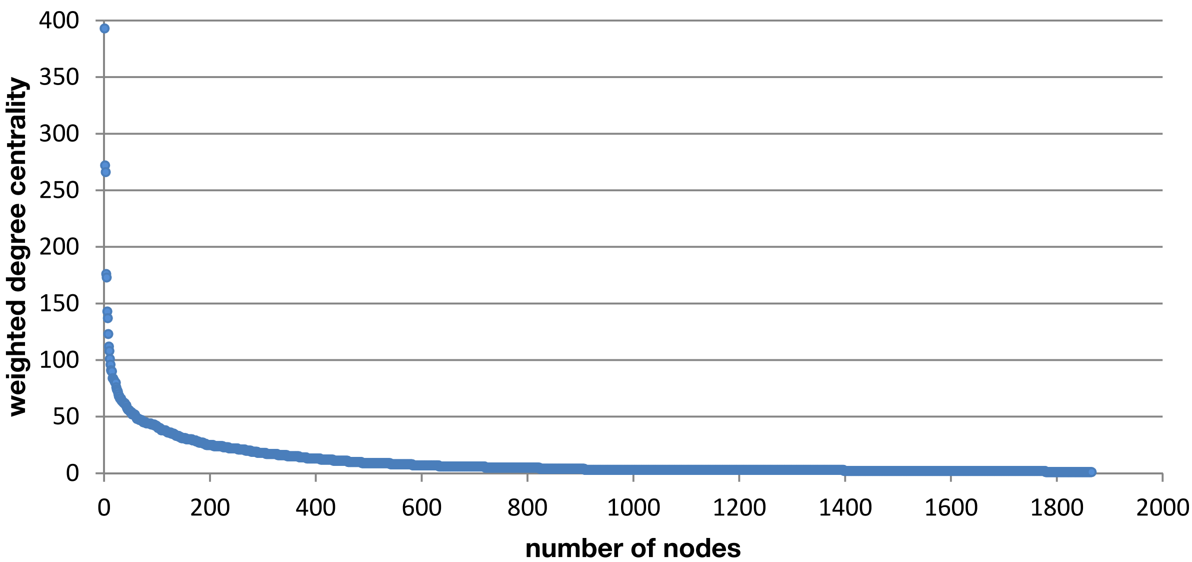

Figure 5.2: Weighted degree centrality distribution (n: 1,873 actors and 4,174 network links) (own calculation)

Interestingly, among the top ten actors in terms of weighted degree centrality are five actors, which are classified as marine engeneering science and, therefore, act as public institutions. The most connected actor – 'Germanische Lloyd AG' – provides maritime services in various fields. This company has merged in the meantime with the Norwegian shipping company 'Det Norske Veritas (DNV)'. The 'Meyer Werft' which operates in the field of ship building is ranked on sixth position. Followed by 'Hamburgische Schiffbau-und Versuchsanstalt GmbH' providing expertise in marine engineering and 'Briese Schiffahrts GmbH & Co. KG' operating as shipping company. The 'Hamburger Hafen und Logistik AG', which organizes and manages port activities within Hamburg - the biggest port of Germany - reaches the thirteenth highest value.

Figure 5.3 shows the entire network of the maritime economy from a relational perspective. This graph was calculated in Gephi and the OpenOrd Algorithm was applied. This algorithm is based on the Frutcherman-Reingold algorithm, which has two guiding principles: vertices connected by an edge should be drawn near each other and vertices should not be drawn too close to each other (Fruchterman and Reingold 1991: 1131). Subsequently, the link between two nodes functions as an attraction force, whereas nodes without links repel each other. Since OrpenOrd displays a relational approach it highlights the subdivisions of the network by separating them visually. Thus, one can obtain a community structure of the network.

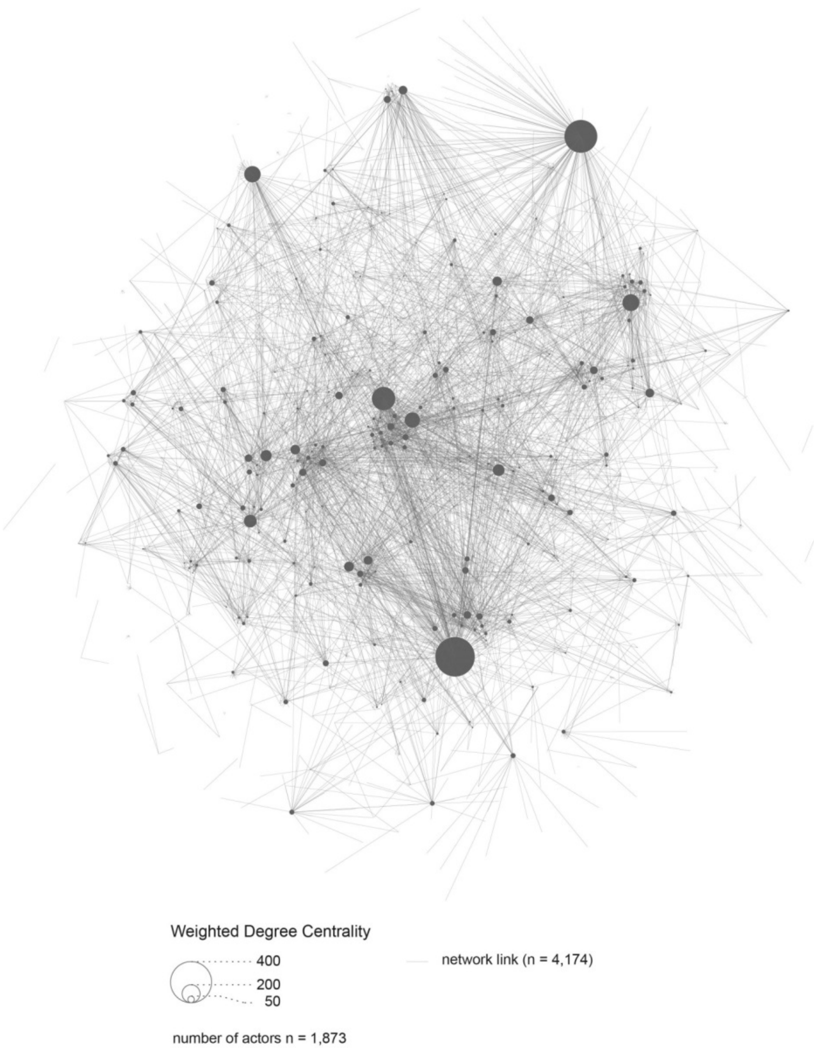

Figure 5.3: the entire network of the maritime economy from a relational perspective. Circle size = degree centrality (own illustration)

The network of the maritime economy constitutes a scale-free network. According to network theory these networks yield the character of preferential attachment (Glückler 2007: 624). This means that it is more likely that actors might link to those actors in the network which already have the most connections. Structural change or diversification of production processes is strongly linked to those central actors (Fornahl et al. 2012). Consequently, economic change within the maritime economy is potentially driven by research institutions and a hand full other actors in maritime services and ship building. Based on their high connectivity and dominance within this network, we assume a higher capability for innovation and economic change. Furthermore, these actors bridge different fields of activity and combine different knowledge bases.

5.5.2 Knowledge in interaction

The second step of the analysis considers the knowledge types 'in interaction'. The maritime economy transcends the sectors transport and storage, services and manufacturing. Therefore, by nature, value chains in the maritime economy integrate labour and material intensive processes as well non-physical processes, which draw exclusively on the skills and knowledge of workers. Thus, the application and generation of knowledge combines different activities ranging from practical experience to formalized and standardized procedures.

The most prominent knowledge types in the maritime economy are transaction and transformation processes representing 1,260 and 1,609 co-operations respectively. Furthermore, the network contains 626 high-tech relations and 301 information links. While transformation processes are based on explicit knowledge, transaction processes revolve around implicit knowledge sources. We expect that the spatial range of these networks is clearly different and that spatial proximity is more important for experienced based knowledge interaction. Figure 5.4 and 5.5 depict the spatial reach of transaction and transformation.

The actors involved in transaction processes form three observable triangles. The first one is located between the cities of Hamburg, Bremen and Bremerhaven. To a large extent the 'Alfred Wegener Institut', which is carrying out research in the fields of oceans, the atmosphere and climate change, forms this triangle. With a weighted degree centrality of 176 this research institute is the fourth best interlinked among all actors.

The second triangle draws on links between Hamburg, Leer and Papenburg. In this sub-network the Meyer Werft GmbH is dominant. Based on the number of links it has a degree centrality of 173. The Meyer Werft, therefore, is ranked fifth and establishes mostly transaction links to actors of port authorities and port logistics and maritime services. These actors tend to be concentrated in Hamburg around port facilities. Furthermore, shipowners are located in Leer and maintain co-operations with the Meyer Werft as well.

The third triangle is less striking in form. The actors of it are located in Hamburg, Papenburg and Emden. Emden hosts a high share of employment in high-tech branches (BBSR 2011) and is, therefore strongly specialized in knowledge intensive manufacturing.

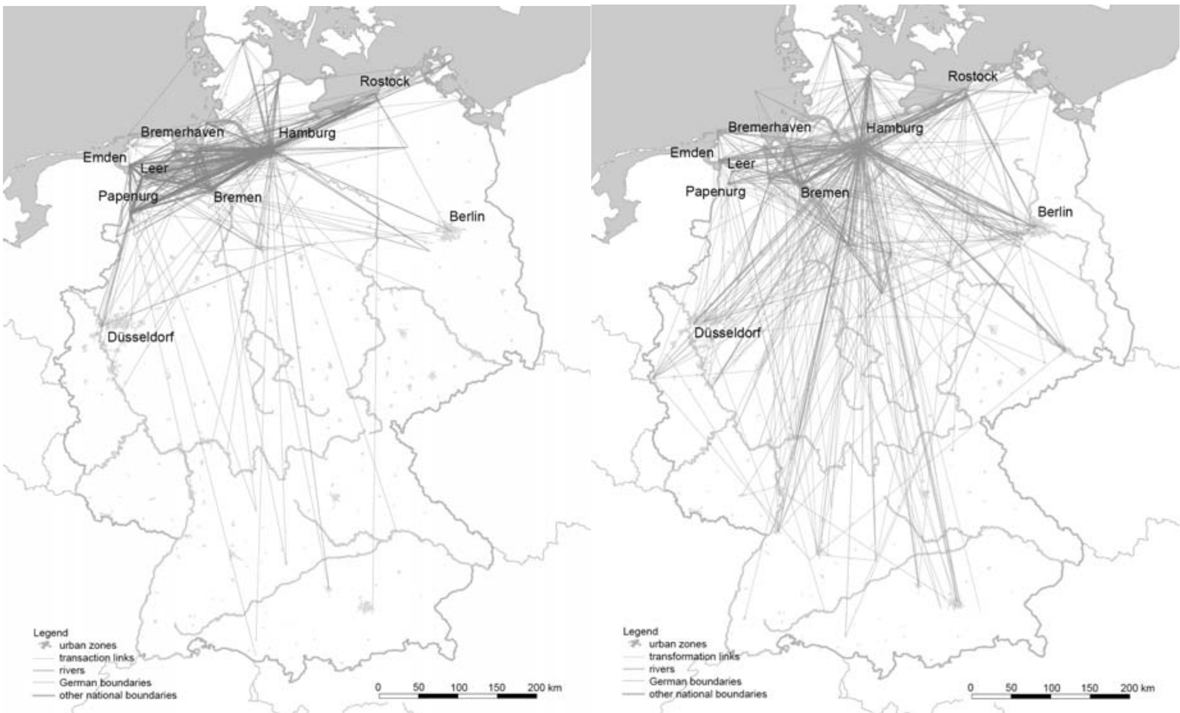

Figure 5.4 and 5.5: Knowledge types in transfer: transaction (left) and transformation (right) links and their geographical range

Interestingly, Hamburg functions as an anchor point for all these triangles, since it lies at the point of superimposition of the most intense edges. There are only a few cross-links between these triangles. This spatial pattern is an indication for an emerging hierarchy in which Hamburg captures the highest rank and acts like a hub. Bremen is a second-tier city in this system. Actors located there tend to form links predominantly to Hamburg but also to a lesser extent to the aforementioned edges of the triangles.

Compared to the network of transformation processes spatial differences are evident. The amount of links in both cases is almost equal. However, actors operating with transactional knowledge tend to be more concentrated on a discrete number of cities. Above all, Hamburg remains the most central position in this sub-network. The re-occurring triangle formed by Hamburg, Bremen and Bremerhaven suggests that these cities form an urban system with a hierarchical tendency.

5.5.3 From knowledge types to community structures

The network of the maritime economy represents a complex economic field in which different knowledge types are employed. Since knowledge is produced in interaction, the network of the maritime economy might dissolve into smaller groups of actors that have strong relations with one another. Therefore, to better understand the structure and inner life of a complex network various approaches exist that enable to detect communities within an entire network (Newman 2004). In our approach we will detect these Small-worlds or sub-networks by applying the modularity algorithm of Newman (2006). Therefore, the third part of our analysis investigates the interrelatedness of certain sub-networks based on the dominant form of knowledge.

The modularity of a complex network represents an index for the community structure between the network nodes that might have quite different characteristics than the overall network. Not least the modularity provides insights in common activities revolving around the functional characteristics of an actor and the type of knowledge. Newman (2006: 8578) defines modularity as “the number of edges falling within groups minus the expected number in an equivalent network with edges placed at random.” The technique focuses on the links between the actors. Belonging to a module subsequently represents intense linkages within this sub-network. This internal interaction is more intense than the connectivity to external nodes. It informs our understanding of the production of knowledge as a complex process in which services, manufacturing and qualification activities are interwoven. Moreover, we hypothesize that cognitive proximity is an important mechanism in shaping such sub-divisions of networks and therefore, modularity may concur with communality between actors, providing additional explanatory power to the aforementioned value relations and different knowledge types.

The modularity calculation indicates reliable results with a value of 0.584. The closer it is to 1 the clearer the communities are differentiated (Lambiotte, Delvenne and Barahona 2009; Blondel et al. 2008). The entire network of the maritime economy dissolves into 48 different modules, which starkly differ in terms of size and composition. See the appendix for further descriptive statistics.

In the following section, we focus on the five biggest modules in our data set. In total, these contain 1,055 out of 1,871 actors. These modules have more than 150 nodes each and clearly differentiate in terms of functional composition and spatial range. Firstly, we discuss their functional composition, which is marked by the fields of activity the actors belong to. In a second part of the analysis we will look at the geographic range of the modules.

Table 5.2 shows the quotient of specialization of each module according to Glaeser et al (1992). This measure is defined by:

$$Secialization = \frac{\frac{m}{M}}{\frac{n}{N}} \quad (1)$$

With m number of actors within an activity field of a module, M number of actors of a module, n number of actors within an activity field of the entire network and N the total number of actors within the entire network. Values above 1 indicate that the module has a higher share in an activity field compared to the overall share of the whole sample. A Value below 1 indicates that the share of a field of activity is below the average (Glaeser et al. 1992: 1141). For instance module 1 - ship-building and suppliers - reaches a value of specialization in the field of shipping suppliers of 2.53 followed by shipbuilding with a value of 2.16 and maritime science with a value of 1.53. It is therefore containing a higher share of actors from these fields than the overall sample. Finally, the values for maritime education, professional development and marine engineering science are slightly above 1. Module 1 is strongly oriented towards manufacturing combined with engineering and qualifying tasks. In other words, this module represents the core of the cluster revolving around the production of ships in the maritime economy.

Module 2 - engineering and science - displays high values in the fields of maritime science, marine engineering and marine engineering science. In contrast to module 1, cooperation in module 2 is underpinned by research and development activities and is less production oriented. Module 3 – ports and education - is strongly specialized in maritime education and professional development and port logistics. Module 4 – ports and shipping - represents a community in which port corporation, port logistics and shipping companies maintain intense corporate networks. These fields of activity are supposed to require access to port facilities. Whether this holds true for the shipping companies will be investigated in a spatial assessment of these modules. Finally, module 5 – services and shipping - is strongly specialized in service activities ranging from education to maritime services, and displays high shares of shipbuilding and shipbuilding suppliers. Thus, this module is placed at the intersection of the services and the manufacturing parts of the maritime economy.

Module and main activities	**1 Ship-building and suppliers**	**2 Engineering and science**	**3 Ports and education**	**4 Ports and shipping**	**5 Services and shipping**
Boat building	0,29	0,00	0,81	0,44	0,00
port corporation	0,10	0,63	**1,61**	**1,60**	0,56
port logistics	0,42	0,25	**2,88**	**1,77**	0,19
maritime services	0,82	0,26	**1,41**	**1,06**	**2,21**
maritime education and professional development	**1,10**	0,00	**3,12**	0,00	**1,99**
maritime science	**1,53**	**2,48**	0,96	0,52	0,31
marine engineering	0,73	**1,95**	0,19	0,55	0,15
marine engineering science	**1,03**	**2,51**	0,22	0,31	0,07
shipping companies	0,88	0,33	**1,20**	**1,31**	**1,96**
shipbuilding	**2,16**	0,16	**1,15**	0,84	**1,95**
shipping supplier	**2,53**	0,27	0,63	0,88	0,86
Other economic actors	0,55	**1,39**	**1,03**	**1,40**	0,89
Other science actors	0,97	**1,61**	0,49	0,96	0,63

Table5.2: The five biggest modules and the quotient of specialization within fields of activity (own calculation)

A closer look on the types of knowledge interaction reveals important characteristics in terms of shared knowledge bases. As mentioned before, knowledge production is a continuous process in which previous knowledge is expanded and complemented by new knowledge. Each actor is embedded in a professional context of knowledge, which determines in which form knowledge is appreciated, accepted, i.e. absorbed and made available for further development. For instance scientific knowledge production is expressed in journal articles. These reflect previous literature and highlight own and new contributions to research. In contrast, knowledge production in engineering results in patents or plans.

Knowledge generation in services tends to initiate new processes, which could not have been managed without it.

The analysis of modules indicates that there is a relation between the relational proximity of actors and their shared knowledge typologies in the sample. Each module shown in table 5.3 revolves around a distinct type of knowledge relation.

Module and main activities		**1 Ship-building and suppliers**	**2 Engineering and science**	**3 Ports and education**	**4 Ports and shipping**	**5 Services and shipping**
Types of knowledge relations within a module	**high-tech**	16,0%	29,7%	1,6%	11,2%	1,3%
	Transaction	30,0%	10,0%	65,6%	67,9%	87,9%
	Transfor-mation	53,1%	58,8%	17,0%	16,5%	6,0%
	Information	0,8%	1,6%	15,8%	4,5%	4,7%
Number of links		636	320	247	224	232

Table 5.3: The five biggest modules and the type of knowledge involved (own calculation)

Module 1 - ship-building and suppliers - displays intense manufacturing activities. Knowledge here is predominantly produced by transformation process, since the share of transformation links within the module accounts for 53.1 %. Knowledge production correlates with the exchange of material goods. Furthermore, transaction links reach a share of 30.0 % as a result of intense knowledge relations between maritime sciences and ship builders and their suppliers. In other words, actors within this module potentially complement explicit knowledge applied in transformation processes with experience based knowledge in order to control and implement these transformation tasks (Niehues, Nissen and Reinhart 2012).

Module 2 - Engineering and science - is also specialized in manufacturing activities. Predominantly, the actors carry out engineering and science activities, but in contrast to the module 1 it focuses stronger on the development of new products, since high-tech relations with a share of 29.8 % are very significant. The modules 3 - ports and education and 4 - ports and shipping - are mainly formed by transaction links revolving around functions of port facilities. Moreover, links within module 3 are characterized by information relations and reach a share of 19.0 %. Contrastingly, module 4 is less specialized within port logistics and has a higher share of high-tech links then the former module. Thus, both modules have broad activities in services in common but differ clearly in terms of second-tier activities. Whereas, module 3 is oriented towards education and qualification, module 4 links services with high-tech activities. Finally, module 5 - services and shipping - is clearly defined by transaction links between maritime services, maritime education and professional development, shipping companies and shipbuilding. Thus, tacit knowledge plays an important role and is applied in a heterogeneous value chain ranging from education activities and services towards shipbuilding.

Finally, complementary specialized clusters tend to be organized in geographical proximity and capture a functional position within the urban system. This, in particular, holds true for modules revolving around transaction relations. Contrastingly, transformation based interrelations reach across the rest of Germany with a strong anchor point in the city of Hamburg. This result sheds light on spatial development options.

5.6 Conclusion

The conceptualization of the maritime economy as an innovation system enriches the discussion of technological and structural change and focuses it to those instances where the port and city retain synergies functionally and geographically. The transcendence of the sectors transportation and storage, manufacturing and services implies that actors which draw on knowledge is a key resource and actors relying on physical labour and land as production factors are interacting, with production factors shifting gradually between these poles. In certain parts, a strong physical relation and interdependence with port facilities remains the critical factor for location choice. The overall spatial development is highly intertwined with the evolution of transportation networks on the land- and seaside and thereby needs to be embedded in a global context. This is not merely a development away from the traditional maritime trade and the manufacturing of vessels, but also a qualitative change within the entire economy. New actors have developed their competencies and oriented themselves towards the modern maritime economy. This, particularly, holds true for service firms, as they provide services not only for the maritime economy but also for other sub-systems of the economy.

The analysis shows three important findings for the maritime economy and its impact on spatial restructuring. Firstly, the network of the maritime economy is predominantly held together by actors of the maritime services, shipbuilders and research institutions. Thus, the network centres on advanced producer services, manufacturing and research institutions. This involves knowledge from transaction, high-tech and information and requires mediation between tacit and codified knowledge. Additionally, modules with a distinct specialization in ship building or engineering tasks emerge. Shipping companies have particularly high betweenness centralities and act as bridging actors between certain sub-divisions.

Secondly, conceiving knowledge as an interactive process, in which transaction, transformation, high-tech and information processes are carried out, deepens our understanding of cognitive and spatial proximity. Whereas spatial proximity is still crucial for experienced based learning, cognitive proximity becomes even more crucial in the context of globalization, since actors are able to expand their absorptive capacity. This interplay is important for the sustainable development of the maritime economy. Our empirical results reveal that the maritime economy revolves around certain knowledge bases and the cognitive proximity between the actors. A common sense of understanding and a shared language drives specialization in engineering and high-tech activities with strong tendencies towards local clustering and services spreading their networks in a regional spatial range. Moreover, the higher the share of implicit knowledge the more the networks are centered on a core activity.

Thirdly, reflecting these findings with regard to the urban system in the northern part of Germany three constituting elements can be identified. The first one is a centralization maritime services in main cities, particularly in Hamburg. These services are assumed to be attracted to urban qualities in which face-to-face contacts and high accessibility occur. Secondly, certain activities in manufacturing, such as shipbuilding and ship suppliers are concentrated in remote areas along the Ems axis. These actors strongly depend on the availability of highly qualified personnel. Since these actors are located in less dense areas geographical proximity seems to be less important to enable knowledge spillover. However, geographical proximity between shipbuilders and their suppliers is still necessary. This might be due to lower the risk of delays in just in time production or ad-hoc problem solving. Finally, as a third element of this urban system, bridging services such as shipping companies and research institutions emerge as actors connecting the production part and the service oriented activities of the maritime economy.

The ongoing structural change might induce changes in the power and control structures of the maritime economy and thereby interlinks spatial development strategies in Germany with the globally operating system of the maritime industry. This points towards spatial policy since the re-organization of economic networks is strongly linked to a relocation of activities in the maritime economy and the potential for the alignment of private and public location strategies. The merger of the shipping companies 'Germanische Lloyd' and the Norwegian competitor DNV represents an example for such a change. The headquarter of the 'DNV GL Group' is located in Norway, whereas activities of ship classification remain in Hamburg. Equally, the planned merger of 'Hapag Lloyd' and 'Hamburg Süd' could change the current situation as it is aiming to establish a competitive logistic enterprise in terms of size and market shares. The main share holders of 'Hapag Lloyd' are the city of Hamburg, the logistic provider 'Kühne & Nagel' and the travel agency 'TUI'. This merger has not been realized yet. The debate on the floatation on the stock market of this new enterprise is still in progress, but is prove of the maritime economy in Germany facing competition of other powerful global actors such as 'Maersk', 'MSC' or 'CMA CGM'. Besides this ongoing reorganization of corporate structures, public-private initiatives in education contribute to the qualification of the maritime economy as an innovation system. The 'Kühne Logistics University' in Hamburg was established in the year 2003 as a cooperation of the 'Technische Universität Hamburg' and the 'Kühne foundation'. The studies in the context of logistics and management aim to secure the provision of young human capital in Hamburg.

Our study has limitations. Further research is required to triangulate these findings with more qualitative methods in the context of the maritime industry. Also the specific role of shipping companies is worth exploring, as they are situated at the intersection of manufacturing and transport related value added processes. Furthermore, it would be worth applying this analysis to another industrial cluster in order to establish in how far the findings are transferable. Lastly, the existence and typology of distinct patterns of organization within the maritime economy, which we have traced in this research needs to be reflected in regards to the governance of value chains and territories.

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Appendix

Selection of network parameters and structural indicators of the modules 1, 2, 3, 4, and 5

			module				
variable		**scale**	**1 Ship-building and suppliers**	**2 Engineering and science**	**3 Ports and education**	**4 Ports and shipping**	**5 Services and shipping**
Number of actors			**157**	**183**	**200**	**232**	**283**
Degree Centrality		mean	4.54	4.42	4.00	4.47	6.91
Closeness Centrality		mean	0.11	0.12	0.09	0.09	0.10
Betweenness Centrality		mean	0.00	0.00	0.00	0.00	0.00
Export ratio		mean	27.23	17.79	25.95	29.68	38.42
Employment		mean	63.81	301.96	380.42	39.69	426.94
Did your company carry out Research and development within the years 2005 and 3008?	yes, continuously	share	18.60	12.24	25.00	43.59	51.16
	yes, continuously	count	8.00	6.00	12.00	17.00	44.00
	yes, occasionally	count	9.00	6.00	8.00	11.00	14.00
	no	count	26.00	37.00	28.00	11.00	28.00
How high were the expenditures for R&D?		mean	3.33	1.66	3.27	20.65	5.15
R&D employment		mean	2.64	2.68	6.32	2.68	14.14
Did you company realize innovation in terms of products or processes?	yes	share	63.16	64.29	70.73	83.33	81.93
	yes	count	24.00	27.00	29.00	30.00	68.00
	no	count	14.00	15.00	12.00	6.00	15.00

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6 Von Zentralen Orten zu Zentralen Knoten.

Über Zentralität, Konnektivität und Spezialisierung in den Metropolregionen München und Stuttgart

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Abstract

Die beiden Metropolregionen Stuttgart und München haben sich mit einer starken industriellen Basis zu international bedeutenden Zentren der wissensintensiven Dienstleistungen und High-Tech Branchen entwickelt. Dabei liegen unterschiedliche Raumstrukturen zu Grunde, die bereits von Walter Christaller in seiner Arbeit zu den Zentralen Orten in Süddeutschland benannt wurden. Demnach ist Stuttgart eher polyzentrisch und München eher monozentrisch strukturiert. Diese Hierarchie wird durch die Ausweitung der wissensintensiven Arbeitsprozesse in Frage gestellt, da das spezifische Wissen Orte zu einzigartigen Knoten in einem Netzwerk macht. Der Beitrag zeigt den Vergleich der Hierarchie von Christaller mit einer eigenen Erhebung zu den Standortverflechtungen der Wissensökonomie und benennt Faktoren, die stabilisierend wirken oder zu Veränderungen im Beziehungsgefüge beider Metropolregionen führen. Dabei werden drei räumliche Entwicklungsprozesse deutlich. Polyzentrische intra-urbane Kräfte werden in den beiden Städte München und Stuttgart gestärkt, zweitens wächst die inter-urbane Polyzentralität durch die Ausweitung der Wissensökonomie in den Städten Augsburg, Heilbronn und Regensburg an. Drittens bewirkt die Kraft der Spezialisierung, dass sich Standorte wie Ingolstadt und Ravensburg als spezifische Netzwerkknoten etablieren.

Keywords:

Wissensökonomie, funktional-räumliche Hierarchie, Zentralität, Konnektivität, Zentrale Orte, Süddeutschland

My contribution:

- Conceptualisation oft eh article and research question
- Comparison of centrality according to Christaller and connectivity
- Interpretation and discussion

6.1 Einleitung

Die Entwicklung von polyzentrischen Metropolregionen steht in enger Verbindung mit der Arbeitsteilung und funktionalen Aufgliederung entlang von Wertschöpfungsketten (Lüthi, Thierstein und Goebel 2010) sowie der Verbesserung von Erreichbarkeitspotenzialen innerhalb und außerhalb der jeweiligen Metropolregionen (Bentlage, Lüthi und Thierstein 2013). Unternehmen, die zu einem bedeutenden Teil mit der Ressource Wissen wirtschaften, sind besonders intensiv in diesen Entwicklungsprozess involviert (Thierstein, Goebel und Lüthi 2007). Die Produktion und Anwendung von Wissen wird dort befördert, wo sich relationale und geographische Nähe zu Partnern und Konkurrenten ergänzen. Dies bedeutet, dass Agglomerationsvorteile und Netzwerkvorteile komplementär zu einander sind und sich entlang eines Kontinuums von Maßstäben vervollständigen (Bathelt, Malmberg und Maskell 2004).

Genauer heißt dies, dass die funktionale Logik der Wissensproduktion in einem Wechselspiel zur räumlichen Arbeitsteilung steht (Lüthi 2011). Denkt man die funktionale und die räumliche Logik zusammen in einem urbanen System, lassen sich Städte als interdependente Knoten in einem Netzwerk mit jeweils abgegrenzten Territorien begreifen (Amin und Thrift 1992; Parr 1973; Dicken und Malmberg 2001; Growe und Blotevogel 2011). Als urbanes System definieren wir die Zusammenschau von Relationen zwischen Räumen und jeweiliger funktionaler Ausstattung, Beispiele sind Handelsbeziehungen, Verkehrssysteme oder firmeninterne Netzwerke von Mehrbetriebsunternehmen. Der Prozess der interaktiven und arbeitseiligen Wissensproduktion kommt durch die räumliche Arbeitsteilung in Form von spezialisierten und diversifizierten Standorten deutlich zum Ausdruck (Duranton und Puga 2000). Als Diversifizierung wird ein Prozess verstanden, in dem neue Arbeitsschritte zu bereits vorhanden hinzugefügt werden und somit alte Verfahrensweisen durch neue ergänzt werden. Jacobs (1969) definiert diesen Prozess als: „Existing divisions of labor multiply into more divisions of labor by grace of intervening added activities that yield up new sums of work to be divided" Jacobs (1969: 58). Diversifizierung bedeutet somit das Zusammenführen von verschiedenartigen Arbeitsschritten. Nach Jacobs ist dieses Zusammentreffen von verschiedenen Strömen das entscheidende Charakteristikum von urbanen Zentren (Jacobs 1969: 50). Im Gegenzug dazu lässt sich Spezialisierung als ein Ausdruck der tieferen Auseinandersetzung mit Wertschöpfungsschritten von Produkten und Prozessen verstehen, in dem Wissen weiterentwickelt und optimiert wird. Unternehmen realisieren dabei einen großen Nutzen, wenn sie von ähnlichen Branchen umgeben sind und somit Vorteile aus der Lokalisation von Wissen schöpfen. Diese Externalitäten werden als Lokalisationsvorteile bezeichnet und gehen auf Alfred Marshall zurück, der die Ansammlung ähnlicher Branchen im Raum als förderlich für die Fortpflanzung von Wissen bezeichnet (Marshall 1947).

Die Metropolregionen München und Stuttgart bieten zwei interessante Beispiele, um die Entwicklung der Wissensökonomie in Zusammenhang mit der Herausbildung von urbanen Systemen zu betrachten. Beide Regionen sind im europäischen Vergleich äußerst innovativ und lassen die Ausweitung wissensintensiver Tätigkeiten deutlich erkennen. Die Mobilitätswirtschaft, die sich um den Automobilsektor und seine Sektor übergreifenden Wertschöpfungsketten kristallisiert, ist in beiden Räumen sehr präsent und hat einen großen Anteil an dieser Entwicklung. Betrachtet man beide Metropolregionen als urbane Systeme werden jedoch deutliche Unterschiede bewusst. Während die Metropolregion München sehr monozentrisch auf die

Landeshauptstadt ausgerichtet ist, hat Stuttgart eine eher polyzentrische Struktur. Walter Christaller hat dies bereits in seiner Untersuchung *Die Zentralen Orte in Süddeutschland* hervorgehoben und erkennt bereits damals eine enge Verbindung zwischen ökonomischen Aktivitäten und räumlich-hierarchischen Strukturen (Christaller 1968).

Unser Beitrag untersucht diese hierarchischen Strukturen und identifiziert die stabilisierenden und dynamischen Faktoren in den Metropolregionen München und Stuttgart. Dabei werden die Erkenntnisse von Christaller mit einer eigenen Erhebung zu den Standortverflechtungen der Wissensökonomie verglichen und vor der Veränderung der räumlichen Hierarchie reflektiert. Seit Christaller haben sich die Ökonomie und deren Raumbezug deutlich verändert. Die Bedeutung von spezifischem Wissen ist gestiegen, Verkehrs- und Kommunikationsmöglichkeiten haben starken Einfluss auf die Interaktion von Menschen und die europäische Integration mit ihren vier Freiheiten – Güter, Kapital, Dienstleistungen, Personen – führen zur Markterweiterung. Dies lässt vermuten, dass sich die Bedeutungsbereiche von zentralen Orten und deren Beziehungsgefüge stark verändert haben Treibende Kraft hierfür sind wissensintensive Unternehmen, die durch den Bedarf an spezifischem Wissen die Komplementarität der Standorte zueinander hervorrufen (Maillat 1998; Camagni 1993). Dadurch ist zu vermuten, dass die Komplementarität und die Spezialisierung von Wissen eine Veränderung der räumlichen Hierarchie auslösen, die durch die Zentrale Orte Theorie nicht mehr erklärt werden kann.

Dazu werden im nächsten Kapitel die Grundlagen der Zentralen Orte Theorie erläutert und neuere Ansätze zur Erweiterung dieser Theorie vorgestellt. Abschnitt 3 führt in das Zusammenspiel von Lokalisations- und Urbanisationsvorteilen sowie Netzwerkeffekte ein. In Abschnitt 4 stellen wir die Untersuchungsanlage vor, in der wir die Ergebnisse von Christaller mit einer eigenen Untersuchung der Standortverflechtung von wissensintensiven Unternehmen vergleichen. Abschnitt 5 identifiziert die stabilen und dynamischen Elemente der räumlichen Hierarchie in den beiden Metropolregionen. In Abschnitt 6 werden die Ergebnisse zusammengefasst und mit einem Blick auf die zukünftige Entwicklung abgerundet.

6.2 Von zentralen Orten zu zentralen Flüssen

Die ökonomische Grundlage des zentralen Orte Systems nach Christaller besteht in der Versorgung bestimmter Räume durch zentrale Güter und Dienstleistungen auf, die an eben jenen zentralen Orten angeboten werden (Christaller 1968: 40). Je zentraler ein Gut oder Dienst ist, umso höher ist deren Reichweite, da Menschen hohe Fahrtzeiten und –kosten auf sich nehmen, um sich diese Versorgung zu sichern (Christaller 1968: 54-63). Diese Zentralität eines Ortes wird als Bedeutungsüberschuss verstanden (Christaller 1968: 146). Ein Ort erfüllt somit Versorgungsleistungen, die den Bereich jenseits seiner Grenzen erfasst und es wird ein Beziehungsgefüge zwischen den zentralen Orten beschrieben. Dies zeichnet hierarchische Strukturen ab. Denn ein Ort mit hoher Zentralität hält die Versorgung bereit, die an einem Ort mit niedriger Zentralität fehlt. Daraus ergibt sich ein urbanes System mit interdependenten Knoten. Die Entwicklung in einer Stadt erklärt sich somit nicht aus sich selbst heraus, sondern in Relation zu anderen, diesem System angehörigen Städten und Orten. Abbildung 6.1 zeigt die Hierarchie der zentralen Orte und deren Beziehungen innerhalb des Systems.

Auf der horizontalen Ebene ist das System der zentralen Orte durch das Prinzip der ‚*Substitution*' gekennzeichnet. Orte mit gleicher Zentralität bieten gleichwertige Güter und Dienstleistungen an. Damit sind sie untereinander austauschbar. Diese Orte haben jeweils abgegrenzte Marktbereiche. In der vertikalen Dimension ist das Prinzip der ‚*Komplementarität*' erkennbar. Ein Ort mit hoher Zentralität bietet Güter an, die in Orten mit niedriger Bedeutung nicht verfügbar sind. Mit Einschränkungen besteht diese Komplementarität auch in entgegengesetzter Richtung. Zwar bieten die hochrangigen Orte auch die Güter an, die auf den unteren Hierarchiestufen verfügbar sind und sind damit unabhängig (Pred 1977: 18-19), jedoch übernehmen alle Orte Versorgungsleistungen für Güter und Dienstleistungen, deren Reichweite eher gering ist.

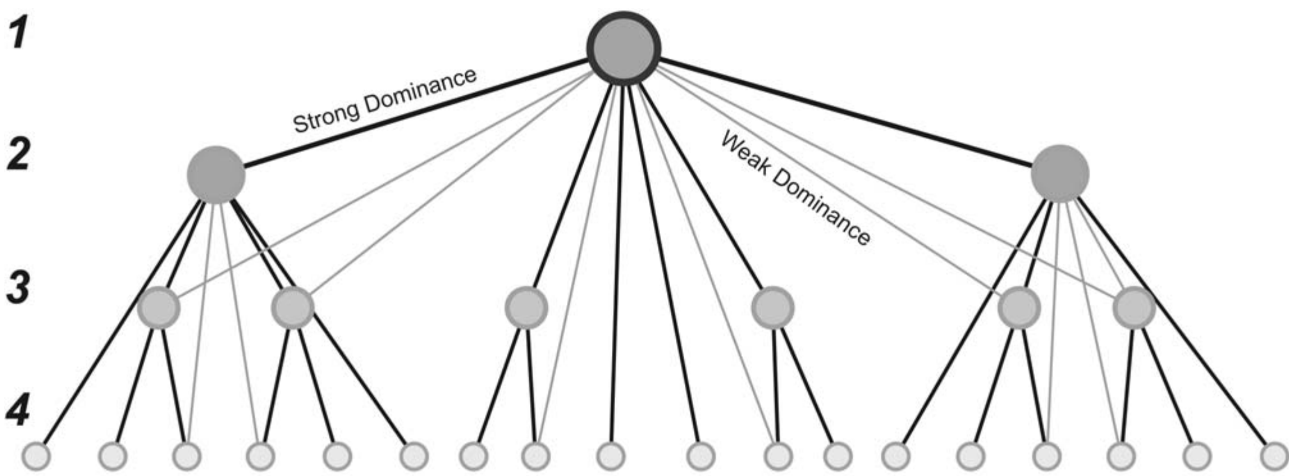

Abbildung 6.1: Die Zentralörtliche Hierarchie nach Christaller (eigene Darstellung nach Pred 1977: 18)

Pred (1977) schlägt eine Weiterentwicklung der Zentralen Orte Theorie vor, in der Komplementarität eine ausgeprägte Bedeutung hat (Abbildung 6.2). Dies kommt vor allem durch polyzentrische urbane Räume zum Ausdruck. Meijers (2007) definiert Komplementarität als

„situation in which different cities fulfil different and mutually beneficial roles” (Meijers 2007: 248). Diese funktionale Teilung zwischen verschiedenen urbanen Zentren findet innerhalb eines gemeinsamen Marktgebietes statt. Somit ergänzen sich diese Zentren, um gemeinsam durch Güter und Dienste Versorgung zu leisten. Daraus resultiert eine symmetrische Austauschbeziehung zwischen diesen Orten und deren Entwicklung steht in einer gegenseitigen Abhängigkeit. Das Prinzip der Substitution wird dadurch geschwächt, da sich die Bedeutung eines Ortes nicht mehr ohne weiteres durch die eines anderen Ortes ersetzen lässt. Dies führt zu Veränderungen in der eigentlichen Hierarchie.

Camagni (1993) macht deutlich, dass diesem System stabilisierende und verändernde Momente innewohnen. Pfadabhängigkeit, öffentliche Einrichtungen und große sowie diversifizierte und qualifizierte Arbeitsmärkte wirken stabilisierend – Spezialisierung und Komplementarität hingegen können das Christaller‘sche System jedoch unterwandern (Camagni 1993: 75-77). Somit wird die Stabilität der zentralörtlichen Hierarchie in heutiger Zeit in Frage gestellt. Die wachsende Bedeutung von spezifischem Wissen und Gütern machen Lokalisationsvorteile geltend und führen zur Spezialisierung an einzelnen Orten. Maillat (1998) erkennt darin sogar das Potenzial zur „Umkehrung der räumlichen Hierarchien“, welches durch die endogene Entwicklung an bestimmten Standorten und die Inwertsetzung von spezifischen Ressourcen angestoßen wird. Hierbei findet eine Konzentration von unternehmerischen Aktivitäten an „neuen wettbewerbsfähigen Standorten“ statt (Maillat 1998: 1-2). Sogenannte Innovative Milieus sind lokal verankerte Innovationssysteme, die durch räumliche und relationale Nähe Transaktionskosten verringern, gelichzeitig aber die Anpassungsfähigkeit an äußere Entwicklungen erhalten (Maillat 1998: 9).

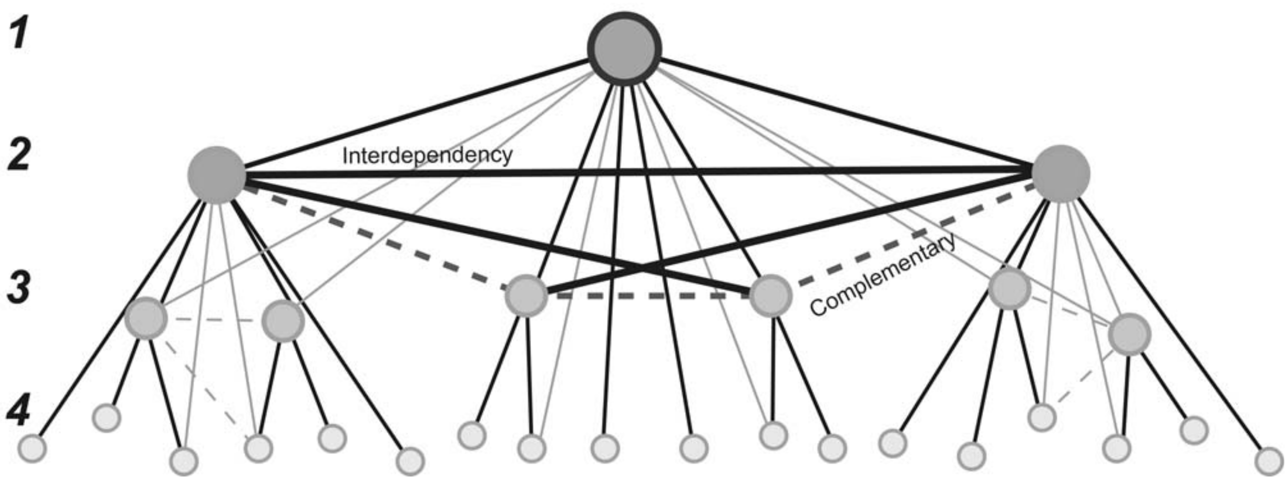

Abbildung 6.2: Komplementarität und die Zentralörtliche Hierarchie (eigene Darstellung nach Pred (1977: 18)

Die Christaller‘sche Hierarchie, eingestuft durch Zentralität, wird in dieser relationalen Lesart also durch das Netzwerk ergänzt, in welchem spezifische Wissensressourcen verbunden sind. Hierarchie und Netzwerk sind demnach Grund verschieden: „Hierarchy and network are fundamentally different and should never be confused or used interchangeably (Taylor, Hoyler und Verbruggen 2010: 2806). Beides zusammen ermöglicht ein umfassendes Verständnis von urbanen Systemen, indem urbane Zentren zum einen als Zentrale Orte und damit als Zentrum eines regionalen Marktraumes verstanden werden, zum anderen jedoch als Knoten in Zentralen Strömen mit extra-territorialen Verflechtungen begriffen werden (Taylor, Hoyler und Verbruggen 2010).

Aufbauend auf der Erkenntnis, dass die Christaller'sche Hierarchie teilweise durch die Standortverflechtungen wissensintensiven Unternehmen unterwandert wird, wird im nächsten Abschnitt das Zusammenspiel zwischen den Agglomerationseffekten, gegeben durch Urbanisations- und Lokalisationsvorteile, und von Netzwerkeffekten erläutert.

6.3 Städte im Wechselspiel zwischen Spezialisierung und Diversifizierung

Raumentwicklung geschieht in einem Wechselspiel zwischen endogenen Kräften, die sich aus dem Inneren der Agglomeration entfalten und damit die intra-urbane Entwicklung adressieren sowie durch exogene Kräfte, die durch intensiver werdende Austauschbeziehungen eigenständiger Zentren hervorgerufen werden. Somit sind Orte in eine inter-urbane Dynamik eingebunden. Dieses Zusammenspiel erzielt sehr unterschiedliche räumliche Ergebnisse und hängt letztlich vom Zusammenwirken von Agglomerations- und Netzwerkvorteilen ab.

Die Ausweitung von wissensintensiven Arbeitsprozessen führt an manchen Orten zu Spezialisierung und anderen wiederum zu Diversifizierung, jeweils in Abhängigkeit davon, wie Agglomerationseffekte in Wert gesetzt werden können. Dies wird innerhalb der *Agglomeration Economies* diskutiert (Eriksson 2011). Grundsätzlich können Unternehmen Agglomerationsvorteile durch die Nähe zu anderen wichtigen Wissensträgern nutzen und dadurch profitieren (Frenken, Van Oort und Verburg 2007: 687). Entweder gehören diese Firmen zur selben Branche und ziehen Nutzen aus einer regionalen Spezialisierung (*localisation economies*) (Marshall 1961) oder sie sind in unterschiedlichen Branchen tätig und haben so Vorteile in der hohen Vielfalt der Wirtschaftslandschaft (*urbanisation economies*) (Jacobs 1969). Beide Argumentationsstränge werden kontrovers diskutiert (Duranton und Puga 2000; Beaudry und Schiffauerova 2009). Empirische Untersuchungen zeigen die Gemeinsamkeit, dass räumliche Nähe zwischen den Akteuren entscheidend ist für das Entstehen von positiven wissensbezogenen Überschwapp-Effekten, *Knowledge Spillovers* (Glaeser et al. 1992; Storper und Venables 2004; Eriksson 2011).

Zum zweiten eröffnen sich Netzwerkeffekte – *Network Economies* – durch die wechselseitigen Beziehungen zwischen Räumen. Diversifizieren und Spezialisieren stehen demnach in enger Verbindung zueinander, denn dann, wenn Wissen weiter vertieft und spezialisiert wird, muss dieses Wissen folglich in andere Prozesse eingegliedert werden und es bedarf der Orte, die diese Vielschichtigkeit aufnehmen und verarbeiten können. Daraus erwächst der Gedanke der relationalen Raumentwicklung (Lüthi, Thierstein und Bentlage 2013; Bathelt und Glückler 2011). Zum Beispiel werden die speziellen Innovationen im Bereich der Informations- und Kommunikationstechnologien im Silicon Valley entwickelt (Sturgeon 2003; Manning 2013). Um jedoch gewinnbringend angewendet zu werden, müssen sie mit anderen Branchen, wie der Logistik oder der Mobilität verknüpft werden. Diese unternehmerische Fähigkeit, spezifisches und lokal verankertes Wissen mit anderen innovationsrelevanten Ressourcen zusammenzuführen, wird hier als ‚Kompetenz' verstanden. Die wissensintensiven Dienstleistungen spielen dabei eine wichtige Rolle, da sie besondere Kontroll- und Entscheidungsfunktionen in einer global agierenden Ökonomie erfüllen (Sassen 1991; Castells 1996; Taylor 2004).

Mit dieser relationalen Sichtweise, die über die umgebenden Markträume eines Ortes hinausgeht, wird das Zusammenwirken von Städten als Knoten in einem Netzwerk als „nodal response" bezeichnet (Parr 1973: 195-196). Damit beschreibt er die gegenseitige Abhängigkeit zweier Orte, die dabei als funktionale Knoten verstanden werden. An die Stelle der Zentralität und die Versorgung eines Hinterlandes richtet Parr die Aufmerksamkeit auf die Einbindung in funktionale Verflechtungen, wodurch ein Ort erst durch die Relationen zu anderen erklärt werden kann.

Kanäle dieser Beziehungen sind laut Pred (1977: 19) Input-Output Verflechtungen oder Entscheidungsprozesse innerhalb von Mehrbetriebsunternehmen.

Network Economies thematisieren damit die positiven Effekte, die erklären können, weshalb Unternehmen bestimmte Teile ihrer Aktivitäten zusehends an globalen Knotenpunkten konzentrieren (Bathelt und Glückler 2011: 114-115). Diese Prozesse der gegenseitigen Beeinflussung finden ihren Ursprung in der Aufgliederung von Arbeit in einzelne Schritte. Die Wertschöpfung wird dadurch in urbanen Räumen ausdifferenziert. "This process is of the essence in understanding cities because cities are places where adding new work to older work proceeds vigorously" (Jacobs 1969: 50). Zum anderen wächst dabei der Grad der Spezialisierung an ganz bestimmten Orten. Der Ursprung dieses Netzwerkgedankens liegt in der geographischen Transformation der kapitalistischen Weltwirtschaft, dessen Produktionssysteme in zunehmendem Maße internationalisiert werden (Friedmann 1986) – und World Cities nehmen in diesem Prozess eine wichtige hierarchische Stellung ein.

Jane Jacobs führt mit ihrem Werk ‚The Economy of Cities' die These ein, dass Städte nicht das Ergebnis eines Entwicklungsprozesses von ländlichen Siedlungen hinzu urbanen Räumen darstellen, sondern dass Städte seit Beginn der Zivilisation existieren und als Knoten- und Handelspunkte in Erscheinung traten (Jacobs 1969: 3-48). Seit je her haben sie also Funktionen ausgeübt, die jenseits der eigentlichen Stadtgrenze verfügbar gemacht werden und damit einen Bedeutungsüberschuss generieren. Die ländlichen Räume stellen dabei eine Form der Spezialisierung dar, da dort bestimmte Produkte erzeugt werden, die wiederum in Städten vertrieben werden. Die Lage dieser Räume ist dabei nicht zufällig gewählt, sondern in Abhängigkeit der Städte, die komplementäre Funktionen bereitstellen, wie zum Beispiel den Handel, und daher Knotenpunkte in einem Beziehungsgefüge einnehmen (Jacobs 1969: 35-38).

Diese Überlegung zeigt, dass in der Tradition der Standortlehre ein systemischer Charakter inne wohnt. Standorte werden demnach in Bezug zu anderen räumlichen Faktoren gesetzt. Seien es das Modell der Lagerente von von Thünen (1826), in dem sich die Landnutzung als eine Funktion von Ertrag, Transportkosten und Nähe zum Verbraucher ergibt, oder sei es der tonnenkilometrische Minimalpunkt, der die Standortwahl der Industrie in Abhängigkeit der Transportkosten der heranzuschaffenden Ressourcen und zu erreichenden Abnehmermärkte optimiert (Weber 1909). Betonung findet diese systemische Sicht vor allem in der Produktion von Wissen, welches durch die Interaktion von Menschen entsteht (Simmie 2003: 617), da erfahrungsbasiertes Wissen erst durch die Ko-Präsenz erlernt und angewendet werden kann (Gertler 2003).

Nimmt man also an, dass spezialisierte Räume einen hohen Beitrag zur Optimierung von Wissen leisten und diversifizierte Räume vor allem gewährleisten, dass diese Prozesse mit anderen Räumen kombiniert werden, dann ergibt sich folgende Dynamik für ein urbanes System: die Entwicklung in spezialisierten Räumen ist stark von der Pfadabhängigkeit beeinflusst, da die Addition von neuem Wissen nur im Rahmen der eigentlichen Spezialisierung möglich ist, es sei denn radikale Innovationen oder historische Ereignisse, wie exogene Schocks oder Krisen, ermöglichen beziehungsweise erzwingen ein Ausbrechen aus diesem Entwicklungspfad (Martin 2010). Diversifizierte Räume hingegen, die wir als Zentren mit hoher Urbanität verstehen, sind seit jeher die wichtigen Knoten von sozialen und ökonomischen Prozessen. In ihnen laufen die unterschiedlichen Ströme zusammen und es findet dadurch eine stetige Erneuerung statt. Damit sind sie durch eine dominante globale und nationale Kontextualisierung langfristig stabil (Pred 1977: 36).

Führt man diese Erkenntnisse zusammen, wird deutlich, dass die Spezialisierung an einem Ort die Diversität in großen urbanen Zentren aufbaut und dass diese Spezialisierung erst durch diversifizierte Orte ermöglicht wird, an denen das spezialisierte Wissen gebündelt und weiter wirksam eingesetzt wird. Somit ist ein urbanes Zentrum ein Ort, an dem verschiedene Austauschbeziehungen zusammentreffen und Netzwerke, seien es Personenströme oder Informationsflüsse, re-kombiniert werden. Damit befindet sich die urbane Hierarchie in einem Stadium des Übergangs von einem traditionellen System mit abgegrenzten Markträumen und hierarchischen Strukturen zu einem Netzwerk von in sich verschachtelten und räumlich ineinandergreifenden Verflechtungen.

6.4 Untersuchungsanlage

Dieser Beitrag vergleicht die empirische Arbeit von Christaller aus den 1920er Jahren mit einer eigenen Erhebung zu den Standortverflechtungen der Wissensökonomie in den Jahren 2009 und 2010. Wir setzen damit die Zentralität von Christaller in Beziehung mit dem Maß der Konnektivität, die auf Grundlage des Interlocking Network Models berechnet wird (Taylor 2004).

Die Theorie der Zentralen Orte nimmt an, dass die Bevölkerung homogen über den Raum verteilt ist und die Bewohner rational über den Konsum eines Gutes oder einer Dienstleistung entscheiden. Dies steht in der Tradition der neoklassischen Gleichgewichtstheorie. Dabei geht Christaller davon aus, dass die Ausstattungsdichte mit Telefonanschlüssen zur damaligen Zeit eine Näherungsgröße zur Messung des Bedeutungsüberschusses eines Ortes darstellt. Christaller begründet, dass alle „Einrichtungen, die dem Austausch von zentralen Gütern und Diensten dienen, stehen unter der gleichen Notwendigkeit, mit einem größeren, hauptsächlich verstreut wohnenden Personenkreis in Verbindung treten zu müssen“ (Christaller 1933: 142). Darauf basierend berechnet Christaller die Zentralität Z_z eines Ortes wie folgt:

$$Z_z = T_z - E_z * \frac{\mathrm{T_g}}{\mathrm{E_g}}$$

Gegeben durch die Telefonanschlüsse T_Z eines Ortes, dessen Einwohnerzahl E_Z, der Anzahl der in dem Gebiet befindlichen Telefonanschlüsse T_g und der dort lebenden Bevölkerung E_g.

Im Gegensatz zur Zentralität ist die Konnektivität ein Maß für die Einbindung von Räumen in die firmeninternen Netzwerke von wissensintensiven Unternehmen und wählt damit nur einen Teil der gesamten Wirtschaft aus. Sie gibt einen Annäherung an die Intensität von Austauschbeziehungen zwischen Firmenstandorten in urbanen Funktionalräumen wieder (Taylor 2004). Das Interlocking Network Model geht davon aus, dass die einzelnen Niederlassungen von wissensintensiven Mehrbetriebsunternehmen untereinander in Austausch stehen. Firmeninterne Standortnetzwerke können somit als Näherungsgröße für den potentiellen Informationsaustausch zwischen urbanen Funktionalräumen herangezogen werden. Mehrbetriebs- und Mehrstandort-Unternehmen wählen ihre Standorte systematisch, um den Wertschöpfungsprozess zu optimieren. Bei wissensintensiven Unternehmen geht man daher von der Annahme aus, dass der Austausch zwischen Unternehmensstandorten letztlich zentral der Wissensgenerierung dient (Lüthi, Thierstein und Bentlage 2013). Diese Messung von Konnektivität weist somit eine deutliche Ähnlichkeit zur Zentralität auf. Da hier jeweils Näherungsgrößen für das Potenzial der Austauschbeziehungen bestimmt werden und nicht die tatsächlich erfolgten Interaktionen. Diese Eigenschaft macht ein Vergleich möglich.

Das hier verwendete Firmensample zur Berechnung der Konnektivität greift auf insgesamt 270 Unternehmen der wissensintensiven Dienstleistungen und 210 Unternehmen der High-Tech Branchen zurück. Darin sind die jeweils 30 größten Unternehmen Deutschlands aus 16 wissensintensiven Branchen enthalten (Tabelle 6.1).

Die Konnektivitätsanalyse basiert auf folgenden empirisch belegten Annahmen (Taylor 2004: 55-70). Wissensintensive Unternehmen wählen ihre Standorte deshalb strategisch und mit Bedacht aus, weil Schaffen und Nutzen von Wissen von zentraler Bedeutung im Wertschöpfungsprozess sind. Daher findet zwischen solchen firmeninternen Standorten ein Informationsaustausch statt. In der Regel sind die Kommunikationsströme von einem Hauptsitz zu seinen Zweigstandorten hochwertiger als zwischen Standorten auf gleicher Hierarchieebene. Wenn man eine hinreichend große Zahl firmeninterner Standortnetzwerke auf diese Weise analysiert und bewertet, können Konnektivitätswerte von urbanen Funktionalräumen berechnet werden. Mit Hilfe dieser Konnektivitätswerte wird die Position einer Agglomeration in der funktional-räumlichen Hierarchie eruiert. Je höher der Konnektivitätswert ist, desto bedeutender ist die Position in der funktional-räumlichen Hierarchie. Betrachtet man das gesamte relationale Wirtschaftssystem, so wird das Gefälle zwischen den Funktionalräumen deutlich. Je unterschiedlicher die errechneten Konnektivitätswerte sind, desto stärker unterscheidet sich diese relative Bedeutung einzelner Standorte, mit anderen Worten fällt die funktional-räumliche Hierarchie steiler ab.

Advanced Producer Services (APS)	**High-Tech**
Banking & Finance: 6511, 6512, 6521, 6522, 6523, 6711, 6712, 6713, 7011, 7012	**Chemistry & Pharmacy:** 2330, 2413, 2414, 2416, 2417, 2420, 2441, 2442, 2451, 2461, 2463, 2464, 2466, 2511, 2513, 2615
Advertising & Media: 7440, 2211, 2212, 2213, 2214, 2215, 9211, 9220, 9240	**Machinery:** 2911, 2912, 2913, 2914, 2924, 2931, 2932, 2941, 2942, 2943, 2952, 2953, 2954, 2955, 2956, 2960
Information and Communication Services: 6430, 7221, 7230, 7240, 7250, 7260	**Electronics:** 3110, 3120, 3140, 3150, 3161, 3162, 3210, 3320, 3330
Insurance: 6601, 6602, 6603	**Computer & Hardware:** 3001, 300
Logistics (3p & 4p): 6030, 6110, 6220, 6230, 6340	**Telecommunication:** 3220, 3230
Management‑ & IT‑Consulting: 7210, 7222, 7413, 7414, 7415	**Medical & optical instruments:** 3310, 3340
Design, Architecture & Engineering: 7420, 7430	**Vehicle construction:** 3410, 3430, 3511, 3520, 3530
Law: 7411	
Accounting: 7412	

Tabelle 6.1: Wissensintensive Dienstleistungen und High-Tech Branchen eingeteilt nach WZ2003 (Quelle: Lüthi 2011 basierend auf Legler und Frietsch 2006)

In unserer Untersuchung beziehen wir uns nach Christaller (1933) auf die beiden L-Systeme Stuttgart und München, die sich mit den heutigen Metropolregionen vergleichen lassen (Parr 2013). Im Süddeutschen Raum weisen demnach München, Stuttgart, Nürnberg-Fürth und Frankfurt einen solchen L-Bereich auf. Abbildung 6.3 stellt die L-Bereiche dieser Orte und die Umrisse der heutigen Metropolregionen dar. Die Darstellung zeigt Übereinstimmungen zwischen den von Christaller identifizieren L-Bereichen und den heute politisch definierten Metropolregionen, wie sie vom Initiativkreis Metropolregionen (IKM) veröffentlicht werden (IKM 2013).

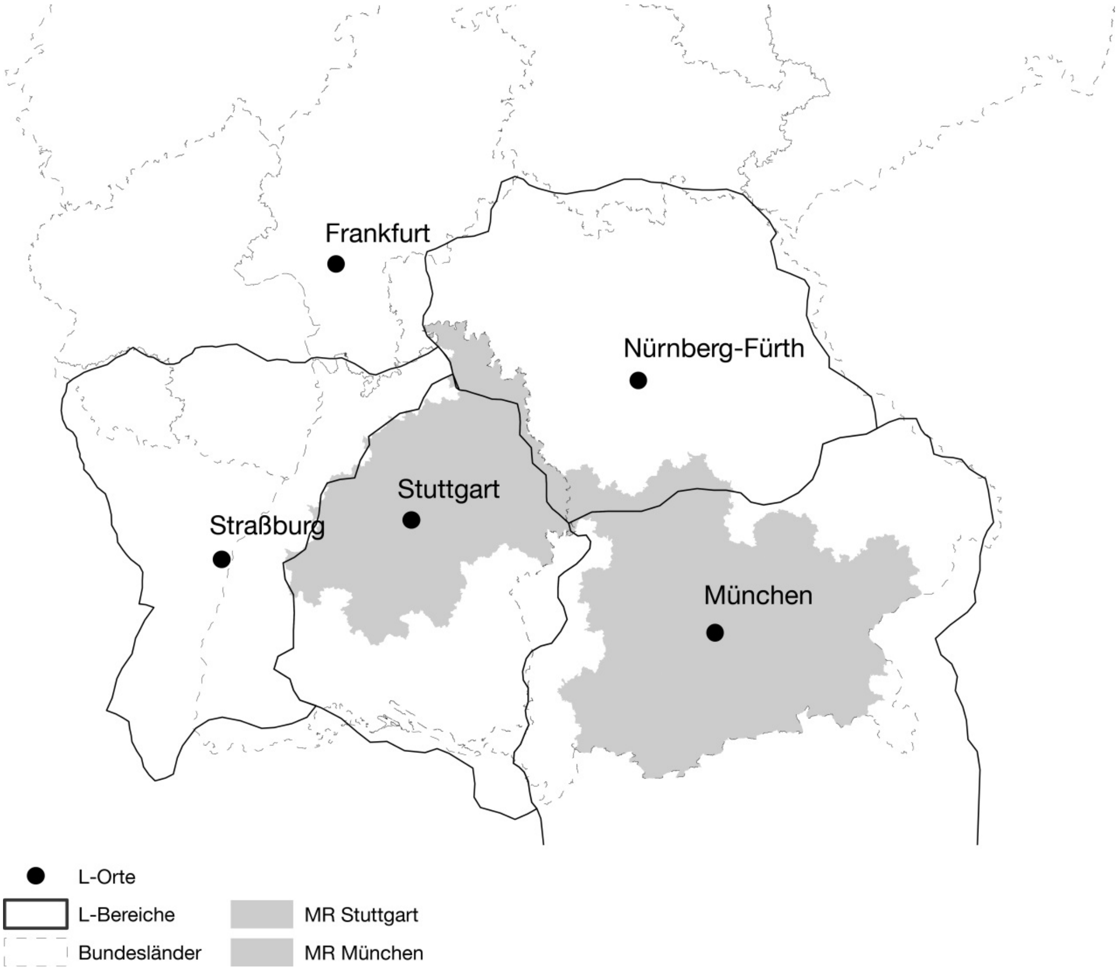

Abbildung 6.3: L-Bereiche in Süddeutschland und die Metropolregionen Stuttgart und München (eigene Darstellung nach Christaller 1933: Karte 4, IKM 2013)

München verzeichnet laut Christaller einen hohen Bedeutungsüberschuss, der über die Grenze Deutschlands hinausreicht und sogar das österreichische Innsbruck einschließt, das nicht Teil der Empirie Christallers ist (Christaller 1968: 176). Der L-Bereich von Stuttgart erstreckt sich bis an den Bodensee und ist im Süden deutlich größer als die Metropolregion. Die nordwestliche Grenze des L-Bereiches verläuft nahezu exakt auf dem heutigen Umriss der Metropolregion Stuttgart. Straßburg nimmt diese Geltung für den Badischen Raum ein, der nach der Zentralitätsrechnung von Christaller keinen L-Ort rechts des Rheins aufweist (Lüthi 2011; siehe auch Beitrag Lüthi, Thierstein, Bentlage in diesem Band).

6.5 Die Hierarchien in München und Stuttgart

6.5.1 Vergleich zwischen Zentralität und Konnektivität

Aus dem System der Zentralen Orten lässt sich eine räumliche Hierarchie abbilden, in der die Zentralität der Orte über die Stellung in dieser Hierarche bestimmt. Dies kommt vor allem durch die Bezeichnung der Zentralen Typen zum Ausdruck (Christaller 1933: 154-155). Auf der obersten Hierarchiestufe stehen die L-Orte, die von Christaller als Landeszentrale bezeichnet werden und einen dazugehörigen L-Bereich bedienen. Nach diesen L-Städten folgen die Provinzialhauptorte, die als P-Orte bezeichnet werden und die G-Orte, die Zentrum eines Gaubezirks sind. Darauf folgen die Bezirksorte, die als B-Orte bezeichnet werden.

Abbildung 6.4 zeigt weiterhin den Vergleich der nach Christaller definierten L, P und G Orte und den von ESPON (2004) bestimmten Functional Urban Areas (FUA), die im wesentlichen Pendlereinzugsbereiche um vorab definierte Zentren darstellen. Auch hier erweist sich eine deutliche Übereinstimmung der beiden räumlichen Aggregate. Die L, P, G Bereiche wurden durch Voronoi-Polygone geometrisch bestimmt. Dabei werden die Mittelsenkrechten zwischen zwei benachbarten Punkten identifiziert und als Grenzlinien der Bereiche herangezogen. Nahezu jede FUA enthält einen P oder G Ort. Während diese Bereiche um München herum sehr weitläufig strukturiert sind, sind die Gebilde von P und G-Beriechen sowie der FUAs um Stuttgart herum deutlich feinmaschiger angelegt.

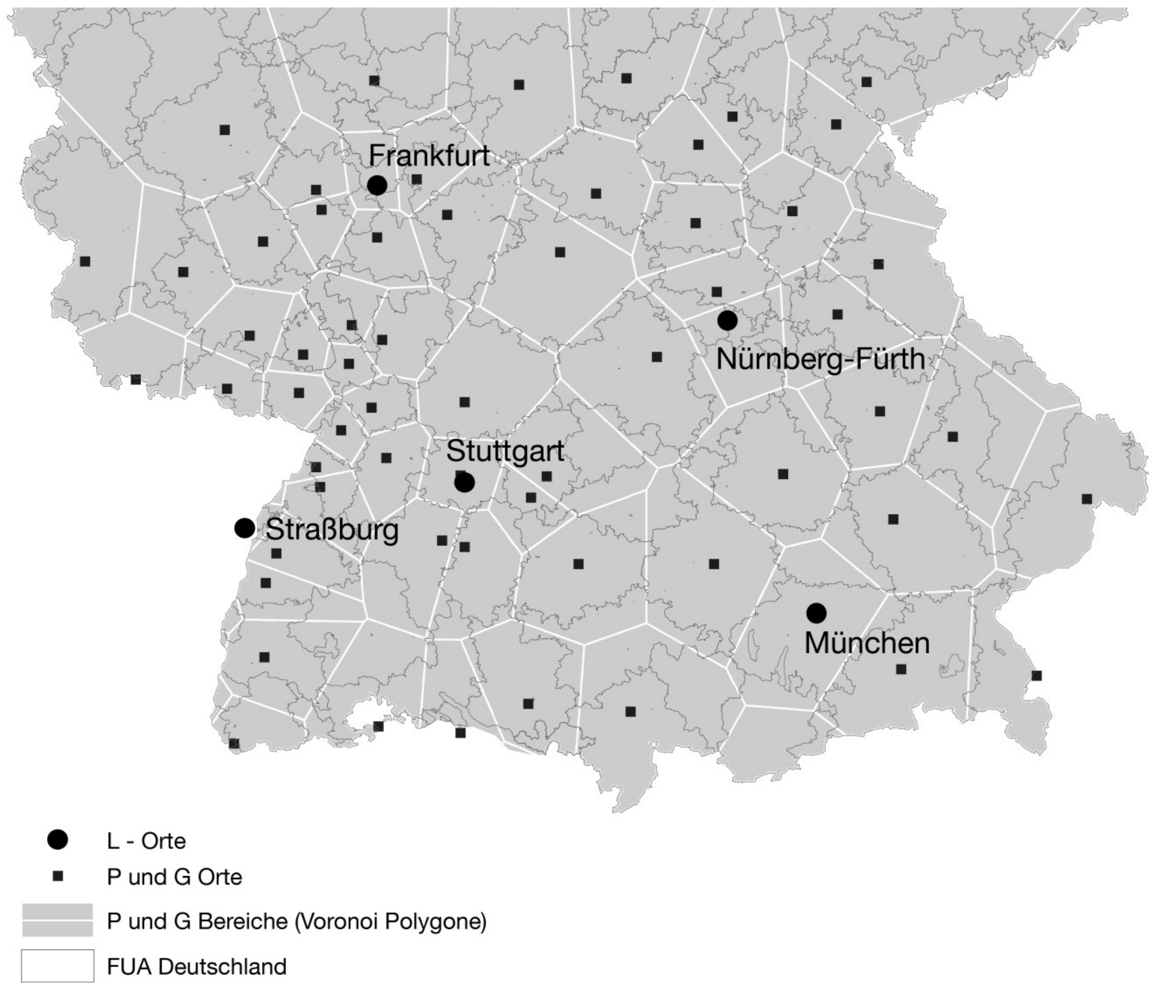

Abbildung 6.4: Vergleich Functional Urban Areas und Voronoi-Bereiche der L, P und G Orte (eigene Darstellung nach Christaller 1968)

Christaller, der seine Untersuchung in den 1920er Jahren im Süddeutschen Raum durchführte, erkannte schon damals, dass Stuttgart eine eher polyzentrische Struktur aufweist. Stuttgart ist von einem Ring mittelgroßer Städte höheren Ranges umgeben. Diese umliegenden Städte weisen eine höhere Zentralität auf, als es das Modell der zentralen Orte vermuten lässt (Christaller 1968: 204). Ersichtlich ist dies an feinteiligen und eher dispersen ökonomischen Aktivitäten um Stuttgart herum. Entgegen der theoretischen Annahme befindet sich um diese Stadt ein Kranz mit Orten, die eine relativ hohe Bedeutung haben, welche wesentlich höher ist als durch die zentrale Orte Theorie zu erwarten wäre. Diese „dichte teils industrielle, teils weinbaubetreibende Bevölkerung hat relativ hohen Bedarf an zentralen Gütern höherer Ordnung“ (Christaller 1968: 204), gleichzeitig ist sie nicht gewillt „hohe Nebenkosten, Wegekosten usw., für die Erlangung dieser Güter aufzuwenden“ (Christaller 1968: 204). Damit begründet Christaller die unerwartet hohe Bedeutung der Städte Reutlingen, Tübingen, Göppingen, Ludwigsburg und Gmünd mit einer hohe Nachfrage durch eine kleinteilige Ökonomie einerseits und einem großen Kostenbewusstsein beim Erreichen dieser Wirtschaftskerne.

München hingegen ist deutlich monozentrisch strukturiert. Die Stadt hat die größte Zentralität im gesamten Süddeutschen Raum und ist dort ebenfalls die größte Stadt. Diese Bedeutung kommt durch den großen Geltungsberiech und die Bereitstellung von zentralen, für das gesamte Land Bayern nötigen Funktionen, wie die Universität, zu Stande (Christaller 1968: 165). Dies führt Christaller auf die Zusammenführung aller wesentlichen Verwaltungseinrichtungen für Bayern und den insgesamt sehr weit reichenden Bedeutungsbereich zurück. Die benachbarten Orte mit ähnlich hoher Bedeutung sind bereits Wien, Zürich, Prag und Venedig, die allesamt relativ weit entfernt liegen. Lediglich Stuttgart und Nürnberg liegen verhältnismäßig nahe an München. Weiterhin scheint München einen Entzugseffekt in seiner näheren Umgebung auszuüben. Augsburg, das beinahe die doppelte Einwohnerzahl wie Würzburg hat, hat eine deutlich geringere Bedeutungszahl als Würzburg (Christaller 1968: 165-166).

Abbildung 6.5 zeigt einen Vergleich der von Christaller berechneten Zentralität und der von uns errechneten Konnektivität für die Branchen APS und High-Tech. Wie eingangs in dieser Sektion gezeigt, weisen beide Aggregatsebenen einen vergleichbaren räumlichen Zuschnitt auf und es ist daher zu erwarten, dass die dahinterliegenden Kennziffern vergleichbar sind. Die Werte der Zentralität und der Konnektivität wurden auf München beziehungsweise Stuttgart normiert. Vergleicht man die Stellung der beiden Landeshauptstädte, so fällt auf, dass sie in der Christaller'schen Hierarchie deutlich stärker von den übrigen Orten abgesetzt waren, als es in unserer eigenen Erhebung der Fall ist.

Bewusst wird erneut die eher monozentrische Struktur von München. In diesem L-System rangieren die Städte Augsburg und Regensburg zwar auf der nächsten Hierarchieebene. Ihre Zentralität erreicht jedoch lediglich 0,08 und damit 8 % derjenigen von München. Die Städte Pforzheim und Ulm/Neu-Ulm erreichen immerhin 13 beziehungsweise 10 % des Wertes von Stuttgart.

Betrachtet man die Ausprägungen der Zentralität und der Konnektivität werden deutlich Unterschiede sichtbar. Insgesamt scheinen die Abstände zwischen den beiden Hauptstädten München und Stuttgart zu den jeweiligen umgebenden Orten geringer geworden zu sein. Dies lässt sich dadurch erklären, dass die Wissensökonomie räumlich eher polyzentrische Strukturen heraus bildet und sich dieser Prozess gerade in entwicklungsstarken Räumen bemerkbar macht. Dieser allgemeine Trend der Herausbildung wissensgetriebener, polyzentrischer Strukturen wird jedoch an manchen Orten durch sehr spezifische Entwicklungen begleitet.

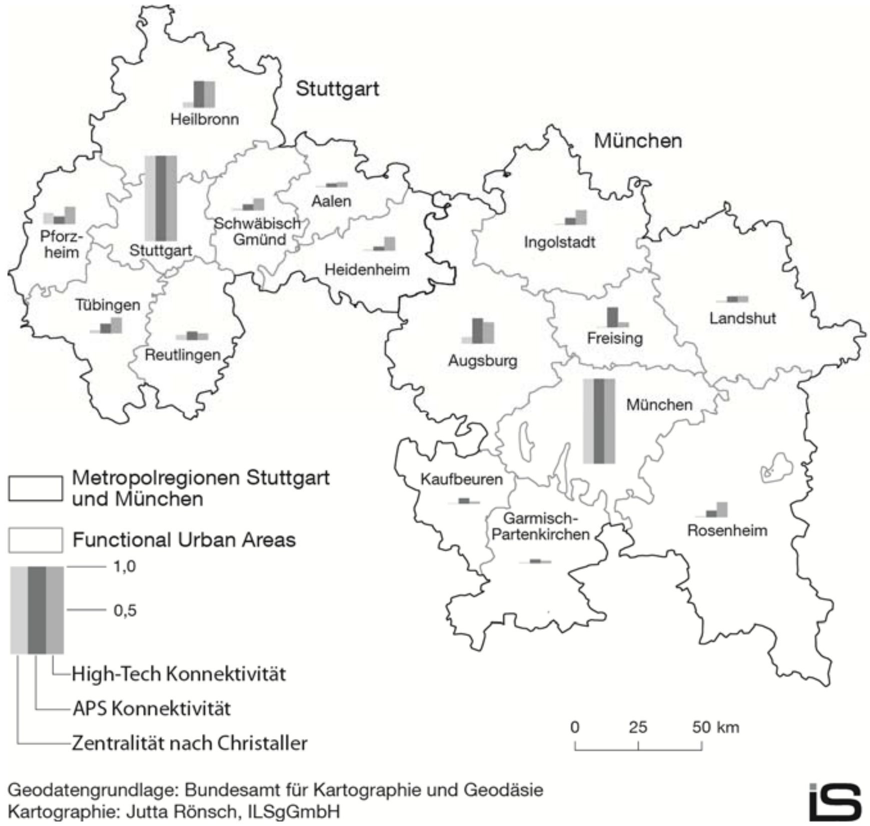

Abbildung 6.5: Vergleich von Zentralität und Konnektivität (eigene Berechnung nach Christaller 1968; eigene Erhebung)

Besonders deutlich ist diese Dynamik in Freising zu beobachten. Dieser Ort hatte nach Christaller eine sehr geringe Zentralität, die sich auf einen Prozent in Relation zu München beläuft. Heute ist Freising ein bedeutender Dienstleistungsstandort und erreicht – bezogen auf APS – einen Konnektivitätswert von 24 % relativ zu München. Auslöser dieses Anstiegs ist der internationale Drehscheiben-Flughafen, der 1992 seinen Betrieb aufnahm und heute der zweitgrößte in Deutschland ist; der Flughafen mit seiner Region ist als neuer ökonomischer Kern zu begreifen und fungiert als wichtiger räumlicher Treiber (Lüthi, Thierstein und Goebel 2010).

Augsburg als Teil der Metropolregion München und Ulm/Neu-Ulm als Teil der Metropolregion Stuttgart haben sich sehr positiv entwickelt. Dies zu verstehen bedarf nochmals der Rückbesinnung auf die Christaller'sche Anordnung der zentralen Orte und die oben gewonnen Erkenntnisse über die gegenseitige Einflussnahme zweier Orte in deren Entwicklungsverlauf. Beinahe ist es verwunderlich, dass sich mit Augsburg und Ulm/Neu-Ulm zwei so bedeutsame Orte in nächster Nähe zu einander befinden. Verantwortlich sind dafür nach Christaller historische Gründe sowie die jeweils nördlich und südlich beider Orte nur sehr geringen Siedlungsdichten (Christaller 1968: 168 und 202). Aus heutiger Sicht birgt diese Nähe jedoch die Gefahr, dass sich beide Orte in ihrer Entwicklung behindern, wenn sie zu ähnliche Strukturen aufweisen und dadurch substituierbar wären. Die hohe Konnektivität von Ulm/Neu-Ulm im High-Tech Sektor und die relativ hohe Bedeutung von Augsburg in APS lassen vermuten, dass sich beide Orte eher komplementieren. Damit ist die Achse Stuttgart-Ulm/Neu-Ulm-Augsburg-München von hoher Bedeutung für beide Metropolregionen und macht bewusst, dass diese Systeme nicht geschlossen sind und vor allem hin zu den Rändern Überlappungen mit anderen

Metropolbereichen bestehen. Die Verbesserung der Erreichbarkeit entlang dieser Strecke durch die TEN Transport-Achse Paris-Wien-Bratislava wird die Interaktionsdichte zudem erhöhen.

6.5.2 Der Einfluss von Urbanisations- und Lokalisationseffekten auf die Hierarchie

Die Bedeutung von spezifischem Wissen setzt einen Mechanismus in Gang, der die zentralörtliche Hierarchie weiterhin aushebeln kann. Dazu betrachten wir die Struktur der Beschäftigten im Vergleich zur Konnektivität in den jeweiligen FUAs. Abbildung 6.6 zeigt die normierte Interlock Connectivity aller deutschen FUAs auf der y-Achse und den Herfindahl-Hirschman Index (HHI) der Wissensökonomie. Der HHI ermöglicht Aussagen über den Grad der Spezialisierung in einem Wirtschaftsbereich. Je höher dieser Index ist, umso stärker ist die Region in einem Sektor spezialisiert. Werte nahe bei null deuten auf eine starke Diversifizierung der Wirtschaft hin. Aus dem HHI wurde in der hier dargestellten Berechnung die Quadratwurzel gezogen, da er sonst relativ extreme Werte annehmen kann.

Die FUAs Wolfsburg, Ludwigshafen und Ingolstadt weisen eine besonders hohe Spezialisierung auf. Allerdings ist deren Konnektivität relativ gering, da dort nur wenige Unternehmensstandorte der Wissensökonomie zu finden sind, die gleichzeitig jedoch eine hohe Anzahl an Mitarbeitern beschäftigen. In Wolfsburg ist zum Beispiel der Volkswagen Konzern ansässig, in Ludwigshafen BASF und Ingolstadt beheimatet die AUDI AG. Diese Standorte sind durch ihr spezifisches und komplementäres Wissen von hoher Bedeutung. München, Hamburg, Stuttgart, Berlin und Frankfurt weisen hingegen eine hohe Konnektivität auf. Gleichzeitig sind diese Räume deutlich diverser ausgerichtet und lassen einen starken Überschuss an Urbanisationseffekten vermuten.

Ein interessanter Fall in dieser Betrachtung ist Ravensburg, das einen HHI von 14,2 und eine normierte Gesamtkonnektivität von 0,2 aufweist. Diese FUA ist in der Abbildung 6.6 nicht gesondert dargestellt, da sie nicht teil der Metropolregion Stuttgart ist. Ravensburg liegt im Metropolen-Dreieck München, Stuttgart, Zürich (Thierstein et al. 2008: 102), wo sich zu damaliger Zeit laut Christaller kein Ort dieser Bedeutung finden lässt (Christaller 1968: 202). Heute weist Ravensburg für APS eine Konnektivität von 25 % in Relation zu Stuttgart auf und rangiert damit auf dem vierten Platz in diesem L-System (vgl. dazu Abbildung 6.5).

Der relative hohe HHI von Ravensburg lässt vermuten, dass vor allem Lokalisationseffekte getrieben durch die Zeppelinwerke in Friedrichshafen ausschlaggebend waren. Dabei scheinen sich diese Lokalisationsvorteile in Urbanisationsvorteile umzuwandeln. Die Unternehmenslandschaft hat sich dabei allmählich ausdifferenziert und beheimatet heute Unternehmen wie die MTU Friedrichshafen GmbH, die ZF Friedrichshafen AG, die EADS Deutschland GmbH, die Zeppelin Silos & Systems GmbH und den Tognum-Konzern (Stadt Friedrichshafen 2013). Boschma und Frenken (2011) bezeichnen diesen evolutiven Prozess, in dem sich neue Industrien aus alten heraus entwickeln, als „regional diversification as a branching process“ (Boschma und Frenken 2011: 69). Wichtig ist dabei die technologische Nähe zwischen diesen alten und neuen Industrien. Eine ähnliche Entwicklung lässt sich in Ingolstadt beobachten. Seitdem sich die Audi AG dort angesiedelt hat, ist der Standort zu einem vielfältigen Wirtschaftsraum geworden, der vor allem Unternehmen der weiter gefassten Mobilitätswirtschaft beheimatet (Thierstein et al. 2011).

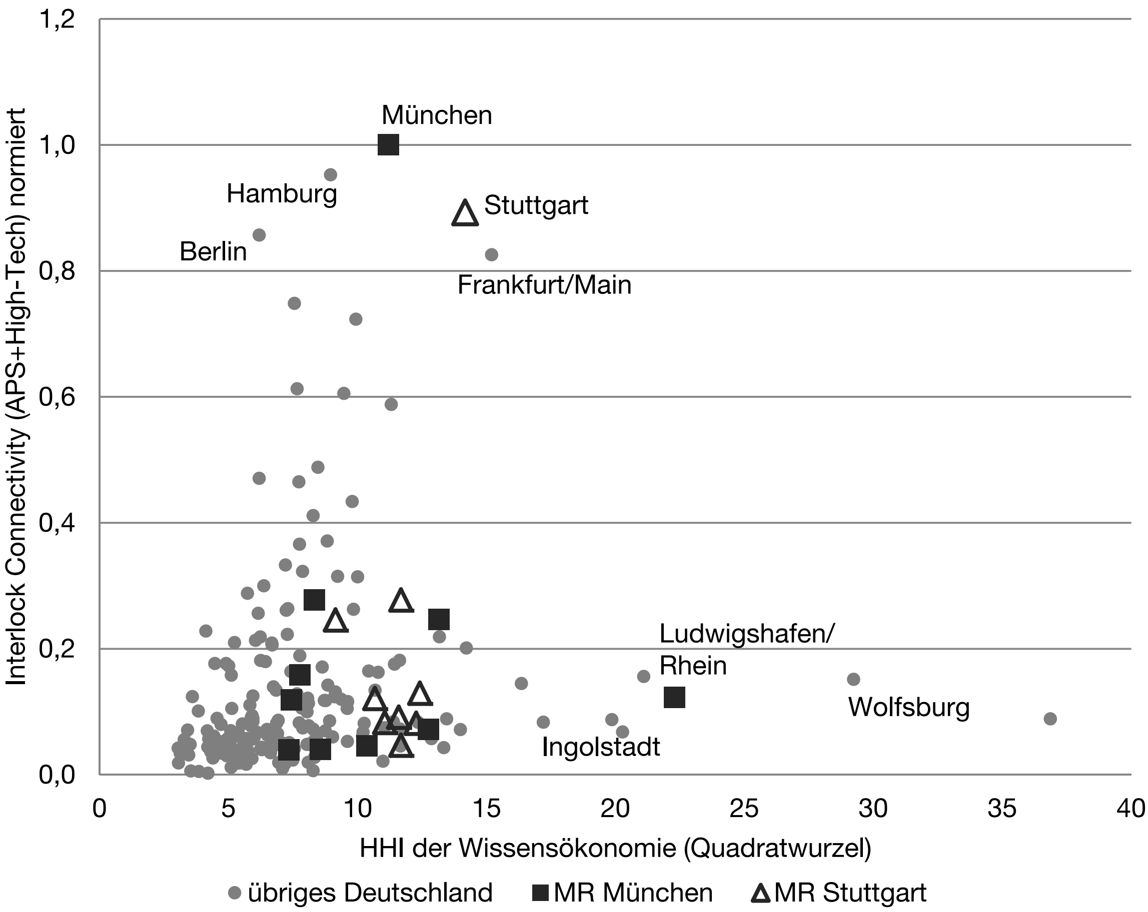

Abbildung 6.6: Normierte Interlock Connectivity (APS und High-Tech) und HHI der Wissensökonomie

Zusammenfassend lässt sich sagen, dass die von Christaller beschriebene räumliche Struktur bis in die heutige Zeit zu erkennen und damit ansatzweise stabil ist. Gleichzeitig haben sich jedoch neue urbane Zentren entwickelt und zur Veränderung im Bedeutungsgefüge der zentralen Orte geführt. Die markantesten Beispiele sind Ingolstadt sowie Ravensburg, die sich durch einen hohen Grad der Spezialisierung, als bedeutsam für die Wissensökonomie erweisen und Freising, das durch den Flughafen eine globale Bedeutung erlangen konnte.

6.6 Schluss

Auf Grundlage der oben durchgeführten Analyse lassen sich folgende polyzentrische Entwicklungen in den beiden Metropolregionen festhalten. Erstens lässt sich ausgehend von einer starken Konzentration wirtschaftlicher Aktivitäten in den Landeshauptstädten München und Stuttgart eine Ausbreitung in das näher umgebende Unland erkennen, was zu einer intra-urbanen Polyzentralität führt. Im Falle von Stuttgart war dieses Umland bereits bei Christaller durch den engen Ring hochwertiger Kreisstädte um Stuttgart herum sichtbar. Deren Bedeutung hat sich durch die Ausweitung wissensintensiver Arbeitsprozesse erhalten. München hingegen, das zu Zeiten von Christaller viel stärker monozentrisch strukturiert war, lässt eine ähnliche Tendenz zu Polyzentralität im näheren Umland erkennen. Treibende Kraft ist dabei der Flughafen in Freising, der eine starke urbane Dynamik zwischen München und dem Flughafengelände nach sich zieht. Weiterhin wächst der Bevölkerungsdruck auf die beiden Kernstädte München und Stuttgart und führt ebenso dazu, dass sich beide noch stärker in ihr Umland ausbreiten. Dies ist zum Beispiel am Wachstum der umliegenden Gemeinden von München, wie Dachau, Ober- und Unterschleissheim oder Ismaning, zu erkennen (Landeshauptstadt München 2012).

Als zweite Entwicklungsdynamik sind inter-urbane Entwicklungen innerhalb der Metropolregionen zu erkennen. Im Falle von Stuttgart ist die wachsende Bedeutung von Heilbronn und von Ulm/Neu-Ulm zu erkennen. Innerhalb der Metropolregion München haben Augsburg und Regensburg ihre Bedeutung als Knotenpunkte im urbanen System bestätigt. Bezogen auf die Wissensökonomie lässt sich also eine *dezentrale Konzentration* an bereits etablierten Standorten erkennen. All diese Orte liegen jeweils in Mitten bedeutender Metropolregionen. Ulm/Neu-Ulm genauso wie Augsburg sind wichtige Knotenunkte entlang der Achse Stuttgart-München. Heilbronn liegt in Mitten des Dreiecks Stuttgart, Nürnberg und Frankfurt. Zum einen nutzt Heilbronn dadurch die Nähe zu Stuttgart, zum anderen behält die Stadt den Charakter eines Scharniers zwischen den beiden anderen Metropolregionen. Dieses eher geometrische Argument lässt erkennen, dass die Untersuchung Christallers zu der räumlichen Ordnung des Verkehrsprinzips, in dem Orte mit niedriger Zentralität zu den Mittlern zwischen Orten mit höherer Zentralität werden, noch immer Gewicht haben.

Die dritte Entwicklung erkennen wir an dem Aufkommen stark spezialisierter Standorte. Wir verorten einen solchen Trend in Ravensburg und Ingolstadt. Beide Standorte haben sich von der untersten Zentralitätsstufe zu wichtigen spezifischen Knoten entwickelt. Diese ‚Reise' lässt vermuten, dass sich eine Sukzession in Gang setzt, die in den Netzwerken einzelner Unternehmen beginnt, Lokalisationsvorteile heraus bildet und die bei weiterer Diversifizierung, guter Erreichbarkeit und hinreichender Größe sich in Urbanisationsvorteile umwandeln können.

Mit dem Erklärungsansatz einer relationalen Wissensökonomie kann gezeigt werden, dass das Beziehungsgefüge beider Metropolregionen, starken Einfluss auf deren unterschiedliche Entwicklung hat. Für beide Wirtschaftsräume spielen Hochtechnologie und Automobilwirtschaft im weiteren Sinne eine zentrale Rolle – beides Wirtschaftssektoren, die sich in einem tiefgreifenden technologischen und Orientierungswandel befinden. Wir vermuten, dass der Süddeutsche Raum in den nächsten zwei bis drei Jahrzehnten weiterhin stark wachsen wird. Ein zentraler Treiber für diese Entwicklung sind, neben einem leistungsstarken dualen Bildungssystem, die Erreichbarkeitsvorteile, die daraus entstehen, dass Haltepunkte von

Hochgeschwindigkeits-Schienenverkehr und internationalen Flughäfen miteinander verknüpft werden und somit ein weiteres Potenzial der räumlichen Entwicklung bieten. Die Frage bleibt, ob beide Regionen dieses Potential nutzen können und sich die Kompetenzen beider Wettbewerbsräume eher ergänzen oder ob beide Räume in Konkurrenz zueinander stehen werden.

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7 General Conclusion

7.1 Main findings

The general conclusion briefly recapitulates the main findings of the former chapters and aims to further the question of how knowledge creation, space, and time have to be explored. Furthermore the final section refers to the impacts on spatial planning and aims to situate the aforementioned results in the context of the Germany's future development options. The following four findings have been deemed worthy of discussion:

The first striking result derives from the interrelation of physical accessibility and non-physical networks; virtual communication drives the movement of people and vice versa. This interplay of agglomeration and network economies provides a profound theoretical background for such an analysis. The interactive process of knowledge production evokes relations between cities, which can be measured in intra-firm networks, global value chains, or air passenger movement. Both these dimensions the physical and non-physical seem to reveal congruent patterns. In line of this, there is a fruitful match between physical and non-physical exchange.

The second result highlights the differences between APS and high-tech networks. Although the congruence of physical and non-physical networks suggests that there is a superior principle of order of how cities establish network links, APS and high-tech firms evoke specific network configurations. This is explained by different processes of value addition, which are in the case of high-tech much more dependent on fixed production factors like capital investment in machinery and plant facilities. Accordingly, high-tech firms tend to be less centralised than APS firms, but still require proximity to metropolitan regions and thus regional access to dense labour markets and urban centres.

Thirdly, the hypothesis of an 'increasing interwoven-ness of network and agglomeration economies' suggests that agglomerations become increasingly interconnected to other places. So far within this dissertation equilibrium between geographical and relational proximity was assumed. Applying an evolutionary perspective on this interplay allowed for the challenging of such equilibrium: the agglomeration shows stabilising effects and persistence by providing increased returns to agents that are located within that agglomeration. From this perspective, increasing returns induce path dependency while using one technology, which in turn hinders the change to other technologies. This consequently implies the hypothesis: if agglomeration economies realise increasing returns, then the agglomeration itself is involved in a path-dependent evolution of space. Accordingly, the agglomeration represents a temporarily spatial configuration which is optimal for localized production systems. Once these benefits of agglomeration economies disappear, the agglomeration of economic activity might devolve and other forms emerge. Thus, diseconomies of agglomeration might lead to other forms of spatial location beyond the agglomeration. The question arises whether the disappearance of agglomeration advantages in one place will lead to the emergence of agglomerations in other places, or even the emergence of a totally new system beyond agglomeration which might be the network. In other words, the question for substitutive effects or relational proximity arises again with every new technology that enables other forms of communication.

Fourthly, the analysis of the dynamics and configuration of the German urban system reveals two further insights. Firstly, since specialised and diversified cities coexist, their development needs to be considered as a relational process. The specialisation in one place is enabled by the diversification in another. The more that labour gets divided in different parts, the stronger the need to recombine these different parts becomes. Thus, specialisation engenders economic growth while furthering existing routines and exploiting economies of scale. Diversity provides stability by integrating these specialised routines. Accordingly, both environments coexist in spatial proximity.

Secondly, one must acknowledge that it is not only one urban system that appears in the process of knowledge creation. Different types of knowledge, the existing knowledge base, and how this knowledge is implemented in production processes lead to different urban systems which in turn have their own spatial logic. Strongly concentrated forms of knowledge relations with a high share of ‘tacit-ness’ and low cognitive proximity tend to form a nested hierarchy (Camagni 1993) with leading urban centres acting as hubs. Other forms of knowledge relations with a lower degree of tacit knowledge and higher cognitive proximity between the agents tend to form a rather ‘non-nested hierarchy’ (Lüthi 2011: 132). Therefore, future development options need to consider different types of knowledge relations.

7.2 The multi-dimensional approach

The multi-dimensional approach applied in this dissertation aimed to provide an overview on different concepts in the context of knowledge creation and spatial development. This approach reflects upon knowledge production from the dimensions of space, time and social structures. Based on the discipline of economic geography, the selection of dimensions represents a broad spectrum for analysis. However, other dimensions could be included into this approach. These dimensions might be:

- the psychological approach to knowledge and how individuals learn
- differences in technologies and industries; since knowledge transfer depends on cognitive proximity which in turn differs strongly within and between economic activities
- forms of collaboration including atomistic market transactions, collaborations and informal relationships

Furthermore, this approach considers three interrelations of knowledge and space. 'Interrelation 1' in which knowledge production is dependent on spatial factors; 'Interrelation 2' in which knowledge production drives spatial development; and 'Interrelation 3' as a combination of these opposing causalities in a cumulative causation. These interrelations focus mainly on the relation of causes and effects. This approach is useful to quantify different relationships but requires a deep knowledge of possible relationships.

However, causal-analytical approaches might have the disadvantage that processes of high complexity are not described adequately. These relationships are not mono-causal. Other variables might intervene in these relationships and cause a multitude of possible and variable causes and effects. Further research should focus on the specificity of the processes within knowledge creation. Systemic thinking might define the boundaries of these processes.

Such a process-based perception requires additional insights into the relationship of space and time. As shown in chapter 1, Knowledge creation is situated within different spatial scales and happens over different durations of time. Furthermore, employees of knowledge intensive work learn not only in one place at one certain point in time. Moreover, these individuals make use of business travels and encounters in different places all over the world. Approaches such as temporary geographical proximity (Bathelt and Schuldt 2008; Maskell, Bathelt and Malmberg 2006) for the purpose of knowledge creation might provide a good starting point for a process-oriented research framework.

Another extension of the research on knowledge and space intersects with the dynamics of mega-city regions and the provision of other fundamental functions such as housing, mobility and leisure. This dissertation refers to the phenomenon of 'decentralised centralisation' and emerging polycentric structures (chapter 3). This daily urban system seems to be in a transformation with different patterns of centralisation and decentralisation. Employees have their own spatial logic in combining private and working life. Firms depend on the qualification of the labour market and proximity to local partners. This spatial logic might differ on the scale of a daily urban system. Accordingly, the working life is in the process of becoming more and more flexible with regard to the place where people work and the time when they work. Since this dissertation focused on the emerging polycentricity provoked by knowledge intensive firms, there seems to be another form of polycentricity when it comes to inhabitants, who now have multiple anchor points within their daily lives.

> *"It will be apparent that the urban system of the modern city-region is to be seen as something other than a static structure, although there may be intervals when the pace of change is relatively slow. As already mentioned, the urban system of a city-region is subject to the effects of external as well as internal change, these taking the form of shocks" (Parr 2013: 10).*

Consequently, working and living are situated in a regional context. Further research might lead towards an integration of these subsystems of working and living within a mega city region while focusing on the dynamics of both subsystems.

7.3 The future of the German urban system

The last section of the conclusion applies a look at future developments in Germany and changes occurring on the global scale. Therefore, we firstly reflect upon the main findings of this dissertation based on the planning principle of comparable living conditions. Afterwards, this section addresses the appearance of the financial crisis in the years 2007 to 2010. This provides three hypotheses about development options of the German urban system. Both topics represent my future interest within the fields of economic geography and spatial planning.

As presented in the introductory chapter, the economic base of Germany is gradually orienting more towards knowledge intensive activities. Structural features of such a change are multifaceted: fierce competition for skilled, mobile and motivated labour force, unemployment of non-qualified labour, longer commutes, multi-local households, re-concentration of the value chain, increased knowledge intensity of innovations, triple-helix collaborative ventures, structural weakness of public budgets, etcetera. Most of all, such a structural change has spatial consequences. Uneven spatial development, concentration in polycentric, large-scale urban regions and increases in spatial disparities are the rule and not the exception. This might affect the planning principle of comparable living conditions (Kuhn and Klingholz 2013; Einig 2008; Herfert 2007; Akademie für Raumforschung und Landesplanung ARL 2005). This principle aims to level the disparities in income, employment, infrastructure and education within the German territory (Kuhn and Klingholz 2013: 8).

This begs the questions: in which way does this structural change affect the territory of Germany, in which securing comparable living conditions still counts among the basic constitutional principles? One scenario might be that knowledge intensive employment tends to concentrate in two different spatial environments: firstly, urban metropolitan centres and secondly, network nodes with specialized knowledge resources.

Urban metropolitan centres, such as Hamburg, Frankfurt, or Munich, are characterised by a diversified labour force, sufficient size, and supra-regional accessibility. Specific network nodes emerge thanks to the integration of highly specialized working routines in global production networks. Both the urban metropolis and specific network nodes are qualified by their combination of agglomeration economies and network economies and the provision of geographical and relational proximity. Whereas large urban centres tend to stabilise the urban hierarchy in a long-term perspective, specialised network nodes might trigger dynamic changes within the hierarchy. We further hypothesize that the functional urban hierarchy in Germany tends to get steeper the more the overall economy transforms into a knowledge economy.

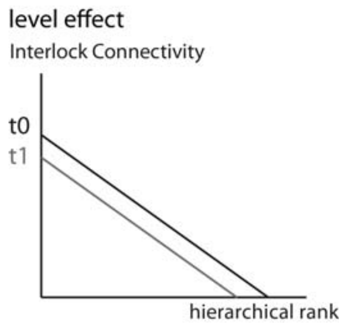
A second outlook refers to the potential impact of the financial crisis. The financial crisis of the years 2007 to 2010 represents a catalyst of economic change (Schwengler and Hecht 2011; Zarth 2011, 2011; Harvey 2011; Schamp 2011; Martin 2011; Thierstein 2009; Brandt 2009; Aalbers 2009). This ongoing crisis yields a superimposition of cyclical and structural effects. The cyclical crisis induced by a collapse of mortgages is a rather short-term phenomenon. The structural crisis, however, affects the world economy in a long-term perspective by increasing regional inequalities (Dicken 2011; Schamp 2011; Thierstein 2009). These inequalities result in long-term disparities of commercial balances (Schamp 2011: 105). For example China and Germany generate a high surplus of trade due to their export-oriented economies. Other countries, such as the USA, tend to have a high demand for these commodities and produce a surplus of imports (Bundeszentrale für politische Bildung 2009, 2009; Dicken 2011).

This crisis triggered unprecedented dynamics in the world economy and it shrank for the first time since World War II (Pohl 2011: 6). This exogenous shock might cause changes in the German urban system (Schamp 2011: 104-106). Innovation represents a crucial driving force against the structural crisis (Thierstein 2009: 43). In particular in Germany and Central Europe which face declining population size and a high share of an older population. Thus, the market area will shrink in the future. These demographic changes result in a decline of domestic demand. Consequently, firms have to explore new markets, products and processes in order to realise growth again. The knowledge economy is instrumental to innovation and development processes. Thus, the reorganisation of this part of the economy with regard to the crisis might fundamentally affect the German urban systems.

Three different scenarios might be possible for the formation of German agglomerations: a level effect, a slope effect, and a ranking effect. The t_o represents the time before the crisis, whereas t_1 displays one point of time in the future which might be 5 to 10 years ahead.

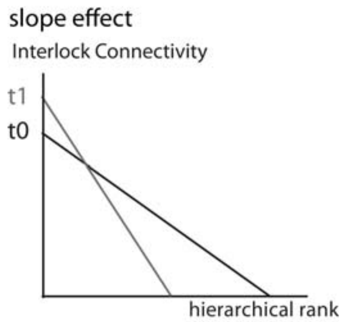
7.3.1 Hypothesis 1 – level effect

Given that the period before the financial crisis represented an era of strong consumption and global interconnectedness, the collapse of this system might affect the level of global activities negatively. If the financial and economic crisis causes a decline of global demand for commodities, the interlocking networks of knowledge intensive firms might follow this decline. Therefore, the level of global connectivity might become lower than before the crisis.



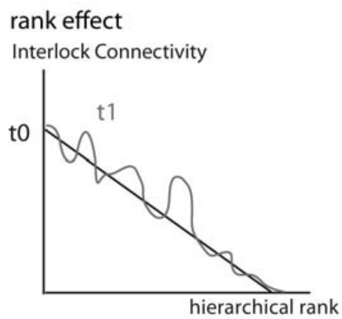
7.3.2 Hypothesis 2 - slope effect

The spatial preconditions for recovering from the crisis differ clearly. Regions with global accessibility, a highly qualified labour force and proximity to educational infrastructure and knowledge intensive firms might provide better conditions for future development. In this regard the functional urban hierarchy will get steeper than it actually is. This process is strongly supported by a strong re-urbanisation of cities such as Munich, Hamburg and Frankfurt.



7.3.3 Hypothesis 3 – ranking effects

Developing countries such as Brazil, Russia, India and China, all with a strongly growing population, are important trading partners for Germany. The positive development and the increasing demand for commodities such as cars and electronical equipment in these countries have compensated for the overall recession of the entire world economy. Therefore, regions with intense trade and interrelations to these countries might benefit stronger than regions that are more dependent on the traditional partners within Europe and USA where markets are saturated to some extent. This might result in changing ranks within the functional urban hierarchy.



Summarising, the outlook on the future development focuses strongly on the aftermath of the financial crisis and how German agglomerations might recover. This crisis is not just a collapse of financial institutions, but a fundamental economic crisis. The aforementioned effects might occur simultaneously and, thus, are not contradictory. However, the future of the German economy and the welfare state depends strongly on the structural change towards the knowledge economy and its subsequent spatial logic. The spatial preconditions for knowledge creation given by network and agglomeration economies tend to differ clearly and might become even more important areas of study during times of shrinking population and employment. A relevant topic for the future will be how the welfare state and spatial planning will sustain comparable living and working conditions in places that do not provide a dense labour market and highly connected environment of knowledge generation. In light of such a foreseeable future friction point, further longitudinal research is required which applies the coevolution of spatial structure and the relational perspective upon economic activities.

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Curriculum Vitae

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2008	Research assistant at the chair for Population and Social Geography, University of Würzburg
2008	Diploma degree in Geography with minor subjects political science and statistics
2007	Internship at the „Institut für Länderkunde“ in Leipzig
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Since 2002	studies in Geography at UniversitätWürzburg
2001/02	travels and language training in Central America
2000/01	Civil service in the hospital of Konstanz
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Teaching

Space Syntax (SS 2012)

European Mega-City Regions (regular course)

Analysieren, Visualisieren, Kommunizieren (WS 2010/11, SS 2011)

Metropolregion München (WS 2009/10)

Short designs (regular course)

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Research Projects

Project management "Networks and Visualization". Contract period: 15.3.2009 - 15.3.2012. Research project together with Nord/LB Regionalwirtschaft. This project aims to develop new visualizations of functional-spatial processes. Therefore we apply GIS-based network analysis.

Project management „Competencies and value added in the Region of Ingolstadt“. Contract period: 1.1. 2010-30.6.2011: Research project for AUDI AG together with Nord/LB, KU Eichstätt-Ingolstadt, Deutschen Institut für Urbanistik and Ernst Basler + Partner AG. This projects assess networks and cooperations of innovation oriented firms in order to increase value added based on research and development

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