Spatiotemporal characterization of megaregional poly-centrality: Evidence for new urban hypotheses and implications for polycentric policies

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ABSTRACT

Poly-centrality is an essential feature of megaregions and is generally considered an important source of megaregional vitality and competitiveness. Numerous studies have highlighted the growing trends of poly-centrality across different megaregions worldwide. However, with accelerated urbanization, some observations suggest that the existing polycentric urban theories must be improved and that decision-makers require more knowledge on the potential trends, spatial characteristics and influencing factors of polycentric development to implement sustainable regional governance under this context. This paper proposes a series of hypotheses on spatiotemporal dynamics of polycentric megaregion evolution and verifies them in an empirical study on the Megaregion around Hangzhou Bay (MAHB). A new algorithm, which is applicable for long time series data, is proposed to evaluate and monitor the status of polycentric development in MAHB. In particular, landscape metrics and average nearest neighbor analysis are employed in the first stage of our algorithm which is designed to implement data compression. Then, the gravity model, minimum spanning tree (MST) and weighed be-tweenness centrality indicator form the second stage which aims to construct and explore the polycentric megaregional network. Results show that: (1) the speed and patterns of built-up land expansion significantly affect the number and distribution of megaregion centers; (2) the value of poly-centrality reaches a maximum in approximately 2013 and then declines, which can be well fitted by a Gaussian curve; and (3) the variation of poly-centrality is successively dominated by an increase and decrease in the number of centers with urbaniza-tion. This paper renews the assumptions in current polycentric evolution models and provides evidences for single-peaked change of megaregion center number instead of "wave-like", "scaling-up" or monotonous change proposed in existing urban theories. The proposed algorithm and assumed mechanisms can also be applied to model and explore poly-centrality dynamics of other megaregions around the world. The results are believed to provide critical implications for polycentric policies.

1. Introduction

1.1. Background

Under the pressure of accelerating population accumulation, global cities, particularly those in developing countries, continue to grow rapidly, and smaller settlements are formed around them to evacuate population (Schneider and Woodcock, 2008). These changes lead to a significant improvement in communication among the naturally close cities. Consequently, clusters are formed spontaneously, and mega-regions appear. As the rise of megaregions shows, poly-centrality is an essential feature of this inter-city system and is more than a morphological description of regional patterns. Constituent cities of megaregions are linked through economics, infrastructure, the environment, information, land use, culture and history (RPA, 2006; Yue et al., 2010). These linkages facilitate the formation of functionally polycentric megaregions that are considered major engines for regional and even global economic development. Florida et al. (2008) noted that the world's 40 largest megaregions make up 66% of the total global economic output and have gathered nearly 20% of world population (40% of world urban population). Seeing the great benefits created by polycentric megaregions, designers and policy-makers tend to guide cities to aggregate into megaregions. The US is striving to establish 11 megaregions (RPA, 2008), which are expected to contribute 74% of the
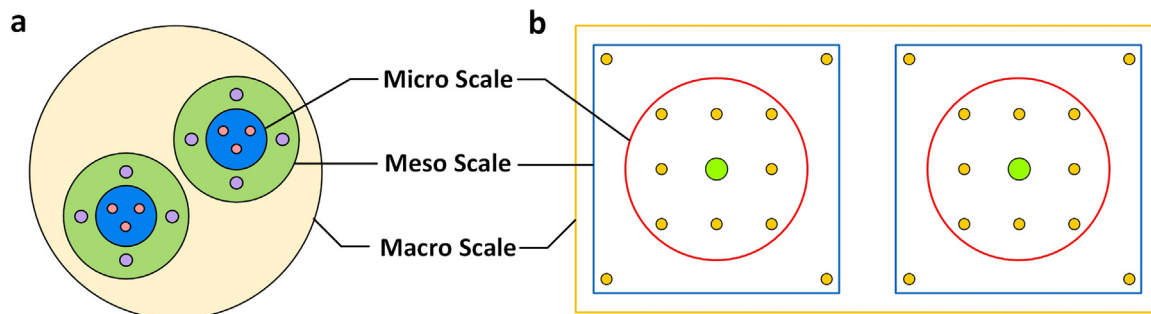
Fig. 1. Visualization of scales in urban studies.

gross domestic product (GDP) of America by 2050. Meanwhile, 20 megaregions have been planned by the Chinese government in the Eleventh Five-Year-Plan, including 5 national-level megaregions, 9 national secondary-level megaregions and 6 regional-level megaregions (Su et al., 2017). For any objective perspective, megaregions have already been new dimension of global urbanization.

Considering the increasing pressures on the limited available lands and the demand for ecological environmental protection, the authorities urgently need suitable planning strategies to achieve sustainable megaregion development. In this context, identifying megaregion centers and revealing the spatiotemporal dynamics of poly-centrality are particularly important. However, although many insightful studies on polycentric megaregion have been carried out, it is still difficult to outline the changes in poly-centrality under rapid urbanization. On the one hand, the rapid emergence or disappearance of centers makes the selection of megaregion centers unable to rely fully on the existing administrative division or heuristic knowledge (Liu et al., 2016a; Zhao and Chen, 2011; Zhao et al., 2017). On the other hand, measurements of poly-centrality are expected to reveal a center's role in a megaregion and variations in their importance overtime (Rozenblat and Melançon, 2013; Wen and Thill, 2016; Yang et al., 2014). Considering the mentioned challenges, new methods for identifying centers and indicators for evaluating centers' importance should be proposed to help improve the existing research paradigms and advance the understanding of the spatiotemporal poly-centrality of megaregions.

1.2. Literature review

The term "polycentric" or "poly-centrality" was originated in the public policy and management field. Polanyi (1951) firstly points out that there are two basic forms of social order, namely, commanding order and polycentric order. For the former, the appearance of order is rooted in manager's powerful leadership. However, when the number of units that need to be coordinated is exceptionally large, this monocenter system is no doubt to collapse. Contrarily, in the latter context, similar units spontaneously form into clusters. Every cluster owns a decision center and every single unit is affected by both internal and external forces. Polycentric management is considered as an effective way to implement massive social resource scheduling. After Polanyi, Ostrom (1981) who provides a polycentric explanation for Adam Smith's "invisible hand" theory is first to bring the "poly-centrality" to economics and urges to regulate public economy using polycentric principles and thoughts. In this context, individuals and businesses that participate in the same market activity are considered as centers. Every unit strives for its maximum profit and this process synchronously affects other units in the market. Controlled by this polycentric strategy, the market seems to be stable and orderly from the macro perspective. Besides, through defining specific centers and relationships, polycentric theory has been extended and applied in many other fields with its profound theoretical connotation, such as constitutional rules research (Vile, 1967), judicial system research (Tullock, 1965) and so on.

With the deepening of research, scholars no longer satisfy with the discussion on the theory itself, but concentrate on tracking cases of polycentric governance and evaluating the benefits of them. As important places for public policy implementation, urban system is gradually becoming a new topic for polycentric research. Moreover, combinations of centers and relationships provide various research perspectives. Gordon et al. (1986) first proposed the term "polycentric city" and regards the proportion of employment as a fundamental relationship between centers. After that, measurements such as the strength of traffic connections (Van der Laan, 1998) and trade volumes (Taylor et al., 2008) were continually included in polycentric policy analyses. In recent years, related studies are increasingly complicated and the definitions of relationships also become more abstract and integrated. Revisiting a large number of research results of POLYCE (Metropolisation and Polycentric Development in Central Europe) project, Hall et al. (2006) believed that relationships that need to be concerned in polycentric governance practices include finance and business service, power and influence, creative and cultural industries and tourism. Besides, America 2050 Plan (RPA, 2006) pointed out that environmental systems and topography, infrastructure systems, economic linkages, settlement patterns and land use and shared culture and history are the five major categories of relationships that define megaregions.

It is also important to note that the typical fractural features of urban forms bring various definitions of centers at different spatial scales (Batty and Longley, 1994; Liu and Wang, 2016b) (Fig. 1a). At the micro scale, research objects include central urban areas and centers generally refer to CBDs (Central Business Districts) and residentially gathered districts (Berry and Kim, 1993; Gordon et al., 1991). At the meso scale, study areas include municipal jurisdictions, and satellite towns are regarded as new centers at this scale (Arndt et al., 2000; Giuliano and Small, 1991; Mcdonald and Prather, 1994). At the macro scale, megaregions are considered, and centers are defined as constituent cities. However, it should be noted that centers at different scales are not completely different. Centers at smaller scales are probably treated as centers at larger scales. For example, both county- and prefecture-level cities are treated as centers in Su et al. (2017). Thus, methods for evaluating poly-centrality at all spatial scales can be important references for research on polycentric megaregion. Additionally, to better illustrate our hypotheses on megaregion evolution in Section 2, the hierarchical urban system is abstracted as shown in Fig. 1b.

The maturity of polycentric urban theory greatly prompted the application of polycentric governance around the world. Under the guidance of the theory, existing megacities and megaregion further optimize regional division and lots of new urban aggregations are being formed or planned. Beijing Urban Overall Planning (2016–2035) (BMCUP, 2017) explicitly defines several sub-centers of Beijing and their major functions. Specifically, Haidian and Shijingshan Districts are planned to be the science and technology innovation center; Chaoyang will be the international business center; Fengtai will be the life service and transportation center. Regional Planning of the Yangtze River Delta (NDRC, 2010) points out that member cities should clear