Measuring Spatial Structure of China's Mega-Regions

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Lincoln Institute of Land Policy
Working Paper

Lincoln Institute Product Code: WP13JY1

Abstract

Reflecting upon China's current path of regional urbanization, this research studies the polycentric structure of China's mega-regions. It defines the concept and measurement for mega-regional polycentricity, and utilizes the spatial statistics tool—standard deviational ellipse of directional distribution—to measure the demographic spatial pattern of individual mega-regions. The result reveals that most mega-regions in China do not have significant polycentricity. They are either dominated by a single major center, or by a number of major centers clustered closely. A challenge for China's mega-regional development is to explore the potential policy instruments that can promote a more polycentric mega-regional spatial pattern and more balanced spatial development.

Keywords: Regional Planning, Polycentric Development, Statistical Measures, Spatial Pattern, China.

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Measuring Spatial Structure of China's Mega-Regions

1. Introduction

The past two or three decades have seen the rise of a new urban unit—the mega-region. Mega-regions are more than just a bigger version of a city or a metropolitan region. Today's mega-regions extend far beyond individual cities and their suburbs and exurbs. Just as a city is not simply a large neighborhood, a mega-region is not simply a large city—it is an "emergent" entity with characteristics that are qualitatively different from those of its constituent cities (Florida, Gulden, & Mellander, 2008a).

The mega-region is not only recognized in advanced territories such as USA or EU. In China, the National Development and Reform Commission identified 10 emerging mega-regions and each mega-region spans multiple cities and even provinces. Such mega-regions exhibit striking differences in their characteristics. This study aims to provide a comprehensive picture of China's mega-regions, focusing on the spatial patterns of demographic distribution and economic activities.

Doing so offers significant policy implications. In the past, China's urbanization has cultivated megacities over 10 million in population, such as Beijing, Shanghai, Guangzhou, and Shenzhen. Those cities feature a heavy concentration of population and economic activities in a dense and crowded urban setting. Traffic congestion and environmental quality have become serious issues. There has been wide discussion of how to plan the cities and regions differently in order to sustain quality of life while accommodating urbanization (Yang, et al, 2011a). One possibility is to coordinate the urban development process at the mega-regional scale.

Conditioned on this regional urbanization context, this research aims to inform policy-making by providing some fundamental information. Namely, how are mega-regions spatially structured? It first provides a picture of the demographic characteristics of China's mega-regions. Based on this, it defines the concept and measurement of mega-regional centers and polycentricity. It then utilizes the GIS spatial statistics tool—Standard deviational ellipse of directional distribution—to measure the demographic spatial pattern of individual mega-regions. Finally, it looks at the implications for planning at the mega-regional scale.

2. The Mega-region as a Global Concept and a China Practice

When Gottmann (1957) first coined the term Megalopolis to describe the almost continuous stretch of urban and suburban areas from Boston to Washington, its main NE-SW axis was about 600 miles long, and within the frame of which dwelt some 30 million people in 1950. The geography of this distribution of habitat is characterized by the coalescence of a chain of metropolitan areas, each of which grew around a substantial urban nucleus. Gottmann's work was enormously influential and, because of his work, the super-metropolitan character and the huge growth associated with the megalopolis become a focus of urban studies.

Following the megalopolis literature, mega-regions have been defined as the extended networks of metropolitan centers and the surrounding areas that include layers of relationships in environmental systems, infrastructure systems, economic linkages, settlement pattern and land use, and shared culture and history (CQGRD, 2006; Regional Plan Association, 2006). In the US, 10 mega-regions have been proposed by the Regional Plan Association (2006). They include the Northeast, Piedmont Atlantic mega-region, the Florida mega-region, the Gulf Coast, the Great Lakes, the Texas Triangle, the Cascadia, Northern California, the Southern California and Arizona Sun Corridor. Most of the rapid population growth, and an even larger share of its economic expansion, is expected to occur in these 10 or more emerging mega-regions, with each mega-region spanning multiple state and regional boundaries, and covering thousands of square miles. The increasingly linked metropolitan areas and the increasingly decentralized nature of the U.S. economy led the Regional Plan Association to promote the mega-region as a key framework for economic analysis and urban policies. Similar mega-regions have been identified in EU. Europe's largest mega-region spans Amsterdam-Rotterdam, Ruhr-Cologne, Brussels-Antwerp and Lille. Other mega-regions include the British mega-region, the Italian mega-region, Greater Paris and the Euro-Sunbelt mega-region (Florida, Gulden, & Mellander, 2008).

China's mega-regions, together with metropolitan cities, become the engine for economic development, and the target areas for regional and national policies. Apart from the three giant mega-regions—Capital Economic Zone, Pearl River Delta and Yangtze River Delta—which account for a large share of the country's economic output, several other inland mega-regions are also emerging and developing. These 10 mega-regions as identified by China's National Development and Reform Commission, cover around 20% of the total area of China, and include more than half of national population (census 2000 data) and 52% of GDP.

In addition, national and provincial policies have been proposed at the mega-region level. Mega-regional planning actions and collaborative planning efforts have already been proposed and started. For example, in recent years, three mega-regions have been designated as the Comprehensive Reform Pilot Regions:

- In 2007, Chuanyu mega-region was designated as the Comprehensive Reform Pilot Region for Urban-Rural Integration. The regional development of the Chuanyu mega-region is suffering severely from this dichotomy between urban and rural disparities, and this initiative aims to achieve a more balanced regional development pattern.

- In 2008, the Wuhan mega-region was designated by National Development and Reform Commission as the Comprehensive Reform Pilot Region for Energy-saving and environment-friendly Development. The region's central location in China, low cost of living, natural resources, highly connected transportation network and competitive innovation and technology base have helped make it the "Sunbelt" in China.

- The Liaoning mega-region has become the "rust belt" of China, and is burdened with a disproportionate share of outdated state-owned enterprises. In 2010, the Liaoning mega-region was designated as the Comprehensive Reform Pilot Region for Innovative Industrialization, aiming to achieve regional industrial revitalization and sustainable restructuring.

Given Chinese governments' deep involvement in mega-region development and planning, it is essential to clarify the connection between mega-region structure and its performance in economic development, environmental protection and social equity. According to Sassen (2007), one of the specific advantages of the mega-regional scale arises from the coexistence within one regional space sufficiently large and diverse as to accommodate a far broader range of types of agglomeration economies than any single metropolitan area typically does. By distributing economic activities across the mega-region, rather than concentrating them in a single metropolitan area, mega-region planning implies alternative spatial organization of economic activities.

Major cities in the mega-region should play a pivotal role and serve as growth poles in the region. The term 'growth pole' was introduced by Perroux (1950), and is defined as an economic center from which centrifugal forces emanate and to which centripetal forces are attracted. It is within those poles that economic growth and changes are initiated. Hirschman (1958) argues that the growth of developed regions may have both favorable trickling-down effects and adverse polarization impacts on the lagging areas. He believes that in the long run, the trickling-down effects will overpower the polarization effects. Friedmann (1972) proposed the core-periphery model, based on the analysis of the linkages between innovation and authority. Like the accumulative causation theory, Friedmann suggests that the dominance of core regions over the periphery tends to be self-reinforcing. However, the rising opposition of the periphery may lead to a sharing of authority or the replacement of the core areas, and this leads to the transformation of the structure of the spatial system.

At the heart of the evolving spatial structure, therefore, is the polycentric urban system, a notion that reflects a wide spectrum of spatial possibilities for an economic region. This concept has gained widespread currency in planning and territorial development strategies. The scale on which the concept is applied ranges from individual cities to regions, and even beyond national borders. A polycentric and more balanced system of metropolitan city regions is not just a descriptive term, but also a means to promote and equalize economic growth (Hague & Kirk, 2003).

However, Davoudi (2003) observes that as the scale increases, the concept of polycentricity becomes gradually less analytical. There is no clear and established definition and measurement of polycentricity at the mega-regional level. Therefore it is necessary to clarify the meaning and measurement of centers and "polycentricity" for mega-regions. The next section elaborates our approach to measuring mega-region polycentricity, using census 2000 data.

3. Measuring Mega-Region Polycentricity

Mega-regional boundaries do not necessarily follow political boundaries, which is a challenge for mega-region research. In this research, the boundary of China's ten mega-regions follows the most commonly accepted definition, which is listed below.

- **Capital Economic Zone**: the core centers of Capital Economic Zone are Beijing and Tianjin, surrounded by 8 cities from Hebei Pronvince, including Shijiazhuang, Baoding, Qinhuangdao, Langfang, Cangzhou, Chengde, Zhangjiakou, and Tangshan.

- **ChuanYu Mega-Region**: the core center of ChuanYu Mega-Region are Chongqing and Chengdu, surrounded by 13 cities from Sichuan Princince, including Zigong, Luzhou, Deyang, Mianyang, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Guan'an, Ya'an, and Ziyang.

- **GuanZhong Mega-Region**: the core center of GuanZhong Mega-Region is Xi'an, surrounded by Xianyang, Baoji, Tongchuan, and Weinan.

- **HaiXia West Mega-Region**: the core centers of Haixia West Mega-Region are Fuzhou and Xiamen, surrounded by Zhangzhou, Quanzhou, Putian, and Ningde.

- **LiaoNing Mega-Region**: the core centers of Liaoning Mega-Region are Shenyang and Dalian, surrounded by Anshan, Fushun, Benxi, Dandong, Liaoyang, Yingkou, Panjin, and Tieling.

- **Pearl River Delta**: the core centers of Pearl River Delta are Guangzhou, Shenzhen, and Hong Kong, surrounded by Zhuhai, Huizhou, Dongguan, Qingyuan, Zhaoqing, Foshan, Zhongshan, Jiangmen, and Macao.

- **ShanDong Mega-Region**: includes Jinan, Qingdao, Yantai, Zibo, Weifang, Weihai, Dongying, and Rizhao.

- **Wuhan Mega-Region**: the core center of Wuhan Mega-Region is Wuhan, surrounded by 14 cities from 3 pronvinces, including Huangshi, Ezhou, Huanggang, Xiantao, Qianjiang, Xiaogan, Xianning, Tianmen, Suizhou, Jingmen, Jingzhou, Xinyang , Jiujiang, and Yueyang.

- **Yangtze River Delta**: the core center is Shanghai, surrounded by 6 cities from Zhejiang Pronvince and 8 cities from Jiangsu Province. These cities include Hangzhou, Jiaxing, Huzhou, Shaoxing, Ningbo, Zhoushan, Nanjing, Yangzhou, Changzhou, Taizhou, Zhenjiang, Wuxi, Nantong, and Suzhou.

- **ZhongYuan Mega-Region**: the core centers are Zhengzhou and Luoyang, surrounded by 7 cities from Henan Province, including Kaifeng, Xinxiang, Jiaozuo, Xuchang, Pingdingshan, Luohe, and Jiyuan.

Among the above 10 mega-regions, six of them are in the coastal areas and four of them are in middle or western part of China. This research uses the prefecture level city boundary as the basis when creating mega-region boundaries, which are shown as blue lines in Figure 1. This figure also includes counties or county-level districts, which are colored according to their population density. Table 1 lists land area, population, and population densities of each mega-region. The Yangtze River Delta has the highest population density (825 people/sq km). Among the ten mega-regions, LiaoNing has the lowest population density, which is 331 people/sq km.

Figure 1: Population Density by County (Census 2000 Data)

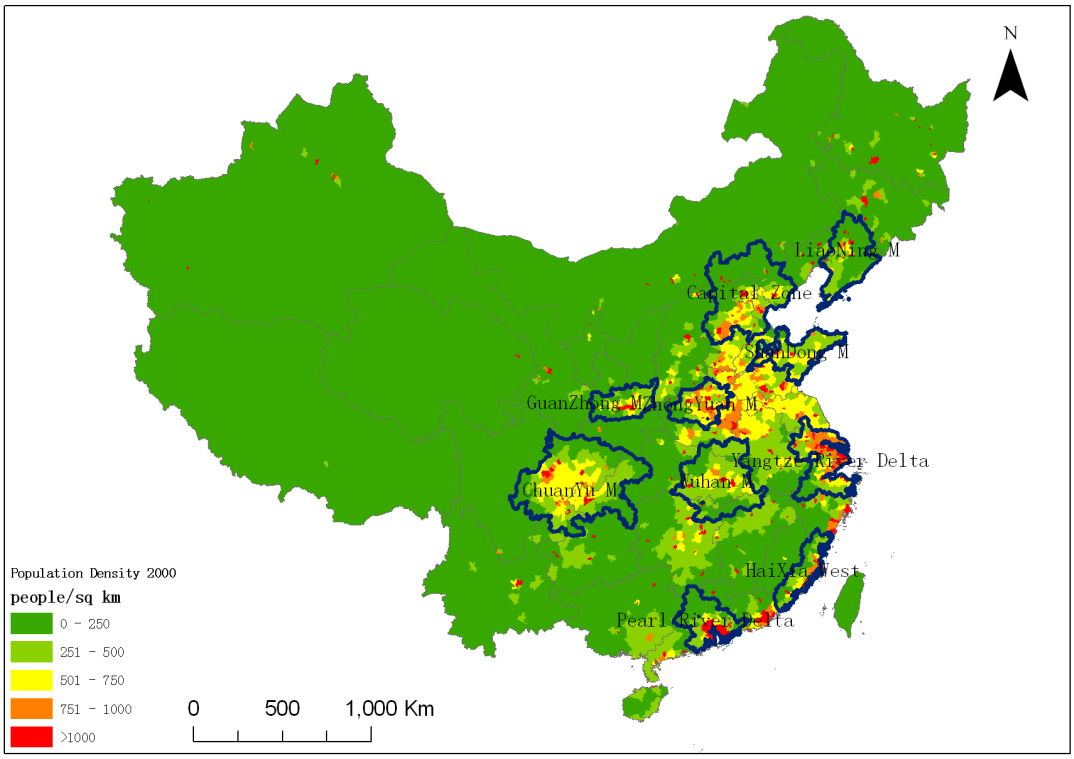


Table 1: Area, Population, and Density of Each Mega-Region (Census 2000 Data)

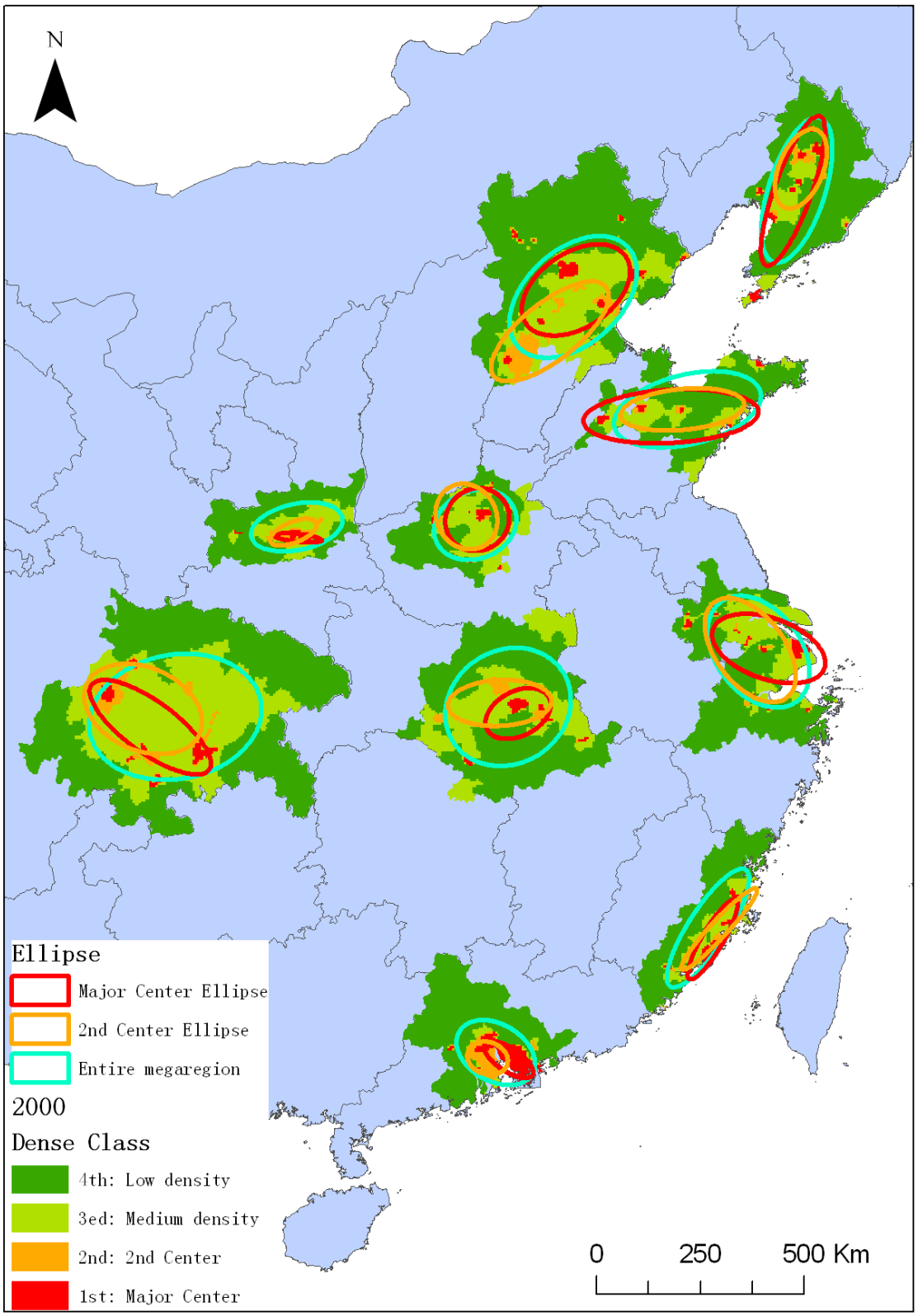
Mega Regions	Area (thousand sq km)	Population (million)	Average Density (ppl/sq km)
Capital Economic Zone	181	70.6	391
ChuanYu Mega-Region	267	105.5	395
GuanZhong Mega-Region	56	21.7	390
HaiXia West Mega-Region	52	24.4	465
LiaoNing Mega-Region	90	29.6	331
Pearl River Delta	73	50.2	691
ShanDong Mega-Region	70	38.9	558
WuHan Mega-Region	147	58.5	397
Yangtze River Delta	93	76.7	825
ZhongYuan Mega-Region	58	37.5	642

Analysis of mega-regional polycentric structure should take into account the different density characteristics of individual mega-regions. In particular, the definition of economic centers should adopt different density standards in different mega-regions. We compare the population density of each county with its mega-regional average density (Table 1) to define whether this county can be classified as part of a mega-regional center. From this perspective, we divide all component counties in each mega-region into four categories.

- **1st class** is the **main center** of mega-regions. Counties with population densities higher than three times of mega-regional average density are defined as mega-regional centers.
- **2nd class** is the **second-tier center**. Counties with population densities between two times and three times of their mega-regional average densities are classified into this category.
- **3rd class** is the **medium class**. Counties with population densities between mega-regional average density and two times of their mega-regional average densities are classified into this category.
- **4th class** is the **low density** class. Counties with population densities lower than their mega-regional average densities are classified into this category.

The GIS spatial statistics tool—Directional Distribution: Standard Deviational Ellipse—is utilized to measure the spatial distribution of different density classes for individual mega-regions. We calculate four ellipses, separately for the first class, the second class, the two classes combined and all classes combined. We first tried to use counties as the component analysis units. Problems were encountered with this approach due to inaccurate geographic boundary in the GIS dataset. Some of the smallest counties (urban districts) have extremely high population densities. Because of their small areas, boundary inaccuracy would cause relatively large error for some of the smallest counties. In order to control this problem, a 5km x 5km grid layer is overlaid and intersected with the county level polygon layer, and then the county level population was reassigned to grids, with each grid inheriting the population density characteristics from its intersecting county. The smallest counties (urban districts) were either completely contained in or split by the grids. The extreme population density values are then flattened. Figure 2 shows the density classes and three ellipses for each mega-region.

Figure 2: Density Classes and Ellipses for Mega-Regions



A key proposition here is that: a mega-region of higher polycentricity should have multiple mega-regional centers and those centers should be spatially distanced from each other to maximum access to economic centers throughout the region. Mapping this proposition to the statistic measure, the standard deviational ellipses of the high density classes (1st and 2nd classes) in a more polycentric region should resemble the standard deviational ellipse for the whole mega-region more closely. If we calculate the ratio of the area of the ellipse of the 1st class to the area of the ellipse of all densities classes, this ratio should typically range from 0 to 1, as high density centers tend to be more geographically concentrated than low-density areas. In addition, a region of higher polycentricity should have a higher ratio.

We calculated three ratios based on varied definition of mageregioal centers.

- Major center polycentricity = $\frac{\text{Ellipse area of 1st center class}}{\text{Ellipse area of all classes}}$
- 2nd center polycentricity = $\frac{\text{Ellipse area of 2nd center class}}{\text{Ellipse area of all classes}}$
- Combined center polycentricity = $\frac{\text{Ellipse area of 1st and 2nd classes combined}}{\text{Ellipse area of all classes}}$

The following table lists polycentricity scores for the 10 mega-regions. Those scores vary significantly from one region to another. We will comment on individual scores in the next section. Note that our score calculation has the following characteristics: 1) centers are defined with normalized density, which helps control the variation of the mega-regional average density; 2) scores are calculated as a ratio, which helps control for the size of the mega-region. One would expect that the polycentricity scores should not be systematically correlated with the land and population size and the density of the mega-region. This is confirmed by a correlation analysis.

Table 2: Polycentricity Scores (Census 2000)

Mega-Region	**Main Center Polycentricity**	**2nd Center Polycentricity**	**Combined Polycentricity**
Capital Economic Zone	0.64	0.58	0.73
ChuanYu Mega-Region	0.34	0.47	0.44
GuanZhong Mega-Region	0.08	0.24	0.20
HaiXia West Mega-Region	0.36	0.35	0.40
LiaoNing Mega-Region	0.69	0.43	0.68
Pearl River Delta	0.27	0.27	0.34
ShanDong Mega-Region	0.89	0.49	0.82
WuHan Mega-Region	0.21	0.32	0.28
Yangtze River Delta	0.68	0.78	0.72
ZhongYuan Mega-Region	0.70	0.70	0.71

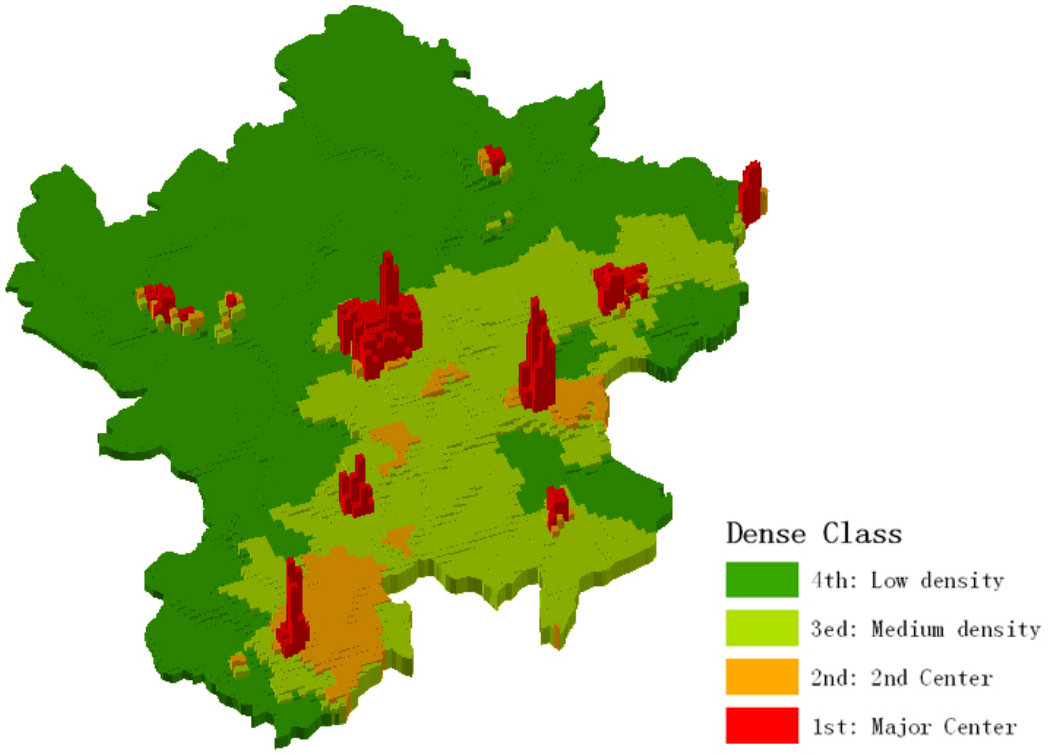
4. Spatial Structure of Mega-Regions

In order to help make sense of the above scores, this section examines the spatial structure of six mega-regions in relative detail. They include the three biggest mega-regions and the three pilot regions mentioned in section 2.

4.1 Capital Economic Zone

The Capital Economic Zone has a major center polycentricity index of 0.64, which ranks fifth among the 10 mega-regions. It has several major mega-regional centers, including Beijing, Tianjin, Tangshan, Shijiazhuang, Zhangjiakou, Qinhuangdao, Chengde, and Cangzou. These major centers are located throughout the mega-region (Figure 3). However, Beijing is the dominating center for Capital Economic Zone, and the sizes of other major centers are not comparable to the size of Beijing. Therefore, although these major centers scatter throughout the region, the whole mega-region manifests only a modest level of polycentric pattern. The second-tier center polycentricity index (0.58) is slightly lower than the main center index, and ranks the third. Tianjin and Tangshan are the two dominating second-tier centers. In addition, there are a few smaller-sized second-tier centers which are concentrated in the southern part of the mega-region. Therefore the second-tier center polycentricity index is also only at a modest level.

Figure 3: 3D Density Map for Capital Economic Zone

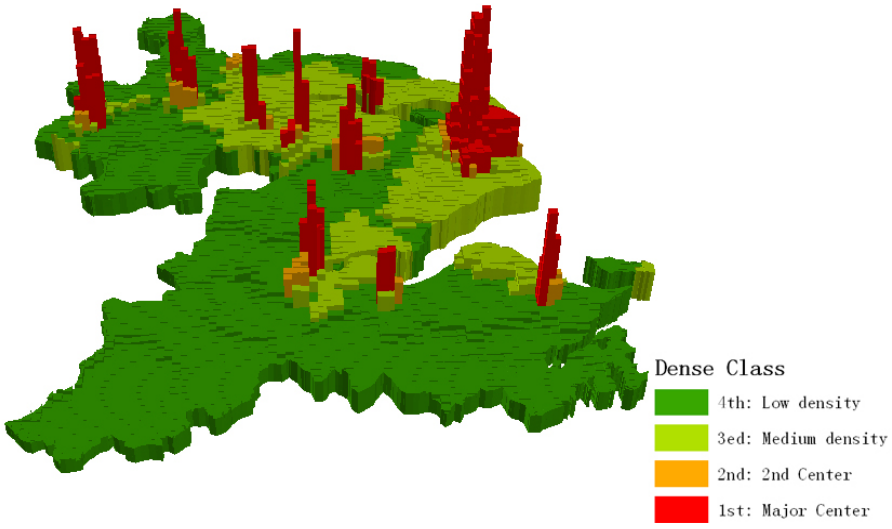


4.2 Yangtze River Delta

The Yangtze River Delta has the highest population density among the 10 mega-regions—825 people per sq km. Therefore, the mega-regional centers and second tier centers of Yangtze River Delta have higher population density compared to other mega-regions.

Yangtze River Delta has the similar major center polycentricity index (0.68) with Beijing. It has several major centers, including Shanghai, Nanjing, Hangzhou, Suzhou, Wuxi, Yangzhou, Ningbo and Shaoxing (Figure. 4). Similar to Beijing, Shanghai is the dominating Center of Yangtze River Delta, and the remaining main centers are relatively small in size. However, unlike the Capital Economic Zone, the second-tier centers are of similar sizes, and are scattered throughout Yangtze River Delta. Therefore the second tier city polycentricity index (0.78) is higher than its main center index, and ranks first.

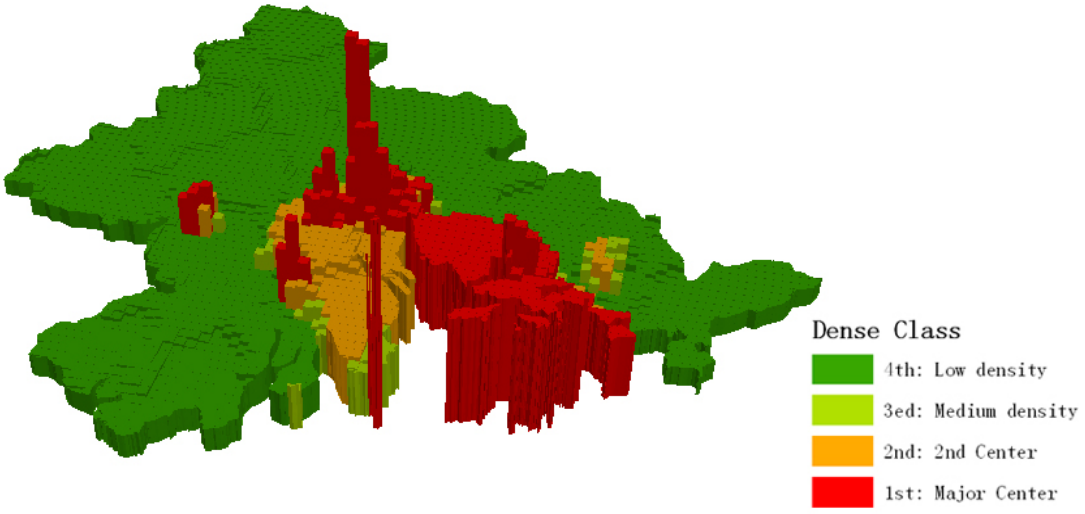
Figure 4: 3D Density Map for Yangtze River Delta



4.3 Pearl River Delta

The population density of the Pearl River Delta is 691 people per sq km, which ranks second among the 10 mega-regions. The Pearl River Delta has a very low major polycentricity index (0.27). This can be explained by the fact Guangzhou, Foshan, Shenzhen and Hong Kong cluster together to form the agglomerated major center of the Pearl River Delta (Figure 5). The second-tier center polycentricity index (0.27) is the same with the major center polycentricity index. Most of the second tier cities cluster around the major centers. Jiangmen, Zhongshan and Zhuhai are the dominating second-tier centers, which have developed into a continuous stretch connected with the major centers.

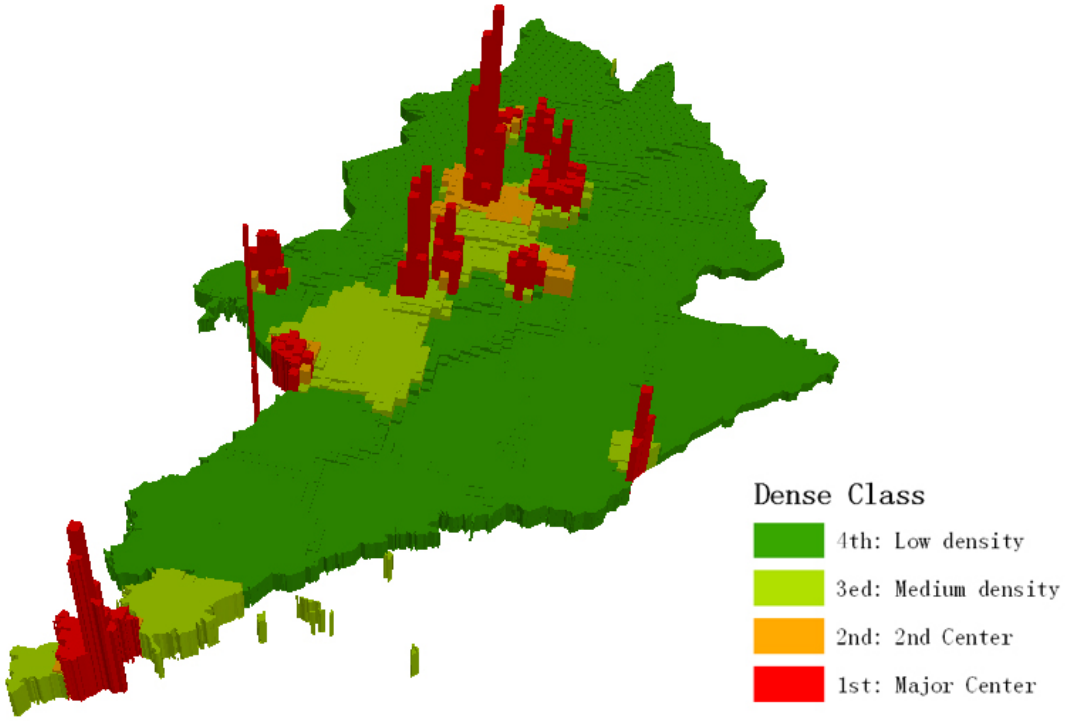
Figure 5: 3D Density Map of Pearl River Delta



4.4 LiaoNing Mega-Region

The Liaoning mega-region has the third highest major center polycentricity index (0.69) among the 10 mega-regions. There are several major centers scattered within the Liaoning Mega-Region, and the sizes of these major centers are comparable to each other without any one dominating the whole region (Figure 6). The second tier center polycentricity index (0.43) is not as high as the major center polycentricity index. This is due to the fact that despite the several second-tier centers throughout Liaoning Mega-Region, large areas of the second-tier center counties are located around Shenyang metropolitan area. Although several smaller areas outside Shenyang are also classified as second-tier centers, they are not comparable to those of Shenyang.

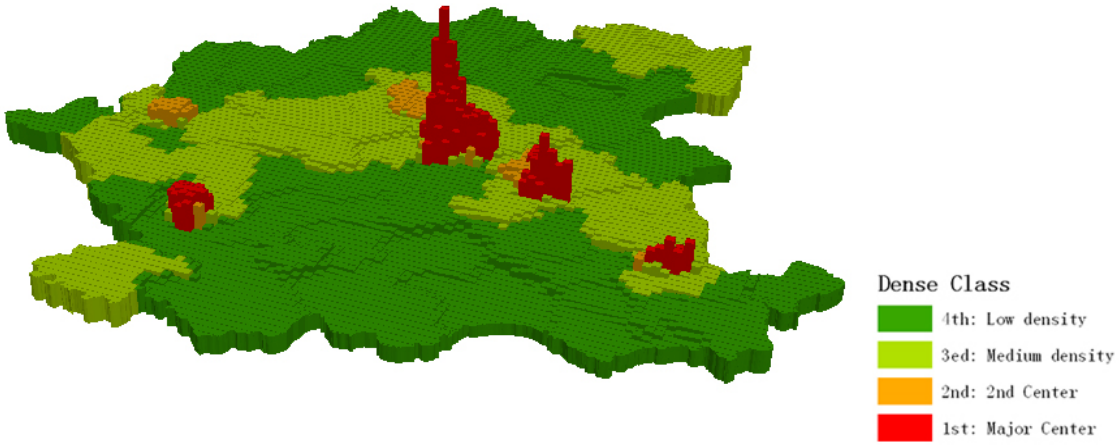
Figure 6: 3D Density Map for LiaoNing Mega-Region



4.5 Wuhan Mega-Region

The Wuhan mega-region's population density is 397 people/sq. km, which ranks fifth among the ten. It has a low major center polycentricity index of 0.21. Wuhan is the dominating center within this mega-region. Although there are several other major centers at the periphery of the mega-region, their sizes are small (Figure 7). It also exhibits a low second-tier center polycentricity index of 0.32. The second-tier centers include Xiaogan, Huangshi, and Shashi, which are located in the central part of the mega-region. Therefore, the Wuhan mega-region exhibits very low polycentricity in terms of both major centers and second-tier centers.

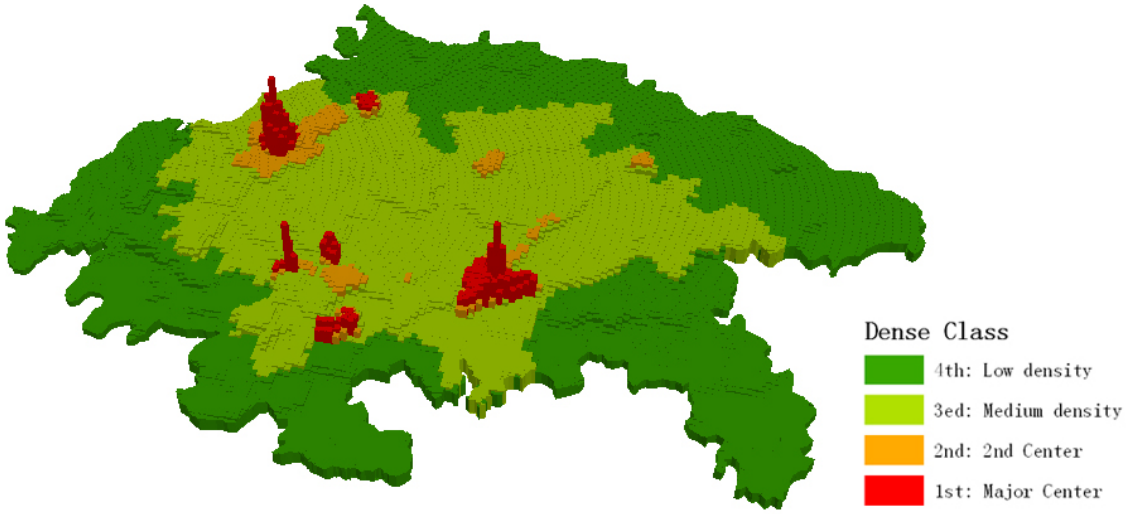
Figure 7: 3D Density Map for WuHan Mega-Region



4.6 ChuanYu Mega-Region

The Chuanyu mega-region has a relatively low population density of 395 people/sq. km. The density map shows that most of the population is concentrated around the Chengdu and Chongqing metropolitan areas, and Chengdu and Chongqing are the two dominating major centers for the region (Figure 8). Therefore, it has a relatively low major center polycentricity index of 0.34. Large, continuous areas surrounding Chengdu, and a few smaller places scattered throughout the mega-region are classified as the second-tier centers. Therefore, the Chuanyu Mega-region has a modest level of second-tier center polycentricity index of 0.47.

Figure 8: 3D Density Map for ChuanYu Mega-Region



4.7 Summary

A highly polycentric interurban spatial pattern at the mega-regional level matters not only from a morphological perspective, but also from an economic and functional perspective. Mega-regions are integrated sets of cities and labor and capital can be reallocated at relatively low cost across their surrounding suburban hinterlands. Administrative and political boundaries have become less important in economic terms. The ongoing fading of political barriers has tremendous economic implications for economic interaction (Baldwin and Venables, 1995).

Among the 10 developed and emerging mega-regions in China, only a limited number have exhibited a significant level of polycentricity. Around half of the ten mega-regions are either dominated by a single major center, or by a limited number of major centers which are located closely to one another. The polycentric patterns regarding the 2nd class centers are even less developed for the majority of these mega-regions. Most of these 2nd class centers are the outer areas of metropolitan areas classified as major centers. In addition, apart from the three most

developed giant mega-regions, large areas within the remaining mega-regions were still under-developed. The emergence and development process of China's mega-regions was at the initial stages at the beginning of the 21st century.

In China, the vertical and horizontal linkages across regions are not well established; functional integration at the mega-regional level is still inadequate; and there is a policy vacuum over cross-border issues and a lack of national vision. A spatially polycentric and balanced geographic pattern is the prerequisite for achieving an economically competitive and environmentally sustainable development trajectory. A mega-regional approach to planning has been identified as one of the key instruments to promote a more balanced regional and national development pattern in China.

5. Discussion

What should be emphasized here is the role of transportation investment in redefining the relative advantage of each part within a mega-region. This is especially so as higher mobility mode can play a significant role in influencing the spatial pattern of urban spaces and further enhance the polycentric spatial pattern. In China, high-speed railways, highways, airports and other traditional transportation modes have been used to establish greater links between cities within and between mega-regions. For example, in the Wuhan Mega-Region, the objective of a "2 hour commute radius" from Wuhan to other cities in the same mega-region has been realized, and the "one hour commute radius" goal for mega-region transportation planning is to be achieved in the near future. This involves the construction of new highways and bridges, the upgrading of conventional rail lines and motorways, and upgrade and extension of existing urban rail system. In the Liaoning mega-region, a 400 kilometer highway system connecting cities within is being constructed, and some sections have already been opened; public transit services (bus and urban rail) connect the core city—Shenyang, and other cities within it have also been strengthened. For mega-regions, the completion of mega-regional transport systems will strengthen connections between cities of the region and cut travel costs between cities (Yang, et al 2011b).

Improved transportation infrastructure could bring development opportunities to some of the second-tier centers and help them grow into major centers. Some areas currently classified as non-centers may also grow into major or second-tier centers. Improved mega-regional transportation infrastructure could contribute to a more balanced spatial pattern of population and economic activities.

The key challenge is to explore and identify the potential instruments to promote a more polycentric mega-regional spatial pattern and truly balanced regional competitiveness. The linkages of transportation investment and urban development have long been recognized. It

remains to be seen in how and to what extent transportation investments have impacted the formation and evolution of mega-regional spatial patterns. Future research should aim to understand and model the dynamics of mega-regional spatial patterns, for example by looking into multi-year spatial pattern shifts from 1980's that may allow us to single out the impacts of transportation investment. As mentioned before, at the beginning of the 21st century, China's mega-regions entered the initial stages of development. Therefore, deeper understanding of the implications of transportation investments for the formation and growth of mega-regional spatial pattern will inform future planning actions.

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