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Polycentric development in China's mega-city regions, 2001-08: A comparison of the Yangtze and Pearl River Deltas

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Abstract

Large-scale urbanized regions are increasingly functioning as the territorial backbone of the global economy. Many of these so-called 'mega-city regions' are 'polycentric' in that they consist of a range of important, densely interwoven cities and towns. The purpose of this paper is to analyse the changing levels of polycentricity in the urban networks, underlying what are arguably China's two most important mega-city regions: the Yangtze River Delta (YRD) and the Pearl River Delta (PRD). To this end, we use an analytical framework focusing on the shifting hierarchies and geographies of the linkages between corporations' headquarters and their branches. In the process, this research seeks to extend and refine the analytical tools that are often deployed to measure polycentricity in mega-city regions. Our results suggest that in the period 2001-2008, both the YRD and the PRD are characterized by an increasing number of linkages. The two mega-city regions also share a pattern of the general level of polycentricity increasing, even though the concentration of headquarters is equally rising, which implies that rising levels of polycentricity are, above all, emanating from higher levels of network density. There are, however, also fundamental differences between the YRD and the PRD: firms in the PRD are more likely to set up branches beyond prefecture boundaries, while there is a relatively 'flatter' intercity network in the YRD compared to the PRD – in the latter case, firms are increasingly connecting the four major cities (Guangzhou, Shenzhen, Dongguan and Foshan) rather than providing linkages with smaller and medium-sized cities.

Zusammenfassung

Großräumig urbanisierte Regionen fungieren zunehmend als territoriale Rückgrate der globalen Ökonomie. Viele dieser sogenannten *mega-city regions* sind polyzentrisch und bestehen aus einer Reihe von wichtigen, intensiv miteinander vernetzten Städten. Ziel des Beitrags ist es, die sich verändernden Ausmaße der Polyzentralität der urbanen Netzwerke in den beiden mutmaßlich bedeutsamsten *mega-city regions* Chinas, dem Yangtse-Delta (YRD) und dem Perlflussdelta (PRD) zu untersuchen. Dafür nutzen wir einen Analyserahmen, der die sich wandelnden Hierarchien und Geographien der Verknüpfungen zwischen Unternehmenshauptsitzen und ihren Filialen in den Blick nimmt. Dabei versuchen wir auch die üblichen für das Messen von Polyzentralität in *mega-city regions* verwendeten Analyseinstrumente zu erweitern und weiterzuentwickeln. Die Ergebnisse zeigen, dass die Zahl der Verknüpfungen im Zeitraum 2001-2008 in beiden Deltas zunahm. Darüber hinaus ist in beiden *mega-city regions* die Polyzentralität generell angestiegen, obwohl die Konzentration von Unternehmenszentralen ebenfalls zugenommen

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hat, was impliziert, dass zunehmende Ausmaße an Polyzentralität vor allem auf höhere Netzwerkdichten zurückzuführen sind. Gleichwohl gibt es fundamentale Unterschiede zwischen dem YRD und dem PRD: Unternehmen im PRD richten häufiger Filialen in anderen administrativen Einheiten der Region ein, während im YRD ein „lockerer" verbundenes Städtenetzwerk als im PRD besteht; im letztgenannten Fall verbinden Unternehmen zunehmend die vier größten Städte (Guangzhou, Shenzhen, Dongguan und Foshan) eher miteinander, als dass sie Verknüpfungen mit kleinen und mittelgroßen Städten suchen.

1. Introduction

In recent years, urban geographers have come to emphasize that global economic integration co-produces an extensive archipelago of large-scale urbanized regions (e.g., *Sassen* 2001; *Parnreiter* 2009; *Borsdorf* and *Coy* 2009; *Reades* and *Smith* 2014). *Allen Scott* (2001), for instance, coined the term 'global city regions' to indicate that large-scale urbanized regions are increasingly functioning as the spatial backbone of the global economy. A plethora of related concepts has been advanced in this literature, with 'polycentric mega-city regions' (see *Hall* and *Pain* 2006) as one of the favoured terms. In its most general guise, the term 'polycentric megacity-region' (PMCR) points to the presence of regional clusters of more or less important cities and towns. The different levels of economic strength and diverse patterns of specialization across these urban centres are often enabled through efficient cross-regional infrastructures, extensive corporate networks, and the knowledge exchanges they facilitate (*De Goei* et al. 2010). In a study of European PMCRs, Hall and Pain (2006: 3) formally defined them as

> *"a series of anything between 10 and 50 cities and towns, physically separate but functionally networked, clustered around one or more larger central cities, and drawing enormous economic strength from a new functional division of labour. These places exist both as separate entities, in which most residents work locally and most workers are local residents, and as parts of a wider functional urban region (FUR) connected by dense flows of people and information carried along motorways, high-speed rail lines and telecommunications cables."*

Following earlier research by *Mogridge* and *Parr* (1997) and the publication of *Hall* and *Pain* (2006), a range of empirical studies has corroborated the emergence of polycentric mega-city regions (*Green* 2007; *Limtanakool* et al. 2007; *Taylor* et al. 2008; *Borsdorf* and *Coy* 2009; *Ross* and *Florida* 2009; *De Goei* et al. 2010; *Münter* 2011; *Reades* and *Smith* 2014). This analytical framework has in recent years also been applied to explore China's major urbanized regions (*Tang* and *Zhao* 2010; *Luo* et al. 2011; *Xiong* et al. 2013; *Zhao* and *Duo*. 2013; *Tang* and *Li* 2014; *Feng* et al. 2014; *Yuan* et al. 2014; *Yeh* et al. 2015; *Qi* and *Wang* 2016; *Zhao* et al. 2016; *Zhao* et al. 2017). This rising interest is in turn fuelled by a range of emerging Chinese urban policies that explicitly recognize the relevance of understanding cities as part of larger regional structures. For example, in the recent planning document 'New Path of Urbanization (2014-2020)' (*Central Committee of the Communist Party of China and State Council* 2014), the central government envisions the existence and the relevance of PMCR-like structures, as large-scale urbanized regions are recognized as being functional wholes consisting of densely connected cities.

Although there is now extensive literature on PMCR-like structures in China, a detailed appraisal of their *evolution* has been lacking. Existing studies have enhanced our understanding of the polycentric nature of China's mega-city regions, but it can be noted that all of these are cross-sectional (e.g., *Zhang* and *Kloosterman* 2016; *Zhao* et al. 2015; *Yeh* et al. 2015), which implies that relatively little is known about how polycentricity in these regions changes over time. Against this backdrop, the purpose of this paper is to analyse polycentric *developments* in China's mega-city regions. To this end, we analyse and compare the evolution of the degree and nature of polycentricity in what are arguably the two archetypical PMCRs in China (cf. *Hall* 1999): the Yangtze River Delta (YRD) and the Pearl River Delta (PRD).

The remainder of this paper is organized in two main sections. First, we review the literature on polycentricity in mega-city regions with the specific purpose of elaborating our own analytical framework. Second, we review and discuss our results. The paper is concluded with a short overview of our major findings.

2. Polycentricity in mega-city regions

2.1 Background

The alleged presence of 'polycentricity' is one of the main features of PMCRs. In general terms, the term 'polycentricity' refers to the regional presence of a group of important cities that are more or less physically separate but often functionally interdependent. Recent research stresses this element of functional interdependence in its measurement schemes. That is, from this perspective, polycentricity does not simply imply that there is a dense, urbanized region with multiple cities of varying sizes in close proximity to each other (see *Meijers* 2008; *Meijers* and *Burger* 2010; *van Oort* et al. 2010). Rather, it highlights there being strong functional linkages between those different cities as well. As a result, empirical research on polycentricity often focuses on there being *myriad strong functional linkages connecting different cities in a megacity-region* (cf. *Liu* et al. 2016; for extensions that take gravitational effects in interactions into account, see *van Oort* et al. 2010).

There are different types of data to assess the strength of functional linkages between a region's cities, ranging from data on infrastructure networks (e.g., *Liu* et al. 2016) to buyer-supplier relations (*Hanssens* et al. 2013) and corporate networks (e.g., *Zhao* et al. 2015). The urban networks underlying a PCMR are therefore multiplex (*Burger* et al. 2014). In the case of corporate networks, the urban networks in a region are often approximated through the lens of the functional and geographical ties between a firms' headquarters and their subsidiaries (cf. *Alderson* and *Beckfield* 2004; *Rozenblat* et al. 2016). In this approach, the urban network specification of a mega-city region results in an asymmetric (from headquarters city to subsidiary city) and valued (number of ownership linkages) inter-city matrix. The linkages in this matrix can then be used to assess the presence of polycentric structures through a series of complementary measures.

2.2 Study area

Although the literature on PMCRs initially focused on Europe (e.g., *Hall* and *Pain* 2006) and North America (e.g., *Ross* and *Florida* 2009), the topic has caught on in the Chinese academic literature (e.g., *Tang* and *Zhao* 2010; *Zhao* and *Duo* 2013). However, comparative studies of the evolution of the functional linkages interconnecting Chinese PMCRs have been deficient in practice. Here, we analyse the shifting level of polycentricity in the urban networks underlying the YRD and the PRD regions in the period 2001-2008, a period of increased global connectivity for China in general and its megacity regions in particular (*Derudder* et al. 2010; *Timberlake* et al. 2014; *Zhao* et al. 2015). Although the YRD and the PRD have major urban centres such as Shanghai and Nanjing (YRD) and Guangzhou and Shenzhen (PRD), they are both large-scale urbanized regions with a sizable number of major cities in relative proximity (*Fig. 1* and *Table 1*). In this paper, we assess to what degree this functional integration has resulted in both regions' cities becoming more/less networked in general, and the evolution of the relative balance in cities' connectivity profiles in particular.

Fig. 1 Location of the YRD and PRD. Source: own elaboration

The YRD and the PRD have long been recognized as China's top-tier mega-city regions (cf. *Hall* 1999). Although Beijing–Tianjin–Heibei (BTH) has equally been designated by the central government of China as a major urban region in its 'New path of urbanization for China (2014-2020)', this region is very much dominated by Beijing, making comparisons difficult. *Table 1* gives an overview of some major characteristics of the YRD and the PRD, including some key data on the prefecture-level cities, which will be the basic units in our analysis. The YRD and PRD consist of 16 and 9 administrative 'prefecture-level regions', respectively. Irrespective of this implication of at least 16/9 'major' cities, the YRD and PRD as a whole are much more complex urbanized regions with population dynamics and massive land-use transformation in the intermediate zones surrounding and in between the major metropolitan centres.

Table 1 Basic features of city regions in the YRD and PRD in 2008.
Source of data: Statistical yearbooks of Shanghai, Jiangsu, Zhejiang and Guangdong in 2009

City region	Cities	Area (km^2)	GDP (Billion Yuan)	Population (Million)	FAI (Billion Yuan)		FDI (Billion US Dollars)	Import and export (Billion US Dollars)
					All	State owned		
YRD	Shanghai	6341	1369.8	18.88	482.95	229.6	10.08	322.14
	Nanjing	6582	377.5	7.59	215.42	48.6	2.37	40.59
	Wuxi	4788	442	6.11	187.7	34.9	3.17	56.03
	Changzhou	4385	220.2	4.41	144.82	21.8	2.04	17.63
	Suzhou	8488	670.1	9.13	261.12	33.6	8.13	228.53
	Nantong	8001	251	7.15	150.54	12	2.94	16.69
	Yangzhou	6634	157.3	4.47	95.00	12.7	1.51	6.18
	Zhenjiang	3847	140.8	3.04	71.85	12.3	1.20	7.46
	Taizhou_JS	9411	196.5	5.74	75.96	16.0	0.24	13.81
	Hangzhou	16596	478.1	7.97	198.05	73.4	3.31	48.07
	Ningbo	9816	396.4	7.07	172.82	48.8	2.54	67.84
	Jiaxing	3915	181.5	4.23	100.68	19.7	1.36	19.83
	Huzhou	5818	103.5	2.82	52.52	7.7	0.8	5.59
	Shaoxing	8256	222.3	4.64	91.33	9.9	0.77	23.83
	Zhoushan	1440	49	1.05	33.94	16.9	0.16	6.05
	Taizhou_ZJ	5797	139.4	4.64	90.05	10.9	1.05	6.34
PRD	Guangzhou	7434	821.6	10.18	210.15	79.7	3.62	81.97
	Shenzhen	1953	780.7	8.77	146.43	49.0	4.03	299.96
	Zhuhai	1688	99.2	1.48	37.23	12.6	1.14	46.84
	Foshan	3848	433.3	5.95	123.06	11.6	1.81	42.21
	Jiangmen	9541	128.1	4.14	37.82	4.4	0.92	13.16
	Zhaoqing	14856	71.6	3.8	32.63	5.4	0.86	3.81
	Huizhou	11158	129	3.93	58.87	16.5	1.35	29.75
	Dongguan	2465	370.3	6.95	94.31	9.6	2.45	113.3
	Zhongshan	1800	140.9	2.51	44.5	6.0	0.75	25.91

Note: FAI=fixed assets investments, FDI=foreign direct investment.

Although this a priori delineation of spatial units has all the bearings of the 'modifiable area (l) unit problem', there are in our view a number of reasons to assume that, in the YRD/PRD context, this delineation produces a reasonable territorial framework for capturing polycentric developments. The most important reason is that, in the Chinese context, administrative boundaries often reflect concrete planning realities and thus represent the most reasonable proxy for assessing spatial patterns. For example, prefecture-level cities often geographically circumscribe competition in the space-economy given that local governments in China increasingly compete with each other to attract firms and especially their headquarters (*Fan* et al. 2007; *Li* et al. 2008; *Pan* and *Xia* 2014).

2.3 Measuring functional polycentricity in corporate networks

The starting point of our measurement scheme is the specification of inter-city relations T_{ij}, represented by the number of branches in city *j* of enterprises with headquarters in city *i*. A city's total centrality C_i in the urban network can be calculated by simply aggregating all these links for a given city *i*. This measure C_i is often disaggregated into its two constituent components: outdegree centrality (O_i) and indegree centrality (I_i). In formal mathematical terms, this can be expressed as follows:

$$O_i = \sum_j T_{ij} \quad (1)$$

$$I_i = \sum_i T_{ji} \quad (2)$$

$$C_i = O_i + I_i \quad (3)$$

Outdegree centrality thus focuses on the number of ties 'departing from' the headquarters in a city, indegree centrality on the number of ties 'arriving in' the subsidiaries in a city. It is quite common for headquarters and their branches to be located in the same city. Thus, we introduce e_i as a measure of the 'self-containment' of a city, i.e., the number of ties between headquarters and branches in the same city *i*. Then the measure of self-containment can be standardized as follows:

$$SC_i = \frac{e_i}{(O_i + I_i + e_i)} \quad (4)$$

The higher the level of self-containment SC_i, the lower the level of a city's interaction beyond its prefecture-level borders. Decreasing levels of self-containment can be interpreted as a possible sign of rising levels of polycentricity.

Following *Hall* and *Pain* (2006) and *Green* (2007), the formal level of polycentricity *P* in the networks of headquarter-subsidiary links can be expressed as:

$$P_O = 1 - \frac{\sigma_O}{\sigma_{max}} \quad (5a)$$

$$P_I = 1 - \frac{\sigma_I}{\sigma_{max}} \quad (5b)$$

with σ_O and σ_I the standard deviations of the distribution of cities' outdegree and indegree centralities, respectively, and σ_{max} the standard deviation of centrality in a two-node network where one node has zero connectivity and the other node has the maximum possible value. The total level of polycentricity is given by:

$$P = \frac{1}{2}(P_O + P_I) \quad (6)$$

P ranges from 0 to 1, with 0 reflecting the case where one city totally dominates the network (= no polycentricity) and 1 reflecting the case where all cities are equally well-connected (= 'perfect' polycentricity). This straightforward measure of polycentricity will be amended by taking into account two further topological dimensions, i.e., the level of interaction in the urban network and the network efficiency.

Following *Green* (2007), the level of interaction Δ in the network beyond intra-city interactions can be measured as:

$$\Delta = \frac{\sum_i \sum_j T_{ij}}{\sum_i (\sum_j T_{ij} + e_i)} \qquad for\ all\ i \neq j \quad (7)$$

With Δ ranging from 0 to 1, in which larger values denote more interaction across the region.

The reason for including a network efficiency measure is that, in contrast to *Hall* and *Pain* (2006) and *Green* (2007), who used data on often-dense commuting flows, this study uses sparser data where many city-dyads are unconnected. This may complicate things, as two networks that are topologically very different may have similar values of density and polycentricity. *Figure 2* shows the extreme case of two networks with six nodes and six edges having the same density Δ and polycentricity *P* but that are nonetheless topologically very different: all the nodes in the left pane are connected in a circle, and each node can be linked with other nodes directly or indirectly; in the right pane, however, the six nodes consist of two unconnected triangles. To account for the effect of the topological structures of sparse networks, we draw on *Latora* and *Marchiori* (2001, 2003), who introduced a global network efficiency parameter η:

$$\eta = \frac{1}{n(n-1)/2} \sum_i \sum_j d_{ij}^{-1} \quad (8)$$

with d_{ij} the paths between nodes *i* and *j* (with $d_{ij} = \infty$ if there is no suitable path between two nodes so that $d_{ij}^{-1} = 0$) and *n* the number of nodes. This global network efficiency η ranges from 0 to 1, with larger values pointing to a more connected network. In the case of

Figure 2, it can be seen that in spite of similar levels of density and standard deviations, the network in the left pane is identified as being more efficient (and therefore 'connected'), as there are more options to interconnect different pairs of nodes.

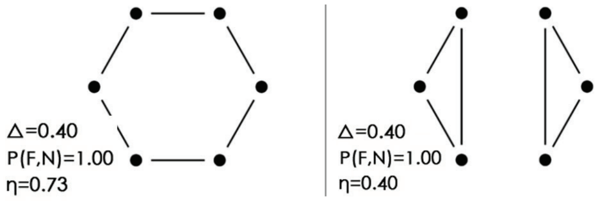

Fig. 2 Difference in network efficiency for two ideal-typical extremes. Source: own elaboration

We incorporate both measures of interaction and network efficiency by adding them to *Green's* framework (2007) so that our extended measures of polycentricity in mega-city regions P' are calculated as follows:

$$P'_O = (1 - \frac{\sigma_O}{\sigma_{max}}) \cdot \Delta \cdot \eta \qquad (9a)$$

$$P'_I = (1 - \frac{\sigma_I}{\sigma_{max}}) \cdot \Delta \cdot \eta \qquad (9b)$$

The interpretation of this measure remains the same but incorporates the 'connectedness' of the network at large. The general level of polycentricity can then be calculated by averaging the polycentricity for outdegree and indegree centralities:

$$P'_C = \frac{1}{2}(P'_O + P'_I) \qquad (10)$$

To mobilize this methodology, we use data on corporations drawn from the enterprise lists published by Ebuy Information Ltd. (http://www.ebuywww.net.cn/) in 2001 and 2008 (see *Zhao* et al. 2017). By locating the headquarters and branches of the enterprises contained in this list, connections T_{ij} between prefecture-levels cities were established. This resulted in 4352 and 28,881 pairs of headquarters–branch links across the PRD in 2001 and 2008, respectively, and 33,180 and 100,399 pairs of links across the YRD in 2001 and 2008, respectively.

3. Results

3.1 Description of centrality patterns

The first major finding is that during the study period (2001-2008), the corporate networks in both mega-city regions have produced strongly connected networks: the total number of ownership links increased substantially (see *Fig. 3* and *4*). *Table 2* lists the level of outdegree centrality, indegree centrality and total degree centrality for all the nodes in both mega-city regions. In both the YRD and the PRD, all cities increased their overall levels of total centrality in the period 2001-08. Shanghai, Suzhou, Hangzhou, Nanjing and Suzhou in particular gained centrality in the YRD. In the PRD, Guangzhou and Shenzhen continue having the largest total degree, followed by Zhuhai, Zhongshan, Foshan and Dongguan.

In the YRD, Shanghai's outdegree centrality stands out; it reflects the large number of headquarters located in that city. Its status in this regard has been strengthened over the years, and this can be traced back to a combination of new firms headquartered in Shanghai with multiple presences across the YRD and the further branching out of firms already headquartered in Shanghai. Shanghai has, above all, strong connections with the other major cities in the YRD, especially Hangzhou and Nanjing. For example, in 2008, Shanghai–Hangzhou was the strongest dyad, with 1607 ownership connections between cities. In 2008, the indegree centrality of all cities, except Shanghai, was larger than that of their outdegree, with Nanjing having the largest number of branch locations in 2008. It is thus clear that Shanghai continues to be the focus for the overwhelming majority of city-dyads throughout the region. Perhaps the single-most important change has taken place in Suzhou: while the difference in centrality between Suzhou and the other poorly connected cities was relatively small in 2001, by 2008, it had 1504 connections with Shanghai alone, making it second in terms of connectivity.

In the PRD, the distribution of enterprises' headquarters *and* branches is concentrated in its two major cities (Guangzhou and Shenzhen). This has remained the case over the study period: the number of city-dyads from both cities increased significantly (to more than 3800 connections), with especially stronger city-dyads with Dongguan and Foshan. Hence, dense connections mainly exist in the four core cities in the PRD. Only the outdegree centrality of Shenzhen, Zhuhai and Dongguan was higher than their indegree centrality in 2008.

This points to a somewhat less centralized pattern than that in the YRD. The Guangzhou-Shenzhen city-dyad was the strongest city-dyad with 2073 ownership connections, followed by Shenzhen-Dongguan with 705 ownership connections.

Table 2 Outdegree, indegree and total degree centrality in the YRD and the PRD in 2001 and 2008. Source of data: Ebuy Information Ltd.

City region	Cities	2001			2008		
		Outdegree	Indegree	Total degree	Outdegree	Indegree	Total degree
YRD	Shanghai	1115	474	1589	7142	1381	8523
	Nanjing	202	306	508	1129	2174	3303
	Wuxi	88	159	247	635	1029	1664
	Changzhou	50	58	108	377	411	788
	Suzhou	127	320	447	679	1916	2595
	Nantong	68	84	152	430	556	986
	Yangzhou	44	31	75	254	297	551
	Zhenjiang	25	28	53	128	275	403
	Taizhou-JS	15	40	55	89	314	403
	Hangzhou	199	363	562	1428	2162	3590
	Ningbo	180	151	331	983	1225	2208
	Jiaxing	24	50	74	110	563	673
	Huzhou	21	21	42	99	245	344
	Shaoxing	16	41	57	145	361	506
	Zhoushan	23	23	46	80	173	253
	Taizhou-ZJ	16	64	80	114	740	854
PRD	Guangzhou	183	263	446	1558	2403	3961
	Shenzhen	230	119	349	2883	949	3832
	Zhuhai	58	46	104	434	282	716
	Foshan	23	59	82	359	662	1021
	Jiangmen	15	17	32	92	146	238
	Zhaoqing	5	5	10	42	90	132
	Huizhou	25	31	56	164	317	481
	Dongguan	50	25	75	459	939	1398
	Zhongshan	30	54	84	250	453	703

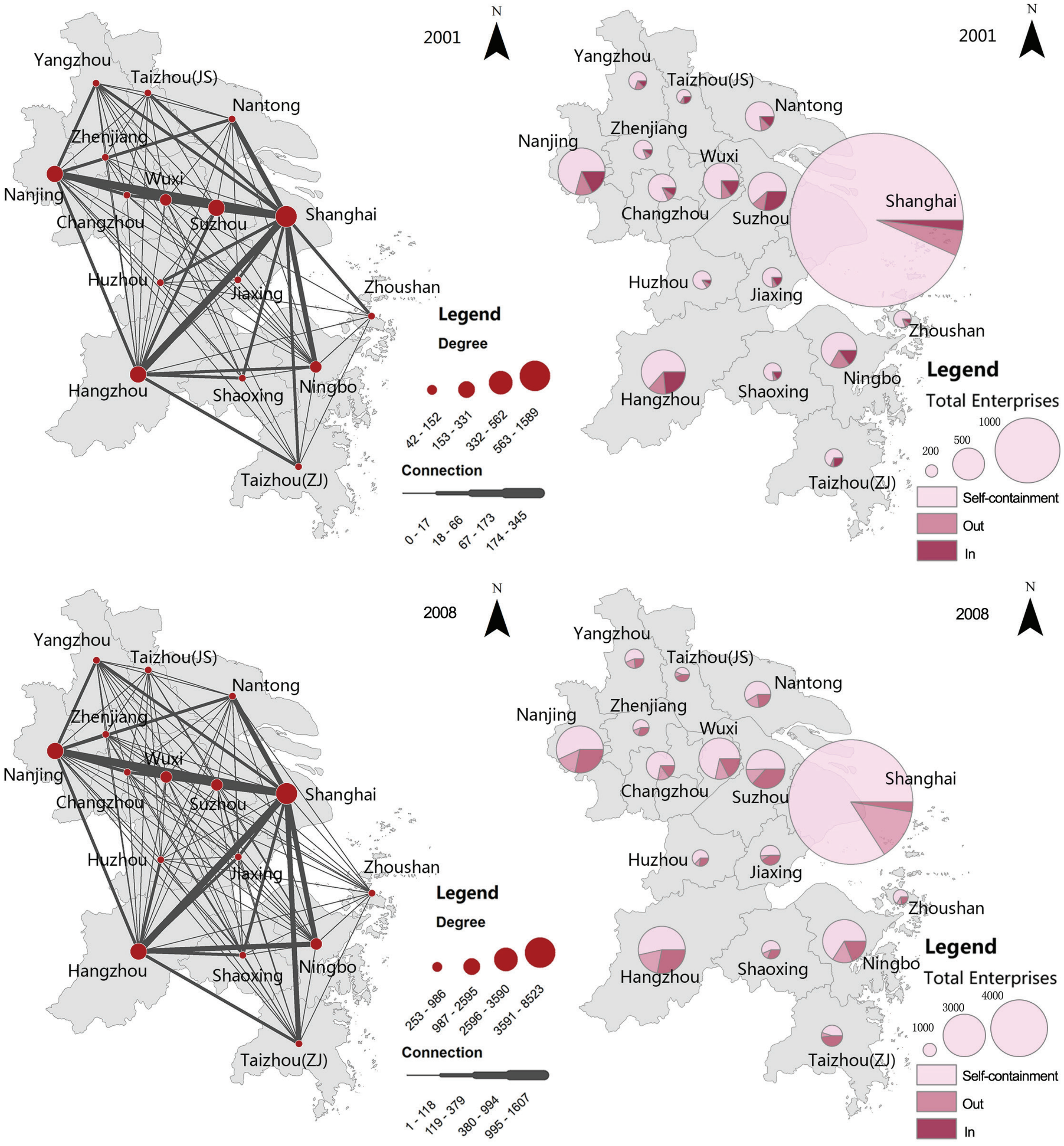

Fig. 3 Urban networks in the YRD in 2001 and 2008. Source: own elaboration

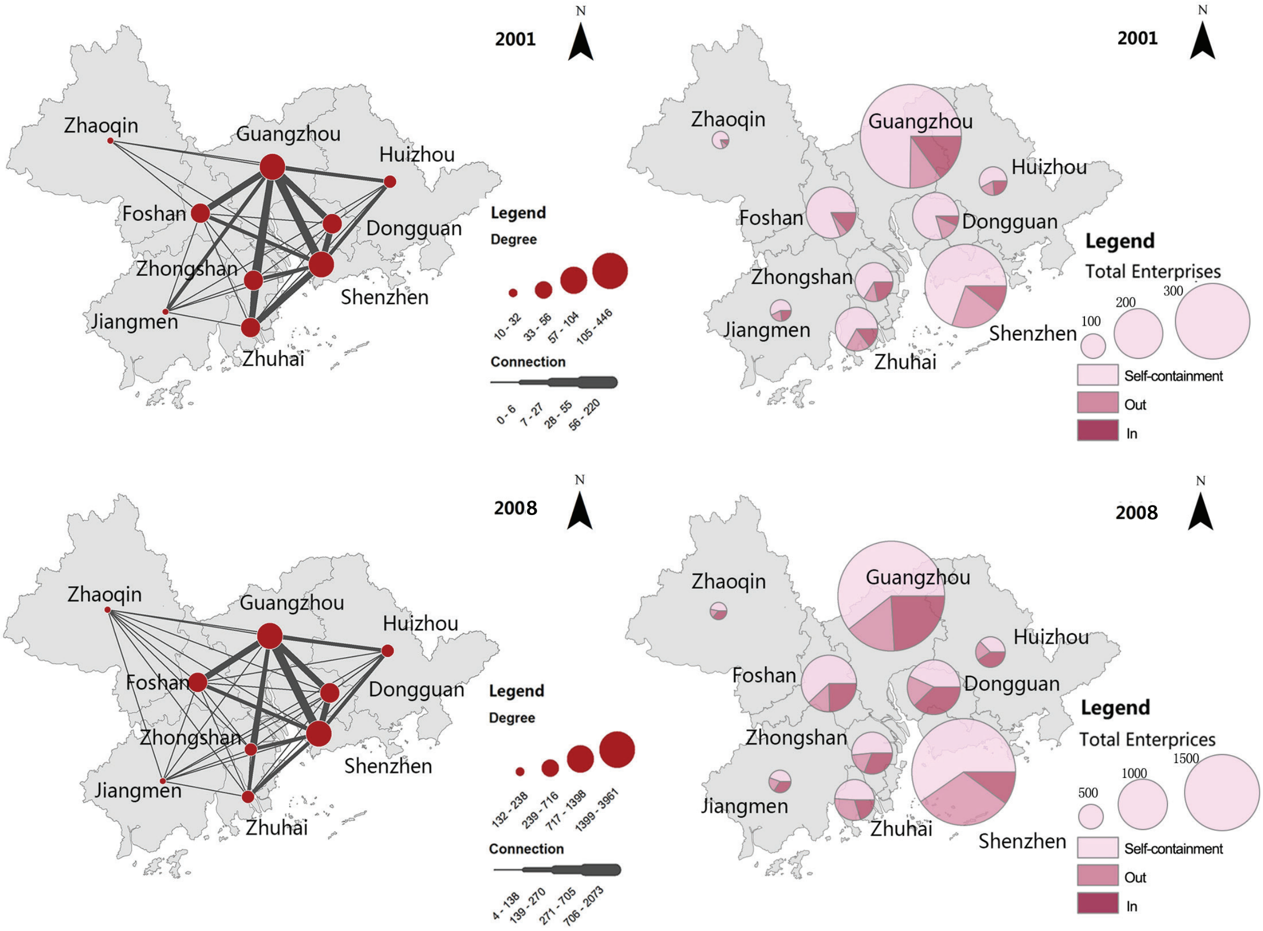

Fig. 4 Urban networks in the PRD in 2001 and 2008. Source: own elaboration

3.2 Description of polycentricity in centrality patterns

Table 3 shows the results of the polycentricity analysis for both regions. Before controlling for interaction and density, the PRD's level of polycentricity seems less marked than that in the YRD. The distribution of headquarter-subsidiary connections has a more imbalanced geography, and this gap has been widening over time. Unsurprisingly, the polycentricity of indegree P_I is more manifest than that of P_O, as headquarters tend to be clustered in a few cities. At the same time, a straightforward comparison of *Figures 2* and *3* suggests that the PRD is more connected overall, which is corroborated by larger values for network density and efficiency (see *Table 3*).

Indeed, the network density for the PRD is higher than that for the YRD in both years. Nonetheless, in the period 2001-2008, the network density increased in both regions, although the gap widens. Similar observations can be made with respect to the network efficiency produced by the corporate networks. By 2008, the PRD was fully connected (i.e., every city-pair had at least one connection), and in the YRD, firm connections now straddle almost the entire region. This points to the emergence of closely connected regional networks. Perhaps most notably, this evolution towards a (nearly) fully connected network has been the result of a rise in connections among small- or medium-sized cities, no matter how thin these connections are (see *Fig. 3* and *4*).

The results of the analysis of P', which incorporates network density and efficiency into P suggest that, when taking into account the overall structure of the network, it is actually the PRD that is and has remained the most polycentric region, a gap that has in fact been widening. The increase is visible in both P'_O and P'_I.

Table 3 Indices indicating polycentricity in the YRD and the PRD in 2001 and 2008. Source: own elaboration

Indices	YRD		PRD	
	2001	2008	2001	2008
P_O	0.785	0.778	0.775	0.738
P_I	0.886	0.913	0.756	0.784
P	0.836	0.846	0.766	0.761
Δ	0.071	0.160	0.158	0.276
η	0.846	0.946	0.903	1.000
P'_O	0.047	0.118	0.111	0.204
P'_I	0.053	0.138	0.108	0.216
P'	0.050	0.128	0.109	0.210

3.3 Interpretation

What can we learn from this straightforward overview? Both the PRD and the YRD are often jointly discussed as examples of PMCRs. It is generally believed that both mega-city regions have similar advantages in terms of location, population density, foreign direct investment (FDI) and transport infrastructure (*Zhu* and *Yang* 2009; *Zhao* et al. 2015). However, as we have seen, there are still differences between the PRD and the YRD concerning their network development (*Tang* and *Li* 2014; *Zhao* et al. 2016), and these changes have not been ironed out over time. The main factors behind those differences can be explained by looking at three aspects.

First, the extent of the intra-regional interaction, captured by network density and efficiency, is largely dependent on the size of the areas under study. The area of four of the nine prefecture-level cities in the PRD, namely Shenzhen, Zhuhai, Dongguan and Zhongshan, occupies less than 3000 km^2 (see *Table 1*), while the average area of county-level spatial units in China is 3,376 km^2 in 2008 according to data from National Bureau of Statistics. Furthermore, the GDP density of the PRD is 54.3 million per square kilometre and more than 49.0 million per square kilometre in the YRD. This indicates that the density of economic activity in the PRD is higher than that in the YRD. The four cities in the PRD were county-level spatial units for more than 1,000 years before becoming prefecture-level units. For example, Shenzhen was a county called Baoan in Huizhou, a prefecture-level region before 1980, while Dongguan was also a county-level city in Huizhou before 1988. Given *Tobler's* (1970) 'first law of geography', the smaller areal extent of cities in the PRD and the higher economic intensity within these cities leads to more interactions (hence *van Oort* et al. (2010) suggestion to incorporate distance in the framework). This is visible in the density and network efficiency of the corporate networks and explains why the gap in polycentricity between both regions has not fundamentally changed over time.

Second, increasing international trade is having a major impact on the transformation of urban networks underlying China's mega-city regions. For example, *Zhao* et al. (2017) revealed how complex network interaction increased significantly in 2001-08 and subsequently slightly declined in 2008-13 when exports were hit by the global crisis. As shown in *Table 1*, cities in the PRD relied more on imports and exports than those in the YRD. To some extent, the higher level of regional integration of corporate spatial organization in the PRD results from the cities' greater relative dependence on international trade, which is closely related to the economic specialization in China (*Zhu* and *Yang* 2009). It should be noted that the impacts of FDI on the levels of regional integration in the YRD and PRD are not yet clear. On the one hand, there is no significant difference between the ratios of FDI to GDP in both mega-city regions (see *Table 1*). On the other hand, in cities dominated by FDI, such as Suzhou in the YRD and Dongguan in the PRD, foreign-headquartered enterprises are thinly embedded in local economies and tend to establish global–local networks amongst themselves (*Yang* and *Liao* 2010; *Wei* et al. 2012).

Third and finally, the political system has an obvious impact on the urban networks in both regions. A company in China can usually only establish branches in other territorial units with the permission of the local government. If an investment from a foreign country exceeds a certain threshold or is related to infrastructure construction, it has to be authorized by the National Development and Reform Commission (NDRC). At the same time, each layer of government has enterprises that rely on officials of the respective political hierarchy for permission to set up branches. In the last 10 years, denser urban networks have facilitated regionalization in terms of the increasing involvement of non-state actors (*Zhu* and *Yang* 2009; *Luo* et al. 2010), but the level of integration in the YRD is generally lower because of its larger number of state-owned companies (*Zhang* and *Wu* 2006). Thus, the more polycentric nature of the PRD that has stayed in place over time can be attributed to differences in regional approaches to governance and the involvement of state-owned enterprises.

4. Conclusions

In this paper, we explored the shifting spatial organization of the Yangtze River Delta (YRD) and the Pearl River Delta (PRD) through the lens of recent research on polycentricity. Based on a review of the current state of affairs in the literature, this research developed a framework to compare the shifting spatial organization of city regions through the lens of enterprises' headquarters–branch links. That is, urban networks were defined by looking at the ownership linkages running from headquarters to other parts of the firm, as these linkages represent a direct interaction between the city where the headquarters are located and the city where the subsidiary is owned (*Alderson* and *Beckfield* 2004; *Zhao* and *Duo* 2013). In the process, we refined the analytical toolkit used in this area of research by considering network density and efficiency as parameters that can be taken into account when assessing urban networks.

Comparing the change in spatial organization of the YRD and PRD allowed us to discuss the unfolding functional-spatial architecture of both mega-city regions. We found that the level of polycentricity has been increasing, even though the concentration of headquarters is also increasing. The growth in polycentricity mainly originates from higher levels of network density, also shown by the fact that self-contained relations have been weakening.

There are, however, fundamental differences between the PRD and the YRD. Firms in the PRD are more likely to set up branches beyond prefecture boundaries, which results in a higher level of network density in the PRD than in the YRD. Nonetheless, there is a relatively 'flatter' intercity network in the YRD than in the PRD, as there are more firms' links interconnecting the four major cities (Guangzhou, Shenzhen, Dongguan and Foshan). There has been a significant shift in the YRD in that Nanjing and Hangzhou have become the cities that attract more branches than Shanghai; no similar change is taking place in the PRD.

The dominance of the regional gateway city (Shanghai and Shenzhen, respectively) is still significant, which reflects that the goal of regional planning has not yet been to reduce the status of these major cities. Although most local governments of small- or medium-sized cities usually compete with each other to attract more firms to maintain the connections (*Fan* et al. 2007; *Li* et al. 2008; *Xia* 2014), the strength of economic agglomeration in these megacities cannot be ignored (*Wang* 2010; *Gu* 2012).

The results of this empirical study also suggest that both regions follow different pathways towards polycentricity. Although denser urban networks have facilitated regionalization in terms of the increasing involvement of non-state actors (*Luo* et al. 2010), the level of integration in the YRD is relatively lower because of its higher number of state-owned companies (*Zhang* and *Wu* 2006). Along with other results on the relationship between firm performance and ownership type across regions (*Jiang* and *Nie* 2014; *Xia* and *Walker* 2015), this suggests that a relatively higher ratio of private companies in the YRD will promote a higher level of network density and efficiency there.

In the planning documents of 'New path for Urbanization in Guangdong (2014-2015)', it is proposed to expand the area of the city region in the PRD because it is relatively smaller than the city region in the YRD. However, our findings indicate that most enterprises are locating their branches in the four large cities rather than in small- or medium-size cities in the PRD. This means that companies still intend to organize production networks within main cities. Thus, policymakers should also pay attention to the current reality of economic gaps within the PRD, instead of simply enlarging the size of the city region.

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