

Knowledge Hubs in the German Urban System: Identifying Hubs by Combining Network and Territorial Perspectives

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Abstract This paper identifies hubs of knowledge-based labour in the German urban system from two perspectives: the importance of a metropolitan region as a place and the importance of a metropolitan region as an organisational node. This combination of a network perspective with a territorial perspective enables the identification of hubs. From the functional perspective, hubs are understood as important nodes of national and global networks, established by flows of people, goods, capital and information as well as by organisational and power relations. From the territorial perspective, hubs are understood as spatial clusters of organisations (firms, public authorities, non-governmental organisations). The functional focus of the paper lies on knowledge-based services. Based on data about employment and multi-branch advanced producer service firms, four main types of metropolitan regions are identified: growing knowledge hubs, stagnating knowledge hubs, stagnating knowledge regions and catch-up knowledge regions. The results show an affinity between knowledge-based work and bigger metropolitan regions as well as an east-west divide in the German urban system.

Keywords Hubs · Space of places · Space of flows · Knowledge economy · Metropolitan regions · Germany

Wissensknoten im deutschen Städtesystem. Die Identifizierung von Knoten durch Kombination territorialer und Netzwerkperspektiven

Zusammenfassung Der Beitrag befasst sich mit Knoten wissensbasierter Arbeit im deutschen Städtesystem aus der Sicht zweier Perspektiven: zum einen wird die Bedeutung von Metropolräumen als Standort und zum anderen als Ankerpunkt für Netzwerke diskutiert. Die Kombination des räumlich-territorialen Fokus mit einer Netzwerkperspektive ermöglicht die Identifizierung von Knotenpunkten. Knoten werden im Rahmen dieses Beitrags als der Teil eines Netzwerkes verstanden, der zugleich einer spezifischen Region dient. Auf der Grundlage relativer Veränderungen werden unterschiedliche Entwicklungspfade von Knotenpunkten analysiert. Im Mittelpunkt der Analyse stehen wissensbasierte Dienstleistungen. Auf der Basis von Daten über Berufstätige und Mehrbetriebsdienstleistungsunternehmen werden vier metropolräumliche Typen identifiziert: Wissensknoten, stagnierende Knoten, schrumpfende Regionen und Start-up-Regionen. Die Ergebnisse zeigen eine Affinität wissensbasierter Tätigkeiten zu großen Metropolräumen sowie ein West-Ost-Gefälle im deutschen Städtesystem.

Schlüsselwörter Knoten · Orte · Netzwerke · Wissensökonomie · Metropolräume · Deutschland

1 Introduction

The traditional geographical focus on territorial scales has been complemented in recent decades by a focus on networks and flows between cities and regions. A concern for networks is seen as a necessary supplement to a territorial perspective in order to facilitate the understanding of the

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processes that produce space (Friedmann 1995; Taylor 2004: 25 ff.; Hall/Pain 2006: 10 ff.).

The importance of the focus on networks arises from different processes. To a large extent the focus on networks can be explained by an increasing concern for the perceived effects of globalisation, particularly the intensification of trading and supply networks, and the consequent need to focus on relational vertical scales (Dicken 2007: 22). However, all networks and flows are grounded in places forming the horizontal, geographical dimension. According to Dicken (2007: 24), spaces with an intersection of horizontal and vertical dimensions are key points of globalisation. There is a wide range of literature that discusses cities and city-regions as spaces, where the horizontal and vertical dimensions of globalisation meet (Hall 1966: 22 ff.; Friedmann 1986: 71 ff.; Sassen 1991: 23 f.; Taylor 2004: 27 ff.; Hall/Pain 2006: 4 ff.). This paper focuses on cities and metropolitan regions as spaces that are determined simultaneously by territorial clusters and by nodes of supra-regional networks.

Due to the fact that knowledge must be seen as a crucial factor for economic processes in post-industrial societies (Drucker 1969; Bell 1989; Stehr 2001), we put a particular focus on knowledge-based services. Knowledge-based services deal with knowledge in two ways: knowledge is used as an input to services but also as a product that is sold (Castells 1996: 29). According to Castells, this is the key development that distinguishes the importance of knowledge today from the use of knowledge in economic processes in the past.

This paper aims to identify important places of knowledge as well as spaces, in which knowledge-flows are 'grounded' by the geographical location of actors and firms. By combining both perspectives we aim to achieve a deeper understanding of the German urban system in order to answer the following questions: Where does a critical mass develop and where do hubs emerge within firm networks? Which cities display both processes and which cities display little or no involvement in such networks? The development of knowledge hubs is discussed on the basis of the measurement of changes over time. As the German urban system displays a quite balanced structure of metropolitan regions with distinct functional specialisations, this system is used as an example.

2 Conceptualising Hubs

A hub is the central part of a wheel and therefore an element that holds together the other elements and enables the wheel to turn. The term hub is also used in transport geography and logistics. A noted use of the term hub arises in the context of aviation, i.e. "airline hubs". Airlines use certain

airports as hubs for transferring passengers to their intended destination if they do not offer direct flights to the final destinations. This system is called the hub and spoke model (O'Kelly 1998). However, as O'Kelly (1998: 171) points out, hubs can be understood as special nodes that are part of a network and, further, hubs are geographical insofar as they refer to a specific spatial cluster. Based on this definition, the term hub is used in the following to refer to nodes in networks that also generate local benefits.

2.1 Understanding of Hubs

An extensive body of literature discusses cities and their integration into non-local networks (e.g. Friedmann 1986; Sassen 1991: 357 ff.; Scott/Agnew/Soja et al. 2004; Taylor 2004: 15 ff.; Hall/Pain 2006: 7 ff.). However, the most distinctive conceptual contribution was developed by Castells (1996) who deals explicitly with the combination of horizontal and vertical dimensions of globalisation and their spatial consequences through the conceptualisation of a space of flows and a space of places. The basic idea here is that there is a reshaping of space through the emergence of a new network society. In the context of this approach, hubs arise through a definition of the spaces of places through the spaces of flows.

Castells defines space in terms of social practice. Through the introduction of information technologies and the development of a network society, the space of places, in which people are located next to each other, is supplemented by the new space of flows. In this context, places do not disappear but come to be defined additionally by their position within flows (Castells 1996: 412).

Castells (1996: 412 ff.) differentiates between three layers of flows. The first layer consists of infrastructural support for social practices including both the internet and global airlines. The third layer consists of the spatial organisation of economic elites, for example segregated residential and vocational locales as well as certain exclusive restaurants or clubs. The second layer refers to the space of social practices that forms society, in which agents who use infrastructure networks to link specific places produce functional networks. Castells (1996: 415) uses the terms nodes and hubs in this context and points out that the most direct illustration of hubs and nodes is provided by global cities. For this reason the paper focuses on processes within the second layer.

To fully understand the processes that determine the functions of metropolitan regions, Camagni (2004: 103) proposed a combination of two spatial logics: a territorial approach ('cities as cluster') and a network approach ('cities as interconnections'). Hence, the role of cities as hubs cannot be understood by simply analysing either clusters within

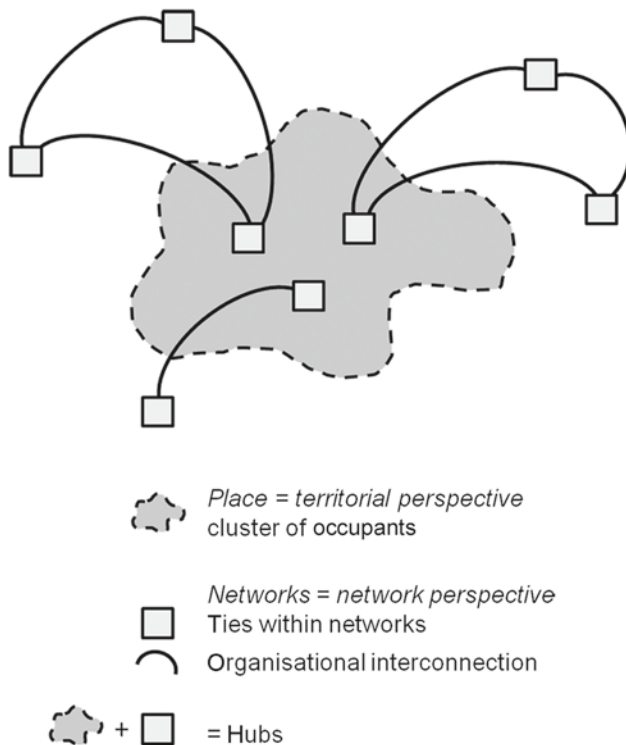


Fig. 1 Conceptualisation of hubs. (Source: authors, based on Bathelt/Malmberg/Maskell (2004: 46))

metropolitan regions or interconnections between metropolitan regions; rather both perspectives must be considered simultaneously (see Fig. 1).

2.2 Knowledge Hubs

The focus of this paper lies on knowledge-based labour. The increasing importance of science and technology for economic processes arises from the systematic use and development of knowledge as a resource in all economic processes (Park 2000: 9). It is important to make a distinction between two types of knowledge in this context: implicit and codified knowledge (Polanyi 1967: 64). Implicit knowledge is embodied in people and organisations, e.g. firms that produce knowledge-intensive services and products. It allows the creation of temporary monopoly profits based on advances in knowledge and is, therefore, crucial to knowledge-based economic processes (Nonaka/Takeuchi 1995: 33; Amin/Cohendet 2004: 23).

The territorial approach adopted in this paper focuses on the creation of 'critical mass'. People who work in knowledge-based professions are assumed to be knowledge-holders in metropolitan regions and form the labour market of a metropolitan region. A certain size of the labour market (often described using the term critical mass) attracts additional knowledge holders and may lead to the emergence of "sticky places" (Markusen 1996). However, firms also

cluster within local areas. Bathelt/Malmberg/Maskell (2004) explain this phenomenon in terms of the advantages resulting from participation in a 'buzz'. As a new understanding of Alfred Marshall's 'industrial atmosphere', a 'buzz' provides information through face-to-face contacts, co-presence and co-location (Bathelt/Malmberg/Maskell 2004: 38). Actors who exchange and participate within the buzz are knowledge-holders, i.e. people who work in knowledge-based processes. These are people who understand the local buzz and use the information gained in a meaningful and effective way.

The creation of a local buzz is not, however, the only resource for the generation, exchange and use of implicit knowledge, although this form of knowledge is mainly associated with local face-to-face exchange (Bathelt/Malmberg/Maskell 2004: 32). Firms also create organisational networks by constructing 'global pipelines'. Bathelt/Malmberg/Maskell (2004) mainly focus on the creation of global pipelines through the building of strategic cooperation, however they also mention the formation of branches. The organisational relationships between the branches and headquarters of a firm are assumed to constitute the basis of knowledge-flows within firms (Taylor 2004: 61). Therefore, the network approach adopted in this paper focuses on multi-location firms that produce knowledge-based work.

3 Data and Methodology

The paper focuses on a comparison of knowledge-based activities in the German city network through the lens of both a territorial and a network perspective. The basis for the territorial perspective is provided by data about knowledge-based professions. Data on organisational networks of knowledge-based firms by sectors provides the basis for the network perspective.

3.1 Data

The territorial data used in this paper are extracted from a data set provided by the Federal Employment Office in Germany (Bundesagentur für Arbeit (BA)). The data include all employees obliged to pay social insurance contributions and represent about 75% of the total workforce.¹ Employees are differentiated on the basis of their occupations (sozialversicherungspflichtig Beschäftigte nach Berufsordnungen) and this, in turn, is based on the occupational classification of 1988 (KldB 88 BA). The classification of employees by occupation depends on the current type of activity that is

¹ Self-employed persons are not included. Especially with regard to creative activities this statistical restriction might underestimate the number of KBP in Germany.

performed and not on recent activities or qualifications. This classification makes it possible to draw conclusions about functional spatial patterns. Following Hall (2007: 8 ff.), occupational groups with a high share in knowledge-based services and research-intensive industries were chosen and will be used in this analysis as ‘knowledge-based professions’ (KBP).² To enable the comparison of changes over time two data-sets from 1997 and from 2007 are used. The data set from 1997 covers 2,900,000 knowledge holders. The data-set from 2007, which covers 3,100,000 knowledge holders, shows an increase in employment in knowledge-based professions. The data are provided on NUTS-3 level and are aggregated by addition on regional level (see Chap. 3.2).

The network data used in this paper are extracted from a data set provided by Hoppenstedt, a commercial data provider in Germany. The database includes all firms that provide information about their locations on a voluntary basis. Hoppenstedt itself claims to include information about the 250,000 largest companies representing about 85% of added value in Germany. As this study is interested in processes within organisational firm networks, only firms with a minimum of two locations are considered. Therefore the database prompts the adoption of a bottom-up approach with a focus on national firm linkages (cf. Hoyler/Freytag/Mager 2008) instead of a top-down approach with a focus on global firm linkages (cf. Taylor 2004). Firms are differentiated by sector (Wirtschaftszweige) based on the classification of economic sectors of 1993 (WZ 93). The classification of firms by sector depends on the similarity of the products or services produced or provided by the firms, the similarity of their production processes or the use of similar raw materials. A matrix of firms is created on the basis of economic sectors that include advanced producer services. Firms in these sectors are used in aggregate form as ‘knowledge-based firms’.³ Data from 2002 and 2009 are considered so as

to enable the comparison of changes in the city network. The 2002 data set covers around 2,000 knowledge-based firms and the 2009 data set covers around 3,000 firms. Information about firm locations is provided on NUTS-3 level. To calculate regional connectivity values, metropolitan regions are treated as one location (see Chap. 3.3).

3.2 Study Area

In order to identify hubs that work as functional important hinges between local hinterlands and inter-urban networks, metropolitan regions are defined by using density categories. The study uses a classification scheme of the Federal Office for Building and Regional Planning (Bundesamt für Bauwesen und Raumordnung (BBR)) for the delimitation of the metropolitan regions. This scheme distinguishes between three main types of regions at NUTS-3 level (Kreise in Germany): regions with large agglomerations, regions with features of conurbation and regions of rural character (BBR 2005).

This study focuses on the first region type, on ten agglomerations, that include large areas with a dense population and one or more core cities. Some of the agglomerations are, therefore, very heterogeneous, e.g. the large agglomeration of the Rhine-Ruhr in North Rhine-Westphalia or the Rhine-axis in South West Germany. These large agglomerations are further differentiated on the basis of a classification by Bade (1991). Bade delimits regions on the basis of ‘Raumordnungsregionen’ (functional spatial units consisting of an economic centre and its hinterland). Based on this, 20 metropolitan regions are differentiated and defined as the spatial basis for the analysis.

3.3 Methodology

Firm-based network data are used to enable the identification of metropolitan regions that are important within flows of knowledge. As there is no direct information about knowledge flows between different cities, organisational firm networks are used as a proxy. Based on the idea of the firms’ different locational strategies, the intercity relations constituted through the multi-local offices represent knowledge flows within the firms. The knowledge flows between different offices mainly consist of electronic communications that include information and knowledge. In the Global and World City (GaWC) model, these flows are seen as constituting the world city network (Taylor 2001: 183; Taylor 2004: 65).

The Global and World City (GaWC) measurement of the city network can be formally represented by a matrix V_{ij} defi-

² The occupations that are aggregated as “knowledge-based professions”—the Kldb 88 BA code is shown in brackets: accountancy (753, 771, 772), advertising (703, 833, 834, 835, 837), architecture (603, 604, 623, 624), consulting (752), consultant engineers (611, 612, 626), data management (774), finance (691, 692), ICT-services (602, 622), insurance (693, 694), law (811, 812, 813, 814), management (751), media (821, 822), real estate (704).

³ Firms from the following economic sectors are aggregated as “knowledge-based firms”—the WZ 93 code is shown in brackets: accountancy (74121, 74122, 74123, 74124, 74125), advertising (74401, 74402, 92113), architecture (74201, 74202, 74203, 74204, 74205, 74206, 74207, 74208, 74209), consulting (74131, 74132, 74141, 74142), consultant engineers (74301, 74302, 74303, 74304), data management (72100, 72201, 72202, 72203, 72301, 72303, 72304, 72400, 72500, 72601, 72602), finance (65110, 65122, 65124, 65126, 65127, 65128, 65129, 65210, 65220, 65231, 65232, 65233, 67110, 67120, 67130), ICT-Services (64201, 64202, 64203, 64204, 64205, 64206, 64207), insurance (66011, 66020, 66031, 66032, 66033), law (74111, 74112, 74114, 74115), management (74151, 74152, 74155, 74156), media (22111, 22112, 22121, 22122, 22131, 22132, 22133, 22141, 22142, 22150, 92111, 92112, 92114, 92115, 92116, 92201, 92202, 92401),

real estate (70111, 70112, 70113, 70121, 70122, 70201, 70202, 70310, 70320, 74153, 74154).

ned by n cities $\times$ m firms, where v_{ij} is the ‘service value’ of city i to firm j . This service value is a standardised measure of the importance of a city to a firm’s office network, which depends on the size and functions of an office or offices in a city. In this study three service values are used (0, 1, and 3). Locations with no offices are valued 0, locations with local offices are valued 1 and locations of firm headquarters are valued 3. The network connectivity NC_a of city a in this interlocking network is defined as follows

$$NC_a = \sum_{i,j} v_{aj} * v_{ij}$$

with ($a \neq i$).

Changes in connectivity from 2002 to 2009 (and in professions from 1997 to 2007) are measured by the change in the importance of an individual metropolitan region in the network of metropolitan regions. The importance is measured by the percentage share each metropolitan region shows in the overall network at different points in time. In a second step, z-scores of the percentage change are calculated. This is carried out to show whether the change in importance (CI) is big or small. CI values between -1 and 1 can be understood as a small change, CI values between -2 and -1 and CI values between 1 and 2 can be understood as a medium change, and CI values $>+2$ or <-2 indicate ‘exceptional change’ in statistical terms.⁴

A conceptual problem outlined by Derudder/Taylor/Ni et al. (2010: 1870) concerns saturation effects. The markets of higher ranking cities are closer to saturation in that they have less opportunity to acquire more and/or more prominent offices because almost every firm already has an office within that city. However, no statistical evidence for the existence of this effect has been found in the network of the 20 biggest German metropolitan regions. This may be explained by the more balanced structure and development of the top stratum of the German urban network compared to the more hierarchical global city network of 315 cities in their study.

⁴ As an example of the measurement procedure we think of two firms A and B with locations in Berlin, Frankfurt and München (firm A) and locations in Berlin and München (firm B). Headquarter of firm A is located in Berlin. Headquarter of firm B is located in München. The following city matrix exemplifies these data:

	Firm A	Firm B	Connectivity
Berlin	3	1	9
Frankfurt	1	0	4
München	1	3	7

Flows between headquarters and branches are counted 3 ($=3 \times 1$) and flows between branches are counted 1 ($=1 \times 1$). Connectivity values are calculated by summing up all potential flows for each city. Berlin, for example, shows two flows, each with a value of 3, in firm A and one flow, also with a value of 3, in firm B. The sum of Berlins’ flows is 9. This is the connectivity value of Berlin. In this example, the percentage connectivity value, used to calculate the CI values, of Berlin is 45% of the overall connectivity.

4 Knowledge-Based Labour in the German Urban System

The following analysis discusses employment and connectivity. For each topic figures and changes are discussed.

4.1 Knowledge-Based Places

The territorial perspective focuses on the creation of a critical mass of knowledge based professions (KBP) employment. The bigger the labour market of knowledge-based professions within a metropolitan region is, the more expertise can be offered and the bigger the market served by the metropolitan region.

Table 1 shows the ranking of the 20 metropolitan regions in Germany as knowledge-based places according to the number of employees in advanced producer services. The development of different strata of knowledge-based places can be identified from 1997 to 2007. The two most distinctive knowledge-based places, both in 1997 and in 2007, were München and Rhein-Main. The second stratum consists of Berlin, Hamburg, Stuttgart, Köln, Düsseldorf and Ruhr in 1997 and in 2007 (see Table 2). The other metropolitan regions rank below average as knowledge-based places. They form the third stratum.

The ranking of the metropolitan regions is largely constant in 1997 and in 2007 (only Düsseldorf and Ruhr as well as Leipzig and Dresden change rank positions) but the gaps between groups of metropolitan regions increase over time. Whereas the gap between München and Rhein-Main decreased, the gap between München and Berlin increased.

Table 1 also indicates spatial disparities within the German territory. The most distinct knowledge-based places are metropolitan regions with large cities (Frankfurt, München, Hamburg, and Berlin, see Fig. 2). However, the importance of metropolitan regions with smaller cities indicates disparities between East and West Germany. The three smaller East German metropolitan regions are ranked within the lowest five metropolitan regions in 1997 and in 2007. Furthermore, the absolute number of KBP employees decreased in only three out of 20 metropolitan regions (Wuppertal, Leipzig, and Chemnitz). Two of these regions are East German metropolitan regions.

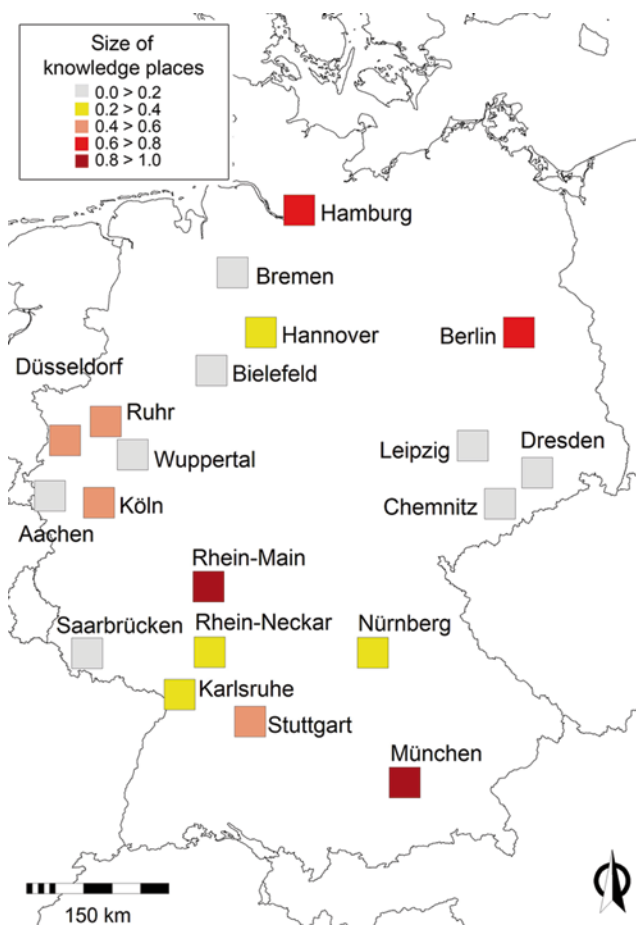
Figure 2 depicts the relative size of metropolitan regions as places of knowledge. The most important place (Rhein-Main) is equated with 1. The values of the other regions show their size in comparison to the largest place.

In the following, changes of KBP will be discussed for the level of the overall urban system and on the regional level.

Whereas the average number of KBP employees in all metropolitan regions increased slightly (see Table 2), the mean and the standard deviation increased considerably.

Table 1 Knowledge-based employment in 20 metropolitan regions. (Source: Bundesagentur für Arbeit; own calculation)

1997			2007		
Rank	City-region	Size of place (KBP employment)	Rank	City-region	Size of place (KBP employment)
1	Rhein-Main	264,488	1	Rhein-Main	287,641
2	München	210,668	2	München	240,792
3	Berlin	178,112	3	Berlin	179,196
4	Hamburg	164,335	4	Hamburg	176,242
5	Stuttgart	153,964	5	Stuttgart	164,823
6	Köln	147,173	6	Köln	158,822
7	Ruhr	131,519	7	Düsseldorf	141,872
8	Düsseldorf	129,174	8	Ruhr	136,021
9	Nürnberg	78,033	9	Nürnberg	85,370
10	Rhein-Neckar	72,147	10	Rhein-Neckar	77,116
11	Hannover	66,352	11	Hannover	65,755
12	Karlsruhe	53,574	12	Karlsruhe	63,448
13	Bielefeld	46,412	13	Bielefeld	48,098
14	Wuppertal	45,496	14	Wuppertal	42,297
15	Bremen	40,221	15	Bremen	41,556
16	Leipzig	38,869	16	Dresden	40,263
17	Dresden	38,692	17	Leipzig	35,767
18	Aachen	30,690	18	Aachen	33,350
19	Saarbrücken	30,258	19	Saarbrücken	33,013
20	Chemnitz	26,699	20	Chemnitz	23,403

**Fig. 2** Relative size of 20 metropolitan regions as knowledge-based places (2007). (Source: Bundesagentur für Arbeit; own calculation)**Table 2** Changes of professions for the level of the overall urban system. (Source: Bundesagentur für Arbeit; own calculation)

KBP employment	1997	2007	Change	%
Sum	1,919,255	1,967,997	48,742	2,5
Mean	97,344	103,742	6,398	6,6
Standard deviation	68,148	75,075	6,927	10,2

This indicates a disproportionately high growth in metropolitan regions that already had a large number of knowledge holders; in contrast, regions with a small number of knowledge-based professions show a disproportionately small change. The development of individual regions will be discussed in the following section.

Figure 3 and Table 3 summarise the changing geography of knowledge-based places at the regional level. Figure 3 depicts the change in importance of the regions as knowledge places based on their CI values. CI values are z-standardised percentage changes (see Chap. 3.3). Disparities between the south-western metropolitan regions and the north-eastern regions increased. The most extreme change (< -2 and > 2) occurred in the München region (employment in this region grew notably more than average). Medium changes can be found in Berlin, Wuppertal and Leipzig (employment in these regions grew less than the average rate) and in Karlsruhe and Rhein-Main (employment in these regions grew more than the average rate). The other regions display smaller changes (see Table 3).

4.2 Nodes in Knowledge-Based Networks

The network perspective focuses on mutual relations between metropolitan regions. The precondition for the deve-

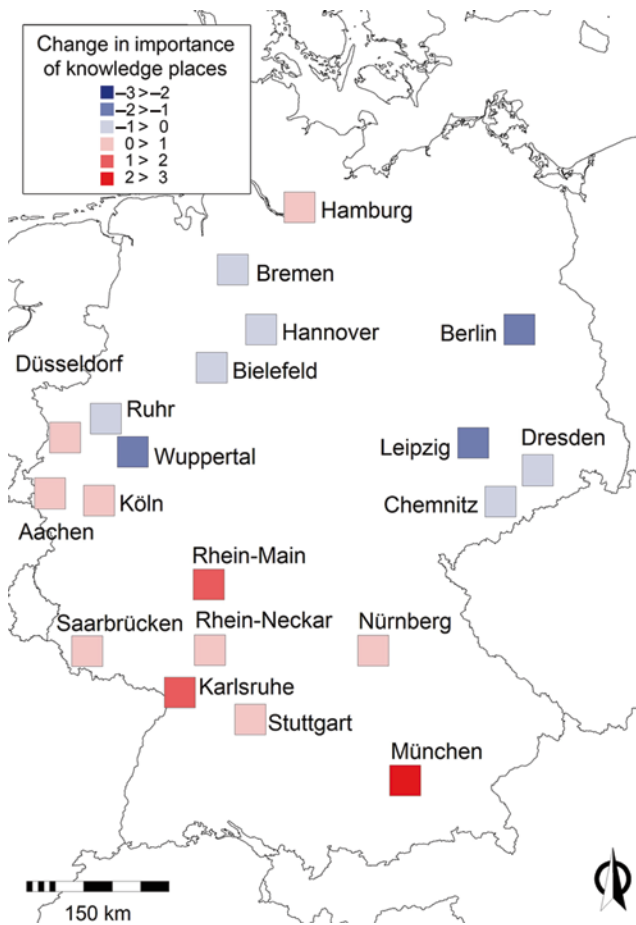


Fig. 3 Change in importance (CI) of 20 metropolitan regions as knowledge-based places (1997–2007). (Source: Bundesagentur für Arbeit; own calculation)

Table 3 Change in importance as knowledge places (1997–2007). (Source: Bundesagentur für Arbeit; own calculation)

City-region	CI place	City-region	CI place
München	2,92	Rhein-Neckar	0,04
Karlsruhe	1,14	Dresden	-0,17
Rhein-Main	1,03	Bremen	-0,23
Düsseldorf	0,75	Bielefeld	-0,24
Nürnberg	0,40	Ruhr	-0,74
Köln	0,35	Hannover	-0,89
Hamburg	0,20	Chemnitz	-0,91
Saarbrücken	0,14	Leipzig	-1,01
Stuttgart	0,13	Wuppertal	-1,11
Aachen	0,12	Berlin	-1,90

lopment of flows is the existence of at least two metropolitan regions. From a network perspective, metropolitan regions are understood as a number of dyads (Taylor/Hoyler/Verbruggen 2010: 2815). The interpretation of network data therefore necessitates that regions be considered as relational spaces.

Table 4 presents an overview of the connectivity of the 20 metropolitan regions within networks of knowledge-based activities in 2002 and in 2009. For each region, the

Table 4 Connectivity in knowledge-based networks of 20 metropolitan regions. (Source: Hoppenstedt; own calculation)

2002			2009		
Rank	City-region	Connectivity	Rank	City-region	Connectivity
1	Rhein-Main	7,156	1	Rhein-Main	10,330
2	München	6,455	2	München	10,251
3	Berlin	6,126	3	Berlin	8,493
4	Hamburg	5,617	4	Hamburg	8,372
5	Stuttgart	5,234	5	Düsseldorf	7,592
6	Düsseldorf	4,874	6	Köln	7,541
7	Köln	4,617	7	Stuttgart	7,513
8	Hannover	3,823	8	Hannover	5,560
9	Ruhr	3,490	9	Ruhr	5,108
10	Nürnberg	3,242	10	Nürnberg	4,750
11	Leipzig	3,215	11	Leipzig	4,311
12	Dresden	3,072	12	Rhein-Neckar	3,522
13	Rhein-Neckar	2,558	13	Dresden	3,246
14	Karlsruhe	1,980	14	Bremen	2,976
15	Bremen	1,669	15	Karlsruhe	2,504
16	Chemnitz	1,428	16	Saarbrücken	2,333
17	Saarbrücken	1,360	17	Bielefeld	1,791
18	Bielefeld	1,241	18	Wuppertal	1,685
19	Wuppertal	862	19	Chemnitz	1,603
20	Aachen	725	20	Aachen	1,504

absolute connectivity increased. This could be the result of two factors: Either the number of firms in that region increased or the firms that are located in this region expanded their office locations in other regions. Therefore, the increasing connectivity of a region is not necessarily the result of an increasing number of firms but might also be the outcome of an expansion of firm networks in other regions.

Compared to the occupational data, more changes arise in the ranking order and the gaps between the strata of the network increased. The two most integrated regions were Rhein-Main and München, both in 2002 and in 2009. Again these regions occupy the top stratum and the gap between them closed. The second stratum contains Berlin and Hamburg. Between 2002 and 2009 connectivity values of these regions increased and converged. The third stratum consists of Stuttgart, Düsseldorf, and Köln. There was some change in the rankings between these metropolitan regions. However, they also remained close in 2009 and the gap to Hannover—the most connected metropolitan region of the fourth stratum—increased.

During the last decade, connectivity in German metropolitan regions has been structured by four strata of which the three strata refer to metropolitan regions with high connectivity values and the fourth stratum refers to metropolitan regions of minor connectivity. KBP employment has been structured by three strata of which the first strata refers to metropolitan regions with distinctive importance as knowledge-based places. The second and the third stratum refer to metropolitan regions with—respectively—medium and lesser importance as knowledge-based place.

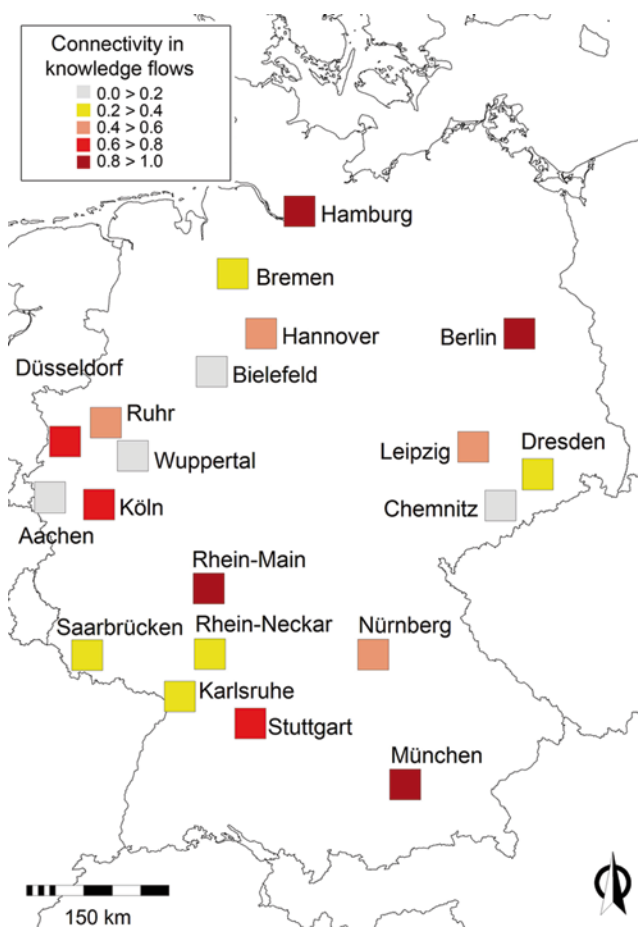


Fig. 4 Relative connectivity of 20 metropolitan regions (2009). (Source: Hoppenstedt; own calculation)

Table 5 Changes of connectivity for the level of the overall urban system. (Source: Hoppenstedt; own calculation)

Connectivity	2002	2009	Change	%
Sum	62,597	82,409	19,812	31,6
Mean	3,437	5,049	1,612	46,9
Standard deviation	1,939	2,895	956	49,3

Eastern regions rank better in connectivity than as knowledge-based places (see Fig. 4). The integration of metropolitan regions in firm networks seems to be less dependent on the size of metropolitan regions than their importance as a knowledge place. This might be explained by the strategic location of firm branches in the eastern regions of Germany.

Figure 4 shows the relative connectivity of the 20 metropolitan regions in Germany as node patterns. As in Fig. 2, the most important place is equated with 1. The most integrated metropolitan regions in 2002 were Rhein-Main and München, followed by Berlin and Hamburg.

In the following, changes of connectivity will be discussed in terms of the level of the overall urban system and at the regional level.

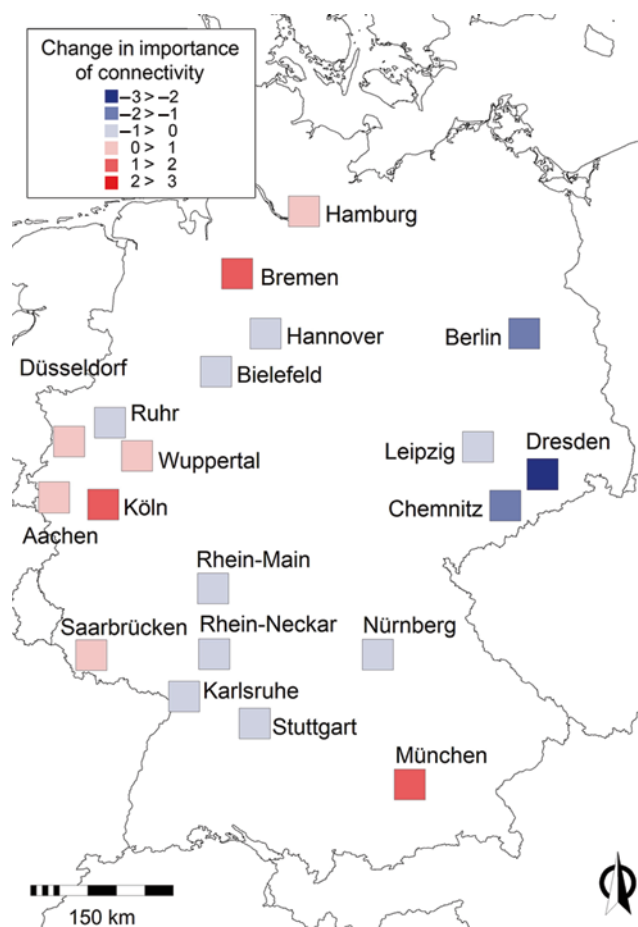


Fig. 5 Change in importance (CI) of network integration for 20 metropolitan regions in 2002-2009. (Source: Hoppenstedt; own calculation)

The average amount of connectivity increased strongly (see Table 5). This indicates an increase in flows between the metropolitan areas. The mean and the standard deviation increase even more. This indicates a disproportionately high change in metropolitan regions that already had a high level of connectivity; in contrast, regions with low connectivity show a disproportionately small change. The development of individual regions will be discussed in the following sections.

Figure 5 and Table 5 summarise the changing geography of knowledge-based flows. Figure 5 depicts the regions' change in importance as organisational network nodes through CI-values, which can be interpreted like z-scores. The map offers a mixed pattern of change. However, the eastern regions again grew less than average. The most extreme change (< -2 and > 2) occurred in the Dresden region (connectivity in this region grew explicitly less than average). Medium changes occurred in Berlin and Chemnitz (connectivity in these regions grew less than average) and in München, Köln and Bremen (connectivity in these regions grew more than average). The other regions show smaller changes (see Table 6).

Table 6 Changed importance of network integration for 20 metropolitan regions in 2002-2009. (Source: Hoppenstedt; own calculation)

City-region	CI connectivity	City-region	CI connectivity
München	1,59	Bielefeld	-0,06
Köln	1,57	Hannover	-0,12
Bremen	1,08	Stuttgart	-0,36
Aachen	0,91	Rhein-Main	-0,38
Düsseldorf	0,89	Rhein-Neckar	-0,49
Wuppertal	0,87	Karlsruhe	-0,84
Saarbrücken	0,69	Leipzig	-0,85
Hamburg	0,25	Chemnitz	-1,02
Nürnberg	-0,03	Berlin	-1,04
Ruhr	-0,04	Dresden	-2,62

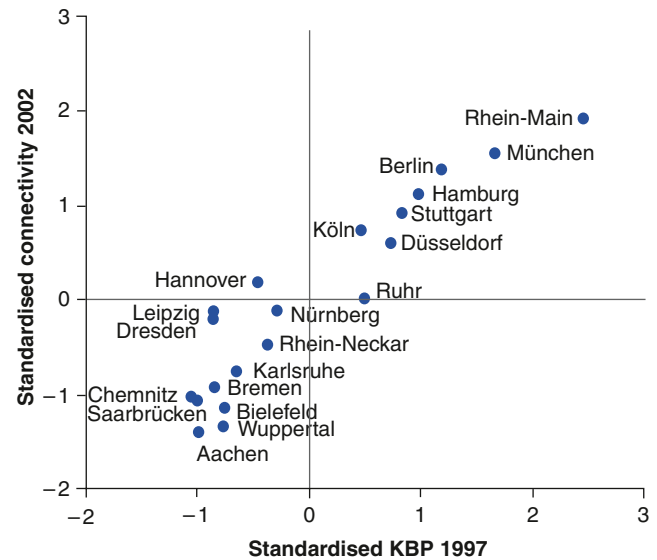
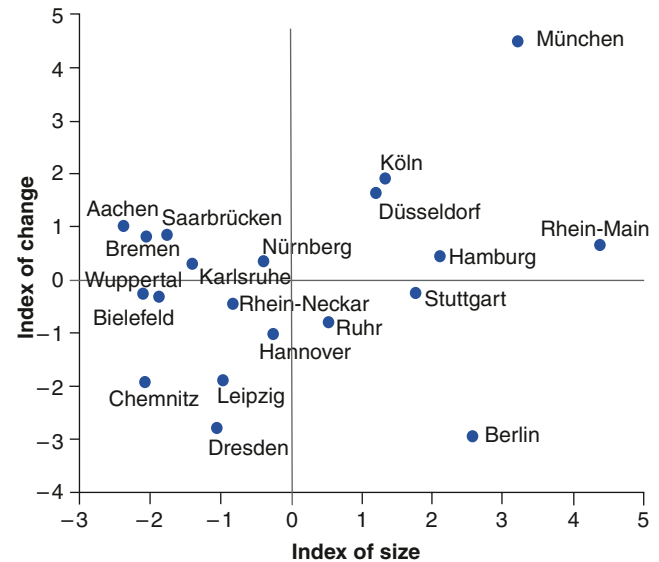
5 Hubs of Knowledge-Based Labour in the German Urban System

Hubs have been discussed as metropolitan regions that are of crucial importance as both places and nodes, i.e. spaces where flows are geographically “grounded”. Moreover, the empirical analysis of metropolitan regions in Germany has revealed the different trajectories of metropolitan regions. Although the bigger metropolitan regions display a disproportionately high level of change and smaller regions show a disproportionately low level of change, the individual trajectories of some regions deviate from this observation. For example, Berlin is the third most important knowledge place and the third most important space for grounding knowledge flows in the German urban system, however it shows decreasing shares in the overall system. On the other hand, Aachen is the third smallest knowledge place and the least important space for grounding flow but displays an increase in its share of both place and grounding flows.

Therefore, in order to identify hubs of knowledge-based labour in the German urban system, four aspects must be considered: firstly the regions’ importance as a place of knowledge-based labour, secondly the change in importance, thirdly the regions’ importance as an organisational node and, finally, the change in this importance.

In a first step, only the regions’ importance as a place and organisational node are considered. To identify metropolitan regions with an above average importance, z-scores for employment and for connectivity are displayed in Fig. 6. The upper right quadrant shows metropolitan regions with an above average importance as a knowledge-based place and an above average importance as an organisational node. Further analysis focuses on these significant knowledge hubs: Rhein-Main, München, Berlin, Hamburg, Stuttgart, Köln, and Düsseldorf. The metropolitan region Ruhr reveals above average employment values but only marginally above average connectivity values and is as such to be considered as a borderline case.

In a second step, adding the degree of change to the analysis enables information about the development of the different metropolitan regions to be gathered. Based on this approach,

**Fig. 6** Above average places and nodes. (Source: Bundesagentur für Arbeit, Hoppenstedt; own calculation)**Fig. 7** Knowledge hubs. (Source: Bundesagentur für Arbeit, Hoppenstedt; own calculation)

metropolitan regions are classified according to their performance in relation to size and development by means of indices, which are calculated on the basis of z-scores. The index of size refers to the size of place and the importance for grounding flows, whereas the index of change refers to the CI values for connectivity and places. The indexes are calculated by (i) using percentage values for employment and connectivity of each region, (ii) standardising these percentage values using a standard normal distribution (z-score); and (iii) calculating the sum of each the z-scores.

Figure 7 shows the index of size (importance of the metropolitan regions at the respective starting points) on the horizontal axis and the index of change (development of the

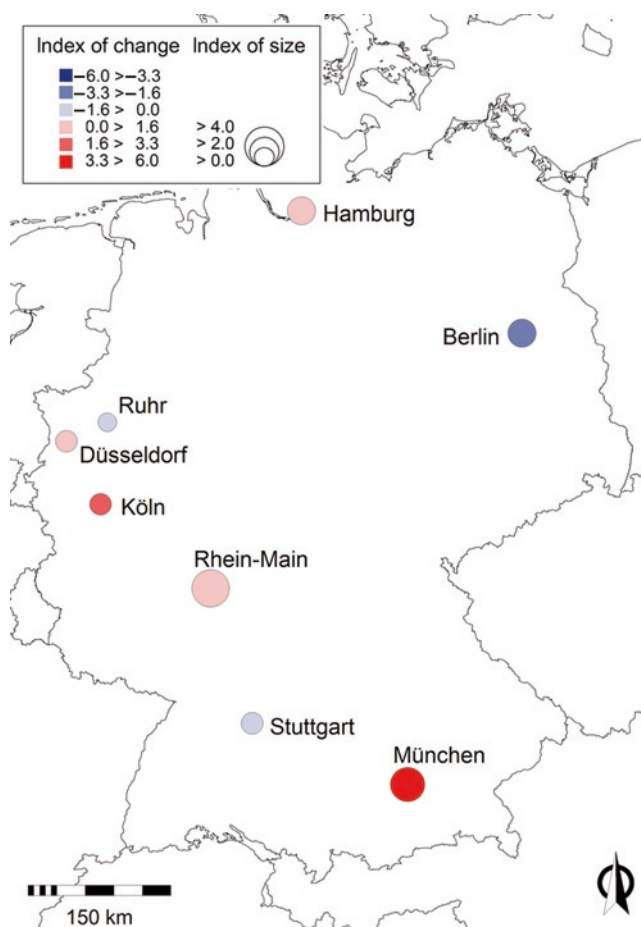


Fig. 8 Knowledge hubs. (Source: Bundesagentur für Arbeit, Hoppenstedt; own calculation)

metropolitan regions) on the vertical axis. The arithmetic mean of all regions is zero for both indices. Consequently, four groups of metropolitan regions can be identified (see Fig. 7):

- Growing knowledge hubs (regions with above average values for both indices, e.g. München).
- Stagnating knowledge hubs (regions with an above average index of size and a below average index of change, e.g. Berlin).
- Stagnating knowledge regions (regions with below average values for both indices, e.g. Chemnitz).
- Catch-up knowledge regions (regions with a below average index of size but an above average index of change, e.g. Aachen).

Based on the data presented above, eight hubs can be identified in the German urban system. The importance of five hubs increased and especially München succeeded in improving its position in the urban system. On the other hand, three hubs dropped in relative importance, most notably Berlin.

Figure 8 shows the geographical pattern of the results presented in Fig. 7. It should be noted that only metropolitan regions with a positive index of size are shown and the size of the sign indicates the importance of the knowledge hub. The colours indicate the development of the hub.

In summary, the biggest hubs of knowledge-based work in Germany are Rhein-Main, München, Berlin and Hamburg. The most dynamic hubs are München and Köln. The hubs observed are mainly large west-German metropolitan regions, therefore the notorious west-east divide is confirmed. Only one hub (Berlin) was identified in the east of the country, and this hub displays diminishing shares of importance in terms of the overall network.

6 Conclusion

The paper has discussed 20 metropolitan regions in Germany as knowledge hubs by analysing their size and their development as places of knowledge-based work and as organisational nodes in firm networks. Eight metropolitan regions have been identified as places and nodes of above average importance. These regions are the large metropolitan regions: Rhein-Main, München, Berlin, Hamburg, Stuttgart, Köln, Düsseldorf, and Ruhr. Changes within the overall urban system also tend to privilege large metropolitan regions. However, on the level of individual metropolitan regions deviations from this pattern can be observed. The causes of these deviations will be discussed in the following section.

First, it should be kept in mind that this analysis focused on professions and firms connected to advanced producer services. Therefore regions with a bias towards industrial production or the public sector will appear as smaller hubs (if at all). The decreasing share enjoyed by the metropolitan regions Ruhr, Stuttgart and Berlin could be interpreted in this light. Stuttgart is a particularly interesting case. The share of knowledge-based professions increased in the region but the share of connectivity declined. The importance of skilled workers can be explained by the fact that the Stuttgart region is characterised by high-tech industries. In contrast, service firms appear to be relatively less important in the Stuttgart region. A closer look at the Ruhr region is also revealing. The regions' above average importance in KBP employment on the one hand, and its average importance as an organisational node in service firm networks on the other, indicate that it is a predominantly industrial region in which much of the knowledge-based labour is carried out in-house. The Ruhr region continues to be afflicted by its industrial past. Although coal and steel are no longer the main sectors in the Ruhr area, the catch-up process does not yet appear to have been completely successful.

This finding also throws new light on studies of the knowledge economy that are based on service firm networks. On the one hand, regions with an industry-based economic structure will be underestimated in these studies (cf. Krätke 2007). On the other hand, studies based on employment data are more dependent on city-size. Therefore a combination of firm data and employment data has proved to be useful.

Second, the results for Berlin are thought-provoking. Although its size qualifies Berlin as an important hub and considerable political efforts have been made since the German reunification to strengthen Berlin as a knowledge place, the results of this analysis indicate that Berlin has a decreasing share within the overall urban system. These results reconfirm a sound scepticism about political objectives to increase knowledge economy on a regional scale in general. Metropolitan regions in Germany have developed a broad range of concepts that deal with requirements of knowledge-based work and aim to strengthen their region with regard to inter-regional competition (cf. Growe 2009: 386 ff.). However, the assumption that all metropolitan regions benefit similarly and increase knowledge-based labour has been shown to be misplaced. Some regions, like München, seem to specialise in knowledge-based services and develop into new service centres. Other regions, like Berlin or Stuttgart, might specialise in the public sector or industrial production. Further research on regional specialisation is necessary in this context.

However, it has to be stated that intra-firm networks are just one way for cities to be connected to flows of knowledge. The assumption that two offices of the same firm in two different cities share knowledge with each other has yet to be verified. Further research on the groundings of other flows of knowledge and on sharing knowledge within firms is necessary.

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References

- Amin, A.; Cohendet, P. (2004): *Architectures of Knowledge. Firms, Capabilities, and Communities*. Oxford.
- Bade, F.-J. (1991): Regionale Beschäftigungsprognose 1995. In: *Mitteilungen aus der Arbeitsmarkt- und Berufsforschung* 1, 555-568.
- Bathelt, H.; Malmberg, A.; Maskell, P. (2004): Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. In: *Progress in Human Geography* 28, 1, 31-56.
- BBR (Bundesamt für Bauwesen und Raumordnung) (2005): *Raumordnungsbericht 2005*. Bonn. = *Berichte*, Band 21.
- Bell, D. (1989): *Die nachindustrielle Gesellschaft*. Frankfurt am Main.
- Camagni, R. (2004): The economic role and spatial contradictions of global city-regions: The functional, cognitive, and evolutionary context. In: Scott, A. J. (ed.): *Global City-Regions. Trends, Theory, Policy*. Oxford, 96-118.
- Castells, M. (1996): *The Rise of the Network Society*. Malden, MA.
- Derudder, B.; Taylor, P. J.; Ni, P.; de Vos, A.; Hoyler, M.; Hanssens, H.; Bassens, D.; Huang, J.; Witlox, F.; Shen, W.; Yang, X. (2010): Pathways of change: shifting connectivities in the world city network, 2000-2008. In: *Urban Studies* 47, 9, 1861-1877.
- Dicken, P. (2007): *Global Shift. Transforming the World Economy*. London.
- Drucker, P. F. (1969): *The Age of Discontinuity. Guidelines to our Changing Society*. London.
- Friedmann, J. (1986): The world city hypothesis. In: *Development and Change* 17, 1, 69-83.
- Friedmann, J. (1995): Ein Jahrzehnt der World City Forschung. In: Hitz, H.; Keil, R.; Lehrer, U. et al. (eds.): *Capitales Fatales. Urbanisierung und Politik in den Finanzmetropolen Frankfurt und Zürich*. Zürich, 22-44.
- Growe, A. (2009): Wissensträger und Wissensvernetzung in Metropolregionen. In: *Raumforschung und Raumordnung* 67, 5/6, 383-394.
- Hall, A. (2007): *Tätigkeiten und berufliche Anforderungen in wissensintensiven Berufen. Empirische Befunde auf Basis der BIBB/BAuA-Erwerbstätigenbefragung 2006*. Bonn. = *Studien zum deutschen Innovationssystem*, Band 3.
- Hall, P. (1966): *The World Cities*. London.
- Hall, P.; Pain, K. (eds.) (2006): *The Polycentric Metropolis. Learning from Mega-City Regions in Europe*. London.
- Hoyler, M.; Freytag, T.; Mager, C. (2008): Connecting Rhine-Main: The production of multi-scalar polycentricities through knowledge-intensive business services. In: *Regional Studies* 42, 8, 1095-1111.
- Krätke, S. (2007): Metropolisation of the European Economic Territory as a Consequence of Increasing Specialisation of Urban Agglomerations in the Knowledge Economy. In: *European Planning Studies* 15, 1, 1-27.
- Markusen, A. (1996): Sticky places in slippery space: A typology of industrial districts. In: *Economic Geography* 72, 3, 293-313.
- Nonaka, I.; Takeuchi, H. (1995): *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation*. New York.
- O'Kelly, M. E. (1998): A geographer's analysis of hub-and-spoke networks. In: *Journal of Transport Geography* 6, 3, 171-186.
- Park, S. O. (2000): Knowledge-based industry and regional growth. Frankfurt. = *IWSG Working Papers* 2-2000.
- Polanyi, M. (1967): *The Tacit Dimension*. London.
- Sassen, S. (1991): *The Global City*. New York, London, Tokyo. Princeton.
- Scott, A. J.; Agnew, J.; Soja, E. W.; Storper, M. (2004): Global city-regions. In: Scott, A. J. (ed.): *Global City-Regions. Trends, Theory, Policy*. Oxford, 11-30.
- Steier, N. (2001): *Wissen und Wirtschaften. Die gesellschaftlichen Grundlagen der modernen Ökonomie*. Frankfurt am Main.
- Taylor, P. J. (2001): Specification of the world city network. In: *Geographical Analysis* 33, 181-194.
- Taylor, P. J. (2004): *World City Network. A Global Urban Analysis*. London.
- Taylor, P. J.; Hoyler, M.; Verbruggen, R. (2010): External urban relational process: Introducing central flow theory to complement central place theory. In: *Urban Studies* 47, 13, 2803-2818.