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Article

Global Pharmaceutical and Biotechnology Firms' Linkages in the World City Network

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Abstract

This article concentrates on the connectivity of global pharmaceutical and biotechnology firms in the contemporary 'world city network' that constitutes a 'space of flows' in which particular urban regions achieve an outstanding nodal centrality. World city network analyses have mostly concentrated on global service providers. Yet globally operating manufacturing firms also select distinct urban regions all across the world as locational anchoring points. Thus the network structures of distinct industrial sub-sectors need to be analysed in order to detect the differing nodal centralities and 'sectoral profiles' of cities functioning as geographical hubs of transnational production networks. A macro-scale analysis is presented of how the top 40 global firms in the pharmaceutical and biotechnology industry connected cities across the world in 2010. Subsequently, the nodal centralities of cities included in this sub-sector's global network are compared with the findings of previous analyses that concentrate on the advanced producer services sector.

Introduction

We are facing a continued extension of transnational economic networks that include more and more cities both in the global North and South in the complex fabric of a 'world city network' (Taylor, 2004; Taylor *et al.*, 2010). Thus urban research should be extended beyond the analysis of a small group of outstanding 'global cities' (such as New York, London, Tokyo) and focus on the large number of 'globalising cities', whose economic development is shaped by their specific positioning within global economic network relations and capital flows. As John Friedmann (1986) has emphasised, in the contemporary era of globalisation the form and extent of a city's integration with the world economy and the functions assigned to the city in the global spatial division of labour will be decisive for its development level and internal structural changes.

In order to advance our knowledge of the contemporary world city network that

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functions as a backbone for channelling world-wide capital flows, this article presents the findings of an analysis of major pharmaceutical and biotechnology firms' global organisational networks that link cities across the world. The 'ranking' of globally connected urban centres of the pharmaceutical and biotechnology sector differs from the well-known rankings of global service centres, so the analysis might strengthen our awareness of 'multiple globalisations' in the world city network (see also Taylor, 2004; Krätke and Taylor, 2004). The article's first section discusses different approaches to the analysis of the world city network. In the second section, we present a network analysis covering the 40 top global firms of the pharmaceutical and biotechnology industry. The analysis covers aspects such as the strength of specific intercity connections, the ranking of cities according to nodal centralities, the differing functional roles of cities in terms of 'relational power' and 'relational prestige', and the urban regions' differing degree of transnational connectivity. In the third section, we compare the nodal centralities of cities included in this sectors' global production networks with the GaWC research findings concerning the finance and producer services sector. The comparison detects differing sectoral profiles of globalising cities in terms of 'multiple globalisations' in the world city network.

1. Approaches to 'World City Network' Analysis

By investigating particular cities' global functions and their impact on urban space and the city's economic and socio-spatial restructuring, Sassen (1991) detected New York, London and Tokyo as the prime centres of a global urban hierarchy. These outstanding urban centres are functioning as major command-and-control centres in a transnationally organised economy. Accordingly, 'global city' research led to new rankings of cities on a global scale (Short *et al*., 1996; Hall, 2001). Yet the case study approach of analysing selected cities' global functions could not detect the connectivity of cities on the level of a truly 'global scale' urban analysis. This kind of research has been advanced particularly by the work of Peter Taylor (2004) and the GaWC (Globalization and World Cities Study Group). The GaWC approach concentrates on the development of a global urban system which includes a vast number of cities beyond the small group of 'leading' global cities. Starting from the thesis that connectivity in the world city network is being created through the multilocal office networks of global service providers, the GaWC analysis of intercity connectivity resulted in the identification and classification of corporate service centres of the global economy.

The most recent GaWC analysis covers the office networks of 175 global service firms across 526 cities world-wide (Taylor *et al*., 2010). The selection of firms includes 75 financial sector firms and 100 producer service firms (with 25 each of the four subsectors accounting, advertising, law and management consultancy). The analysis confirms the premier position of London and New York at the top level of global service centres and the rise of cities in emerging markets. Overall, the world city network analysis highlights the geographically uneven spread of globalisation as well as the rise of new urban nodes of globally connected business activity particularly in countries of the global South.

The GaWC approach concentrates on the respective cities' functions as financial centres and centres for the provision of specialised corporate services. However, by taking into account the structural diversity of the world-wide urban system, we could empirically detect that many cities in the global North and South are linked to transnationally extended production networks (Henderson *et al.*, 2002; Dicken, 2007) and function as major locations in the global value chains of *manufacturing industries* (Derudder and Witlox, 2010; Krätke *et al.*, 2012). The concept of global value chains (Gereffi and Korzeniewicz, 1994; Sturgeon, 2000; Gereffi, 2006) interprets globalised production as a series of cross-border transactions between the different production stages of commodities as well as between different corporate establishments. The chain links are geographically distributed over a series of locations and entail cross-border flows (knowledge and capital flows) between the respective spatial nodes of activity. However, most contributions to the analysis of global value chains rely on national state territories as spatial units of reference and thus remain in the realm of 'methodological nationalism'. Although the literatures on globalising cities and on global value chains/production networks share a similar general conceptualisation of economic space in terms of the discontinuous territoriality of global network relations, they have not yet been constructively integrated (first attempts at an integration have been collected in Derudder and Witlox 2010). Yet the concepts of global value chains and global production networks offer an approach to meet the demand for a multisectoral perspective on the economic geography of 'globalising cities'. We claim that all cities included in the world city network are characterised by specific profiles of globally connected economic functions. The world city network includes global cities focusing on advanced producer services and the financial sector in particular, as well as many other cities with differing profiles of their globally connected activities. In order to confirm the 'differing profiles' thesis, the second section presents the findings of new empirical research on the cities' role in global networks of manufacturing industries, focusing on the 'high-technology' sector of the pharmaceutical and biotechnology industry.

A second approach to the analysis of the world city network, which refers to a broader range of economic sub-sectors as compared with the GaWC research, has been presented by Alderson and Beckfield (2004) and, most recently, by Wall and van der Knaap (2011). These contributions depart from the GaWC focus on advanced producer service firms and claim that the multinational firm—regardless of its particular activity branch or sub-sector—stands at the heart of network relations connecting the global urban system (see also the debate between Taylor, 2006; and Alderson and Beckfield, 2006). Consequently, Wall and van der Knaap (2011) include in their analysis the top 100 multinational corporations which stem from various industrial sectors. Wall and van der Knaap advance research on the global urban system by analysing the hierarchical differentiation of the included multinationals' organisational and geographical structure. The distinction of several hierarchy levels within the corporate structure demonstrates that a prominent position in the locational network is not only occupied by the top-level headquarter city, but also by cities that are situated at the intersection of different hierarchy levels: these cities take on a significant role in the direction of capital flows, since they are hosting subsidiaries which themselves control further subsidiaries that are located in other urban regions. In total, the analysis reveals the nodal centralities within the 'all industries sector' network and the 'producer services sector' network. Wall and van der Knaap (2011) also show that a strong correlation exists between both sectoral networks, particularly at the level of top-rank urban nodes of global connectivity.

However, the analysis presented by Wall and van der Knaap (2011) is based on a selection of global firms from both the service and manufacturing sectors, and thus does not reveal the role of particular manufacturing industries in the formation of the global urban network. The selected 'Fortune Global 100' multinationals (2005) are composed of 43 finance and service sector firms (also including a small number of global retail groups), 19 firms of the utilities sector (particularly oil and gas multinationals) and only 38 manufacturing industry firms of medium-high-technology sub-sectors such as the automotive industry and high-technology sub-sectors such as the information technology or pharmaceutical and biotechnology industries. Consequently, the results are to a large degree shaped by the major influence of the included finance and service sector firms. A strong correlation between the 'all industries sector' network and the 'producer services sector' network could thus be expected. As stated earlier, we suggest that the network structure of distinct industrial sub-sectors should be analysed in order to detect the differing nodal centralities and functional roles of cities that appear as geographical hubs of transnational production networks within the global urban system.

2. Interurban Linkages in the Global Pharmaceutical and Biotechnology Firms' Network

Through their globally extended organisational networks, manufacturing industries contribute to the formation of a world city network. This article starts from the assumption that globalising city-regions are exerting distinct functions in global value chains (such as distinct manufacturing functions located in the urban region's industrial areas, and the supply of specific producer services for the management of these global value chains). Secondly, we assume that many relevant nodes or chain links of global value chains are located in cities outside the group of top global centres of the finance and service sector. This refers particularly to the 'globalising cities' of the global South (Krätke *et al.*, 2012). According to Taylor (2004), the world city network can be characterised as an 'interlocking network' that allows relations between cities to be measured through data collected on firms. An interlocking network denotes a specific type of network (see Knoke and Kuklinski, 1982) that consists of a nodal level—the cities—and the sub-nodal level of firms. The cities are connected through actors on the sub-nodal level (the global firms' establishments). They are embedded in networks of corporate relationships that enclose transnational intrafirm transactions such as knowledge flows and capital flows.

In order to present an empirically based account of the world-wide connectivity of cities that has developed in the pharmaceutical and biotechnology industry, a network analysis was performed. The industry's 40 largest global firms were identified according to the 'Forbes 2000' listing (see Appendix), which contains in total the world's 2000 largest firms of all sectors in 2010. Subsequently, the prominent firm database 'corporate affiliations' (covering more than 1 million corporations) was utilised in order to detect the selected firms' national and international organisational network and its linkages within the global urban system. The firm database offers information on the geographical location of individual corporate establishments and on the multilevel corporate hierarchy of the firms included—such as the parent company, divisions and regional headquarters, subsidiaries, affiliates and joint ventures. The multilevel hierarchy means that, for example, a parent company located in city

A can have a division in city B, which directs a subsidiary firm in city C, etc. In this way, the pharmaceutical and biotechnology industry's 40 largest firms contain in total 1985 corporate establishments. The locations of the registered enterprise units are distributed across the world in a total of 279 cities (urban regions) in 84 different countries. The locations of included firm units were assigned to the respective urban region. The urban region of large cities and metropolises was delimited to cover a radius of 50 km around the city core. For extraordinarily extended metropolitan regions such as the cases of Tokyo, London and New York, the radius has been slightly enlarged. In many cases, the global pharmaceutical and biotechnology firms' establishments are located in the fringe area of the respective urban region, contributing to the spatial expansion of major cities' economic territory. We have also to note that in some tabular representations the city label of 'San Jose' in fact represents the whole extended urban agglomeration of the so-called Silicon Valley.

The network analysis detects the geographical destination and strength of the organisational links within the global urban system. As a result, the analysis reveals the positioning of particular cities within the respective sub-sector's global network. This extended network structure might be interpreted as an organised system of channels for capital flows between cities. With regard to the interpretation of the cities' functional roles within the global network, the analysis differentiates between 'incoming links' (the so-called 'indegree' of a city), which demonstrate an urban region's role as a destination of capital flows, and the urban region's 'outgoing links' (the so-called 'outdegree' of a city) that reveal an urban region's role as the source and control centre of capital flows. Similarly, the indegree can be interpreted as a measure of an urban region's attractive power or 'relational prestige' in terms of its platform function—for example, for the penetration of foreign markets, the utilisation of local production capacities, or the access to specific knowledge resources and innovation capabilities. The outdegree of a city can be interpreted as a measure of an urban region's control capacities or 'relational power'. The comparative ranking of outstanding network nodes in the global urban system is thus based on different measures of centrality such as the outdegree-based and the indegree-based centrality and, additionally, the urban region's 'betweenness-centrality' (which particularly indicates its role as an intersection in the channel system of world-wide capital flows). The methodological approach of a network analysis which takes into account the direction of intercity links (i.e. the distinction between outgoing and incoming links) has also been applied by Alderson and Beckfield (2004) and by Wall and van der Knaap (2011).

Before presenting results of the global urban network analysis, it should be noted that there are several limitations to this methodological approach. Except for headquarter functions of primary and secondary order, the data on corporate affiliations do not reveal specific functions of individual corporate establishments such as manufacturing and R&D. Thus the global analysis presented here does not specify manufacturing activities at distinct locations; it deals with the corporate organisational networks of a particular branch of the manufacturing sector, which include establishments with differing functions. The global urban network analysis cannot reveal actual flows of information, knowledge and capital on the nodal and sub-nodal levels—it rather detects the 'channel system' and the nodal intersections of potential flows. Moreover, some strategically important links in the pharmaceutical and biotechnology industries are based on collaborative agreements, licensing agreements, research collaborations and manufacturing insourcing and outsourcing. These important interfirm links cannot be deciphered by a network analysis based on corporate affiliations. The importance of specific functions of individual corporate establishments, the strength of interfirm links and particular innovation-related knowledge flows, which extend to the sector's well-established university-science-corporate networks, can be revealed by a regional network analysis approach (such as presented by Owen-Smith and Powell, 2004; Krätke, 2010) or by qualitative research on specific corporate production and innovation networks. Research that focuses more specifically on the flows of knowledge and capital investments in the pharmaceutical and biotechnology industries and is mostly based on qualitative methods, has been presented for example, by Cooke (2004), Gertler and Levitte (2005) and Zeller, (2010). Other contributions apply an evolutionary perspective (Orsenigo *et al.*, 2006). However, contributions based on detailed qualitative research are regularly concentrating on individual firms, a selection of specific actors or particular regions linked by knowledge and capital flows, whereas the global urban network analysis approach offers a comprehensive presentation of the organisational links and major anchoring points of the pharmaceutical and biotech industries' most important global firms. The more detailed qualitative approach is quite valuable in deepening our knowledge of specific locations' functions and related interfirm links, yet it does not offer a comprehensive picture advancing our knowledge of the global urban network's sectoral differentiation (in terms of 'multiple globalisations'), which is the main ambition of this article. Compared with detailed qualitative analyses, the global urban analysis approach is situated on a different scale level of analysis.

2.1 Urban Nodes of the Global Pharmaceutical and Biotechnology Industry: Research Findings

Those urban regions that show a particularly large number of network links can be characterised as outstanding nodes of the pharmaceutical and biotechnology industry on a global scale. This kind of ranking refers to the nodal centralities of cities included in this sub-sector's global network structure. The presentation of research findings starts with an account of the strength and direction of specific intercity connections in order to demonstrate properties of the network structure that are not sufficiently recognised in the quantitative accounts of nodal centralities.

Figure 1 demonstrates the strength of specific intercity connections (as a relevant aspect of network structure) in the global pharmaceutical and biotechnology industry for all corporate hierarchy levels. We do not present a picture of all relations here, since only the cities whose connectivity exceeds a degree of 1 are included. Yet this selection offers a 'less overloaded' graphical account, in which the major intercity links become visible. The strongest interlink has been detected between the urban regions of New York and London. This comparatively outstanding 'NY–LON' link has also been detected with regard to the finance and service sector (Taylor *et al.*, 2010) and the 'all industries sector' (Wall and van der Knaap, 2011). The crucial importance of London and New York requires additional clarifications. Neither the central city of London nor of New York hosts major manufacturing or R&D sites of the pharmaceutical industry. As stated earlier, the industry's firm establishments are predominantly located in the fringe area of these urban regions' territory, in contrast to the locational concentration of the finance and service sectors' establishments in the central-city areas. In the case of

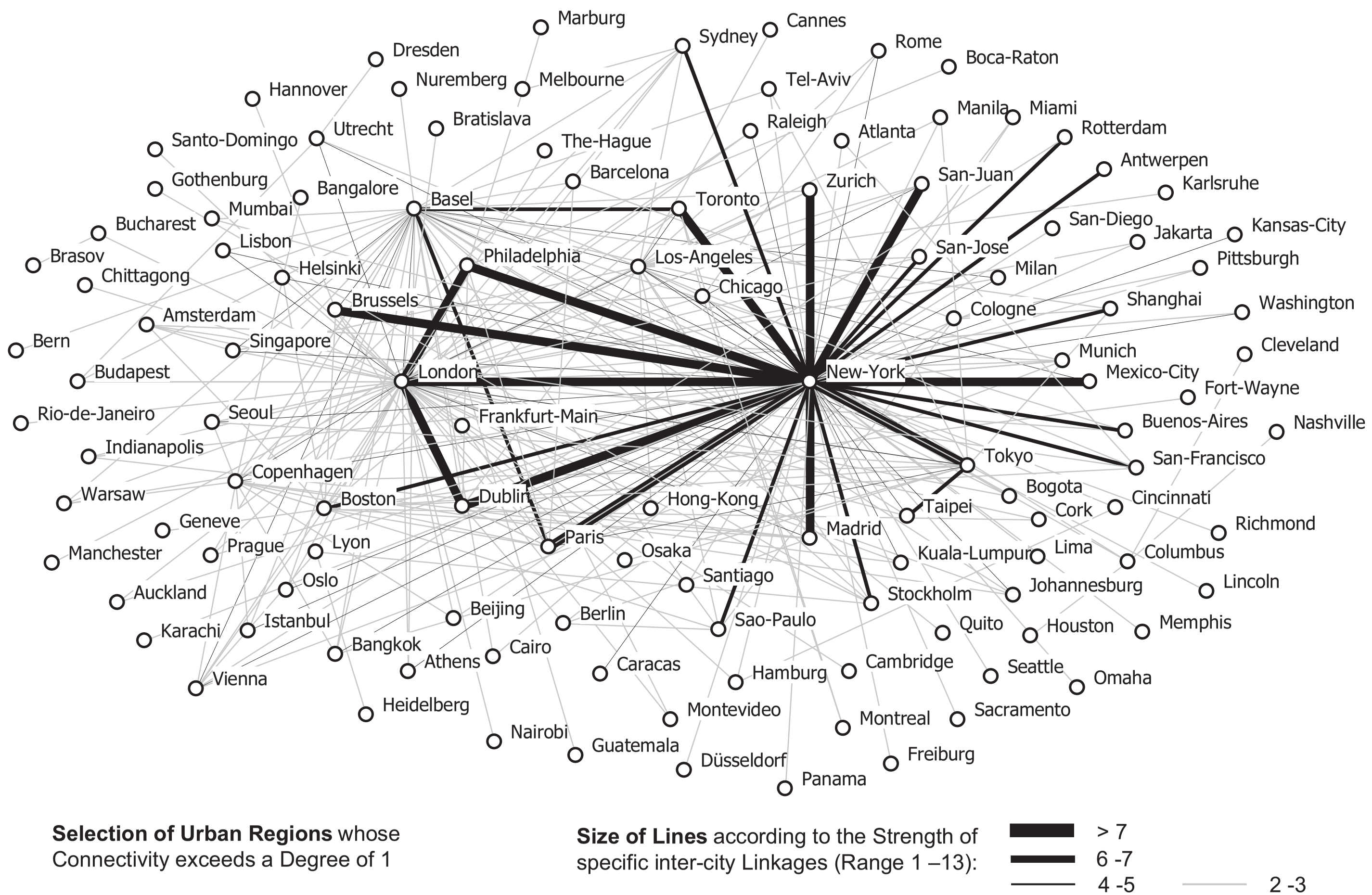

Figure 1. Strength of specific intercity connections in the Global pharmaceutical and biotechnology industry, 2010: aggregated relations on all hierarchy levels.

cities such as New York, London and Paris, our analysis deals with spatially extended 'global city-regions' (see Scott, 2001). For example, GlaxoSmithKline's R&D sites are located in Harlow, Stevenage and Ware, all about 30–50 km north of London. Other major pharmaceutical companies have located their R&D sites in similar distances from the centre of London. Many of the major pharmaceutical companies have R&D or manufacturing sites in New Jersey or in the north of New York City, also between 20–50 km from Manhattan. The same picture applies to the global city-region of Paris. By contrast, most locations in Basel, which does not posess a comparatively extended urban territory, are located in a much smaller radius around the city core. Nonetheless, an approach focusing on central-city areas would be misleading, since the manufacturing sectors' establishments that are located in the wider metropolitan area of large cities are of crucial importance to the respective cities' global connectivity.

Secondly, the network structure presented in Figure 1 contains several 'triadic' links of particular strength, such as the connection between New York, Philadelphia and London, and between New York, Dublin and London. Additionally, we find a number of comparatively strong 'dyadic' links between New York and European cities such as Brussels, Paris, Madrid, Zurich and Stockholm, as well as a strong connection between New York and Tokyo, Shanghai, Mexico City and São Paulo. In North America, New York is strongly linked to Toronto, Boston and San Jose (i.e. the 'Silicon Valley'). This representation offers an account of the outstanding channels of capital flows in the global pharmaceutical and biotechnology industry. The network structure suggests that the 'space of flows' constituted by a particular industry's global network might be conceived as a structured fabric of channels which contains some particularly intensive links and a number of major branching points (interfaces). Moreover, many of the mentioned cities with particularly strong interlinks concerning the pharmaceutical and biotechnology industry are also included in the group of 'high connectivity' global service centres—such as New York, London, Tokyo, Paris, Madrid, Brussels and Zurich (see Taylor *et al.*, 2010). This finding supports our initial thesis that the formation of a world city network should be conceived as the outcome of 'multiple globalisations', in which global firms from a variety of economic sub-sectors are contributing to the creation of transnational intercity connectivity.

However, the graphic representation of the network structure and the particularly strong intercity links at a global level does not enable a detailed interpretation of individual cities' network positions. As we will show in the next section, the strongest dyadic intercity links detected do not necessarily correspond to the nodal centrality of individual cities. Some cities in the network (such as Copenhagen, Berlin, Cologne) achieve a comparatively high degree of nodal centrality without being involved in any dyadic link of outstanding strength—i.e. these cities' strong degree of global connectivity is based on a specifically broad spread of intercity links.

Based on a simple measurement of nodal centrality that refers to the count of a city's outgoing and incoming links, the cities can be grouped according to their degree of connectivity in the realm of the pharmaceutical and biotechnology industry. The outstanding urban nodes in this sub-sector (total degree over 100) are New York, London and Basel. A second group of urban nodes with a comparatively strong global connectivity (total degree over 40) includes the European cities of Paris, Copenhagen, Zurich, Berlin and Cologne. Of the cities in Asia, Tokyo is assigned to this group. In the US, the second group contains Boston, Los Angeles, Chicago, San Francisco and Indianapolis. Again, we have to note that many of these cities with particularly strong nodal centrality are also included in the group of 'high connectivity' global service centres (see Taylor *et al.*, 2010), confirming the 'multiple globalisations' thesis (see earlier).

In order to detect different functional roles of cities that appear as geographical hubs of transnational production networks within the pharmaceutical and biotechnology industry, we proceed to a comparative 'ranking' of urban regions according to their outgoing and incoming links. Table 1 presents a detailed account of selected urban regions' 'relational power' and 'relational prestige' within the pharmaceutical and biotechnology industry's global corporate networks. This ranking of cities does not refer to specific functions of individual corporate establishments or subsidiaries, or to the respective firms' output and employment figures in a particular urban region. The ranking solely refers to the positioning of individual cities in the capital-based production network of globally operating manufacturing firms.

The tabular representation (see Table 1) is sorted according to 'outdegrees' and demonstrates the top 65 selection of a total of 279 cities included in this sub-sector's network. The table distinguishes between 'outdegrees' (outgoing links) and 'indegrees' (incoming links). The measurement of degrees takes the differing strength of individual intercity links into account—i.e. the degrees of connectivity also reflect multiple links between distinct pairs of cities. Furthermore, for each city the difference between outdegree and indegree is indicated. Urban regions with a strong 'surplus' of outdegrees (such as New York, London and Basel) are primarily functioning as command-and-control centres of capital flows in the pharmaceutical and biotechnology industry. In order to highlight the role of corporate headquarters in shaping the 'network power' of cities, the number of prime and second-order headquarters for the 40 parent companies included in the study has been indicated in Table 1 (last row). These data confirm, at least at the upper ranks of the tabular representation, a strong correlation between the strength of headquarter functions and the number of outdegrees. Yet with regard to the criterion of a 'surplus' of outdegrees, some cities such as Paris, Tokyo, Philadelphia, Dublin and Brussels dispose of headquarter functions without showing a strong surplus of outdegrees due to a comparatively large number of indegrees. A comprehensive view on the data in Table 1, however, indicates that the 'network power' of cities in terms of 'relational power' seems to be not solely based on headquarter functions, since there are many cities which are functioning as strong nodes in the global urban network (according to the sum of degrees) without possessing a particular strength of headquarter functions. As compared with an analysis primarily focusing on corporate headquarters, the network analysis approach is thus capable of detecting many more cities functioning as local hubs of transnationally extended corporate networks.

Urban regions with a strong 'surplus' of indegrees (such as Toronto, Sydney, Taipei, Stockholm, Hong Kong and Vienna) are primarily functioning as 'platform' locations for the supply of distinct market regions, the utilisation of local production capacities or the access to specific knowledge resources and innovation capabilities. We might say that these cities possess a significant 'relational prestige' in the respective industry's global networks. Of course, there are also urban regions which show a rather 'balanced' relation of outdegrees and indegrees (such as Amsterdam, Atlanta,

Table 1. Urban nodes of global networks in the pharmaceutical and biotechnology industry (based on the organisational networks of the sector's 40 largest corporations, 2010)

Number	*Urban region*	*Outdegree*	*Indegree*	*Difference Out–In*	*Betweenness*	*HQ 1st/2nda*
1	New York	410	42	368	12,965	6/1
2	London	185	57	128	8165	2/1
3	Basel	155	6	149	6062	3/0
4	Los Angeles	71	15	56	1107	3/1
5	Chicago	70	10	60	2114	1/0
6	Copenhagen	67	20	47	2717	2/0
7	Boston	48	27	21	1236	2/4
8	Indianapolis	47	2	45	1510	1/0
9	San Francisco	45	15	30	2079	2/1
10	Paris	45	42	3	1041	1/1
11	Cologne	44	2	42	557	1/0
12	Berlin	42	7	35	2174	0/1
13	Tokyo	37	42	−5	1316	3/0
14	Philadelphia	31	29	2	1359	1/0
15	Tel Aviv	28	9	19	1424	1/0
16	Zurich	26	30	−4	759	0/0
17	Lyon	25	5	20	116	0/0
18	Dublin	24	31	−7	338	2/0
19	Columbus	23	2	21	702	1/1
20	Utrecht	22	14	8	1900	0/0
21	Amsterdam	19	18	1	258	0/0
22	Brussels	18	33	−15	830	1/0
23	Miami	17	7	10	696	0/0
24	Osaka	16	8	8	592	2/0
25	Munich	14	18	−4	344	0/0
26	San Diego	13	8	5	328	1/0
27	Ljubljana	12	2	10	1149	0/0
28	Bern	12	6	6	873	0/0
29	Melbourne	12	7	5	323	1/0
30	Pittsburgh	11	4	7	480	1/1
31	Vienna	11	33	−22	528	0/0
32	Frankfurt Main	10	8	2	472	1/1
33	San Jose (Silicon Valley)	10	15	−5	874	0/0
34	Dallas	9	4	5	300	0/0
35	Fort Wayne	9	1	8	70	0/0
36	Gothenburg	9	3	6	315	0/0
37	Geneve	8	5	3	37	0/0
38	Atlanta	8	7	1	89	0/0
39	Marburg	8	5	3	90	0/0
40	Ulm	7	1	6	16	0/0
41	Gent	6	2	4	23	0/0
42	Nijmegen	6	2	4	282	0/1
43	Raleigh	4	14	−10	122	0/1
44	Sydney	4	26	−22	335	0/0
45	The Hague	4	6	−2	50	0/0

(continued)

Table 1. (Continued)

Number	*Urban region*	*Outdegree*	*Indegree*	*Difference Out–In*	*Betweenness*	*HQ 1st/2nd*[a]
46	Washington	3	9	−6	29	0/0
47	Hong Kong	3	20	−17	105	0/0
48	Stockholm	3	31	−28	211	0/0
49	Toronto	3	39	−36	437	0/0
50	New Delhi	2	7	−5	7	0/0
51	Glasgow	2	1	1	3	0/0
52	Cincinnati	2	3	−1	2	0/0
53	Leeds	2	3	−1	33	0/0
54	Hartford	2	3	−1	3	1/0
55	Saint Louis	2	4	−2	349	0/0
56	Bucharest	2	3	−1	277	0/0
57	Aachen	2	1	1	260	0/0
58	Mannheim	2	1	1	29	0/0
59	Houston	1	6	−5	9	0/0
60	Cambridge	1	8	−7	4	0/0
61	Kansas-City	1	10	−9	39	0/1
62	Rotterdam	1	11	−10	1	0/0
63	Taipei	1	27	−26	92	0/0
64	Liverpool	1	2	−1	2	0/0
65	Sacramento	1	4	−3	3	0/0

[a]HQ 1st/2nd = number of headquarters: 1st = prime headquarters of parent companies; 2nd = divisional or regional headquarters—i.e. second-rank headquarters.

Frankfurt Main, Philadelphia, Paris), so that no definite ‘primary’ functional designation can be assigned to these cases.

Outdegree and indegree represent relevant measures of centrality in the network analysis context. However, the network analysis method offers a variety of more complex measures of centrality, such as the ‘betweenness-centrality’ (Wassermann and Faust, 1994), which is also reported in the tabular representation for each city included. The measure of betweenness-centrality indicates the extent to which an urban region is positioned as an intersectional node within the connecting links of all other cities included in the network, and thus has a mediating position in the capital flows that run through the overall network structure. The highest betweenness-centrality is recorded for the urban regions of New York, London and Basel, which also corresponds to their outstanding position in terms of other (degree-based) measures of centrality. Comparatively high values of betweenness-centrality are also indicated for the urban regions of Copenhagen, Berlin, Chicago and San Francisco, which are all positioned on the upper-level ranks of outdegrees. However, the presentation of research findings will focus on the degree-based measures of centrality, which can be interpreted more easily.

The top 65 cities in Table 1 are sorted according to the number of outgoing links, which are interpreted as a measure of a city’s ‘relational power’ within world-wide capital flows. With regard to the pharmaceutical and biotechnology industry, the urban regions of New York, London and Basel take on the top ranks. In the subsequent ranks, we find the urban regions of Los Angeles, Chicago, Copenhagen, Boston, Indianapolis, San Francisco, Paris, Cologne and Berlin. Other cities with an outstanding degree of global connectivity—as measured by the total sum of outgoing and incoming links—include Tokyo, Philadelphia, Zurich and Dublin. The overall picture indicates the dominance of global firms from the US and some European countries. It is remarkable that only a small number of urban regions of the 'global South' (such as Hong Kong, New Delhi and Taipai) are included in the top 65 rank positions. Nonetheless, major cities of the 'global South' are integrated into the global production networks of the pharmaceutical and biotechnology industry. Yet these cities are primarily functioning as 'platform' locations due to a lack of outgoing links and a strong surplus of incoming links. Cities of the 'global South' with an outdegree of 0 and a comparatively strong indegree include for example Mexico City (indegree 28), São Paulo (26), Buenos Aires (24), Singapore (22), Seoul (20), Bangkok (19), Shanghai (16), Johannesburg (16) and Kuala Lumpur (16). This finding confirms the increasing integration of the socalled emerging markets in global production networks. As regards cities of the 'global North' which are primarily functioning as 'platform' locations and thus possess a strong 'relational prestige' within the pharmaceutical and biotechnology industry's global networks (measured according to a surplus of incoming links), the urban regions of Toronto, Stockholm, Vienna, Sydney and Brussels stand out.

As regards the group of 'leading' global cities which have been characterised as prime centres of the global financial industry and the advanced producer services, our top 65 ranking includes the urban regions of New York, London, Los Angeles and Chicago due to their outstanding surplus of 'relational power' within global networks of the pharmaceutical and biotechnology industry. This finding supports the thesis that prominent 'global city-regions' are particularly attractive locational anchoring points for global firms of 'high-technology' manufacturing industries such as the 'life sciences' sector. Secondly, the finding confirms the thesis that global cities are characterised by a variety of global functions in terms of a specific composition of globally connected economic sub-sectors.

The analysis of global firms' networks included the distinction of several hierarchy levels within the corporate structure (see earlier), since not only the respective firm's headquarter city occupies a prominent position in the locational network, but also cities that are situated at the intersection of different hierarchy levels. These cities are hosting subsidiaries which themselves control further subsidiaries in other urban regions, and thus take on a significant role in the direction of capital flows. A city which achieves a high rank (measured by outdegrees) on the firms' hierarchy levels 2 and 3 thus functions as a comparatively strong 'branching point' of capital flows and information flows. Table 2 presents a disaggregated picture of those cities that are positioned on the top 15 ranks of different corporate hierarchy levels. Cities such as Paris, Boston, Tel-Aviv, Philadelphia and Berlin achieve a higher rank on levels 2 and 3 as compared with hierarchy level 1, which contributes to an improved positioning at the aggregated level. Cities such as New York, London, Basel and Chicago are characterised by a comparatively strong outdegree at both the first and second hierarchy levels, which strengthens their overall position as outstanding nodes of the global pharmaceutical and biotechnology industry's network.

The cities are characterised by varying degrees of transnational connectivity. 'Truly' global connectivity would mean that an

Table 2. Comparative ranking of urban nodes' positioning at three corporate hierarchy levels (according to outdegrees in the pharmaceutical and biotechnology industry, 2010)

Rank	*Rank at hierarchy level 1*	*Rank at hierarchy level 2*	*Rank at hierarchy level 3*	*Rank at all three levels together (see Table 1)*
1	New York	New York	Berlin	New York
2	London	Basel	Los Angeles	London
3	Basel	Paris	Lyon	Basel
4	Copenhagen	Zurich	New York	Los Angeles
5	Chicago	Boston	Munich, Philadelphia, Bern	Chicago
6	Los Angeles	London	Geneve, San Francisco	Copenhagen
7	Indianapolis	Amsterdam, Chicago	Miami	Boston
8	San Francisco	Tel Aviv	Gent, Chicago	Indianapolis
9	Cologne	Cologne, Utrecht	San Jose, Boston	Paris, San Francisco
10	Tokyo	Vienna, Dublin, Philadelphia	Raleigh, Indianapolis	Cologne
11	Boston	Brussels	Cologne	Berlin
12	Osaka	Gothenburg, Marburg, Indianapolis, Atlanta, Ljubljana	Kansas City, Pittsburgh, Cambridge, Melbourne, Zagreb, Frankfurt Main	Tokyo
13	Columbus	Tokyo, Ulm		Philadelphia
14	Dublin, San Diego, Tel Aviv	Miami, Dallas		Tel Aviv
15	Paris, Frankfurt Main	Pittsburgh, Nijmegen, Fort Wayne		Zurich

urban region's relational network extends to cities in many different countries of various world regions. Table 3 presents a measure of the transnational spread of interlinks (within global networks of the pharmaceutical and biotechnology industry) for selected cities. New York, London and Basel show the largest absolute number of connected countries and directly linked cities. Yet a relative measure of the transnational spread of a city's connections can be based on the relation between the number of connected countries and directly linked cities. The maximum value is 1.00—in this case, each linked city involves a different country. Note that, due to multiple links between distinct pairs of cities, the number of directly linked cities in Table 3 neither matches the outdegree nor the sum of outdegree and indegree. Among the top ranks of cities included in Table 3, Berlin and Copenhagen show the greatest transnational spread of interlinks within global networks of the pharmaceutical and biotechnology industry, as regards the relative measure of transnational spread. By comparison, the urban regions of New York, San Francisco and London reveal a comparatively low transnational spread of interlinks.

2.2 Comparison of Outstanding Global Network Nodes of the Service Sector and the Pharmaceutical and Biotechnology Industry

Recalling the thesis that the world city network analysis can be further deepened particularly with regard to the differing sectoral profiles of globalising cities, we proceed to a

Table 3. Selected cities' transnational spread of interlinks within global networks of the pharmaceutical and biotechnology industry, 2010

No.	*Urban region*	*(A) Directly linked cities*	*(B) Connected countries*	*Relation (B)/(A)*
1	New York	139	57	0.41
2	London	108	50	0.46
3	Basel	86	56	0.65
4	Chicago	60	41	0.68
5	Copenhagen	59	48	0.81
6	Los Angeles	46	27	0.58
7	Indianapolis	44	33	0.75
8	Berlin	43	37	0.86
9	San Francisco	44	19	0.43
10	Cologne	39	26	0.66
11	Paris	50	29	0.58

comparative ranking of the outstanding network nodes of global services and the global pharmaceutical and biotechnology industry. The ranking of global service centres offered by the GaWC (Taylor *et al.*, 2010) will be compared with the ranking of globally connected centres of the selected manufacturing sub-sector presented in the foregoing section.

However, due to the differing calculation methods, we cannot directly compare both analyses' connectivity measures. In the GaWC approach, the measure of intercity connectivity sums up the products of each firm's 'service value' in a distinct city with the same firm's service value in all other cities included in the respective firm's organisational network. The 'service values' are differentiated according to an investigation of the relative importance of each firm's establishments (Taylor *et al.*, 2010). The GaWC operation of multiplying the 'service values' of firm units assigns a particularly strong weight to global firms' headquarters and regional headquarters or divisions. In the network analysis approach presented here, the global firm's establishments are classified according to their position in the corporate hierarchy and the measurement of intercity connectivity is based on counts of outgoing and incoming links. The benefit of a network analysis that includes the differing directions of intercity links is to enable a distinction between the 'functional' roles of cities in the respective sector's global network. Nonetheless, it is still possible to compare the *cities' rank positions* concerning their degree of connectivity in global services and global manufacturing. In the GaWC ranking, the individual cities' degree of connectivity is expressed as a fraction of the highest-scoring-city's connectivity (i.e. London = 1.00). The same expression of relative connectivity has been calculated for the cities' degree of connectivity in the pharmaceutical and biotechnology industry. The ranks of the cities' connectivity in manufacturing were calculated according to the sum of outdegrees and indegrees.

The comparison focuses on the difference between the cities' rank positions in global services and manufacturing activity in distinct sub-sectors. In the tabular representation of selected cities (see Table 4), the left section (cities numbered 1–25) displays cities that possess a 'surplus rank' in manufacturing in terms of a positive rank

Table 4. Comparison of cities' global connectivity rankings with regard to the service sector and the pharmaceutical and biotechnology industry

Number	*Urban region*	*GaWC rank*	*Manufact. rank*	*Rank difference*	*Number*	*Urban region*	*GaWC rank*	*Manufact. rank*	*Rank difference*
1	Basel	55	3	52	26	Stockholm	20	19	1
2	Utrecht	58	18	40	27	New York	1	1	0
3	Indianapolis	52	13	39	28	London	1	2	−1
4	Cologne	53	14	39	29	Paris	3	4	−1
5	Philadelphia	45	9	36	30	Brussels	11	12	−1
6	San Jose	54	24	30	31	Montreal	38	39	−1
7	Lyon	50	21	29	32	Tokyo	5	7	−2
8	Copenhagen	31	4	27	33	Amsterdam	15	17	−2
9	Osaka	51	25	26	34	Helsinki	29	31	−2
10	San Juan	50	24	26	…	…	…	…	…
11	Boston	33	8	25	35	Mexico City	15	22	−7
12	Columbus	48	24	24	36	Madrid	9	17	−8
13	Raleigh	55	31	24	37	São Paulo	15	23	−8
14	San Diego	47	28	19	38	Frankfurt Main	19	31	−12
15	Los Angeles	23	5	18	39	Buenos Aires	12	25	−13
16	S. Francisco	26	9	17	40	Sydney	6	21	−15
17	Pittsburgh	51	34	17	41	Prague	20	36	−16
18	Berlin	29	13	16	42	Milan	7	24	−17
19	Munich	33	20	13	43	Seoul	11	29	−18
20	Kansas City	51	38	13	44	Kuala Lumpur	12	33	−21
21	Tel Aviv	27	17	10	45	Warsaw	14	37	−23
22	Chicago	13	6	7	46	Singapore	4	27	−23
23	Vienna	21	15	6	47	Hong Kong	2	26	−24
24	Zurich	15	10	5	48	Shanghai	7	33	−26
25	Dublin	16	11	5	49	Mumbai	12	40	−28
…	…	…	…	…	50	Beijing	8	38	−30
					51	Moscow	10	42	−32

difference. These cities are characterised by strong global connectivity in the manufacturing sector (as represented here by the pharmaceutical and biotechnology industry), which considerably exceeds their rank position in the sphere of global services. This applies for example, to Basel, Utrecht, Cologne, Philadelphia, Lyon, Copenhagen and Boston. The right upper section of Table 4 (cities 26–34) presents cities with a relatively balanced relation of global connectivity in both the service *and* manufacturing sectors. Global cities such as New York, London, Paris, Brussels, Tokyo and Amsterdam are functioning to nearly the same extent as globally connected centres of manufacturing firms in the pharmaceuticals and biotechnology sub-sector than as global service centres. The right lower section of Table 4 (cities 35–51) contains cities with a negative rank difference, which means that these cities possess a 'surplus rank' in the finance and service sector. Here, we find well-known examples of global cities such as Madrid, Frankfurt Main, Sydney and Milan as well as a number of global(ising) cities such as in particular Seoul, Kuala Lumpur, Singapore, Hong Kong, Shanghai, Mumbai and Beijing in the world region of Asia, and Mexico City, São Paulo and

Buenos Aires in the world region of Latin America. Cities that appear in this section of Table 4 are characterised by strong global connectivity in service sector activities, which exceeds the degree of global connectivity they have achieved in the sphere of manufacturing (as represented by the pharmaceuticals and biotechnology sub-sector). However, the definite point of delimitation between the three city groupings mentioned before is in some way open to adjustment.

The results of the comparative ranking of course reflect the sector-specific locational strategies of included economic sub-sectors. Global firms of the high-technology manufacturing sub-sectors—as represented here by the pharmaceutical and biotechnology industry—show a comparatively strong presence in prominent global city-regions such as New York, London and Paris (see earlier). The pharmaceutical and biotechnology industry is a particularly 'knowledge-intensive' industrial sub-sector, for which access to specific knowledge resources and innovative capacities is crucial (Zeller, 2003, 2010). However, we can expect differing results if the rank comparison referred to the positioning of cities in the global networks of other manufacturing sub-sectors such as the automotive industry. Nonetheless, the inclusion of just one distinct sub-sector of manufacturing industries in the world city network analysis already confirms the thesis that globalising cities are characterised by differing sectoral profiles of global functions and activities.

3. Conclusion and Outlook

This article started from a relational perspective on economic geography that characterises the geography of the world economy as a globally extended network of cities and metropolitan regions. According to Taylor (2004), urban development might be regarded as a process of networking that is unfolding on different but intertwined spatial scales. Transnationally operating firms from different sectors are most important actors in the formation of these multiple relational networks. Our analysis confirms the thesis that globally operating manufacturing firms are connecting cities across the world and thus contribute to the emergence of 'multiple globalisations' in the world city network. The 'ranking' of globally connected urban centres of the manufacturing sector—as represented here by the pharmaceutical and biotechnology industry—differs considerably from the well-known rankings of global service centres.

Based on the example of the pharmaceutical and biotechnology industries, our analysis detected different sectoral profiles and functional roles of globalising cities all across the world. Thus there are possibly different pathways or sectoral trajectories of cities in globalisation, a perspective which might have significant implications for urban economic development strategies. This concerns the question of how a city's development potential might be enhanced by the integration of global firms in urban innovation networks, and the question of how urban government might be able to actively influence the upgrading of a city's role in global economic networks. A large number of cities are striving to take on global city functions in order to strengthen their reputation and position in a world-wide interurban competition. Very often, urban governance in the globalisation arena is geared towards restructuring the city's spatial fabric and built environment according to the presumed 'needs' of global finance and service firms, with the consequence of fostering socio-spatial polarisation. Yet there exist *different pathways* for cities in globalisation. A city's integration in the globalisation process might as well be taken as a resource for upgrading its industrial structure and employment standards in favour of the city's ordinary population.

In theoretical terms, the analysis aimed at an extension of the conceptual framework of the world city network analysis. It engaged critically with the literature on global urban networks and posed new research avenues, particularly with regard to the role of global production networks and global value chains in shaping the sectoral profiles and functional roles of cities in globalisation. There is tremendous scope to blend the insights of the global value chains literature with the notion of urban networks and 'network power'. On the one hand, this blending could add to the global value chains analysis a proper conceptualisation of the spatial or locational dimension of value chains; on the other hand, it could advance the conceptualisation of global urban networks by including the role of manufacturing industries and detecting the intersections of different value chains in the globalising cities of today. The inclusion of many cities in global production networks and value chains of the manufacturing sector also highlights the *variable* positioning of cities in a globalising economy. This concerns the question of how the rather 'peripheral' cities—i.e. cities showing a comparatively weak connectivity to the established prime centres of globalised economic activities—could improve their position and functional role in global value chains and production networks, drawing on upgrading strategies largely discussed in the global value chain literature. With regard to the spatial fabric of globalising cities, global firms' activities contribute to the formation of transnational urban spaces. This challenging field of urban research can draw on the global-scale analysis of connectivity, functions and specialisations in the world city network, and extend the analysis to the regional- and local-level impacts of global networks on the urban space of distinct cities, particularly including cities beyond the group of outstanding global service centres.

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Appendix: Listing of included Firms (Pharmaceutical and Biotechnology Industry)

Bayer, Pfizer, Sanofi-Aventis, Roche, Novartis, AstraZeneca, Eli Lilly, Johnson and Johnson, GlaxoSmithKline, Merck and Co, Abbott laboratories, Amgen, Bristol-Myers Squibb, Teva Pharmaceutical Industries, Takeda Pharmaceutical Company, McKesson Corporation, Cardinal Health, Novo Nordisk, Astellas Pharma, Merck KgaA, Gilead Sciences, Eisai Corporation, Biogen Idec, UCB S.A., Genzyme Corporation, Allergan, Daiichi Sankyo Co., CSL Limited, Celgene Corporation, Forest laboratories, Mylan, Shire, Warner Chilcott, Life Technologies Corporation, Cephalon, Actelion, Novozymes, Ono Pharmaceutical Co., Alexion Pharmaceuticals, Watson Pharmaceuticals.