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The world city network: national versus global perspective

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The world city network: national versus global perspective

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Abstract

World cities are important nodes in the global networks of knowledge-based economies. As a result of the growing complexity of knowledge creation, firms increasingly organise their activities in business networks that operate across different spatial scales. On the global scale, new information and communication technologies enable the control of business processes across multiple locations. On the regional scale, the advantage of geographical proximity plays an important role. Collective learning processes require a common cognitive, social and cultural context as well as regular face-to-face contacts. Short distances bring people together, thereby stimulating information spillovers and the creation of new ideas. These places of intensive interaction are no longer exclusively located in the traditional inner cities. Rather, they are increasingly found in new urban centres, edge cities, airports or at the stations of high-speed rail networks. The result is a highly polycentric metropolitan

system, characterised by accelerated growth in and around smaller cities and towns within the wider metropolitan orbit of one or several big cities.

The growth of the knowledge economy has led to new forms of business networks linking cities and towns across different spatial scales. Various attempts have been made to analyse these networks empirically using the interlocking network model of the Globalization and World Cities (GaWC) research network. Two approaches can be distinguished from a spatial perspective: a global approach that studies the world city network from the perspective of the largest advanced producer service firms, and a national approach that starts with the most important knowledge-intensive firms located within specific territorial boundaries. This paper compares the methodological implications and empirical outcomes of both approaches with reference to recent case studies of the German space economy. Both approaches pursue similar objectives: to investigate external relations of German cities, both transnationally and on the national scale. Furthermore, both approaches use the same analytical instrument: the interlocking network model of GaWC. Differences exist in the theoretical argumentation: the global approach is grounded in world city research; the national approach, on the other hand, is anchored in debates in regional science, economic geography and spatial planning. In this paper, we argue for the need of scale-sensitive interpretations of connectivity patterns built by the interlocking network model and conclude with some tentative recommendations for the methodological direction of future research in world city network studies.

Keywords: world city network, Germany, mega-city region, knowledge economy

JEL codes: R12 (Size and Spatial Distributions of Regional Economic Activity); R58 (Regional Development Planning and Policy)

1. Introduction

World cities are important nodes in the global networks of knowledge-based economies. The knowledge economy can be defined as an interdependent system of advanced producer services (APS) and high-tech firms combining highly specialized knowledge and skills from different parts of the value chain in order to create innovations and to sustain competitive advantage (Lüthi 2011). On the input side of the innovation process, knowledge-intensive firms are dependent on cutting-edge information and highly skilled employees. On the output side, they create new knowledge in the form of innovative products and services by combining different types of knowledge and experience-based skills.

As a result of the growing complexity of knowledge creation, firms increasingly organise their activities in business networks that operate across different spatial scales. On the global scale, new information and communication technologies enable the control of business processes across multiple locations. Faulconbridge's empirical study (2007) of London's and New York's advertising and law clusters, for example, shows that both advertising and law firms hold close contacts with internal overseas offices, forming global learning networks based on relational proximity and regular conversations with colleagues and peers (Faulconbridge 2007). On the regional scale, the advantage of geographical proximity plays an important role. Collective learning processes require a common cognitive, social and cultural context as well as regular face-to-face contacts (Storper and Venables 2004). Short distances bring people together, thereby stimulating information spillovers and the creation of new ideas. These places of intensive interaction are no longer exclusively located in the traditional inner cities. Rather, they are increasingly found in new urban centres, edge cities, airports or at the stations of high-speed rail networks (Hall and Pain 2006). The result is a highly polycentric metropolitan system, characterised by accelerated growth in and around smaller cities and towns within the wider metropolitan orbit of one or several big cities (Hall 2004). These polycentric 'mega-city regions' represent a re-scaling of the strategic locations of the knowledge economy, by which firms reap the benefits of both local agglomeration and global-scale production networks (Hoyler et al. 2008b).

Various attempts have been made to analyse these networks empirically using the interlocking network model (INM) of the Globalization and World Cities (GaWC) research network (Taylor 2004, 2012a, 2012b) (see Table 1). The INM has its origin in the literature on global and world cities. Taylor (2001) developed an analytical instrument to model the world city network based on the relationships between head offices and other internal branches of APS firms all over the world, building theoretically on Friedmann's (1986) world city concept, Sassen's (2001) identification of APS as crucial economic actors in global cities and Castells' (2000) notion of a space of flows (Friedmann 1986; Sassen 2001; Castells 2000). In its initial specification, the INM is conceptualised as a global *top-down approach* that studies the world city network from the perspective of the largest APS firms in order to identify the most highly connected cities in the world (Taylor 2001, 2004; Taylor and Aranya 2008; Taylor et al. 2011). This global approach has been used to document the development of the world city network and to track changes dependent on economic trends, e.g. in the context of the current financial and economic crisis (Derudder et al. 2010; Hanssens et al. 2011). The most recent publications taking such a top-down perspective are Taylor et al.'s (2011) comprehensive analysis of the external relations of 525 cities worldwide and Taylor et al.'s (2012) new world regionalisation based on APS location strategies (Taylor et al. 2011; Taylor et al. 2012).

In the European INTERREG IIB research project POLYNET – Sustainable Management of European Polycentric Mega-City Regions – Taylor’s INM was first applied at a regional level using a *bottom-up approach*. This approach analyses the world city network from the perspective of the most important knowledge-intensive firms located within a specific territorial boundary, i.e. the macro-regional scale is taken as the starting point of data collection. POLYNET aimed to investigate the polycentricity and interlocking network patterns of eight mega-city regions in North West Europe (Hall and Pain 2006). The POLYNET study advanced the theoretical debate on large polycentric urban regions on the basis of new empirical evidence. One of its main conclusions is that polycentricity emerges as a scale-dependent phenomenon based on the coming together of various business service networks of different organisational architectures and scalar reach. The mega-city region, in its various guises, is becoming a more general phenomenon in advanced economies (Halbert et al. 2006; Thierstein et al. 2006; Hoyler et al. 2008b; Taylor et al. 2009; Lüthi et al. 2010).

Recently, the INM has also been applied to the study of the German space economy: Hoyler (2011) investigated the German urban system from a global top-down perspective; Lüthi et al. (2011) employed a macro-regional bottom-up approach using data from firms located within Germany and its adjacent functional urban areas. Both approaches pursue similar objectives: to investigate external relations of German cities, both transnationally and on the national scale. Furthermore, both approaches use the same analytical instrument: the INM. Differences exist in the theoretical argumentation: the top-down approach is grounded in world city research; the bottom-up approach, on the other hand, is anchored in debates in regional science, economic geography and spatial planning.

Table 1: Application of the INM on different spatial scales (selected studies; author’s compilation)

	Top-Down	Bottom-Up
Global Scale	(Taylor 2001) (Taylor 2004) (Derudder and Taylor 2005) (Taylor and Aranya 2008) (Taylor et al. 2011) (Taylor et al. 2012)	
National Scale	(Taylor et al. 2011) (Hoyler 2011)	(Taylor et al. 2009) (Growe and Blotevogel 2011) (Lüthi et al. 2011) (Lüthi et al. 2013) (Schmitt and Smas 2012)
Regional Scale		(Hall and Pain 2006) (Thierstein et al. 2006) (Thierstein et al. 2008) (Taylor et al. 2008) (Hoyler et al. 2008a) (Lüthi et al. 2010) (Zhang and Kloostermann 2012)

In this contribution, we compare and contrast the methodological implications and empirical outcomes of the top-down and the bottom-up approach. The paper is structured in six main sections. Following the introduction, the second section explains the general analytical framework of the INM as well as its main strengths and weaknesses in analysing external relations of cities and agglomerations. Sections three and four present the specific empirical settings and main analytical findings of the top-down and bottom-up analyses of the German case studies. In the fifth part, we compare the results and discuss the respective benefits and limitations of both approaches. The

paper concludes with some tentative recommendations for the methodological direction of future research in world city network studies.

2. The interlocking network model: general analytical framework

The INM provides one specific way of addressing the question how inter-city relations can be empirically measured despite the chronic lack of data on inter-city information flows. The model uses a *proxy* – intra-firm networks of multi-branch, multi-location enterprises – to estimate potential flows of knowledge-creating information between cities (Taylor 2001). Once the relevant knowledge-intensive firms are identified, information is gathered on their office locations worldwide. The prime source of this information is the firms' corporate websites. It is necessary to scavenge all relevant information available online, supplemented by additional material such as annual reports or company brochures. For each firm, two types of information are collected (Taylor et al. 2002): First, information about the *size* of a firm's presence in a city. In the best case, information can be found on the number of professionals working in each of the firm's offices. Secondly, information about the *extra-locational functions* of a firm's office in a city is gathered. For this, not only headquarters functions have to be recorded, but also other features such as extra-territorial functions. Based on this information, all office locations are rated on a scale of 0 to 5. A location that houses a company's headquarters scores 5. A location that houses a standard office scores 2. If an office has a special relevance within the firm network, the scoring is upgraded to 3 or 4. If the overall importance of an office is low, the scoring is downgraded to 1. The end result is a *service activity matrix* (V_{ij}), defined by cities in the rows and knowledge-intensive firms in the columns. Each cell in the matrix shows the rating of an office location in a city: the so called *service value* (v). This service activity matrix is used to run the algorithm of the INM. The primary output of this analysis is network connectivity, a measure that estimates how well connected a city is within the aggregated intra-firm network. Here, different kinds of connectivity values can be calculated (Taylor 2001):

The connectivity between two cities (a, b) of a certain firm (j) is analysed by multiplying their service values (v), representing the so-called *elemental interlock* (r_{abj}) between two cities for one firm:

$$r_{abj} = v_{aj} \cdot v_{bj} \quad (1)$$

This approach seems reasonable when the following assumptions are made (Derudder and Taylor 2005, p. 74-75): 1) Offices generate more flows within their own firm network than to other firms in their sector. 2) More important offices generate more flows, which has a multiplicative effect on inter-city relations. Based on these assumptions, the elemental interlocks for all firms located in two cities are summarised, in order to calculate the total connectivity between the two cities. This leads to the so-called *city interlock* (r_{ab}):

$$r_{ab} = \sum_j r_{abj} \quad (2)$$

Aggregating the city interlocks for a single city produces the *interlock connectivity* (N_a). This measure describes the importance of a city within the intra-firm network of all knowledge-intensive enterprises that have been analysed.

$$N_a = \sum_i r_{ai} \quad (a \neq i) \quad (3)$$

Finally, relating the interlock connectivity for a given city to the city with the highest interlock connectivity in the sample shows its relative importance in relation to all other cities that have been

considered. These scores – creating a scale from 0 to 1 – can be used to indicate hierarchical tendencies within the world city network.

Even though the INM is an innovative way to calculate inter-city business relations, some limitations have to be acknowledged. The main limitation is the absence of *extra-firm* networks in its conceptualisation. Intra-firm trade in trans-national corporations accounts for an increasing share of international trade in today's global economy (OECD 2008), but intra-firm networks are only one set of relevant connections among many others (Coe et al. 2010). It is now widely acknowledged that the most advanced activities of knowledge-intensive firms are deeply inscribed into external networks of suppliers, subcontractors and business clients. Extra-firm linkages are of increasing significance because firms have to rely not only on in-house knowledge, but also on resources external to the firm (Howells 2000).

A second limitation is that the strength and importance of *actual* linkages between cities are not recorded by calculating city interlocks. Whether information is passing between cities by email, telephone or business travel can only be discovered by other means. The connectivity measures derived from the interlocking network model are therefore a proxy based on assumptions about the intensity of flows between offices. Nordlund (2004) for example criticised the assumption that the elemental interlock between two large office locations is greater than between a large and a small office location as there may in reality be more interaction between large and small offices because of command, control and support functions (Nordlund 2004). Even if this assumption is accepted for the global scale, where advanced producer service firms tend to operate across rather than through segmented markets (Sassen 2001), this may not hold true to the same extent for other scales. Multiple office locations within a nation state or large city-region, for example, may indicate intensive intra-firm flows but could also signal a subdivision into separate markets serviced by different office locations with few flows across (Hoyler et al. 2008a, p. 1097).

A third critique concerns the INM's potential for structural determinism (Neal 2012b; Liu and Derudder 2012b). While Neal (2012b) points out how the application of the INM in past GaWC analyses potentially constrains certain overall network structures and affects the analysis of city cliques and network density, Liu and Derudder (2012b) argue that the practical implications are much less severe than suggested. Both papers call for an increased application of social network analysis techniques to complement existing studies of the world city network (Hennemann and Derudder 2012; Liu and Derudder 2012a).

3. The interlocking network model as a top-down approach

In its original conceptualisation, the interlocking network model was devised to allow the identification of the globally most integrated nodes in advanced producer service networks, and to provide a more inclusive perspective on cities in globalization that takes into account hundreds of cities across the world rather than focus on a select few cities perceived to be atop an 'urban hierarchy'. However, the data gathered on the locational strategies of the most important APS firms globally can also be used to analyse cities at other scales. For example, Taylor et al. 2011 provide a detailed analysis of city connectivities at world-regional and national scales, highlighting substantive contrasts in the integration of major regions and states into the world city network. At the national scale, global network connectivities adhere broadly to the importance of a city in its national context

but there are significant differences between countries dominated by a primate city (e.g. the UK) and those with a more balanced urban network (e.g. Germany).

In the following we use the example of Germany to illustrate the potential benefits and limitations of applying a ‘top-down’ approach to the study of city connectivities in a national context. This approach utilizes data collected on the global scale but focuses on the analysis of a subset that covers the external relations of German cities. Data were gathered in 2008 for 175 advanced producer service firms in 375 cities worldwide (Taylor et al. 2011). The firms were chosen for five APS sectors: finance (75 firms), accountancy, advertising, law and management consultancy (25 each) and represent the largest and most important firms as indicated by published rankings for the respective sectors. Table 2 provides an overview of the distribution of offices by sector for different scales. Across all scales, accountancy firms are the most ubiquitous and corporate legal services the most concentrated sectors. However, even this basic comparison of office distributions reveals specificities of the German urban system, such as the exceptionally high number of law firm and management consultancy locations compared to the global distribution. This hints at particular sectoral strengths but is also an outcome of the federal territorial structure and distribution of key economic functions across a large number of cities and towns that makes international servicing from a single gateway city more difficult than in countries with a more primate urban system.

Table 2: Studied APS sectors and their branches (author’s compilation)

	Number of Firms	Branches in Germany	Branches on the European scale (without Germany)	Branches on the global scale (without Europe)
Financial Services (Banking and Insurance)	75	106	811	2.456
Accountancy	25	166	998	2.893
Advertising	25	68	607	1.407
Legal Services	25	62	188	282
Management Consultancy	25	85	399	951

Note: There are 20 German, 96 other European and 410 non-European cities in the GaWC 2008 global data matrix of 526 cities x 175 firms. Multiple branches of one firm in one city are counted as one.

Network connectivities calculated on the basis of the 175 major APS firms used in the global approach identify 14 German cities that score at least 5 per cent of the highest ranked city globally, London (Hoyler 2011). Table 3 lists the top 10 cities, confirming Frankfurt’s role as leading international financial centre, followed by a group of major German cities with similar levels of integration into the world city network: the capital Berlin, Hamburg and Munich as major economic centres in Northern and Southern Germany, and Düsseldorf as principal centre for international business services in Rhine-Ruhr. Frankfurt and Munich stand out as headquarter locations (service value 5), but Düsseldorf also houses a number of offices with extra-territorial functions (e.g. regional headquarters; service value 4). Command-and-control functions of the 175 largest global firms in advanced services are limited in Germany (six headquarters and 18 offices with extra-territorial functions) and highly concentrated, but all major German cities are well integrated through typically sized offices, ensuring that six German cities are among the 100 globally most integrated cities in advanced producer services. This contrasts starkly with the UK and France, whose global cities

London and Paris rank 1 and 4 in the world in terms of their global network connectivity but where no other city is among the 100 most connected in the world (Taylor et al. 2011).

Table 3: Interlock Connectivity and Service Values of the highest ranked German cities (author's calculation)

German Rank	Global Rank	City	Gross Connectivity	Proportionate Connectivity (1.00=New York)	Number of Service Values					Number of office locations
					1	2	3	4	5	
1	32	Frankfurt	48.165	0.50	0	65	28	8	3	104
2	55	Berlin	37.825	0.39	0	16	30	1	0	47
3	60	Hamburg	35.574	0.37	0	27	25	1	0	53
4	67	Munich	33.482	0.35	0	60	9	1	3	73
5	76	Düsseldorf	30.575	0.32	0	53	2	5	0	60
6	91	Stuttgart	26.295	0.27	0	36	3	1	0	40
7	166	Cologne	14.499	0.15	0	24	3	1	0	28
8	197	Leipzig	11.762	0.12	0	15	0	0	0	15
9	199	Dresden	11.628	0.12	0	15	0	0	0	15
10	233	Bremen	9.916	0.10	0	13	0	0	0	13

The key advantage of using such a top-down approach for the analysis of cities in a specific national context lies exactly in this provision of globally comparable data and measures. These allow the exploration of national and macro-regional contrasts, for example the different degrees of primacy in 'national urban systems' based on a measure of economic integration (global network connectivity) rather than population size. Other relevant measures include comparative evaluations of the orientation of the external relations of individual cities, for example the degree to which they are relatively over or under linked to leading cities in the world economy (e.g. New York – London), or to cities within their own national context (Taylor et al. 2011). All of these comparative analyses can also be disaggregated in sectoral analyses of the constituent advanced producer service sectors.

However, disaggregation is where a global approach reaches its limits relatively quickly. Although the firms included in the analysis are generally the leading global firms, with operations across a wide number of countries, their number in each sector is relatively small. Their role can perhaps best be described as that of an 'indicator species', highlighting the major patterns of connectivity in advanced servicing but unable to capture the myriad of extensive linkages that exist beyond the key global players. This is particularly significant for analyses of smaller and economically less dominant places in the economy that may well be linked into global processes via smaller multi-city firms with national or limited transnational scope. Equally, those interested in detailed analyses of advanced service firm location in larger metropolitan regions may find that the global data offer limited if any options to explore city-regional divisions of labour in advanced producer servicing. This is where a bottom-up approach can significantly extend the application of the interlocking network model.

4. The interlocking network model as a bottom-up approach

In contrast to Hoyler (2011), Lüthi et al. (2011) use a bottom-up approach to investigate the integration of the German city-system into the world city network, i.e. they take the national scale as the starting point for data collection. The final set of APS firms are defined by using data from the commercial data provider Hoppenstedt, complemented by business rankings, such as Forbes' Global 2000, Fortune's Global 500 and all firms listed in the prime standard of the Deutsche Börse. In order to be selected, the firms have to belong to the largest APS firms in Germany in their corresponding

sub-sector, measured by employment size. They also need to be multi-branch enterprises with at least one office location in Germany. All in all, *180 APS firms* in five sub-sectors are analysed here (Table 4). Financial services prove to be the most nationally based economic sector, which reflects the large networks of bank branches and other financial and insurance services supplying final demand. Accountancy and management consulting are the most global APS sectors. This information is important in order to assess the potential bias towards Germany in the bottom-up approach in comparison to the global top-down approach.

Table 4: Studied APS sectors and their branches (author's compilation)

	Number of Firms	Branches in Germany	Branches on the European scale (without Germany)	Branches on the global scale (without Europe)
Financial Services (Banking and Insurance)	60	1.598	639	653
Accountancy	30	396	1127	1.240
Advertising	30	231	336	301
Legal Services	30	162	259	227
Management Consultancy	30	248	901	1.064

Lüthi et al.'s (2011) analytical focus is on Germany and its adjacent agglomerations in neighbouring countries, up to 50km distance from the German border. All in all, the authors integrated 1.417 agglomerations from different continents and countries into the final data matrix. Table 5 shows the interlock connectivity of the top 10 German agglomerations from this bottom-up perspective: Frankfurt is top, followed by Munich, Berlin, Hamburg, Düsseldorf and Stuttgart. In comparison to Hoyler (2011), there are only slight differences: Munich ranks higher, but note that ranks 2 to 5 in the top-down approach are very close together. Furthermore, Nuremberg and Hanover replace Leipzig and Bremen in the top 10.

Table 5: Interlock Connectivity and Service Values of the highest ranked German cities (author's calculation)

German Rank	Global Rank	City	Gross Connectivity	Proportionate Connectivity (1.00=New York)	Number of Service Values					Number of office locations
					1	2	3	4	5	
1	3	Frankfurt	40.896	0.85	1	61	19	9	12	102
2	5	Munich	37.196	0.78	1	60	21	7	15	104
3	6	Berlin	36.170	0.75	5	51	28	7	6	97
4	8	Hamburg	33.568	0.70	4	58	15	9	9	95
5	17	Düsseldorf	28.961	0.60	3	45	16	5	6	75
6	18	Stuttgart	28.920	0.60	2	40	16	3	8	69
7	30	Cologne	24.920	0.52	3	36	15	3	11	68
8	39	Nuremberg	23.166	0.48	2	30	4	0	4	40
9	48	Dresden	21.498	0.45	0	37	7	0	0	44
10	50	Hanover	20.857	0.44	3	29	5	1	8	46

In terms of headquarter functions; Munich ranks first, with 15 APS headquarters, followed by Frankfurt (12) and Cologne (11). As in the case of Hoyler (2011), this finding shows the importance of Munich and Frankfurt as leading German command-and-control centres in the APS sector. The

corporate headquarters in these cities are responsible for all the major strategic investment decisions that shape the intra-firm networks of the whole enterprise.

Another similarity in outcome is the identification of Berlin as an important location for unusually large offices. Berlin's second place in the connectivity ranking of the top-down approach is mainly the result of the many large offices (service value 3) located in the city. The same can be observed in the bottom-up approach: Berlin has the most office locations with a service value of 3, followed by Munich and Frankfurt. For Berlin, Germany's capital city with a history of economic challenges pre- and post-unification (Krätke 2004), this can be interpreted as an opportunity. Large offices with additional functions constitute an intermediate level in the corporate organisational structure. Thereby, they act as a kind of "strategic window" (Kriger and Rich 1987, p. 45) for firms operating on a global scale. Thus, an opportunity for Berlin lies in its role as complementary business location to the established command-and-control centres in Germany. Berlin's proximity to German policy-makers might play an important role here.

5. Discussion

In the previous sections we have seen that the top-down and the bottom-up approach produce quite similar results, confirming the general robustness of the INM: Frankfurt, Munich, Berlin, Hamburg, Düsseldorf and Stuttgart form part of an "urban circuit" that constitutes the top of the German functional urban hierarchy (Hoyler et al. 2008a, p. 1102). In terms of the *shape* of this hierarchy, however, there are differences (see Figure 1). From the global top-down perspective, the German space economy tends to be much less polycentric than from the national bottom-up perspective. Nevertheless, the German urban system still shows a comparatively high degree of polycentricity even in the top-down perspective when compared to other national urban systems (e.g. UK, France; see Taylor et al. 2011).

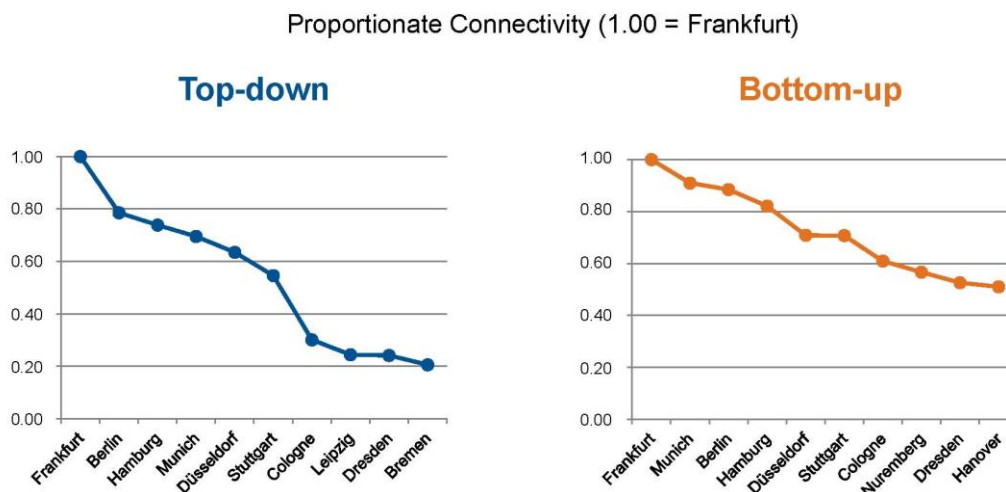


Figure 1: Functional urban hierarchy in Germany (author's calculation)

Against this backdrop, the question arises of the relative merits of each approach for the analysis of external relations of German cities. In order to identify the causes of the discrepancies between the top-down and the bottom-up approach, a number of questions will be discussed in greater detail:

Does the INM work better on some scales than on others?

To answer this question, we must first recall the conceptual background of the INM. The INM follows Sassen's (2001) understanding of global cities as major service centres where APS are concentrated. As a consequence, the INM is conceptualised as a network with three levels (Derudder et al. 2003): a *sub-nodal level*, which refers to the knowledge-intensive firms providing advanced producer services; a *nodal level*, which considers the individual cities; and a *network level*, which constitutes the entire world city network.

The top-down approach analyses the German urban system from a global perspective. Thereby, it focuses on three central questions. On the *sub-nodal level*: How do the world's largest APS companies use German cities as strategic nodes in their global locational strategies? On the *nodal level*: What level of connectivity is reached by German cities, taking the most connected cities in the world as a benchmark? On the *network level*: How is the German urban system integrated into the world city network?

The bottom-up approach, on the other hand, looks at the German urban system from a national point of view. Global connectivities are analysed using an 'egocentric' or 'hinter-world' perspective. Here, too, cities are understood as service centres where knowledge-intensive firms are concentrated for servicing their business clients. Again, three questions are of particular interest. On the *sub-nodal level*: How do Germany's largest APS companies use cities in Germany and abroad as strategic nodes in their locational strategies? On the *nodal level*: What level of connectivity is reached by German cities, taking the most connected cities in Germany as a benchmark? On the *network level*: How intensively are German cities connected with each other and with other cities in the world? This national bottom-up analysis is not interested in analysing the world city network as a whole. Rather, it aims to identify the connectivity patterns within the German urban system and its connection to selected destinations elsewhere.

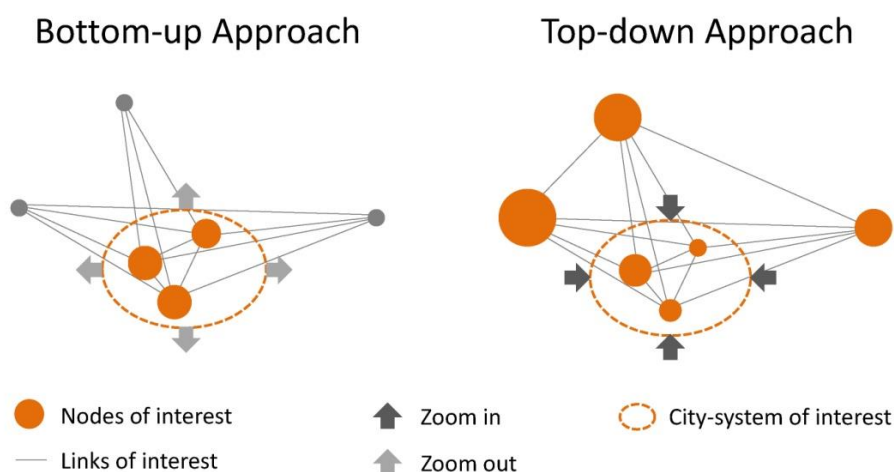


Figure 2: Top-down versus bottom-up approach (author's illustration)

However, if the INM is applied on the national level, the methodology and interpretation require some level of adaptation. A remarkable difference between the top-down and the bottom-up approach is the position of German cities in the global ranking: the latter suggests much higher global connectivity ranks for German agglomerations. This, of course, is the consequence of the Germany-

based bottom-up approach in selecting the APS firms. This focus was necessary in order to reveal meaningful connectivity patterns not only for the biggest German agglomerations but also for small and medium sized cities and towns. However, global rankings based on regional data collections have to be interpreted with caution, as the connectivity values represent a specific regional perspective. Basically, the INM creates the best results if the firms are selected on the spatial scale to which the analysis primarily refers: a global analysis should capture the biggest global firms; a regional analysis should capture the biggest regional firms. The biggest *global* firms may also be used for a regional analysis, but only if enough of these firms have office locations in the corresponding agglomerations. The biggest *regional* firms may also be used for a global analysis, but only in order to assess the city-interlocks to global destinations. In the bottom-up perspective, for example, it is possible to assess the link between Hamburg and New York, but not the link between Tokyo and New York or the position of Hamburg and New York in the whole world city network.

Can the INM be applied to sectors other than APS, e.g. high-tech industries?

According to Sassen (2001), APS firms create world-wide office networks covering major cities in most or all world regions through their transnational spatial strategies. International high-tech firms pursue similar strategies. Lüthi et al. (2011) show that high-tech firms are on average more globalised than APS firms. High-tech production has a great industrialisation- and modularisation potential, whereby the various stages are located across different sites as firms find it advantageous to source more of their inputs globally (OECD 2008). Clearly-defined technical standards reduce the risk of misunderstandings to such a degree that even complex information can be communicated over long distances (Gereffi et al. 2005).

Hence, by limiting the INM to describe only the details of APS networks, a chance is missed to make the findings work more analytically. Sassen (2010, p. 156) herself underlines that the integration of high-tech sectors is an important complement and enrichment of analysing cities in globalization (Sassen 2010). Similarly, Castells (2000) argues that what is true for top managerial functions and financial markets is also applicable to high-tech manufacturing. As in the case of APS, the spatial division of labour that characterises 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 production process (Castells 2000). Krätke (2011) has recently extended a social network approach on the global scale to three industrial subsectors, the automotive industry, technology hardware and equipment industry (focusing on ICT and semiconductors), and the pharmaceutical and biotechnology industry (Krätke 2011).

However, APS and high-tech firms are not the only agents that interlock cities in contemporary globalisation. Other 'global networkers' include, for example, media corporations (Krätke and Taylor 2004; Hoyler and Watson 2012), non-governmental organisations, UN agencies and diplomatic missions (Taylor 2005). Indeed, a case can be made for the INM as a generic model for understanding 'cityness' in terms of external inter-city relations (Taylor et al. 2010; Taylor 2012a).

How many cities and firms should be integrated in the network analysis?

In order to answer this question, let us recall the calculation of the INM. The INM calculates the interlock connectivity, a measure of how strong a city is integrated into the world city network through intra-firm networks of knowledge-intensive firms: a high interlock connectivity is the result of three parameters: (1) a large number of office locations in a city, (2) a large size of the

corresponding firms in terms of office locations worldwide, and (3) a high rating of the respective service values.

Regarding the first parameter, the question arises how many firms have to be present in a city in order to produce reliable connectivity values? If the data of the global top-down approach are evaluated on the national or even regional scale, the connectivity values might refer to very few companies, especially in small and medium sized cities and towns. Thereby, the key principle of empirical aggregation gets lost. In this regard, the bottom-up approach, which focuses on Germany and its adjacent agglomerations, includes several advantages. The selection of the biggest Germany-based firms enables a fine grained covering of the study area with a multiplicity of cities. This, in turn, makes it possible to identify the role of small and medium sized cities and towns that are located at the peripheries of – or between – the main mega-city regions. Furthermore, the inclusion of adjacent agglomerations up to 50km distance from the German border makes it possible to identify and contextualise large-scale urban structures and hierarchies of cross border agglomerations.

But also the second parameter – the firm size in terms of office locations worldwide – has a lasting effect on the INM, particularly in the bottom-up approach. Since the latter analyses a very high number of cities worldwide – 1,417 in total – the size of one APS firm becomes highly significant for the total interlock connectivity of a city. PricewaterhouseCoopers, for example, has over 700 office locations worldwide. Because of the adding-up of over 700 elemental interlocks, PricewaterhouseCoopers becomes very important for a single agglomeration, especially in small agglomerations with only very few other APS firms. Hence, in order to reduce the influence of a single firm on the interlock connectivity in small agglomerations – and thereby to stabilise the INM – the maximum number of cities in the whole network analysis should be restricted.

Similarly, the third parameter – the rating of service values – calls for a limitation of the number of cities analysed. This is due to the potential for uncertainty in the connectivity values that results from the subjectively assigned scores that rate the importance of a city within a firm's office network. A robustness analysis of the global approach suggests that connectivity values derived from the INM for the top 130 cities are relatively insusceptible to significant rank shifts, but that lower-ranked cities are more sensitive to changes in service values (Liu and Taylor 2011).

6. Conclusions

One of the most important aspects of the INM is that it analyses the spatial patterns of the knowledge economy by putting the activities of the firms – their strategic decisions and organisational structures – at the centre of the argument. It provides an empirical instrument for quantifying inter-city relations in terms of the organisational structure of the global knowledge economy. For future research, however, it will be important to learn more about the locational strategies that shape the world city network. There is a need to reveal the more subtle and strategic processes underlying the spatial activities of the knowledge economy. This can be achieved in several ways.

(i) Mix of attribute and relational measures: Relational approaches have gained in popularity in economic geography. Some authors speak of a “relational turn” (Yeung 2005) or of a “shift towards a relational economic geography” (Bathelt and Glückler 2011, p. 22). However, along with other authors, we place the emphasis above all on the methodological enrichment of a relational perspective rather than on the way it is built up to form a new theoretical paradigm (Dicken et al.

2001; Sunley 2008). The INM in particular is a methodological approach and starting point for empirical research. However, urban systems are not only defined by their non-physical connectivity as specified in the INM. Metropolitan functions and urban attributes – for example in terms of innovation, regulation, human resources, economic structures and trends – play an important role, especially in the context of increasing economic specialisation and division of labour. As we have seen above, the interpretation of the service values – which are in fact attribute measures – provides important evidence to assess the quality and composition of the connectivity values more accurately. For a single agglomeration, it is central to know whether the connectivity values result from subsidiary offices, regional headquarters or corporate headquarters. Furthermore, in the context of the knowledge economy – and the associated need for regular face-to-face contacts – regional and international accessibility plays a key role. Here, the question of causality remains to be clarified: Is a high interlock connectivity the result of good physical accessibility, or is a good physical accessibility the result of a high interlock connectivity? (Neal 2012a; Bentlage et al. 2013).

(ii) Mix of global and regional scales: A particular strength of the INM is that it integrates various spatial scales, rather than preferring any one of them. This opportunity should not be missed. Nevertheless, the global top-down approach is often not detailed enough to analyse connectivity patterns on the national or regional scale. Here, the bottom-up approach provides important insights. Thus, a combination of various approaches – global scale analysis complemented by national and regional case studies – will yield additional insights into the regional patterns of the world city network.

(iii) Mix of economic sectors: APS firms are not the only determining element in the process of structural change towards the knowledge economy. In order to understand the geographies of economic globalisation more fully, one has to account for both the APS and the high-tech sectors. For the European urban system, for example, Krätke (2007) shows that in both sectors an on-going process of selective spatial concentration in metropolitan regions leads to the development of strong cluster potentials. The majority of these regions are marked by a development path wherein the dynamics of high-tech manufacturing activities play a considerable role (Krätke 2007). The integration of different sectors of the knowledge economy is useful and enlightening, not only as an analytical control group, but also and especially as an important theoretical underpinning of the INM. The knowledge economy as a whole – not only APS – is the key driver of the world city network. The functional logic of the knowledge economy and its strategic use of agglomeration and global network economies forms a core process in the development of functional urban networks and hierarchies (Lüthi 2011). The INM is a suitable proxy for capturing these networks, at least in terms of intra-firm business activities. Furthermore, the focus on sub-sectors of the knowledge economy – e.g. legal services, advertising, chemistry & pharmacy, vehicle construction etc. – is a suitable means to increase the analytical strength of the INM and to better understand the causalities in the world city network, especially in combination with qualitative research methods. But it is also possible to group the knowledge economy by other criteria, for example in terms of analytical, synthetic and symbolic knowledge bases (Asheim et al. 2007). Here, the main question is: What are the different connectivity patterns of firms using and producing analytical, synthetic or symbolic knowledge? It even can be argued that the spatial logic of the knowledge economy can only be understood through the simultaneous consideration of business networks beyond the knowledge economy (Sassen 2010, p. 151).

(iv) *Mix of quantitative and qualitative research methods*: In recent years, the methods to analyse relational data have increased in sophistication and sensitivity. Nevertheless, the analytical instruments remain quite polarised “between the binaries of positivist, often quantitative, and more theoretically diverse, typically qualitative, approaches” (Pike 2007, p. 1143). There is clearly the necessity to combine both quantitative and qualitative approaches in studying the changing geographies of the knowledge economy. Whereas the quantitative analysis provides more easily measurable evidence across large data bases, qualitative methods elicit case study evidence on the subtle and strategic processes underlying the identified patterns of connectivity. Like most social processes, network activities are based on people’s perceptions, their strategic choices and their willingness to act. The best way to capture these subjective motivations is by using qualitative research methods as a complement to quantitative evidence.

(v) *Mix of intra-firm and extra-firm approaches*: Intra-firm networks do not tell the whole story of the nature and quality of business activities between different locations. Information exchange and business activities arise not only through internal branch office networks, but also from the division of labour between different companies. According to Gomes-Casseres (1996), the overwhelming majority of strategic networks are between competitors reflecting a new form of business relationships: a “new rivalry... in the way collaboration and competition interact” (Gomes-Casseres 1996, p. 2). Since the late 1990s, this trend has been accelerated, particularly in the electronics, automobile, finance and logistics sectors (Gereffi et al. 2005). To grasp these networks fully, it is necessary to analyse not only intra-firm connectivities but also the value chain relations between different enterprises and sectors. Even though there is still little cross-referencing between the world city network and the value chain literatures, they display a remarkable conceptual overlap and promise many methodological synergies and rich empirical findings (Derudder and Wiltox 2010).

7. References

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