Raumforsch Raumordn (2011) 69:161–174
DOI 10.1007/s13147-011-0088-0

WISSENSCHAFTLICHER BEITRAG

Interlocking Firm Networks in the German Knowledge Economy. On Local Networks and Global Connectivity

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Received: 2 October 2010 / Accepted: 22 March 2011 / Published online: 13 April 2011

Abstract The knowledge economy is a key driver of spatial development in metropolitan regions. A relational perspective on its business activities emphasizes the importance of knowledge-intensive firms and their networking strategies. The aim of this paper is to analyse the spatial networking patterns created by the interaction of knowledge-intensive firms and to place these activities in the theoretical context of the knowledge economy. Our central question is which large-scale interlocking networks and functional urban hierarchies are produced by Advanced Producer Services and High-Tech firms located in Germany. The intra-firm locational networks of these companies are analysed on three spatial scales: global, national and regional. The empirical findings show that the functional urban hierarchy in the German city system proves to be steeper than is claimed by the political debate on German Mega-City Regions.

Keywords Germany · Knowledge economy · Advanced Producer Services firms · High-Tech firms · Interlocking firm networks

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Standortverflechtungen in der deutschen Wissensökonomie. Über lokale Netzwerke und globale Konnektivität

Zusammenfassung Die Wissensökonomie ist ein zentraler Treiber der Raumentwicklung. Eine relationale Perspektive auf deren Aktivitäten unterstreicht die Bedeutung von wissensintensiven Unternehmen und ihren Vernetzungsstrategien. Das Ziel dieses Beitrages besteht darin, die räumlich bestimmten Verflechtungsmuster durch die Interaktionen wissensintensiver Unternehmen zu analysieren, und diese in den theoretischen Kontext der Wissensökonomie zu stellen. Im Zentrum steht die Frage, welche großräumigen Netzwerkstrukturen und funktional-räumlichen Hierarchien wissensintensive Dienstleister und High-Tech Firmen in Deutschland kennzeichnen. Die firmeninternen Standortverflechtungen dieser Unternehmen werden auf drei räumlichen Maßstabsebenen in ihrer Intensität betrachtet: global, national und regional. Die Forschungsergebnisse zeigen, dass die funktional-räumliche Hierarchie im deutschen Städtesystem deutlich steiler ist, als die politische Debatte um deutsche Metropolregionen es vermuten lässt.

Schlüsselwörter Deutschland · Wissensökonomie · Wissensintensive Dienstleistungen · High-Tech Firmen · Netzwerkanalyse

1 Introduction

The process of internationalization and globalization of economy, politics and culture seems again to boil down to the question of whether ‘the world is flat’ (see Friedman 2005) or whether ‘the world is spiky’ (see Florida 2005). Friedman’s hypothesis builds on the levelling effect of informa-

tion and communications technology (ICT), arguing that it is a series of ICT-related modes of organization of production and services that has enabled a workforce of millions of well qualified people to enter global competition. India and China, together with Russia and other post-Soviet countries, have therefore helped to make the world flatter with regard to opportunities to compete for jobs and added value (Friedman 2005: 49). Florida's hypothesis, in contrast, argues that the world—despite the flattening impacts of information and communications technology—is still a very spiky place, with only a very limited number of truly global players. Florida argues that globalization has indeed had a levelling effect in as much as more players have entered the competition. But the growing importance of the knowledge economy—and its requirements for talented and creative people, high-quality urban locations and organizational networking—produces a counter-force that brings about a spatial concentration of added value and innovation to only a very few truly global urban areas (Florida 2005: 50). Indeed, although technological developments in information and communications technology have shrunk the world, the 'end of geography' or 'the death of distance' have not come to pass (see O'Brien 1992; Cairncross 1997). 'Sticky places' continue to exist in 'slippery space' (see Markusen 1996). While the world's major cities are being pulled closer together in relational terms, smaller cities and peripheral areas are being left behind.

The growing relevance of the knowledge economy and its tendencies towards both spatial concentration and global dispersal have induced new forms of hierarchical and network development, as well as functional differentiation between cities and towns leading to the emergence of polycentric Mega-City Regions. This newly-emerging urban form is spread out over a large area containing a number of physically separated but functionally networked cities and towns, and one or more international airports that link the region with other city-regions of the world (Hoyler/Kloosterman/Sokol 2008: 1055). According to Brenner (1999: 431) this re-scaling of cities and states "constitute[s] an intrinsic moment of the current round of globalisation".

Against this backdrop, spatial development policies in Germany have been reformulated in recent years in order to find a balance between spatial cohesion and regional competitiveness. In the course of this political strategy, eleven Mega-City Regions have been proclaimed as engines of economic, social and cultural development with international importance (see MKRO 1995; MKRO 2006). Even though the international importance of some of these regions obviously remains rather weak, the political concept of European Mega-City Regions has developed into a powerful communicative instrument in the German spatial development policy (Blotevogel/Schmitt 2006: 55).

The aim of this paper is to set out a theoretical context and then to empirically investigate the functional urban hierarchy in the German space economy and to evaluate its impact on the politically designated Mega-City Regions in Germany. We start from a conceptual background that brings together the location behaviour of multi-branch, multi-location firms with a world city network approach. More than a pure locational perspective, this relational research design makes it possible to highlight how cities and towns within and beyond the German territory are interlocked with each other. The paper is structured in eight main sections. After the introduction, we provide a conceptual definition of the knowledge economy and its two main pillars: Advanced Producer Services and High-Tech industries. Then we focus on the functional logic of the knowledge economy by discussing both the functional logic of knowledge creation and the main features of business organization. The fourth section presents the spatial consequences of these functional patterns by examining two key spatial processes in the knowledge economy: agglomeration economies and global network economies. Based on these findings, we then introduce three hypotheses with respect to the German space economy. Subsequently, the empirical model is explained and the main findings are presented. The last section concludes by synthesizing the main results and discussing strengths and weaknesses of the empirical approach.

2 Defining the Knowledge Economy

In recent years a considerable body of work has been developed in order to explain the shift towards a knowledge-based economy (see OECD 1996; Cooke 2002; Amin/Cohendet 2004; Kujath 2005). Nevertheless, there is no commonly accepted definition of what the knowledge economy is. Cooke (2002: 4) argues that "knowledge economies are not defined in terms of their use of scientific and technological knowledge (…). Rather, they are characterized by exploitation of new knowledge in order to create more new knowledge".

Based on this argument, we suggest a definition of the knowledge economy that not only accounts for the knowledge creation process but also for its strategic importance in the innovation process. It needs to be recognized that the profit imperative is an important logic 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/Williams 2008: 1143). Therefore, we apply the following definition:

> 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.

This definition underlines the fact that the knowledge economy is causally determined by four mutually reinforcing attributes (see Fig. 1). First of all, the knowledge economy uses highly specialized knowledge and skills based on the combination of scientific knowledge and operating experiences. Secondly, as knowledge and technology have become increasingly complex, 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. The outcome of these networking activities is innovation in a Schumpeterian sense, which is the creation of new products, new production methods, new services, new markets or new organizational structures, and—most importantly—the transformation of these into marketable results. And finally, the continuous development of new knowledge and innovations enables the knowledge economy to benefit from temporary monopoly profits and to sustain competitive advantage.

In terms of economic sectors, the knowledge economy can be understood as an interdependent system of Advanced Producer Services (APS) and High-Tech firms. Advanced Producer Services can be defined as "a cluster of activities that provide specialized services, embodying professional knowledge and processing specialized information to other service sectors" (Hall/Pain 2006: 4). According to Wood (2002: 3) they offer expertise in a wide range of areas: management and administration, production, research, human resources, information and communication, and marketing. 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).

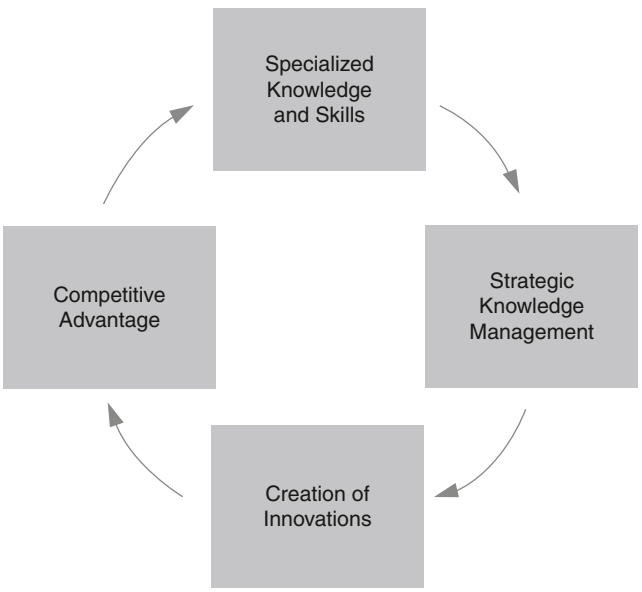

Fig. 1 Key attributes of the knowledge economy

However, Advanced Producer Services are not the only determining element in the process of structural change towards the knowledge economy. In order to understand the geography of globalization, one has to account simultaneously for both APS- and High-Tech-sectors. Castells (2000) for example argues that what is true for top managerial functions and financial markets is also applicable to High-Tech manufacturing. As in the case of Advanced Producer Services, the spatial division of labour that characterizes High-Tech manufacturing translates into worldwide connections with a series of intra-firm and extra-firm linkages between different operations in different locations along the value chain (Castells 2000: 444).

All in all, the importance of the systemic interplay between Advanced Producer Services and High-Tech industries has to be emphasized. Wood (2005: 430) for example warns us to beware of the "sector fallacy", separating service and manufacturing functions rather than recognizing them as essentially inter-dependent and complementary of each other. The competitive advantage of firms never depends on a single input, but always on conjunctions of expertise in and between various phases of the production process.

3 The Functional Logic of the Knowledge Economy

If researchers want to analyze how space is affected by the production processes of Advanced Producer Services and High-Tech firms, they have to understand the functional logic of knowledge creation and business organization. We shall deal with these issues in the next two sections.

3.1 The Functional Logic of Knowledge Creation

When one considers the knowledge intensity of Advanced Producer Services and High-Tech firms, it is clear that knowledge creation has become increasingly complex and interdependent in recent years. There is a large variety of knowledge sources that may be used by firms, and there is more collaboration and division of labour among actors along the value chain. The process of knowledge creation requires a dynamic interplay between tacit and explicit forms of knowledge as well as a strong interaction of people within and between organizations. Furthermore, combining analytical, synthetic and symbolic knowledge bases is an important prerequisite for knowledge-intensive firms to create innovations and to sustain competitive advantage: analytical knowledge refers to activities where scientific knowledge based on formal models and codification is highly important; synthetic knowledge refers to economic activities, where innovation mainly takes place through the

application of novel combinations of existing knowledge; and symbolic knowledge is related to the aesthetic attributes of products involving the creation of designs and images in order to create economic value from cultural artefacts (Cooke/De Laurentis/Tödtling et al. 2007: 57). In regional science, these concepts have been used by Asheim and Gertler (2005) and Asheim and Coenen (2005) to explain the geographies of innovation for different firms and industries.

3.2 The Functional Logic of Business Organization

The knowledge-creating process is influenced by the organizational capacity of knowledge-intensive firms. They must be flexible to respond rapidly to competitive and market changes. They must benchmark continuously to achieve best practice. Often, they must outsource to gain efficiencies and they must nurture a few core competencies to stay ahead of rivals. Increasing competitive pressure forces them to optimize coordination between entrepreneurial tasks as well as the range of services and products that are provided (Picot/Reichwald/Wigand 2008: 237). Dicken (2007: 154) argues that production networks are coordinated and regulated primarily through the various forms of intra- and extra-organizational relationships of business firms.

Intra-firm networks of transnational corporations provide an important internal framework for identifying and transferring information between different business units. According to the OECD (2008), the importance of transnational corporations is linked to their strengths in a range of knowledge-based assets that allow them to take advantage of profitable opportunities in foreign markets by setting up subsidiaries and affiliates abroad, to co-ordinate production and distribution across many countries, and to shift their activities according to changing demand and cost conditions (OECD 2008: 8). Similarly, Bartlett and Ghoshal (2002: 101 f.) argue that the organizational architectures of transnational corporations are converging toward a configuration, in which specialized units worldwide are linked to form an integrated network of operations enabling them to achieve efficiency, responsiveness, and innovation.

Extra-firm networks, on the other hand, are intended to integrate external knowledge sources in order to increase efficiency and performance. It is now widely conceded that most advanced activities of knowledge-intensive firms are deeply inscribed in extra-firm networks of suppliers, subcontractors and business clients (Storper 1992: 81). In many cases, outsourcing strategies in respect of single activities are more efficient and lead to a higher quality of products and services. Many firms concentrate on their key competencies, which are produced in-house, while activities that do not belong to the core business are outsourced to other companies. Even networks and strategic alliances between competitors open the opportunity for formal and informal information exchange within the same field of business (Porter 1990: 71).

The specific design of intra-firm and extra-firm networks depends on whether tacit or codified knowledge form the basis of the organizational design. Firms have to decide whether face-to-face communication is preferable, whether knowledge of experts can be codified, or whether knowledge brokers such as consulting firms should be engaged (Picot/Reichwald/Wigand 2008: 464). In the empirical part of this paper (see Sect. 6), we focus on intra-firm networks of the knowledge economy. Empirical findings on extra-firm relations along the value chain have been illustrated in previous publications (see Thierstein/Lüthi/Kruse et al. 2008; Lüthi/Thierstein/Goebel 2010).

4 The Spatial Logic of the Knowledge Economy

The functional logic of the knowledge economy has a significant impact on spatial development in metropolitan areas. Based on the requirements for knowledge creation and business organization, most corporations in the knowledge economy develop their location network as part of their overall business strategy. This strategy considers both where a firm's internal functions should be placed and where suppliers and customers should be located. These internal and external linkages are woven across physical space, not only connecting firms and parts of firms together, but also more or less dispersed cities and towns, leading to two fundamental spatial processes in the knowledge economy: agglomeration economies and global network economies. The interplay between agglomeration economies and global network economies is strongly subject to increasing returns leading to Mega-City Regions as essential spatial nodes of today's global economy (Lüthi/Thierstein 2009: 763). Similarly, Rozenblat (2010: 2841) argues that agglomeration economies create multiplier effects, which strengthen the efficiency of interurban linkages and therefore affect the centrality of cities in global business networks. In the following section, the main features of agglomeration economies and global network economies are explained in greater detail.

4.1 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 were strongly inspired by Marshall 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 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 from the 1980s onwards to explain why local space is still important for newly-developing forms of production. For example: the new industrial district (Becattini 1991), the innovative milieu (Maillat/Quévit/Senn 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 used econometric methods to demonstrate that knowledge spillovers are closely related to spatial proximity (see Jaffe/Trajtenberg/Henderson 1993; Anselin/Varga/Acs 1997; Bottazzi/Peri 2003; Breschi/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 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 knowledge-intensive firms (Howells 2000: 58 f.). Malecki (2000: 110) describes this aspect as the "local nature of knowledge" and highlights the necessity of accepting knowledge as a spatial factor of competition; "if knowledge is not found everywhere, then where it is located becomes a particularly significant issue" (Malecki 2000: 110).

4.2 Global Network Economies

The functional logic of the knowledge economy has not only significant impacts 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 for innovation in a firm 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 research and development 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/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/Cohendet 2004: 105).

All in all, the spatio-economic behaviour of knowledge-intensive firms leads to the emergence of a world city network. Two major world city network approaches are of particular importance for this study. The first approach is John Friedmann's (1986) world city concept, which focuses on the decision-making activities and power of transnational corporations 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 Advanced Producer Services firms in the world economy (Sassen 2001: 90). She 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).

A central motivation of the world city literature has been to rank cities according to their economic power in the worldwide city-system (Beaverstock/Smith/Taylor 1999: 446). In much of this comparative research, different urban settlements are ranked according to one or more variables, such as population and employment size, number of headquarters etc. In this context, however, the term 'hierarchy' is ambiguous. There is a great temptation to interpret such rankings as hierarchies. But such rankings, of course, do not prove the existence of an urban hierarchy, since this can only be defined through relations between cities and towns (see Taylor 2007).

In order to overcome this shortcoming, the empirical part of this paper applies the 'world city network' approach of Taylor to analyze global connectivity patterns and functional urban hierarchies in the German knowledge economy (see Taylor 2004). This approach provides an empirical instrument for analyzing inter-city relations in terms of the organizational structure of knowledge-intensive firms. It reveals the relationships between head offices and other branches located all over the world, building theoretically on Saskia Sassen's identification of Advanced Producer Services as a crucial production process in global cities.

5 Three Hypotheses

The purpose of this paper is to elaborate on the question of how German agglomerations are integrated into the world city network by the functional logic of the knowledge economy. Starting from the theoretical and conceptual considerations discussed above, we propose three central hypotheses with respect to the German space economy.

Hypothesis 1: Interlocking firm networks in the German High-Tech sector are more globalized than interlocking networks in the Advanced Producer Services sector.

This first hypothesis compares the connectivity patterns of Advanced Producer Services and High-Tech firms at a global scale. Much of the world city research has been related to the emergence of a globally networked knowledge economy in which Advanced Producer Services firms play a predominant role. However, the present arguments imply that these same principles are also applicable to High-Tech industries or multinational enterprises in general. Indeed, in the international business and management literature, the importance of these connectivity mechanisms is more or less taken for granted (see Dunning 2000: 163; Bartlett/Ghoshal 2002: 65).

Hypothesis 2: Global network economies create a steep functional urban hierarchy in the German space economy, in which only few agglomerations establish substantial international connectivity; in terms of national connectivity, this functional urban hierarchy is less pronounced.

The second hypothesis suggests that knowledge-intensive business operations and flows are associated with a hierarchical polycentric pattern of urban development. The central question concerns the extent to which the functional urban hierarchy within the German space economy is associated with different geographical scales of knowledge-intensive activities. Previous studies of Advanced Producer Services networks in European Mega-City Regions show that network connectivities vary with the geographical scale of services, with global services being highly concentrated in 'first' cities (see Hoyler/Kloosterman/Sokol 2008: 1060; Taylor/Evans/Pain 2008: 1086; Thierstein/Lüthi/Kruse et al. 2008: 1129). In this paper, we investigate whether this also applies to the whole German functional urban system, not only to Advanced Producer Services but also to High-Tech companies.

Hypothesis 3: The mere size of a German agglomeration does not automatically correlate to its functional significance in terms of global connectivity.

The third hypothesis refers to the relationship between the sheer size—measured by the sum of inhabitants and jobs—and the connectivity of an agglomeration. According to McCann and Acs (2011), the last sixty or seventy years have seen a fundamental change in the previously fairly direct relationship between city size and city connectivity. By the early twentieth century, the world's leading economies contained all of the world's largest cities and companies. Nowadays, the size of a city is much less important for its economic connectivity, especially in industrialized countries (McCann/Acs 2011: 17).

6 The Interlocking Network Model

In order to reveal the complexities of the German functional urban system and to test the above hypotheses, we use the interlocking network model developed by the Globalization and World Cities (GaWC) Research Network centred at Loughborough University (see Taylor 2004). The model was originally devised to measure connectivity between global cities derived from presumed communications within intra-firm Advanced Producer Services networks as business was conducted across office locations worldwide. Hence, the model uses a proxy—i.e. intra-firm networks of multi-branch, multi-location enterprises—to measure flows of knowledge-creating information between cities and towns. In this contribution, the model is adapted to measure potential relations between cities within and beyond the German space economy. Thereby, we assume that all types of knowledge forms mentioned above—explicit, tacit, analytical, synthetic and symbolic—are shared in intra-firm networks of the knowledge economy. A detailed formal specification of the interlocking network model is presented by Michael Hoyler in this special issue. Nevertheless, in the following section, we address some important specifications of our empirical approach.

In the first stage of the empirical analysis, we created a company database comprising the biggest Advanced Producer Services and High-Tech firms in terms of employment size in Germany. The firms had to be multi-branch, multi-location enterprises with at least one office location in Germany. The selection of these firms was based on various information sources. In the first place, the data set of the commercial data provider Hoppenstedt was used, which includes over 245,000 profiles of German companies and their branches. The result of this selection process was a basic set of 270 Advanced Producer Services and 210 High-

Tech companies, whose intra-firm networks were analyzed on different spatial scales.

In the second stage, we rated the office locations of these firms on the basis of their importance in the overall intra-firm network. By analyzing the firm's websites, all office locations were rated at a scale of 0 to 5. The standard values were 0 (no presence), 5 (company headquarters) and 2 (standard presence). If there was a clear indication that a location has a special relevance within the firm network (e.g. large office with many practitioners; regional headquarters) its value was upgraded to 3 or even to 4. If the overall importance of a location in the firm-network was very low (e.g. small agency) the value was downgraded to 1. This exercise took several months, running from December 2008 to May 2009.

In the third stage, finally, these 'service values' were used to run the interlocking network model and to estimate how well-connected German agglomerations are within the overall intra-firm network of the knowledge economy. The basic premise of this method is that information flows between two cities that are the locations of large and important offices of a firm will be greater than flows between two cities with just minor offices in the firm's network.

A particular strength of this methodology is that it allows analysis of connectivity patterns on different spatial scales. Our main focus is on Germany and its adjacent agglomerations in Germany's neighbouring countries. On this spatial scale, 338 functional urban areas—or agglomerations—constitute the analytical building blocks. They are defined as having an urban core of at least 15,000 inhabitants and a total population of over 50,000; the definition of the rings is based on 45-minute isochrones (see ESPON 2004; Schürmann 2004). However, Germany is not a self-sustaining system. In fact, there is a complex intermingling of different geographical scales. The interlocking network model allows assessment of how well connected functional urban areas in Germany are—not only to other German locations—but also to European and global destinations. All in all—based on the worldwide locations of our main sample of knowledge intensive firms—2926 agglomerations from different continents and countries all over the world were integrated in the final network analysis. In order to illustrate the opportunities of such a multi-scale analytical approach, the research findings will be presented on three spatial scales: global, national and regional.

7 The Functional Urban Hierarchy in the German Knowledge Economy

The following sections present the main findings of the interlocking network analysis. We start with the connectivity patterns on the global scale, and then zoom in to show the finer-grained hierarchical textures at the national and regional level.

7.1 The Functional Urban Hierarchy on the Global Scale

According to Ohmae, the world is essentially organized around a tri-polar macro-regional structure comprising North America, Europe and East Asia as its main economic pillars (see Ohmae 1985). Looking at statistical data, Dicken (2007: 38) shows that these three macro-regions together contain 86% of both total world GDP and total world merchandise exports. Generally, this global triad hypothesis is supported by the findings of our interlocking network analysis, but with some striking differences between North America, Europe and East Asia.

Figure 2 shows the top 20 cities in terms of global network connectivity for Advanced Producer Services firms: a big font size in dark red illustrates high connectivity; a small font size shows low connectivity. New York, London, Hamburg, Paris and Frankfurt display the highest connectivity values.

Generally, three macro-regions seem to be of particular importance for Advanced Producer Services firms located in Germany. Firstly, there is Germany itself. Six German functional urban areas rank in the top 20: Hamburg, Frankfurt, Munich, Berlin, Stuttgart and Düsseldorf. These agglomerations can be regarded as a kind of 'urban circuit' that constitutes the top of the German functional urban hierarchy (Hoyler/Freytag/Mager 2008: 1102). The fact that many Advanced Producer Services networks are concentrated on the national scale might be related merely to the size of the German domestic market, which seems to create enough demand and growth potential for knowledge-intensive firms located in Germany. But also cultural and linguistic requirements as well as specific national regulations and non-tariff barriers to trade tend to hamper internationalization strategies (Thierstein/Kruse/Glanzmann et al. 2006: 71).

Secondly, there is Western Europe. 14 European cities rank in the top 20. Obviously, the political and economic integration of German functional urban areas in Europe has had an enormous effect on the German national urban system, especially in terms of its complementary functional and sectoral specialization. Today—with the completion of the European single market—German agglomerations no longer compete only with one another, but also with London, Paris, Milan and other European metropolises.

And thirdly, there are three highly connected cities in Asia: Hong Kong, Singapore, Shanghai, plus Tokyo as a traditional global city. Taken together, they clearly match North America in terms of global network connectivity. In this sense, the German space economy seems to be well equipped in its Advanced Producer Services connections to face the challenges of the rising East Asian economy, alt-

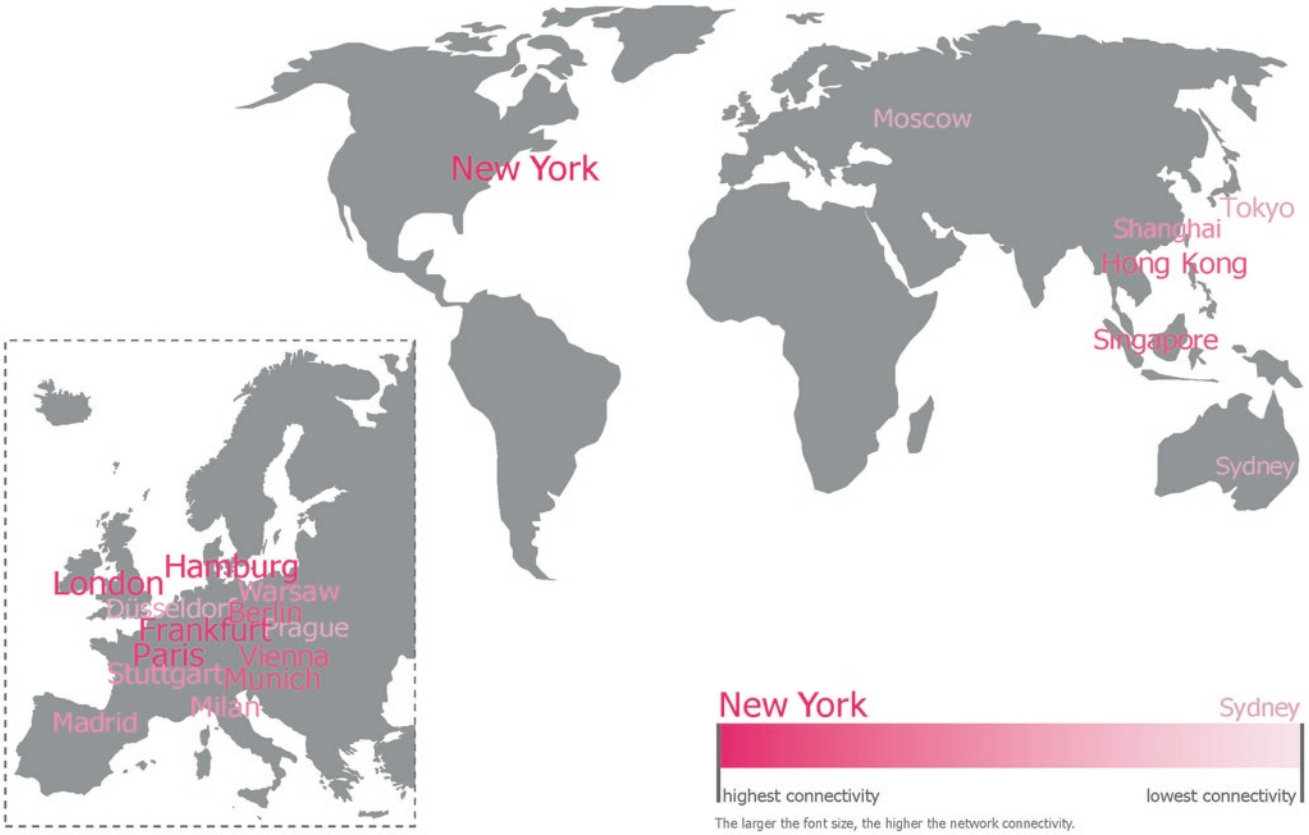

Fig. 2 Global connectivity based on Advanced Producer Services interlocking networks

hough there is still further room for improvement, especially in comparison with the High-Tech sector (see Fig. 2).

Figure 3 shows the top 20 cities in terms of the interlock connectivity of High-Tech firms. In contrast to the Advanced Producer Services sector, High-Tech firms seem to be much more networked with extra-European locations. With Shanghai, Singapore, Tokyo, Seoul, Peking, Bangkok and Hong Kong, East Asia clearly emerges as the most important economic area for High-Tech industries located in Germany. The chemicals, mechanical engineering and the electronics sectors in particular are highly represented in East Asia. In the semi-conductor industry, for example, East Asian producers have developed their own highly specialized knowledge so that firms from Europe and North America can effectively exploit not only cheap labour but also increased technical expertise in East Asian countries (Borrus 2000: 58).

But also three Eastern European cities—Vienna, Budapest and Prague—rank in the top 20. This means that many High-Tech firms located in Vienna also have office locations in Prague and Budapest. Vienna seems to act as a kind of gateway to Eastern Europe, a hypothesis that has been cited many times in the context of the eastward expansion of the European Union. An empirical analysis by Musil, for example, confirms that Vienna derived great benefit from its geostrategic position within the European Union (Musil 2009: 263). However, it is highly questionable whether Vienna can sustain this gateway position. It can be assumed that—in the course of the economic development of Eastern Europe—many firms may re-locate their offices from Vienna to other Eastern European cities such as Budapest, Prague or Warsaw.

7.2 The Functional Urban Hierarchy at the National Scale

Within Europe, Germany is by far the biggest economy in global terms: it is the third largest manufacturing producer, the third largest commercial services exporter, and the third most important source of foreign direct investment (Dicken 2007: 42). However—as Dicken (2007: 42) indicates—for a long period of time, Germany's GDP growth has been below the world average and it still faces problems in integrating the former East Germany into the world economy. This gives rise to a relatively steep functional urban hierarchy in the German space economy, as the following analysis shows.

Figure 4 illustrates the functional urban hierarchy in the German space economy for global interlocking networks. On the X-axis are the top 20 German functional urban areas with the highest global connectivity. On the Y-axis,

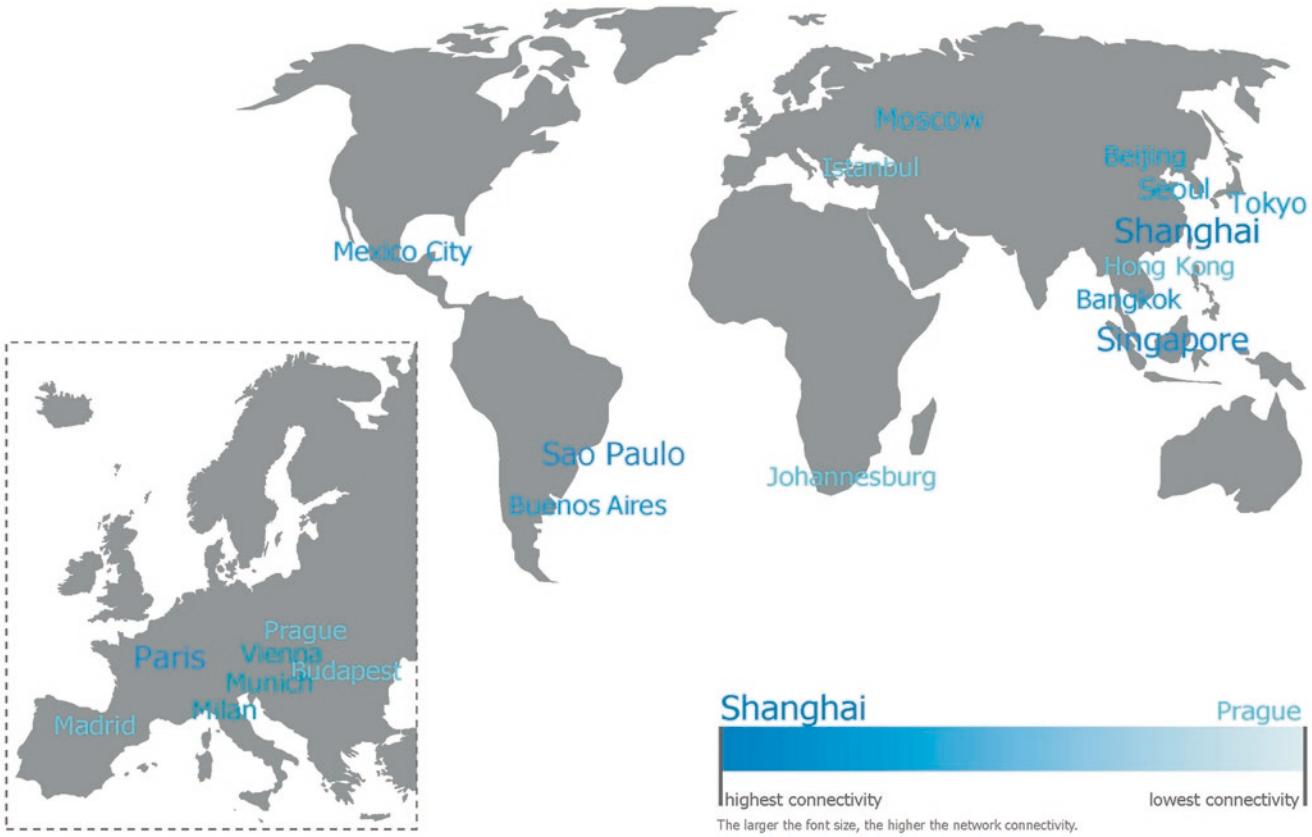

Fig. 3 Global connectivity based on High-Tech interlocking networks

the global connectivity values relative to the top functional urban area are displayed. These values illustrate how well a functional urban area is connected to extra-European destinations such as New York, Tokyo and Sydney. The size of the circles illustrates the sum of employees and inhabitants giving an impression of the overall size of the functional urban area in question.

The slightly concave curve progression for both Advanced Producer Services and High-Tech firms indicates a *relatively* polycentric national urban pattern. In the case of Advanced Producer Services, there is a top group of six functional urban areas: Frankfurt in the first position, followed by Hamburg, Munich, Düsseldorf, Stuttgart and Berlin. In the case of High-Tech, there is a top group of four functional urban areas: Munich in the first position, followed by Stuttgart, Hamburg and Berlin. Interestingly enough, Frankfurt—which is in the first position in Advanced Producer Services networks—does not emerge in a top position in the High-Tech sector.

Figure 5 shows the same setting for national interlocking networks; i.e. these values illustrate how well the top 20 German agglomerations are connected with all functional urban areas in Germany. Again, the curve progression indicates functional polycentricity. In Fig. 4, showing functional urban hierarchy based on global interlocking networks, Hamburg ranks first, followed by Munich, Berlin, Frankfurt and Stuttgart. In the High-Tech sector, Munich ranks first, followed by Stuttgart, Hamburg and Berlin; the remaining German functional urban areas seem to be less integrated into the national intra-firm circuits of High-Tech companies.

All in all, the analysis reveals a geography of Advanced Producer Services and High-Tech connectivity that is quite polycentric in character, especially compared with countries such as the UK or France, where economic activities are strongly concentrated in London and Paris respectively (see Halbert 2008; Pain 2008). Nevertheless, the functional urban hierarchy in Germany proves to be steeper than is claimed by the federal structure and the political debate on German Mega-City Regions. Not eleven, but a maximum of six functional urban areas—Munich, Frankfurt, Hamburg, Düsseldorf, Stuttgart and Berlin—can be regarded as being engines of economic development with international importance.

Furthermore, the functional urban hierarchy in the German space economy emerges as a scale-dependent phenomenon, depending on the organizational architectures and scalar reach of the different business networks: the larger the spatial scale of internal relations, the steeper the functional urban hierarchy (see also Hoyler/Freytag/Mager 2008: 1108). In the Advanced Producer Services sector, for exam-

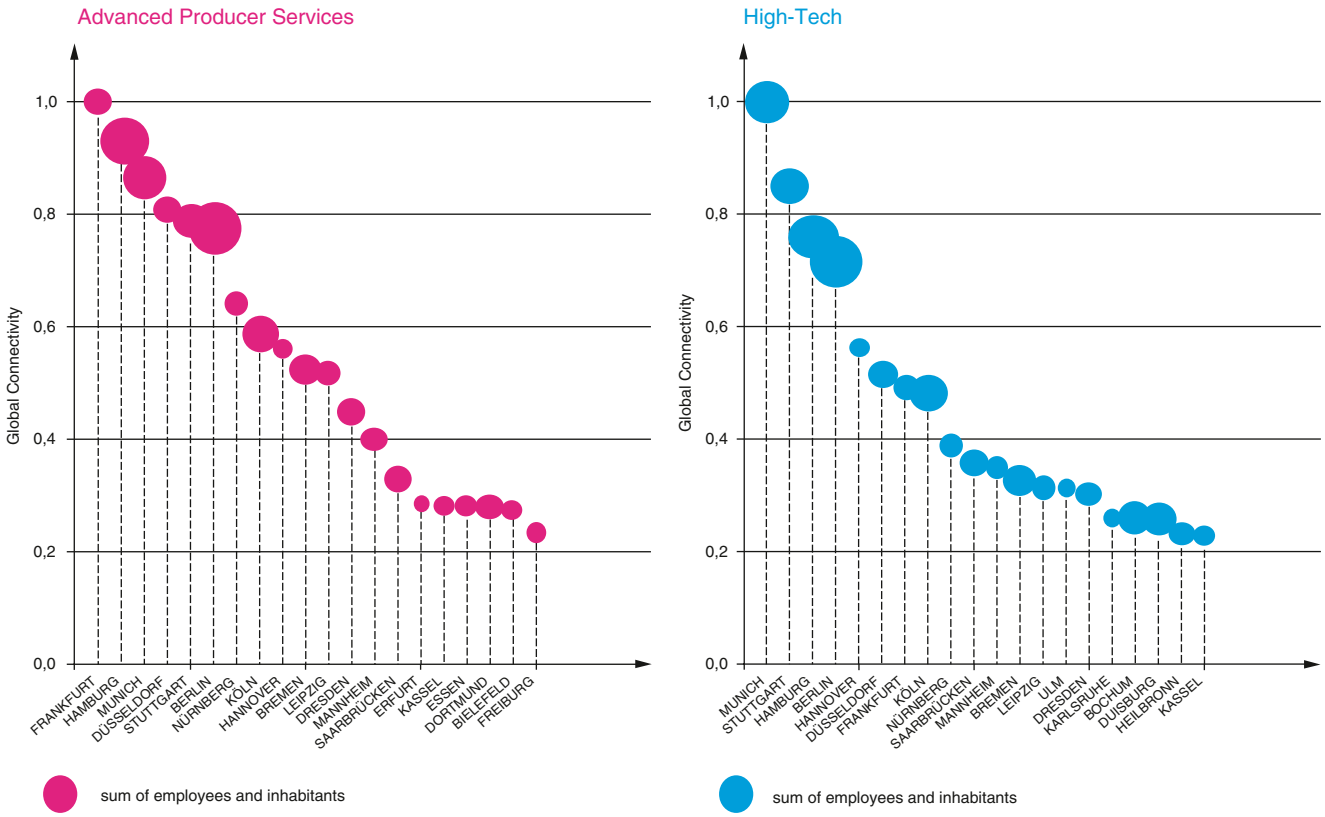

Fig. 4 Functional urban hierarchy based on global interlocking networks

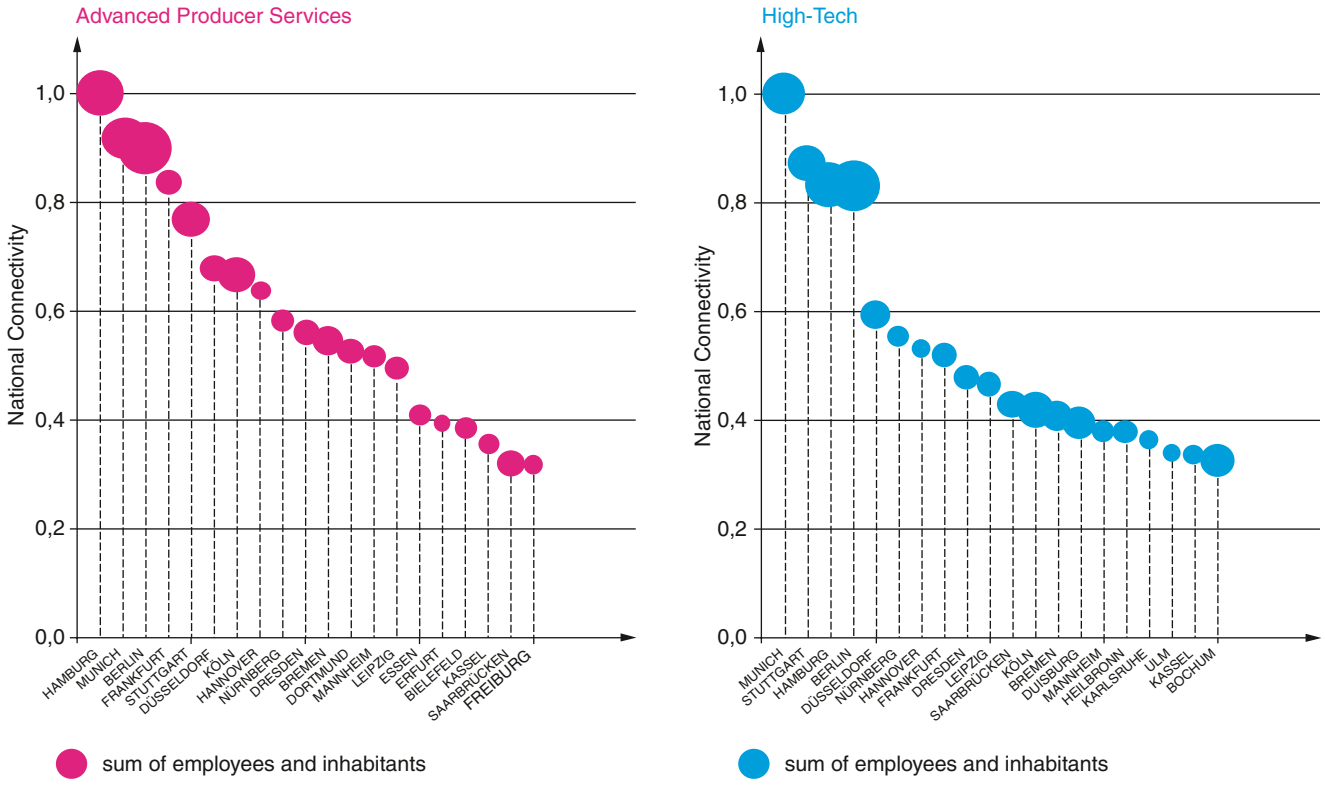

Fig. 5 Functional urban hierarchy based on national interlocking networks

ple, the functional urban area ranked 20th has 32% of the top functional urban area's national connectivity. In the case of global connectivity, by contrast, the functional urban area ranked 20th has only 23% of the top functional urban area's connectivity. This means that firms that are engaged in international business are mainly located in top German functional urban areas, whereas smaller agglomerations are rarely home for global firms of the knowledge economy.

Figures 4 and 5 not only show the functional urban hierarchy in the German space economy; in some cases, they also illustrate a pronounced discrepancy between the sheer size of a functional urban area—measured by the sum of inhabitants and jobs—and its global or national connectivity. Generally, two spatial patterns can be observed. On the one hand, the biggest German functional urban areas—Berlin, Hamburg, Munich, Stuttgart and Cologne—always rank within the first 12 functional urban areas in terms of connectivity. It seems that a certain critical mass has to be reached in order to generate a minimum degree of connectivity. On the other hand, however, critical mass is not enough to get to the first position in the connectivity ranking. In the Advanced Producer Services sector, for example, Berlin only ranks sixth, even though it is by far the biggest functional urban area in Germany. Frankfurt, by contrast, ranks first, even though it is rather small in terms of inhabitants and jobs. A similar situation can be observed for national connectivities in the High-Tech sector, in which Cologne—the biggest functional urban area in Rhine-Ruhr—ranks only 12th and clearly falls behind the smaller agglomeration of Düsseldorf. This finding will be supported in the following section, where the example of seven functional urban areas in the Rhine-Ruhr region will be analyzed in greater detail.

7.3 The Functional Urban Hierarchy at the Regional Scale—The Case of Rhine-Ruhr

Based on previous connectivity studies in Rhine-Ruhr (see Knapp/Scherhag/Schmitt 2006), we define the Rhine-Ruhr region by the functional urban areas of Bonn, Cologne, Düsseldorf, Duisburg, Essen, Bochum and Dortmund. Rhine-Ruhr has been chosen because it is internationally known for its polycentric urban structure, and because—all functional urban areas taken together—it indicates the highest connectivity values of all Mega-City Regions in Germany on the regional and international scale. Although Rhine-Ruhr still has a relatively strong industrial base, de-industrialization is taking place across the region. However, some cities—such as Düsseldorf—have been able to offset job losses in the Ruhr's industrial sector with new jobs in the emerging knowledge economy. Today it is one of the leading centres of the German advertising and fashion industry (Knapp/Scherhag/Schmitt 2006: 155).

Figure 6 clearly confirms Düsseldorf's leading position within the Rhine-Ruhr region. In order to get an impression of the relative significance of a single functional urban area—compared to all seven Rhine-Ruhr functional urban areas—its network connectivity is illustrated in relation to its sum of inhabitants and jobs. The coloured circle illustrates the network connectivity. The black ring shows the sum of inhabitants and jobs. An outer coloured circle indicates a higher connectivity than expected in terms of inhabitants and jobs, representing a surplus of significance. A smaller coloured circle indicates a lower connectivity than expected, representing a deficiency of significance.

For Advanced Producer Services networks, Düsseldorf, Dortmund and Essen are the only functional urban areas that show a clear surplus of significance. Highly populated areas such as Duisburg and Bochum, on the other hand, indicate a clear deficiency of significance, at least in terms of their integration into international intra-firm networks of knowledge-intensive service companies. According to Hoyler (this issue) this indicates that there is a certain limit to the number of cities in a region that can achieve critical importance as hubs for global service activities. Primary cities—such as Düsseldorf—create a kind of "shadow effect" that hinders international Advanced Producer Services firms from locating in secondary cities (see Holyer, this issue).

For High-Tech networks, Düsseldorf and Essen are the only agglomerations with a clear surplus of significance. Essen is the location for the headquarters of some major German corporations such as REW, Hochtief, Evonik, Schenker or ThyssenKrupp. Moreover, some global mechanical engineering companies are situated there, for example MAN and the Voith Corporation. The intra-firm networks of these international companies mean that Essen has surprisingly high network connectivity in the High-Tech sector.

A special case in the Rhine-Ruhr region is Bonn, the former capital of Germany. After German reunification at the end of the 1990s, many ministries were relocated from Bonn to Berlin. Subsequently, despite many negative prognoses, Bonn developed quite successfully in economic terms, not least because of the huge amount of subsidies paid in compensation for the loss of status as the capital of Germany (Knapp/Scherhag/Schmitt 2005: 3). For a long time, this led to a surplus of significance, as previous studies confirm (see Knapp/Schmitt/Danielzyk 2006; Thierstein/Kruse/Glanzmann et al. 2006). However, this advance seems to be slowing—Fig. 6 indicates that Bonn now shows a slight deficiency of significance.

8 Conclusion

The key aim of this paper has been to set out a theoretical context and then to empirically investigate the functional

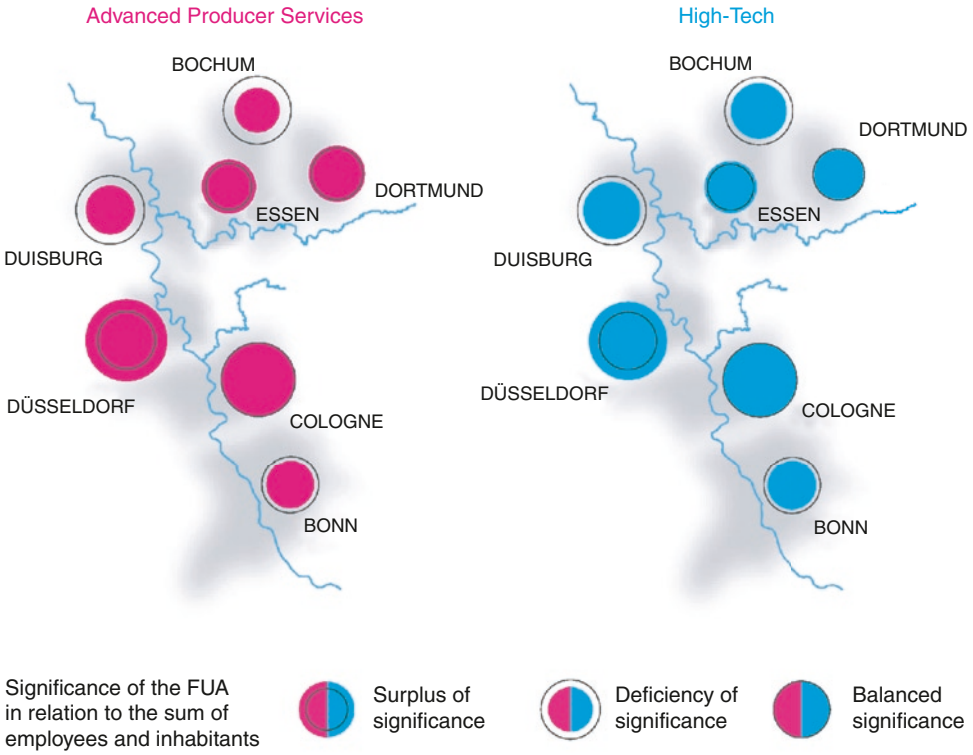

Fig. 6 Relative significance of the functional urban areas (FUA) in the Rhine-Ruhr region in comparison to each other

polycentric patterns and interlocking networks of Advanced Producer Services and High-Tech firms in the German space economy. In the theoretical section, we saw that the functional logic of the knowledge economy has become a key driver of spatial development in advanced regions and nations. The growing variety of different knowledge forms—synthetic, analytical and symbolic—increasingly forces firms to combine knowledge and skills from different parts of their value chain. In order to create innovations and to sustain competitive advantage, knowledge-intensive firms establish various forms of intra-firm and extra-firm networks on different geographical scales. These internal and external linkages are woven across physical space, not only connecting firms and parts of firms together, but also more or less dispersed cities and towns.

In the empirical section, we used the interlocking network model of Taylor (2004) to reveal some aspects of the complexity of the German functional urban system. All in all, the empirical research provides much evidence for the initially proposed hypotheses.

Firstly, interlocking firm networks in the German High-Tech sector seem to be more globalized than interlocking networks in the Advanced Producer Services sector. East Asia and Eastern Europe emerge as important destinations for High-Tech firms. Advanced Producer Services networks, by contrast, are strongly focused on the German and Western European space economy.

Secondly, global network connectivity creates a functional urban hierarchy, which proves to be steeper than is claimed by the political debate on German Mega-City Regions. A maximum of six German functional urban areas—Munich, Frankfurt, Hamburg, Düsseldorf, Stuttgart and Berlin—can be regarded as engines of economic development with international importance. In terms of national connectivity, this functional urban hierarchy is less pronounced. In other words: from the external perspective of global business, the German functional urban system seems to be much less polycentric than the patterns of its national business networks imply.

Thirdly, the mere size of a German agglomeration does not automatically correlate to its international significance. Berlin, for example, never ranks among the top three in terms of global connectivity, even though it is by far the biggest functional urban area in Germany. Cologne also—the biggest functional urban area in Rhine-Ruhr—is clearly less integrated in global networks of the knowledge economy than the smaller functional urban area of Düsseldorf.

Even though our empirical analysis—based on Taylor's interlocking network model—is an innovative and smart way to calculate inter-city relations, it has some limitations that have to be acknowledged. The main limitation, in our view, is that it does not consider extra-firm networks in its conceptualization. As shown above, both intra- and extra-firm networks are important for understanding the functional and spatial logic of the knowledge economy.

Lüthi/Thierstein/Goebel (2010) for example combined the interlocking network model with a value chain approach to analyze networks of knowledge-intensive firms in the Mega-City Region of Munich.

A second limitation of the empirical approach is that the importance and the qualitative composition of the actual linkages between functional urban areas cannot be determined from the quantitative measurement of intra-firm network connectivity. Whether information is flowing between the functional urban areas—by e-mail, telephone or through business travel—has to be detected using other relational data (Pain/Hall 2008: 1070). Nevertheless, given the difficulty of obtaining such relational data, the interlocking network model provides a useful proxy for measuring information flows between cities and towns on different spatial scales.

Finally, it has to be acknowledged that our empirical study is static, even though the functional logic of the knowledge economy is framed in a dynamic context. We are perfectly aware that the current picture cannot be isolated in time. By including the time dimension in the analysis of spatial strategies of firms, further information on changing spatial patterns and its drivers can be revealed. Nevertheless, this contribution provides an ideal starting point for carrying out comparative analyses. Some steps in this direction have already been made (see Taylor/Ni/Derudder et al. 2011); but more work remains to be done to further our understanding of the evolving relational geographies of the German space economy.

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