TITLE: Urban co-opetition in megaregions: measuring competition and cooperation within and beyond the Pearl River Delta

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HIGHLIGHTS:

- We develop asymmetric indicators for intercity competition and cooperation using niche overlap theory
- Competition and cooperation networks in the PRD are shaped by different development trajectories and cooperation frameworks
- Guangzhou is the dominant PRD city in terms of posing competition and providing cooperation to other PRD cities

KEY WORDS: competition; cooperation; niche overlap theory; urban networks; Pearl River Delta

ABSTRACT: Megaregions are often argued to be characterized by complex dynamics of both competition and cooperation. To better understand this 'co-opetition', this research draws on network thinking to theoretically conceptualize, methodologically specify, and empirically assess competitive and cooperative relations between a megaregion's constituent cities. Conceptually, we draw on insights from niche overlap theory to develop a methodology for assessing the direction and strength of cooperative and competitive intercity relations in megaregions. Empirically, the methodology is illustrated for the case of the Pearl River Delta (PRD) by drawing on human mobility big data as a proxy for flows of human capital. By comparing patterns on a regional, provincial, and national scale, insight is gained into the positions and roles of cities within the megaregion. Based on the results, we discuss the added value of this novel framework for understanding megaregional dynamics and reflect on possible avenues for further research.

1. INTRODUCTION

Megaregions are often hypothesized to function as key territorial units in contemporary economic globalisation. Although there has been much academic debate surrounding its fuzziness as a concept (Harrison & Hoyler, 2015), a megaregion is generally defined as a network of metropolitan centres and their surrounding areas. As they are constituted of geographically clustered and functionally integrated cities, megaregions play a pivotal role in interlocking agglomeration advantages with network externalities (Burger & Meijers, 2016), in turn nurturing their potential as environmentally sustainable (Marull et al., 2013) and economically performant entities (Florida et al., 2008).

However, the economic competitiveness of megaregions requires close coordination in terms of a well-organised spatial division of labour, functional specialisation, and sharing of transport infrastructure among centres (Hoyler et al., 2008). Urban policy makers and a range of private actors therefore tend to cooperate across megaregional cities to achieve an economic potential exceeding that of its constituent, individual cities (Meijers, 2005). Paradoxically, these actors are often situated in a competitive environment where positioning themselves favourably compared to the other centres is necessary to preserve their strategic position in the urban network (Goess et al., 2016). For example, city governments and business service firms increasingly rely on the mobilisation of a talented and skilled workforce to compete in a knowledge-intensive services economy. In that regard, it may well be the case that ‘megaregions are not becoming competitive actors within the global economy but rather […] a new space of competition’ (Wachsmuth, 2015, p. 66). Research towards the concurrence of competition and cooperation within megaregions nonetheless remains relatively scarce.

Against the backdrop of megaregions’ relevance as key territorial units and their understudied dynamics of ‘co-opetition’, this paper aims to provide more insight in the competitive and cooperative intercity relations of cities in a megaregion setting. We do so by approaching these relations from a network perspective, which allows to disentangle the underlying mechanisms of competition and cooperation both conceptually (Camagni, 2007) and methodologically (Wall, 2009; Burger, van Oort et al., 2013). By the same token, this allows us to differentiate the analysis in light of the scale of analysis (Li & Phelps, 2018) given that intertwined, scale-dependent dynamics of co-opetition likely coexist in city networks (Burger, 2011; Lai, 2012; Pasquinelli, 2013).

Even though these aspects of urban competition and cooperation have been linked to some extent in earlier work (e.g., Taylor, 2011), studies that have consolidated both concepts in one coherent framework remain thin on the ground. In the face of this methodological research gap, the primary objective of this paper is to devise a framework that allows to conceptualise and systematically measure competition and cooperation in an urban network for a particular function across multiple scales. In conceptual terms, we build on Wall’s (2009) niche overlap-based approach and introduce a set of indicators – one for competition and one for cooperation – capturing the directional intensity of competition and cooperation between two cities based on their network structures. In addition, we derive four indicators capturing overall competition posed/faced and cooperation provided/received by an individual city. In empirical terms, we illustrate this framework by applying it to the case of the Pearl River Delta (PRD) using a network of daily human mobility at three scales: the region, Guangdong province, and China as a whole. Human mobility flows thereby reflect the spatial distribution of the skills and talent embodied in human capital and functions as a useful proxy for economic development in a knowledge-based economy. The PRD is a sensible choice as a study area as it is often claimed an archetypical megaregion that features strongly in research on both interurban competition (Lu et al., 2017) and cooperation (Xu & Yeh, 2013; Li et al., 2018) in the knowledge economy (Lu & Wei, 2007), and this from a multi-scalar angle (Zhang & Kloosterman, 2014).

The remainder of this paper is organized as follows. First, we situate our research in the literature on cooperation and competition in urban systems and link it to a megaregional context. Second, these theoretical ideas are conceptualised drawing on niche overlap theory to distil a measurement scheme that allows to capture competitive and cooperative relations in a region. Third, we introduce the PRD as a case study and assess the direction and intensity of interurban competition and cooperation between its constituent cities. Finally, we reflect on potential improvements of the developed methodology.

2. COOPERATION AND COMPETITION IN URBAN SYSTEMS

Urban systems have long been thought of as being mainly hierarchical in nature (Taylor, 2011). Following Christaller's (1933) central place theory, a system of cities is traditionally characterised by a clear hierarchy in which a few centres at the top rival and dominate others, and in which the position of one city comes at the expense of others. Intercity relations in such a system are inherently competitive: cities essentially compete with each other for market share (Begg, 1999). These market shares are reflected in the extent of the contiguous geographic area a city serves: its hinterland. The larger the surrounding hinterland, the larger the base where the city can offer services. Only higher-order centres are thus able to offer higher-order services in extensive hinterlands and are said to outcompete their lower-order rivals serving limited hinterlands with a limited set of higher-order services. In other words, inter-city competition leads to asymmetric, hierarchical links that structure the urban system (Taylor, 2011).

Central place theory falls short, however, in explaining the spatial organization of economic configurations in which cities are effectively carrying out some highly specialised functions despite their relatively small hinterlands (Gordon, 1999). For example, Rotterdam and Amsterdam function as major transport and services hubs regardless of their limited hinterland. Complementing central place theory, this is explained through what Taylor (2010) called central flow theory: as cities are increasingly interconnected at larger scales, the networks in which they are embedded allow them to specialize in certain functions while importing others through mutually beneficial exchanges (Powell, 1987). In such cases, the basis for functional specialization is no longer exclusively determined by the size of a city's local hinterland, but rather by its position within a broader network – its hinterworld (Taylor, 2010): the more connected the hinterworld, the larger the base where the city can offer services. Since the functional specialization of a centre is made possible by exchanging goods and services with other specialised centres, successful cooperation among cities is required for networks to materialize (Begg, 1999). Thus, relations between cities structuring the urban system are not solely competitive, but also potentially cooperative in nature (Burger, 2011).

Central flow theory does not imply that competition in networks does not exist or matter. As Taylor and Aranya (2008, p. 2) argue: 'competition is less fundamental but still significant'. To be specific, competition should be thought of as an external network characteristic rather than an internal central place characteristic. As cities increasingly depend on different types of flows that occur at a variety of spatial scales, their competitiveness is primarily derived from the functional links they are able to establish in order to strengthen their relative position in urban networks that stretch from the local to the global scale (Gordon, 1999). One process through which cities compete for a strategic network position are, for example, 'gateway battles' (Taylor, 2011). When two cities strive to become the single access point into a region where there is only the capacity for one, one city will inevitably outcompete the other – e.g. Sao Paulo replacing Rio de Janeiro in connecting the Brazilian finance sector to the world (Rossi & Taylor, 2006). Instead of thinking about cooperation and competition as opposites and as representing networked and hierarchical phenomena respectively, both likely coexist in urban networks (Lai, 2012). City networks are thus shaped by a complex interplay of both competitive and cooperative relations, sometimes referred to as 'co-opetition' (Burger, 2011; Pasquinelli, 2013). In the next two sections, we turn to both types of relations in turn.

2.1 Synergy, cooperation, and complementarity in megaregions

At the regional level, Meijers' (2005) notion of 'synergy' is a useful concept to specify cooperation more clearly. Synergy refers to 'the rise in performance of a network through efficient and effective interaction' (Meijers, 2005, p.767). Meijers (2005) distinguishes two mechanisms associated with synergetic relations: cooperation and complementarity. Cooperation or 'horizontal synergy' denotes a situation in which multiple actors have a shared objective so that by collaborating with each other through parallel transaction chains, positive externalities such as economies of scale can be achieved by all actors in the network. One such example entails proximately located cities sharing road, rail, or air infrastructure. Complementarity or 'vertical synergy', in turn, refers to a situation in which each actor specialises in a distinct niche, the serial combination of which leads to positive externalities by enabling each actor to focus on just one core activity. The functional specialization of cities then allows them to fulfil different economic roles, while their physical proximity grants them access to large, overlapping labour and consumer markets throughout an entire region (Camagni, 2007). For instance, Amsterdam is held to function as the commercial and financial services centre of the Randstad, whereas The Hague specialises in public administration and Rotterdam operates as the main manufacturing and transport hub (Kloosterman & Musterd, 2001). Hence, the actors constituting cities in the Randstad can benefit from specializations elsewhere in the network. Due to these complementary roles, a degree of interdependence among cities emerges in the form of exchanges of goods, people, and capital. However, these exchanges are in turn made possible through cooperation, i.e. by sharing the infrastructure through which these flows materialize.

In other words, cooperation is required for the realisation of complementary specializations, which we label as a form of 'cooperation through complementarity'. Even though Meijers (2005) presents cooperation and complementarity as distinct mechanisms, they are essentially paired: Amsterdam can only fulfil its commercial function since it relies on Rotterdam for the import and manufacturing of goods and vice versa. This interdependency relates to an umbrella definition of 'cooperation' (e.g., by Begg, 1999; and Gordon, 1999): since the functional specialization of one centre requires exchanges with other specialised centres, successful cooperation among cities is required for networks to take shape. In other words, exchanges and specialization are seen as mutually conditional and this is the view we adopt in this paper: we interpret cooperation between cities as the exchanges following from complementary orientations.

2.2 Competition in urban regions

Similar to synergetic mechanisms, the logic behind competition can be more clearly specified with regard to megaregions (Burger, van Oort et al., 2013). The competitiveness of cities in megaregions used to be primarily defined by the geographic extent of their market areas and was thus curtailed by the presence of other, physically proximate cities (Gordon, 1999). Therefore, while the physical proximity of nearby cities in a megaregion might have led to confined market areas and strong internal competition in the past, it now presumedly allows for complementary relations (e.g., by means of a spatially unfolding division of labour; Meijers, 2007). As such, interurban competition might be evaded by strengthening complementary functional links that stretch beyond the local and regional scale.

However, the rise of activities that are less spatially bounded (e.g., inter- or intra-firm online meetings or knowledge collaborations) does not entirely rule out competition. Moreover, megaregions are not necessarily becoming more competitive as a whole, but may well induce competition among its constituent cities (Wachsmuth, 2015). As competition processes now occur at *any* scale, be it international, national, regional or local (Gordon, 1999), interurban cooperation on one scale does not rule out competition on another scale. Two cities might cooperate on the international scale for a particular function but compete on the regional level for that same function. For example, cities in the Yangtze River Delta cooperate for the attraction of capital and a talented workforce internationally by proclaiming their coherence as a megaregion, whereas regionally they are in fact competing over that same pool of resources (Lu et al., 2020). As Wall (2009) points out, there is a need to gain insight into what scales are most likely to be associated with urban competition.

3. METHODOLOGY

3.1 Niche overlap theory

Niche overlap theory provides a set of analytical tools that is particularly useful in measuring and relating competition and cooperation in network-analytical terms. Niche overlap theory was first developed in the field of ecology to describe competition and complementarity within and between species based on the similarity of their resource needs. It has since been transferred to a variety of domains such as social network analysis (Popielarz & Neal, 2007) and organizational studies (Sohn, 2002; Ingram & Yue, 2008; Mascia et al., 2016). In general, more niche overlap points to stronger competition, whereas less niche overlap indicates possible complementarity.

Applying this framework to urban networks, the niche of a city can be regarded as the combination of two components: (i) the geographic market area in which the city operates and (ii) the economic function it fulfils within this area (Wall, 2009; Burger, van der Knaap & Wall, 2013). First, geographic niche overlap occurs when two cities serve the same geographic markets. As mentioned, these markets are not characterised as hinterlands comprising physically proximate cities, but rather as sets of flows that can originate from cities on a variety of scales. Second, functional niche overlap occurs when two cities fulfil the same organizational function in the same sector (Wall, 2009).

When two cities have similar sets of flows for the same function, they are essentially competing for the attraction of the same resource from the same places. Two cities thus compete when their geographic and functional niches simultaneously overlap. In the PRD, for example, both Guangzhou and Shenzhen aim to attract producer services from Beijing and Shanghai (Yeh et al., 2014) and are therefore in competition. Additionally, the amount of geographic niche overlap may differ depending on the scale of analysis. For instance, Guangzhou and Shenzhen could heavily compete on a national scale – i.e., in trying to attract producer services from Beijing and Shanghai – but less so on a provincial or regional scale. Note that the degree of competition is always measured between two cities, and therefore regarded as an attribute of their relation (Wall, 2009). Since this research focuses on just one type of function, niche overlap is considered in terms of geographic market overlap alone. To summarise: *two cities compete if their geographic markets overlap at a certain scale*.

Following this logic, complementarity occurs when geographic markets do not overlap. Complementarity is however not synonymous with cooperation. As argued, complementarity between two cities only turns into cooperation when a strong, direct interconnection between both cities materializes. For example, Beijing and Shanghai have complementary hinterworlds in terms of advanced producer services given their geographic orientations towards politically important cities and commercially important cities worldwide, respectively (Taylor, 2011; Lai, 2012). Both cities are also strongly interconnected, and they can therefore be said to cooperate. Through their strong connections, Beijing is able to indirectly tap into Shanghai's hinterworld and vice versa. The intensity of their cooperation is proportional to the strength of their intercity flow as well as the degree of non-overlap of their geographic niches. Thus, *two cities cooperate if they have a strong intercity connection and complementary geographic markets at a certain scale.*

To further illustrate how competitive and cooperative relations are conceptualised based on niche overlap, Figure 1 represents a region comprising three cities α, β, and γ and their weighted link structures for one type of flow originating from cities at a particular scale. First, α and β are connected to different cities (a, b, c & d and g & h respectively) and therefore do not compete. On the other hand, they cooperate given the link between them and their non-overlapping link structures. Second, α and γ have no overlap in their link structures and therefore do not compete either. Despite having complementary niches, they do not cooperate due to the absence of a link between them. Third, β's geographic market is entirely overlapped by the stronger links of γ and therefore β experiences competition from the latter. The competition posed by β to γ is less intense because β does not compete for the attraction of flows from cities e and f and because γ's links to cities g and h are stronger and outweigh those of β. Thus, the amount of overlap is determined both by the spatial extent of the niche and by the strength of its links. Similarly, the degree of cooperation between the two is not symmetrical. Given the link between β and γ, they are able to cooperate. However, β's link structure only renders accessible a limited fraction of the links in g and h. The other way round, γ has stronger connections to g and h and extends the niche of β with two additional connections therefore providing more cooperation to β.

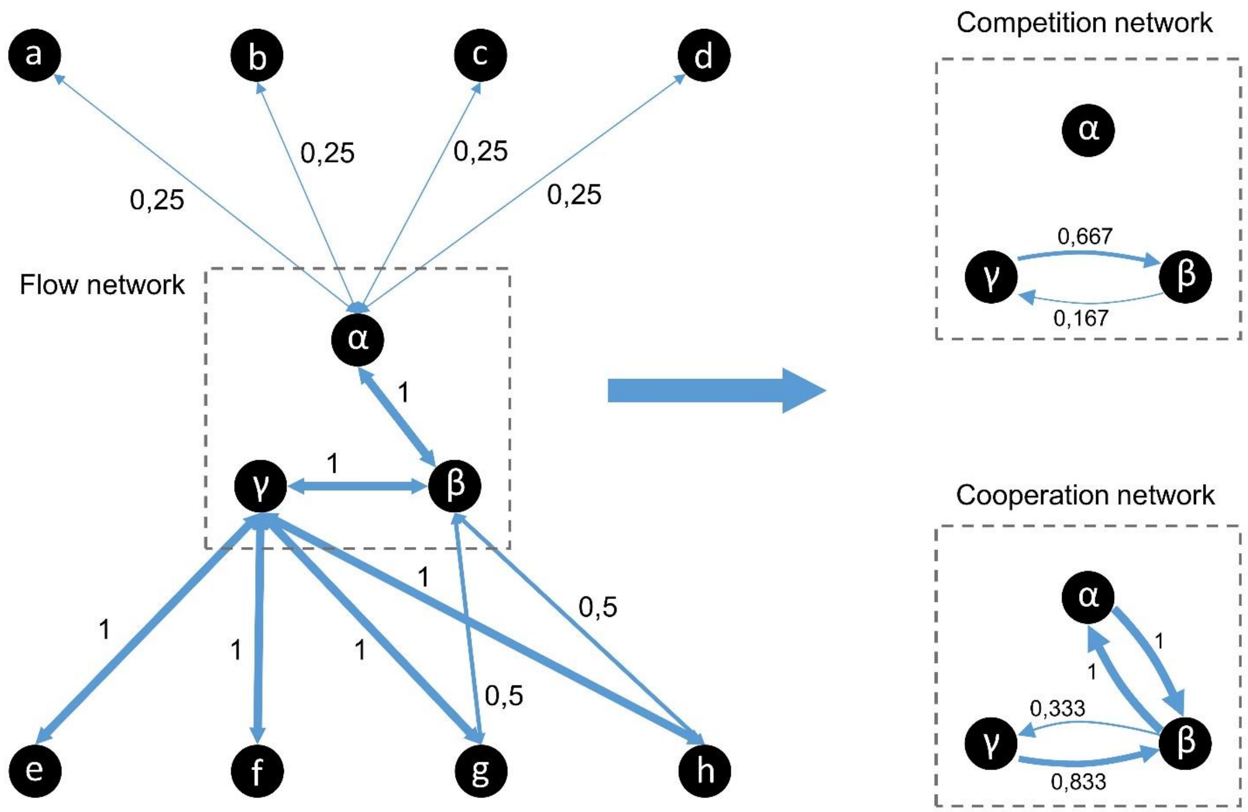

Figure 1: schematic overview of competitive and cooperative relations derived from intercity flows. The strength of each flow is given as a ratio from 0 to 1. The competition and cooperation are calculated using Equations (3) and (4) respectively.

Taken together, this example illustrates that intercity competition and cooperation are neither necessarily opposites nor symmetrical. Conceptualizing both phenomena using niche overlap theory thereby allows us to derive directed networks of intercity competition and cooperation. These potentially capture complex situations of cities simultaneously pursuing cooperative interaction and competition, or in short: co-opetition (Bouncken et al., 2015).

3.2 Measuring competition

To formalise the above interpretation of competitive and cooperative relations, we use Wall's (2009) method as a starting point for the measurement scheme. Wall (2009) assesses the absence of geographic market overlap between two cities in terms of their relative Manhattan distance. The relative Manhattan distance is a symmetric dissimilarity (SD_{ij}) measure where the lack of niche overlap between the niches of cities i and j is calculated as follows:

(1) $$SD_{ij} = 1 - \sum_{h=1}^{p}\left[min\left(\frac{a_{ih}}{\sum_{h=1}^{p} a_{ih}}, \frac{a_{jh}}{\sum_{h=1}^{p} a_{jh}}\right)\right] = \frac{1}{2}\sum_{h=1}^{p}\left|\frac{a_{ih}}{\sum_{h=1}^{p} a_{ih}} - \frac{a_{jh}}{\sum_{h=1}^{p} a_{jh}}\right|, i \neq j \neq h$$

where SD_{ij} is the symmetric dissimilarity between the niches of cities i and j; a_{ih} is the strength of the link between cities i and h, i.e. the value of their flow; where h is a city in a predetermined set of p cities, i.e. all cities located at a specific scale. In other words, this measure sums the relative differences between the strengths of the two flows between the same city h and cities i and j respectively. The distance measure is relative in the sense that the absolute strength of a link is standardised over the absolute sum of the strengths of all other links both cities have. As a result, the outcome scales from zero to one, where higher values indicate greater dissimilarity and greater complementarity of geographic markets and therefore less intercity competition (Wall, 2009).

This measure interprets the non-overlapping proportion of two cities niches as being of the same size, i.e. as being symmetrical. However, niche overlap should be assessed from the perspective of one city. Wall's (2009) measure thereby does not incorporate two conditions that may lead to asymmetric non-overlap and thus to asymmetric competition and cooperation. First, the *spatial extent* of only one city's link structure should matter (e.g., of city i if the overlap of i's niche by j's niche is considered). For links of i with every city h only the relative importance of that link in i's total link structure is then considered (Burger, van der Knaap & Wall, 2013). Whether or not j connects with cities that i does not connect to, has no effect on the (non-) overlapped proportion of i's niche. Second, for each link of i with every other city h, the *prevalence* of i's link strength over j's link strength with h should be compared on an absolute rather than a relative basis. If j has a stronger connection with h than i does in absolute terms, the non-overlapped part of i*'s* niche should decrease. Taken together, if one city has a spatially more extensive link structure than another and if that city's links are consistently more prevalent within the overlapping parts of the link structure in terms of absolute link strength, then the former city should pose more competition to the latter. This is evident when examining the competition between γ and β in the toy example in Figure 1. In that sense, our proposed indicator differs from Wall's (2009) indicator as well as others (e.g., the indicator by Burger, van der Knaap & Wall, 2013)[1].

Accordingly, niche overlap is measured using a weighted asymmetric dissimilarity index (AD_{ij}) that indicates to what extent the link structure of one city is overlapped by the link structure of the other. We therefore devise an asymmetric dissimilarity index between two cities i and j:

$$(2)\quad AD_{ij} = \sum_{h=1}^{p}\left[\frac{a_{ih}}{\sum_{h=1}^{p} a_{ih}} * \frac{a_{ih}}{a_{ih}+a_{jh}}\right], i \neq j \neq h$$

where AD_{ij} is the proportion of city i's niche that is not overlapped by city j's niche. All other terms are the same as in Equation (1). The first factor within the summation of Equation (2) essentially captures the relative importance of the link with city h in the link structure of city i while the second factor captures the prevalence of that link given the strength of city j's link with city h. Again, the index scales from zero to one, where higher

[1] Burger, van der Knaap & Wall's (2013) indicator does account for asymmetric competition, but only when the extent of overlapped cities changes rather than when the prevalence of one link over the other changes.

values indicate greater dissimilarity or non-overlap. In order to obtain the amount of overlap or competition posed by city j to i, the dissimilarity is simply subtracted from one:

$$(3)\ Competition_{ij} = 1 - AD_{ij} = 1 - \sum_{h=1}^{p}\left[\frac{a_{ih}}{\sum_{h=1}^{p} a_{ih}} * \frac{a_{ih}}{a_{ih}+a_{jh}}\right], i \neq j \neq h$$

where higher values now point to greater similarity and overlap of niches, and thus greater competition posed by city j to city i.

3.3 Measuring cooperation

Intercity cooperation is considered as the combined effect of direct exchanges between cities and the degree of complementarity of their niches. The intensity of the former is proportional to the strength of an intercity flow while the degree of complementarity is proportional to the non-overlap of geographic markets. Similar to the competition measure, cooperation is considered as an asymmetric relation between two cities which can be relatively more important to one city than to the other. Whereas the intensity of direct exchanges is equal for both cities, the complementarity term should reflect what one city can gain from these exchanges with the other city. The size of the non-overlapping part of the other city's niche thereby reflects hitherto untapped connections with other cities. Put differently, by connecting to a city with a complementary niche, the city gains access to assets originating from the other city's niche it previously had no access to. Recall that the size of this non-overlapping part of another city's niche is reflected by the asymmetric dissimilarity index. Complementarity from the perspective of one city should thus be considered in terms of the dissimilarity of the niche of the city it connects to rather than that of itself. Taken together, the degree of cooperation 'received' by one city i is then measured as the product of the strength of its direct exchanges with the other city j and the size of the non-overlapping part of the other city j's niche:

$$(4)\ Cooperation_{ij} = a_{ij} * AD_{ji} = a_{ij} * \sum_{h=1}^{p}\left[\frac{a_{jh}}{\sum_{h=1}^{p} a_{jh}} * \frac{a_{jh}}{a_{jh}+a_{ih}}\right], i \neq j \neq h$$

where a_{ij} is the strength of the link between cities i and j, i.e., the value of their intercity flow; and AD_{ji} is the asymmetric dissimilarity between j and i, or the size of the non-overlapping part of city j's niche from the perspective of city i. The first term captures the condition of a direct exchange between the two cities, while the second term reflects the condition of complementary niches. As both terms can theoretically range from zero to one, both have an equal weight on the outcome of the indicator. The composite cooperation coefficient then ranges from zero to one, where higher values point to more cooperation.

3.4 Averaging the indicators

Drawing on the above framework, measures of cooperation and competition between any set of city-pairs can be calculated and bundled in a cooperation and competition matrix. To illustrate, we provide the competition and cooperation matrix for the toy example of Figure 1 in Table 1.

Table 1: competition matrix (left) and cooperation matrix (right) for the toy example of Figure 1.

	α	β	γ	**Comp. faced**
α		0,000	0,000	0,000
β	0,000		0,667	0,333
γ	0,000	0,167		0,083
Comp. posed	0,000	0,083	0,333	

	α	β	γ	**Coop. received**
α		1,000	0,000	0,500
β	1,000		0,833	0,917
γ	0,000	0,333		0,167
Coop. provided	0,500	0,667	0,417	

Per city, it is then possible to derive two individual competition and two individual cooperation indices. First, a city's *competitiveness* reflects the average degree of competitive threat it poses to another set of cities. Its competitive *crowding*[2] reflects the average competitive threat it faces from these cities. Second, the average degree of cooperation is calculated per city in terms of the cooperation it receives from other cities – its *received cooperation* – and the cooperation provided to other cities due to their link with the city in question – its *provided cooperation*. Taken together, the use of the intercity and city-specific indices then allows for a thorough understanding of competitive and cooperative relations between a predetermined set of cities.

4. DATA

4.1 Pearl River Delta

[2] The term 'competitive crowding', or 'crowding' in short, has been used to denote the overall pressure of competitive intensity experienced by an actor, both in ecology (e.g., Hurlbert, 1978) and organizational studies (e.g., Ingram & Yue, 2008).

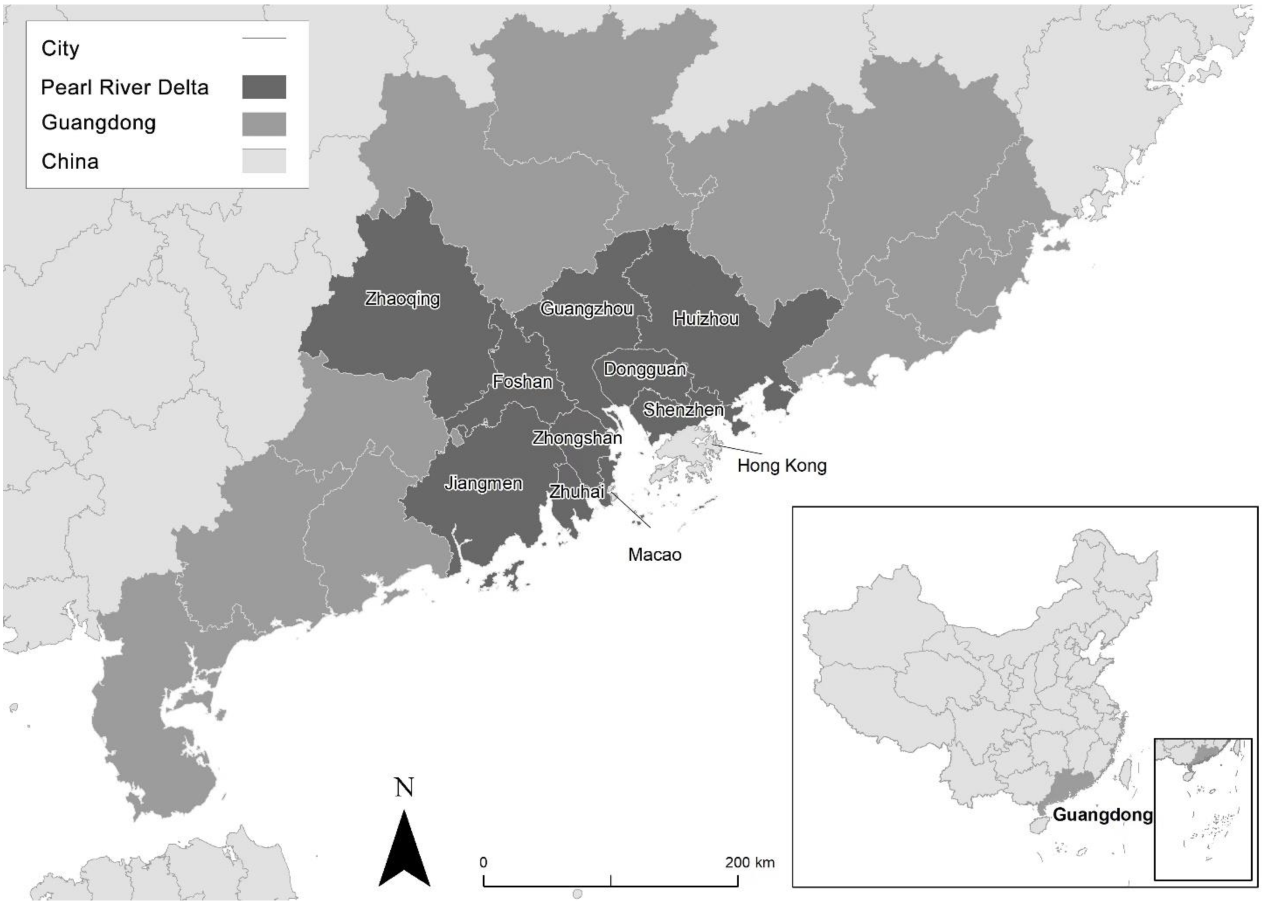

Figure 2: location of the PRD and its constituent cities in Guangdong province and China. Hong Kong and Macao are not included in the analysis.

As one of the most researched megaregions in terms of urban competitiveness (Schiller et al., 2015; Lu et al., 2017) and regional cooperation (Xu & Yeh, 2008; Zhang et al., 2018; Yang et al., 2018), the PRD is the stage for our analysis. We apply the methodology outlined above to its nine constituent prefecture-level cities (Figure 2): Guangzhou, Shenzhen, Foshan, Dongguan, Huizhou, Jiangmen, Zhongshan, Zhuhai and Zhaoqing. The analysis excludes Hong Kong and Macao due to a lack of data availability. However, given their special administrative status it seems fair to not yet consider them as being fully integrated in the megaregion. Additionally and relatedly, they are not defined by the administrative-territorial hierarchy that characterizes urban China (Cartier, 2013; Wu, 2016).

As with other research interested in capturing networked phenomena in China through a multiscalar lens (Zhang & Kloosterman, 2014; Li & Phelps, 2018), the degree of competition and/or cooperation posed by cities may differ depending on the scale of analysis. Therefore, the method is applied separating flows on a regional, provincial and national level. On the regional scale, niche overlap between all city-pairs is calculated using geographic market areas that are defined by connections with other PRD cities. Provincially, flows with other cities of Guangdong province are the focus of the analysis. Bisecting both scales is particularly relevant as the erstwhile dominant provinces are increasingly replaced by urban agglomerations such as the PRD as the main level at which the state aims to regain planning control of fragmented urban space (Wu, 2016; Harrison & Gu, 2021; Wu & Zhang, 2022). Finally, geographic markets based on links with extra-provincial cities are considered to determine competition and cooperation for national flows.

4.2 Intercity mobility flows

As urban networks are multiplex in nature, deciphering one type of flow reveals patterns specific to that particular function (Burger et al., 2014). In this research, daily intercity flows of people are chosen to specify functional links as they comprehensively depict a broad range of functional intercity interactions resulting from tangible socioeconomic processes such as daily commutes, business travel and tourism. Specifically, human mobility constitutes one of the most important drivers of the spatial distribution of productivity and economic development among cities in the shape of human capital. People that are physically present in the same location have a higher chance of transferring valuable skills, competencies and tacit knowledge as these transfers are facilitated by lower communication costs, higher likelihoods of chance meetings and greater mutual trust arising through frequent face-to-face contacts (Storper & Venables, 2004; Agrawal et al., 2006). By moving between cities, knowledge obtained in one location is transferred to the next and its value is partially relocated. Accordingly, the geographic pattern of human mobility flows plays a determining role in the spatial distribution of productivity and economic growth among cities (Faggian & McCann, 2009). Indeed, daily intercity mobility is a significant factor in shaping urban economic growth in China (Lei et al., 2021). Our research thus gauges the economic competition between cities over the attraction of human capital as well as their cooperation in terms of allowing access into each other's aggregated pools of talent.

In order to gather data on the strength of intercity mobility flows, we make use of Baidu Mobility Data[3] from January 1st to January 9th (China Data Lab, 2020). This dataset comprises aggregated and anonymized location records of smartphones[4] that are turned on and use Baidu Maps, the web mapping app of Baidu, China's largest search engine provider. A mobility flow from one city to another is detected through changes in a device's location. Consequently, the mobility flows represent actual demand for mobility rather than implicitly derived supply side data. The potential of Baidu mobility data for analysing intercity geographical patterns has been demonstrated before (e.g., by Cui et al., 2020; and Zhang et al., 2022).

[3] Since we want to capture a representative sample of general spatial patterns of population movements in China, data from January 1st 2020 until January 9th 2020 are used. This cushions daily fluctuations and excludes large-scale distortions caused by the Chunyun travel rush from the 10th of January onwards and the first COVID-19 travel restrictions from the 23rd of January onwards (Wei & Wang, 2020). Because COVID-19 travel restrictions have been in place at least in someplace in China from the initial outbreak until the time of writing (November 2022), we believe the ten day pre-COVID-19 window to be the only representative sample of general spatial mobility patterns.

[4] Data originating from phone location records are inevitably subject to sampling bias (Kitchin, 2013). However, prior research shows that differential phone ownership among different demographic groups does not dramatically distort estimates of overall population mobility, even in non-Western contexts (Weselowski et al., 2013). Indeed, smartphone penetration in China has significantly increased over the past years and reached 64 % in March 2020. Still, a slight bias towards young, highly-educated, high-income urban dwellers remains (China Internet Network Information Centre, 2020).

By multiplying the daily in- and outflow intensities of every city with their respective top destinations and origins and aggregating opposite directional flows from all days, an undirected matrix of $335 * (335 - 1) / 2 = 55\,945$ flows between all 335 spatial units at the prefectural level and above in China is constructed. Since the flow values are considerably positively skewed and include zero values, the $\log(x + 1)$ of all values is used. The data is then normalised with a min-max normalization in order to obtain values from zero to one reflecting the intensity of an intercity mobility flow. Equations (3) and (4) are then applied to all 72 city-pairs in the PRD considering their sets of mobility flows bounded by the regional, provincial, and national scale.

5. RESULTS & DISCUSSION

Our results comprise three cooperation matrices and three competition matrices, of which the city-specific indices are highlighted in Figure 3 and of which the strongest intercity relations are visualised in Figure 4. All city-specific and intercity values are given in Figure 5. Based on the derived networks of competition and cooperation, a series of general observations can be made. Drawing on these, we then examine the PRD's two main centres: Guangzhou and Shenzhen.

5.1 General observations

First, differences between PRD cities in terms of their posed/faced competition and provided/received cooperation increase with scale (Figure 3). In general, this can be traced to most cities having many strong criss-cross links within the region in the face of few cities establishing strong ties with distant cities. Regional geographic niches tend to be similarly sized and thereby produce intercity competition and cooperation coefficients that vary little (e.g., from 0,393 to 0,604 for competition; Figure 5a). This observation reflects the emergence of a polycentric landscape with diffuse and fragmented labour markets at the expense of clear, spatially bounded hinterlands surrounding each city (Ren et al., 2020). Provincially and nationally, differences between cities' network structure are more marked, and competition measures therefore exhibit more variation. Only a handful of cities have an outwardly oriented market, e.g., Guangzhou and Shenzhen, and thereby pose significant competitive pressure to cities with more local labour markets, e.g., Zhaoqing and Jiangmen. Similarly, the latter receive more cooperation as they benefit from connecting to a city with an extensive national embeddedness, more so than is the case provincially or regionally.

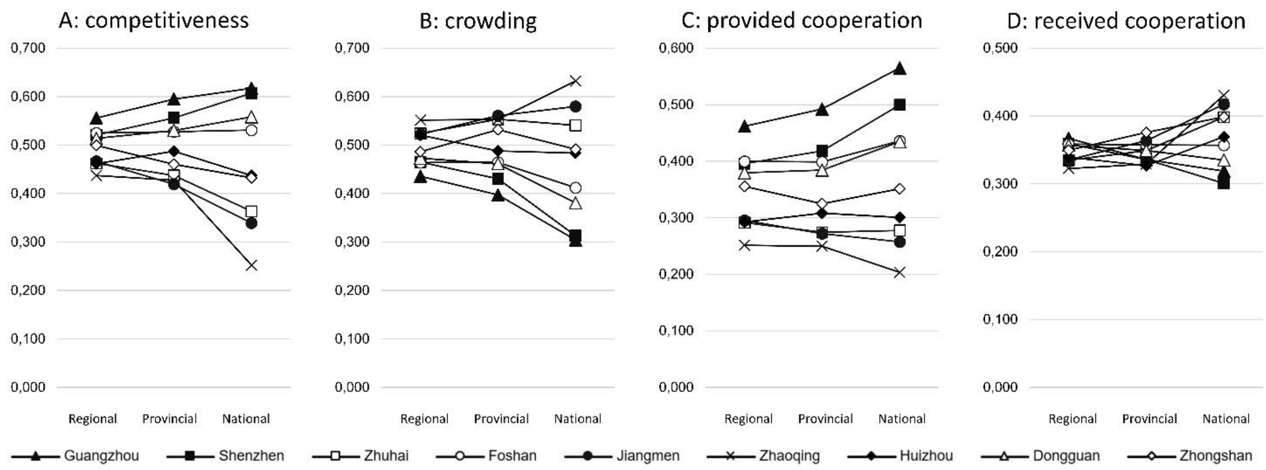

Figure 3: the city-specific scores of competitiveness (a), crowding (b), provided cooperation (c) and received cooperation (d) of all nine PRD cities based on their regional, provincial and national geographic markets.

Second, these differences in competition across cities have a clear geographical dimension. As evident from Figure 4e (and to a lesser extent from 4b and 4d), cities on the east bank of the Pearl River tend to pose more competition to those on the west bank. This can be traced to the different stages of the PRD's economic development. At first, production activities gradually permeated from the 'front shop' of Hong Kong to the industrializing 'back factory' comprising the nearby inland cities of Shenzhen, Dongguan, Guangzhou and Foshan (Zhang & Kloosterman, 2014; Ren et al., 2020). Since then, the manufacturing powerhouses on the east bank have gained from Hong Kong's knowledge spillovers and initiated a shift towards a services-based economy (Shiller et al., 2015). Concurrently, the lagging cities on the west bank (and Huizhou) are increasingly functioning as the new low-end manufacturing hubs. The current urban division of labour in the PRD is therefore one of high-end services in the main east bank centres such as Shenzhen and Guangzhou – services that require the attraction of talent nationwide –, whereas local pools of low-skilled labour seem to suffice for manufacturing centres such as Zhongshan and Jiangmen (Li et al., 2022). As a result, the niches of the higher-order cities out-overlap those of the lower-order cities and increasingly do so at larger scales.

Third, cooperative relationships are generally stronger between cities that are more proximate, further reinforced by existing cooperation frameworks (Figure 4b, 4d, 4f). On the one hand, these frameworks include bottom-up alliances between local policy makers responding to concrete needs for intercity cooperation, especially in the realm of infrastructure development (Li & Wu, 2018). Examples thereof include the integration between Guangzhou and Foshan through the joint construction of the GuangFo metro line (Zhang, Shen & Gao, 2021) and the negotiation of Zhuhai, Jiangmen, Foshan and Guangzhou policy makers over the Guangzhou-Zhuhai railway construction (Xu & Yeh, 2013). Both projects have extended population mobility on the west bank and ameliorated the cooperation of Guangzhou with Foshan, Jiangmen and Zhuhai, with the latter receiving 22%, 15%, and 12% more cooperation than average from Guangzhou on the provincial scale (Figure 5d). On the other hand, top-down regional plans are imposed by the central government to actively shape coherent city-regional units. These prevent intercity competition and achieve more coordinated regional development (Wu, 2016; Wu & Zhang, 2022). The success of such top-down plans often varies in space. For example, the National Development and Reform Commission's（NDRC) Outline of the Plan for the Reform and Development of the PRD (2008–2020) promotes close cooperation between three subclusters of cities in the PRD: an eastern cluster comprising Shenzhen, Dongguan and Huizhou; a central cluster comprising Guangzhou, Foshan and Zhaoqing; and a western cluster comprising Zhuhai, Zhongshan and Jiangmen (Enright et al., 2019). Although the former two clusters have materialised their cooperation to some extent (most visible in Figure 5e), cooperation between the latter three cities remains limited. The averages of the intercity cooperation indices in the Shenzhen cluster and Guangzhou cluster respectively amount to 11,7% and 9,4% above the average on the national level, whereas this is only 3,8% in the Zhuhai cluster (Figure 5e).

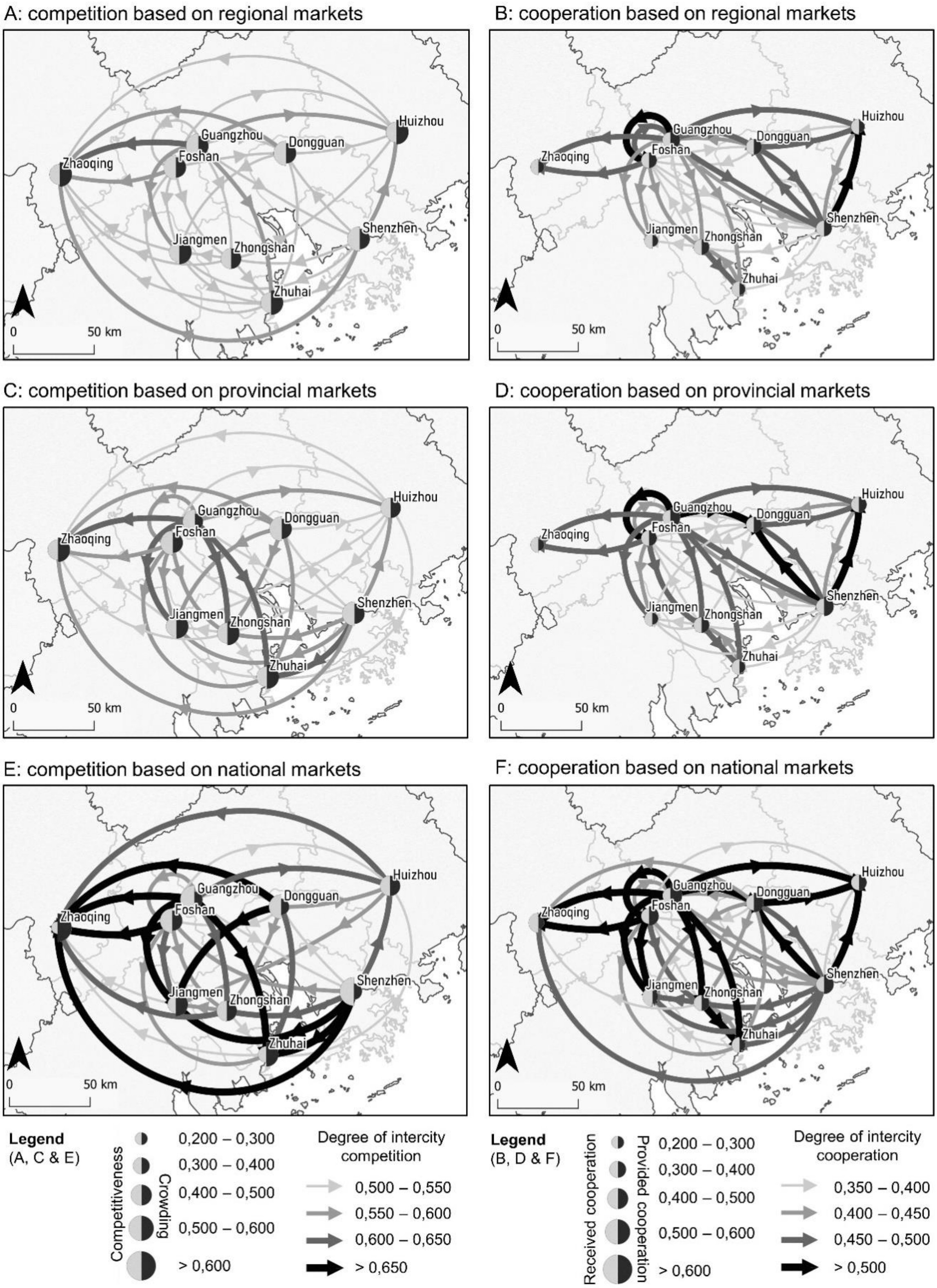

Figure 4: overview of the strongest competitive (left) and cooperative (right) relations between cities in the PRD based on their regional (top), provincial (middle) and national geographic markets (bottom).

A: competition based on regional markets

	Guangzhou	Shenzhen	Zhuhai	Foshan	Jiangmen	Zhaoqing	Huizhou	Dongguan	Zhongshan	**Crowding**
Guangzhou		0,468	0,413	0,471	0,418	**0,393**	0,413	0,461	0,448	**0,436**
Shenzhen	0,524		0,437	0,493	0,441	0,417	0,445	0,493	0,469	0,465
Zhuhai	0,573	0,540		0,549	0,501	0,471	0,488	0,535	0,534	0,524
Foshan	0,525	0,489	0,442		0,445	0,418	0,436	0,484	0,472	0,464
Jiangmen	0,575	0,538	0,495	0,550		0,471	0,487	0,532	0,530	0,522
Zhaoqing	**0,604**	0,565	0,516	0,581	0,523		0,515	0,560	0,550	**0,552**
Huizhou	0,571	0,553	0,485	0,539	0,489	0,466		0,546	0,515	0,520
Dongguan	0,531	0,507	0,445	0,501	0,448	0,424	0,453		0,476	0,473
Zhongshan	0,542	0,507	0,464	0,515	0,467	0,438	0,455	0,500		0,486
Competitiveness	**0,556**	0,521	0,462	0,525	0,467	**0,437**	0,461	0,514	0,499	

B: cooperation based on regional markets

	Guangzhou	Shenzhen	Zhuhai	Foshan	Jiangmen	Zhaoqing	Huizhou	Dongguan	Zhongshan	**Coop. received**
Guangzhou		0,416	0,310	0,475	0,321	0,299	0,338	0,421	0,357	**0,367**
Shenzhen	0,465		0,300	0,369	0,275	0,238	0,411	0,485	0,330	0,359
Zhuhai	0,427	0,367		0,336	0,318	0,208	0,235	0,317	0,469	0,335
Foshan	**0,529**	0,366	0,271		0,335	0,332	0,279	0,362	0,393	0,358
Jiangmen	0,439	0,333	0,315	0,414		0,243	0,221	0,321	0,397	0,335
Zhaoqing	0,458	0,318	0,227	0,460	0,270		0,225	0,321	0,301	**0,323**
Huizhou	0,463	0,510	0,234	0,341	0,222	**0,205**		0,467	0,272	0,339
Dongguan	0,484	0,499	0,266	0,375	0,272	0,245	0,388		0,326	0,357
Zhongshan	0,431	0,355	0,407	0,428	0,350	0,241	0,242	0,342		0,350
Coop. provided	**0,462**	0,396	0,291	0,400	0,295	**0,251**	0,292	0,380	0,356	

C: competition based on provincial markets

	Guangzhou	Shenzhen	Zhuhai	Foshan	Jiangmen	Zhaoqing	Huizhou	Dongguan	Zhongshan	**Crowding**
Guangzhou		0,465	0,359	0,437	**0,343**	0,350	0,406	0,440	0,378	**0,397**
Shenzhen	0,530		0,387	0,465	0,367	0,374	0,441	0,472	0,406	0,430
Zhuhai	0,637	0,602		0,578	0,483	0,487	0,539	0,580	0,520	0,553
Foshan	0,560	0,523	0,417		0,403	0,411	0,461	0,500	0,438	0,464
Jiangmen	**0,639**	0,600	0,508	0,587		0,504	0,535	0,583	0,529	**0,561**
Zhaoqing	0,634	0,594	0,498	0,581	0,489		0,530	0,577	0,520	0,553
Huizhou	0,582	0,555	0,436	0,516	0,411	0,420		0,526	0,456	0,488
Dongguan	0,558	0,525	0,414	0,495	0,396	0,403	0,465		0,434	0,461
Zhongshan	0,619	0,583	0,479	0,560	0,464	0,470	0,520	0,561		0,532
Competitiveness	**0,595**	0,556	0,437	0,527	**0,419**	0,428	0,487	0,530	0,460	

D: cooperation based on provincial markets

	Guangzhou	Shenzhen	Zhuhai	Foshan	Jiangmen	Zhaoqing	Huizhou	Dongguan	Zhongshan	**Coop. received**
Guangzhou		0,410	0,264	0,440	0,272	0,276	0,330	0,397	0,297	0,336
Shenzhen	0,467		0,259	0,345	0,238	0,222	0,409	0,467	0,279	0,336
Zhuhai	0,466	0,400		0,350	0,310	0,216	0,258	0,335	0,455	0,349
Foshan	**0,563**	0,387	0,254		0,308	0,331	0,293	0,366	0,357	0,357
Jiangmen	0,496	0,377	0,326	0,445		0,261	0,254	0,351	0,400	0,364
Zhaoqing	0,490	0,342	0,220	0,466	0,253		0,244	0,333	0,284	0,329
Huizhou	0,469	0,513	0,211	0,326	0,201	**0,198**		0,457	0,240	**0,327**
Dongguan	0,502	0,519	0,240	0,362	0,242	0,236	0,404		0,286	0,349
Zhongshan	0,485	0,398	0,420	0,456	0,351	0,257	0,272	0,369		**0,376**
Coop. provided	**0,492**	0,418	0,274	0,399	0,272	**0,250**	0,308	0,384	0,325	

E: competition based on national markets

	Guangzhou	Shenzhen	Zhuhai	Foshan	Jiangmen	Zhaoqing	Huizhou	Dongguan	Zhongshan	**Crowding**
Guangzhou		0,487	0,244	0,377	0,210	**0,152**	0,287	0,400	0,276	**0,304**
Shenzhen	0,507		0,250	0,385	0,215	0,155	0,297	0,413	0,283	0,313
Zhuhai	0,688	0,679		0,600	0,414	0,323	0,504	0,616	0,501	0,541
Foshan	0,579	0,569	0,327		0,301	0,223	0,392	0,517	0,388	0,412
Jiangmen	0,685	0,673	0,478	0,640		0,383	0,557	0,655	0,567	0,580
Zhaoqing	**0,704**	0,691	0,531	0,674	0,545		0,604	0,687	0,621	**0,632**
Huizhou	0,618	0,613	0,384	0,549	0,367	0,280		0,590	0,466	0,484
Dongguan	0,544	0,540	0,297	0,458	0,273	0,202	0,373		0,359	0,381
Zhongshan	0,614	0,604	0,395	0,562	0,387	0,298	0,482	0,587		0,491
Competitiveness	**0,617**	0,607	0,363	0,531	0,339	**0,252**	0,437	0,558	0,432	

F: cooperation based on national markets

	Guangzhou	Shenzhen	Zhuhai	Foshan	Jiangmen	Zhaoqing	Huizhou	Dongguan	Zhongshan	**Coop. received**
Guangzhou		0,431	0,227	0,421	0,238	0,223	0,301	0,409	0,301	0,319
Shenzhen	0,448		0,209	0,312	0,195	0,169	0,355	0,453	0,265	**0,301**
Zhuhai	0,550	0,489		0,405	0,329	0,202	0,281	0,402	0,529	0,398
Foshan	0,623	0,444	0,240		0,269	0,258	0,273	0,393	0,355	0,357
Jiangmen	0,596	0,467	0,370	0,521		0,232	0,273	0,422	0,457	0,417
Zhaoqing	0,640	0,461	0,291	0,614	0,315		0,303	0,445	0,375	**0,431**
Huizhou	0,562	**0,646**	0,226	0,368	0,191	**0,167**		0,535	0,259	0,369
Dongguan	0,539	0,578	0,220	0,350	0,200	0,174	0,350		0,269	0,335
Zhongshan	0,564	0,480	0,437	0,497	0,323	0,203	0,267	0,418		0,399
Coop. provided	**0,565**	0,500	0,277	0,436	0,257	**0,203**	0,301	0,435	0,351	

Figure 5: competition (left) and cooperation (right) indices for every city pair based on regional (top), provincial (middle) and national (bottom) geographic markets. Darker tones indicate higher values. The highest and lowest values of the intercity and individual indicators are in bold.

5.2 Guangzhou

As the cultural, administrative, and political epicentre of the PRD, Guangzhou is the most competitive, least crowded and most cooperative city across all scales (Figure 3). Given its administrative status as the provincial capital, this dominance is most pronounced in terms of its provincial hinterland (Ma, 2005). Guangzhou has deep-rooted historical ties with other provincial cities which translates into it being the central hub for the province to this day (Ng & Xu, 2014). Provincially, there is a gap with Shenzhen's competitiveness and provided cooperation of 0,039 and 0,074, respectively (Figure 5c). In other words, Guangzhou has stronger ties with cities from Guangdong province (other than those in the PRD) and provides more access to untapped connections to the PRD cities than Shenzhen.

Nationally, Guangzhou remains the prime city of the PRD, yet here it faces more competition from Shenzhen (0,487; Figure 5e) than provincially (0,465; Figure 5c). It nonetheless remains instrumental in providing cooperation at this scale, most notably to Foshan (0,623) and Zhaoqing (0,640; Figure 5e). Guangzhou's and Foshan's city centres are located a mere 20 km apart and comprise a physically and functionally integrated urban area (Chen & Yeh, 2022). Local policy makers of both cities have mostly focused on socio-economic integration, e.g., through constructing shared transport infrastructure such as the GuangFo metro line (Zhang, Shen & Gao, 2021). Such integration efforts require close governance and are beneficial as they facilitate human mobility and easier access to each other's talent pools (Li & Wu, 2014). Guangzhou thereby functions as a platform through which Foshan's actors can tap into nationally important connections, e.g., through Guangzhou's international airport. Interestingly, Foshan simultaneously poses most competition to Guangzhou on the regional level (0,471; Figure 5a) indicating their double-sided 'co-opetitive' relation. Zhaoqing, on the other hand, receives most of its cooperation from Guangzhou as it further extends Zhaoqing's limited niche outside Guangdong.

As an 'Economic Circle' planned for in the NDRC's PRD development plan, the ongoing cooperative ties between Guangzhou, Foshan and Zhaoqing are illustrative of envisaged integration efforts effectively taking place. The regional plan focuses on cooperation in the infrastructure realm (e.g., on the construction of rail and expressways), industry complementarity, as well as on intercity knowledge transfers (Enright et al., 2019). It is therefore unsurprising to see the concentration of human capital springing from Guangzhou's nationally ingrained network being diffused towards nearby Foshan and Zhaoqing.

5.3 Shenzhen

Although Shenzhen is overshadowed by Guangzhou regionally and provincially, it has become a leading city at the national level. Its firm national basis allows Shenzhen to bridge the gap with Guangzhou on the national level as their average degrees of competitiveness (0,617 and 0,607 resp.; Figure 5e) and crowding (0,304 and 0,313 resp.; Figure 5e) are nearly equivalent. This is clearly visible in Figure 4, with Shenzhen's increase/decrease of its competition/cooperation measures being steeper for the provincial than the national level compared to Guangzhou. The city thereby plays a pronounced role in connecting the PRD to cities of national importance in comparison to the provincial and regional scale. It has, for example, stronger links with Beijing and Chengdu than Guangzhou does, although very marginally so. Parallel to mobility flows, Beijing-Shenzhen is in fact one of the most influential city dyads in China's inter-firm service (Pan et al., 2017) and technological knowledge networks (Ma et al., 2015). Shenzhen's strategy of becoming a(n) (inter)national hub parallel to Guangzhou has been actively pursued by policy makers through infrastructure construction – i.e., Shenzhen has the third busiest airport of China and functions as a central high speed rail hub – which plays a major role in its overall competitiveness. This pursuit of attracting human capital largely stems from Shenzhen’s ambition to become a high-tech and creative city (Lu et al., 2017), although it continuously has to find new ways to attract the limited supply of talents (Ng & Xu, 2014).

Huizhou and Dongguan both benefit significantly from Shenzhen’s hub function as it provides them most cooperation on all scales. This is a result of both strong intercity ties – they are located on the same bank of the Pearl River, thus naturally falling more under Shenzhen’s sphere of influence – and Shenzhen’s national orientation complementing Huizhou’s and Dongguan’s regional orientation. Both cooperative aspects have actively been stimulated through inter-governmental cooperation frameworks, starting with the PRD’s 1994 ‘Economic Region Urban Cluster Plan’ in which the three cities were appointed as the region’s eastern development core (Enright et al., 2019). In addition, the Shenzhen, Dongguan and Huizhou city boards have formalised their agreements on topics such as transport planning to allow for direct courses of action in infrastructure development. Over time, however, the Dongguan municipal government has steered away from close cooperation with Shenzhen in pursuit of an individual development path. As a result, the Shenzhen government is increasingly leaning towards Huizhou as its primary cooperation partner (Zhang & Sun, 2019). With Shenzhen fulfilling a more complementary role for Huizhou than Dongguan, the result is a stronger tangible cooperative relation with the former (0,646) than with the latter (0,578; Figure 5f) on the national level.

Shenzhen still remains less embedded in the region than Guangzhou in terms of providing (0,565 and 0,500; Figure 5f) and receiving cooperation (0,319 and 0,301; Figure 5f) despite its similarly-sized national network. In this regard, it comes as no surprise that Shenzhen is aiming to ameliorate its direct regional connectivity – instrumental for tangible cooperation to materialize – with cities on the west bank that hold great potential as cooperative partners. For instance, in response to Hong Kong’s westward bridge connection with Macao and Zhuhai and Guangzhou’s similar advances towards Dongguan, Shenzhen and Zhongshan have now allied over the construction of a new bridge to cut travel times and allow for industrial transfers between them (Li et al., 2022). Developments equivalent to these will likely alter mobility patterns and influence both cooperative and competitive relations in the region.

6. CONCLUSION

The main contribution of this paper is the development of a comprehensive framework that allows formalizing competition and cooperation in city networks by drawing on a niche overlap approach. While most megaregions research focuses either on competitive or cooperative intercity relations, we argue that they are essentially two sides of the same coin (even though not being exact opposites). Competition results from overlapping market areas whereas cooperation results from spatial complementarity and direct exchanges among cities. Operationalizing both aspects as asymmetric attributes of an intercity relation allowed us to shed a new light on the megaregional dynamics of the Chinese PRD.

While the PRD is exemplary in terms of its convergence of local and national efforts of regional integration, it is also subject to intense competitive pressures that prevent individual cities of pursuing more spatially complementary paths (Li et al., 2022). Regionally, the PRD's constituent cities are highly integrated and compete for often subtle variations in market orientation. This leads to large overlapping labour markets and points to a suboptimal spatial configuration thereof. When considering flows at the provincial and national scale, the gap between the region's higher-order services centres and low-end manufacturing centres becomes evident. The national orientation of the main centres, most notably Guangzhou and Shenzhen, simultaneously leads to more competitiveness posed and cooperation provided to their neighbouring PRD cities. In sum, then, Guangzhou remains the main gateway into the region, especially on the provincial level.

The results also indicate that the spatial organization of both competitive and cooperative relations are not the result of a 'natural' logic of networked economies, but rather an outcome of place-specific processes such as institutionally arranged cooperation agreements and path-dependent political and socioeconomic developments. This points to a broader conclusion stemming from our analysis: the indices developed here are best interpreted alongside other network measures (e.g., density and centrality measures; cfr. Zhang et al., 2018) and qualitative data (e.g., interview data; cfr. Lai, 2011). Even though network thinking has become a key scientific paradigm for describing macroscopic relations – both competitive and cooperative – among collective actors like cities (Camagni, 2007), conceptual limitations remain (Watson & Beaverstock, 2014).

Finally, we highlight some limitations of this research and propose potential extensions of our methodology. First, we believe that a wider consideration of *international* mobility flows in the framework would render interesting insights. As cities in the PRD become increasingly dependent on transnational mobility networks, examining links with major international centres seems particularly pertinent given the proximity of Hong Kong and Macao. For instance, if connections with nearby Hong Kong were taken into account, Shenzhen would likely surpass Guangzhou in terms of its international competitiveness (Ng & Xu, 2014). Second, differentiating between different types of flow data (e.g., commute data, business travel and touristic trips) would allow for a more nuanced analysis. We adopted a broad definition of market overlap based on *any* form of daily mobility, but for a more thorough understanding of *functional* differentiation across cities and their associated geographic market orientations, our method could be adapted to allow for comparisons across functions by applying it using different types of flow data. Third and finally, extending this framework to compare different megaregions seems a worthwhile avenue for further research, especially since our developed indicators are scored within a standardised interval, enabling comparisons between megaregions from similar (e.g., urban agglomerations across China) or different geographical contexts (e.g., the Randstad, PRD and San Francisco Bay Area). Moreover, the competition and cooperation measures are not clearly bound by geographical scale and therefore enable applications beyond megaregions.

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