

The Identification of Developmental Pattern of Urban Agglomerations in China based on GIS

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Abstract. Urban agglomeration is an advanced spatial organization form that occurs when urban areas develop into a certain mature stage, and is regarded as the main form of new urbanization strategy in China. Nevertheless, the past few years have witnessed an acute shortage of research on urban agglomeration's dynamic evolution at large scale and over multiple periods. This shortage has aroused widespread concern about how to scientifically and quantitatively identify the developmental boundary of urban agglomeration, and this remains an urgent scientific issue to be solved. Following the objective logic of urban development and evolution, metropolitan area is the basic component unit of urban agglomeration, while joint metropolitan area, quasi metropolitan interlocking region and metropolitan interlocking region are the main types of urban agglomeration. With the aid of GIS, this paper identified the developmental pattern of urban agglomeration in virtue of socio-economic indexes such as urban population, urbanization rate, per capita GDP, the proportion of non-agricultural GDP/employment, economic density and population density of 2858 county-level administrative units in 2010. As the result showed, there were 325 metropolitan area units among 657 cities, including 239 big central cities, 86 small central cities and 196 peripheral compliant counties. The overall pattern of urban agglomeration was formulated by 156 metropolitan areas, 25 joint metropolitan areas, 3 quasi metropolitan interlocking regions and 3 metropolitan interlocking regions. In the future, in consideration of the evolutionary trend of urban agglomeration and the guiding role of national economic spatial structure, China will form one giant metropolitan interlocking region, two large-scale metropolitan interlocking regions, five metropolitan interlocking regions, seven quasi metropolitan interlocking regions, which together forming a spatial developmental pattern including fifteen key urban agglomerations.

1. Introduction

Urban agglomeration is an advanced spatial organization form bearing both the national economic and social strategy. Nobel laureate in economics Joseph E. Stiglitz regards urbanization in China and

high technology in USA as two important events mostly influenced the process of human for the twenty-first Century. On the one hand, the speed and scale of urbanization in China has already exceeded any developed countries. Nowadays, about 15 million people from rural countries transform to urban population every year, which pushes the urbanization rate in China to 58.52% in 2017. As the data showed, it only took 27 years for china to lift the urbanization rate from 20% to 50%, which was around twice as fast as western developed countries on average. On the other hand, the urban agglomeration has been the dominant form in the process of urbanization in China. With the rapid development of science, technology, transportation and communication, it presents a grand picture that modern urban function expands to a broader area gradually and regionalization trend of urbanization appears. At the same time, the connections and influences between cities have been more and more intense and different sizes of cities in a certain geographical range interweave with each other to become urban agglomeration, which occupy the key position in the global urban system and become a brand new geographical unit participating in the global competition and international division of labor.

Urban agglomeration contributes to increasing economic efficiency, promoting knowledge centralization, and improving energy efficiency, which is a rather suitable spatial scale for implementing regional sustainable development policies [1]. As an excellent example, eleven urban agglomerations (metropolitan areas) in northeast coast, Midwest, south of California, the Gulf of Mexico in USA aggregate 80% big cities (population > 1 million) and are home to 197 million people, almost accounting for 68% of national total population. According to the world development report 2009 (World bank), as giant functional areas with high density, short distance and shallow segmentation emerge, these years have seen a widespread phenomenon that urban agglomerations were centered on large cities that are orderly arranged and divided by labor cooperation[2]. It's without saying that urban agglomeration is the most dynamic and potential core growth pole in the field of economic development in the future[3]. Therefore, the "12th Five-year" plan for national economic and social development put forward policy as follows. According to the principle of unified planning, rational layout, perfecting functions and pushing forward the small ones by developing the big ones, and following the objective rules of urban development, depending on big cities and focusing on small cities, gradually forming urban agglomeration with radiation effects and foster the coordinated development of large, middle and small cities as well as small towns. President Xi's report at 19th Party Congress further pointed out clearly that we should strive for the urban pattern of coordinated development both large and medium-sized cities as well as small towns with urban agglomeration as the strong emphasis. As an essential spatial carrier of urbanization, urban agglomeration has been the focus of national regional policy. In response, the local governments have carried out a large number of planning practice focused on urban agglomerations. It is roughly estimated that except from Qinghai Province, Tibet Autonomous Region and a few other provinces and cities have organized 54 urban agglomeration plans one after and other [4]. Exclusion of some urban agglomerations overlapped spatially, there are at least 23 urban agglomerations that are well known to the public and discussed in academic fields. What's most discussed is that governments at all levels lack unified standards, tend to be arbitrary, often ignore the growth and evolution tend of urban agglomeration and transcend the stage of development when determining the planning scope. It's without hard work to find the underlying reasons. For one thing, urban agglomeration is a kind of dynamic space with vague boundary and different radiation range. For another, the concept of urban agglomeration itself remains many disputes in the academic fields and even views on the same urban agglomeration may also differ. Also, identifying the growth boundary dynamically and reflecting on the planning scope of urban agglomeration are the basic premises for: (1) Theoretically analyze and deepen the academic research in urban agglomeration. (2) Scientifically predict and plan for the urbanization process.

2. Methodology

2.1. Definition and concept

The definition of urban agglomeration hasn't been in a robust consensus both at home and abroad. The foreign terms related to urban agglomeration are as follows, Megalopolis [5], Town Cluster [6], Courbation, Urban Agglomeration [7], Metropolitan Area [8], Desakota [9] and so on. While in China, the corresponding terms are as follows, Urban Concentrated Region, City-and-Town Concentration Area [10], Metropolitan Area, Metropolitan Interlocking Region [11], Metropolis [12] and so on. After comprehensive consideration of various expressions and analyses of relevant concepts, this paper deems that the most common and essential characteristics of urban agglomeration lie in three aspects, that is, the centralization of national elements, the decentralization of regional elements and the connection between cities. Besides, it's noteworthy that metropolitan area is the basic and indispensable component unit of urban agglomeration. Accordingly, this paper is oriented towards the evolution of urban agglomeration, which ranges from built-up area, municipal district, metropolitan area, joint metropolitan area (or metropolis) to metropolitan interlocking region. To be more specific, the built-up area is physically built area within a certain city, the municipal district is a kind of urban region under the administrative jurisdiction of a single government, the metropolitan area is the basic functionally component unit of urban agglomeration, which links the urban and rural closely together, and finally the joint metropolitan area and metropolitan interlocking region are the primary forms of urban agglomeration. From the perspective of spatial scale, metropolitan area is generally the extended linkage area of urban and rural 50 km away from the built area. Moreover, the joint metropolitan area covers an area with a radiation radius of 100 km and the quasi metropolitan interlocking region covers an area closely linked with a radiation radius of 200 km. The most advanced form, metropolitan interlocking region covers an extended area with a radiation radius of 300 km. In the wake of economic development to a certain extent, the centralization of non-agriculture industry and other urban functions commences exerting an ever-growing impact on the surrounding areas, leading to high social and economic ties between the central city and the surrounding areas to a certain range. On the basis of tied connections, a new form bearing the intention of integration called Functional Urban Regions [13] thus comes into being with sharing of resources, environment and infrastructure as well as close relevancy of industrial economic activities. Functional urban regions are composed of the core city and its surrounding areas which maintain close relationship with the core city, providing basic functions like residence, employment, shopping, medical care and recreational activities [14]. Joint metropolitan area is highly connected intercity area which is made up of several coterminous metropolitan areas with tied social and economic connections. Following this logic, joint metropolitan area is the component unit of metropolitan interlocking region. Metropolitan interlocking region is a giant urban and rural integration area cored on several big cities, develops along transportation corridors and maintains strong interaction in social and economic ties with surrounding areas [15]. For one thing, metropolitan interlocking region itself is the result of spatial concentration of various physical and non-physical elements. For another, metropolitan interlocking region is also the phenomenon presented in the stage of gradually dispersed development instead of absolute concentration during the process of urbanization. Concentration goes hand in hand with the function of hub and incubator, while the dispersion is the reasonable logical extension of incubator. Thus, the dual processes of concentration and dispersion strengthen the regional poly-centric structure and render continuous impetus for the metropolitan area. Exactly in such a continuous and dynamic process under the dual interaction power of concentration and dispersion in the urban region as the core of social life, the function of hub and incubator mutually promotes each other and develops unceasingly, thus forming the metropolitan interlocking region.

2.2. Data sources

The research is bounded by mainland China territory (Hong Kong, Taiwan and Macao temporarily excluded owing to the acquisition of data) and the research subjects includes 283 prefecture-level cities and 2003 county-level administrative units (municipal district excluded). The statistical scope for cities (administrative level above prefecture) is municipal district. Meanwhile, the main data sources derives from China County Statistical Yearbook, China City Statistical Yearbook, China Statistical Yearbook for Regional Economy and the Sixth National Population Census. To be more discreetly academic, the statistic of urban population is subject to statistic caliber of Sixth National Population Census.

2.3. Standards and procedures

As the basic component unit of urban agglomeration, metropolitan area is the foundation when identifying the growth boundary of urban agglomeration. Furthermore, the essence of identifying metropolitan area is that metropolitan area consists of central cities and peripheral counties. Drawing lessons from related researches, this paper brings forward standards to define central cities and peripheral counties which are suitable for China: (1) Central city. Based on the general recognition of metropolitan area and in consideration of densely populated conditions, this paper also learns from metropolitan statistical area in America, which divides metropolitan area into micro metropolitan and macro metropolitan on account of central city's population scale. With above preparations, this paper ultimately determines the threshold population of central city at 200000. More specifically, to be central city, the population of municipal district of prefecture-level city should be above 200000 or the urban population of county-level city should be more than 300000. Among them, the municipal district of prefecture-level city which lives more than 500000 people is identified as big central city. Similarly, the municipal district of prefecture-level city which lives between 200000 and 500000 people or the county-level city which lives more than 300000 urban people is identified as small central city. (2) Peripheral county. The county or county-level city is identified as compliant county unit if meeting the needs of the following indexes. The urbanization rate, per capita GDP (reference to the division standard of middle stage of industrialization by United Nations and Hollis B. Chenery), the proportion of non-agriculture in GDP, the proportion of non-agriculture in employment, the density of population must be more than 40%, ¥15000, 80%, 60% and 200 people/km² respectively. Broken down further, compliant county directly or indirectly adjacent to the central city is identified as adjacent compliant county. In case one county (or county-level city) can be divided into two metropolitan areas simultaneously, the principle of administrative divisions should be applied to determine which metropolitan area it should belong to.

Two or more metropolitan areas adjacent to each other spatially constitute a joint metropolitan area. When developing to a relatively mature and large scale stage, joint metropolitan area evolves into the phase of metropolitan interlocking region. Statistically, on the basis of definition for joint metropolitan area and relevant standards, this paper selects metropolitan interlocking regions from joint metropolitan areas by indexes like population, population density, economic density, urbanization rate and so on. To be specific, the standards of definition are as follows: at least two joint metropolitan areas with one extra-large city holding over 2 million people, at least 500 people/km² in population density, at least 15 million in total population and ¥25 million/km² in economic density. Accordingly, this paper further divides satisfactory areas into two types. For those whose population is over 2 million and economic density is more than ¥60 million/km², this paper identifies them as metropolitan interlocking regions. For the rest, this paper identifies them as quasi metropolitan interlocking regions which are in between.

3. Results

In line with technique standards and procedures, this paper obtained the overall developmental pattern of metropolitan areas in 2010 (Figure 1). As the result showed, there were 325 central cities (totally 657 cities) including 239 big central cities and 86 small central cities, 228 compliant counties (or county-level cities) including 196 peripheral counties (or adjacent compliant counties) and 32 non adjacent compliant counties. Based on the division of metropolitan areas, this paper recognized 156 metropolitan areas (including 135 metropolitan areas without peripheral counties and 21 relatively mature metropolitan areas with peripheral counties), 25 joint metropolitan areas (or metropolis), 3 quasi metropolitan interlocking regions and 3 metropolitan interlocking regions, collectively forming an overall developmental pattern of urban agglomerations during the rapid urbanization process. There were 31 urban agglomerations in all if considering the geographical units ranking above joint metropolitan area as urban agglomerations, totally occupying 0.5977 million km², 0.495 billion people, 0.342 billion urbanites and ¥25.82 trillion of GDP. In terms of percentage, they accounted for 36.93% of the total population, 51.46% of the urban population and achieved 64.87% of the national GDP with only 6.23% of the national territorial area. The average economic density was ¥43.2 million/km², which was 10.41 times as many as the national average level.

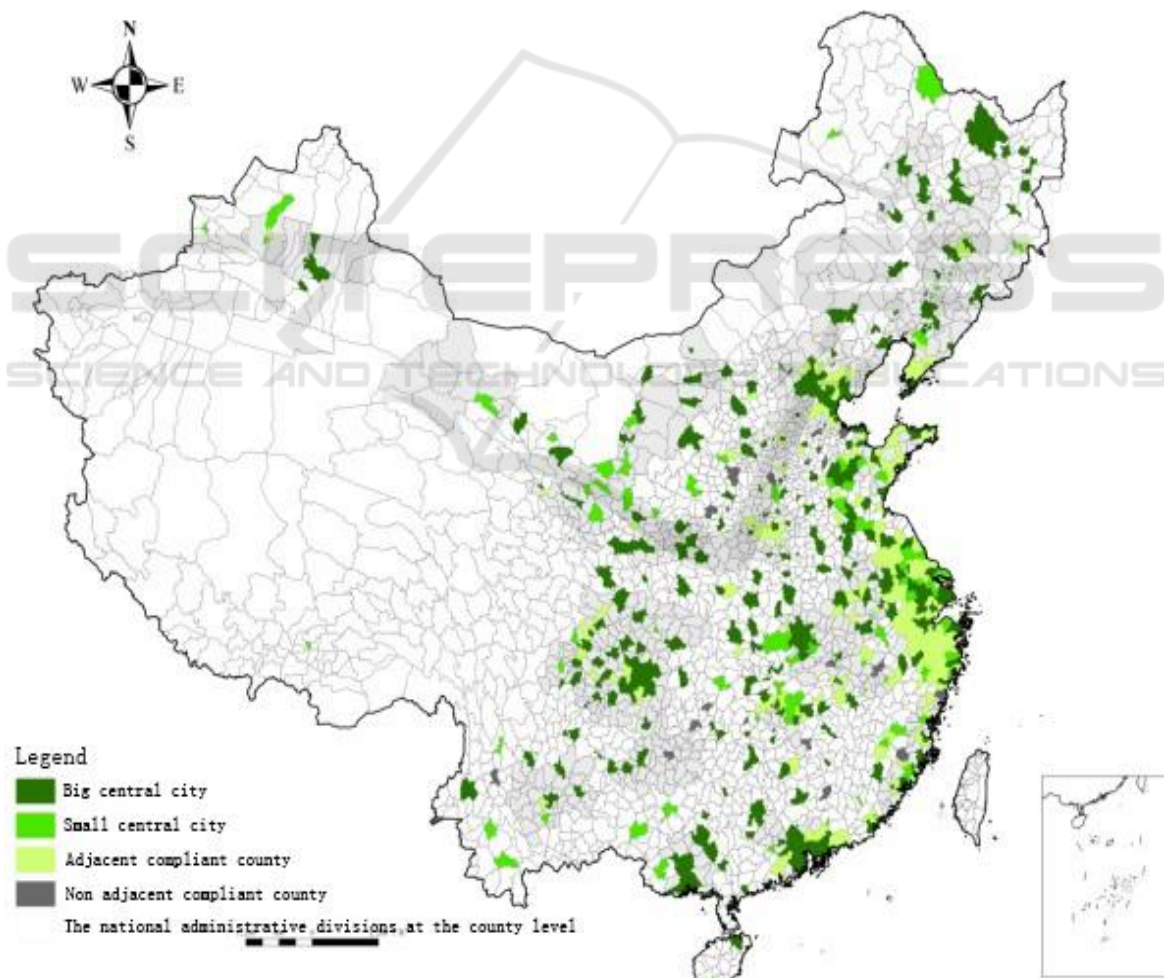


Figure 1. The distribution of metropolitan areas in 2010.

(1) The urban agglomerations centralized in eastern region while distributing dispersedly in central and western region, expressing obvious regional distribution difference. Three metropolitan interlocking regions were all located in the eastern coastal area and three quasi metropolitan interlocking regions spread over eastern, central and western China. As for joint metropolitan areas, there were 12 in eastern China, which accounted for 46.06%, 47.42% and 51.08% of entirely 25 joint metropolitan areas in terms of total area, urban population and GDP. As for the central China, there were 7 joint metropolitan areas, which accounted for 25.65%, 27.98% and 29.96% of entirely 25 joint metropolitan areas in terms of total area, urban population and GDP. Speaking of the western China, there were 6 joint metropolitan areas, which accounted for 28.29%, 24.60% and 18.96% of entirely 25 joint metropolitan areas in terms of total area, urban population and GDP (Figure 2). The metropolitan areas in eastern China shared the attributes of high development degree, contiguous areas and close social and economic connection with peripheral counties, which also bred joint metropolitan areas across provincial borders such as Xuzhou and Nanjing. While in central China, the spatial development of joint metropolitan areas can't compete with those in eastern China, which mostly evolved around provincial capitals, important prefecture-level cities and county-level cities with relatively pleasing development conditions. In comparison, without enough metropolitan areas and undeveloped peripheral counties, the spatial development of joint metropolitan areas in western China (mainly derived from provincial capitals with exception of Sichuan and Chongqing) were the weakest.

(2) According to the evolution logic of metropolitan area, as the basic unit, its quantity and quantity increased step by step along with the economic and social development. Correspondingly, metropolitan interlocking areas grew gradually, whereas as the transitional form, the number of joint metropolitan area saw a phased characteristic of increasing first and decreasing later. The reason lies in that metropolitan areas had a tendency towards integration at the initial growth stage resulting in the increasing number of joint metropolitan areas, while the joint metropolitan areas tended to integrate into metropolitan interlocking regions constantly leading to the decreasing number of joint metropolitan areas at the late growth stage. In 2010, the population density of Jiuquan-Jiayu Pass, Yichun-Hegang and Sanming-Nanping joint metropolitan areas was less than 200 people/km², which was partially responsible for entering into the critical stage not compliant with the population definition standard. The rest 23 joint metropolitan areas grow relatively well with an average economic density of ¥24.33 million/ km², which were 5.87 times as many as the national average level.

(3) The urban agglomerations were chiefly distributed along the national transportation economic development zone. As it showed, three quasi metropolitan interlocking areas and three metropolitan interlocking areas were all located in the "T-shaped" economic development zone with four in eastern coastal development zone and three in the Yangtze River development zone, rendering the intersection point of the Yangtze River development zone and coastal development zone as the biggest metropolitan interlocking area in China and even in the world (Figure 2). In 2010, these six urban agglomerations carried 23.12% of the national population, 33.23% of the urban population, 46.62% of the national GDP and achieved an economic density of ¥ 80 million/ km² (19.12 times as many as the national average level) with an growth area of only 0.3326 million km² (accounted for 3.46% of the total national territorial area). The rest 23 joint metropolitan areas were all distributed along the "π-shaped" development zone with 12 in coastal area, 6 along Yangtze River and 6 along the Gansu-Lianyung Port-Lanzhou-Xinjiang railway line.

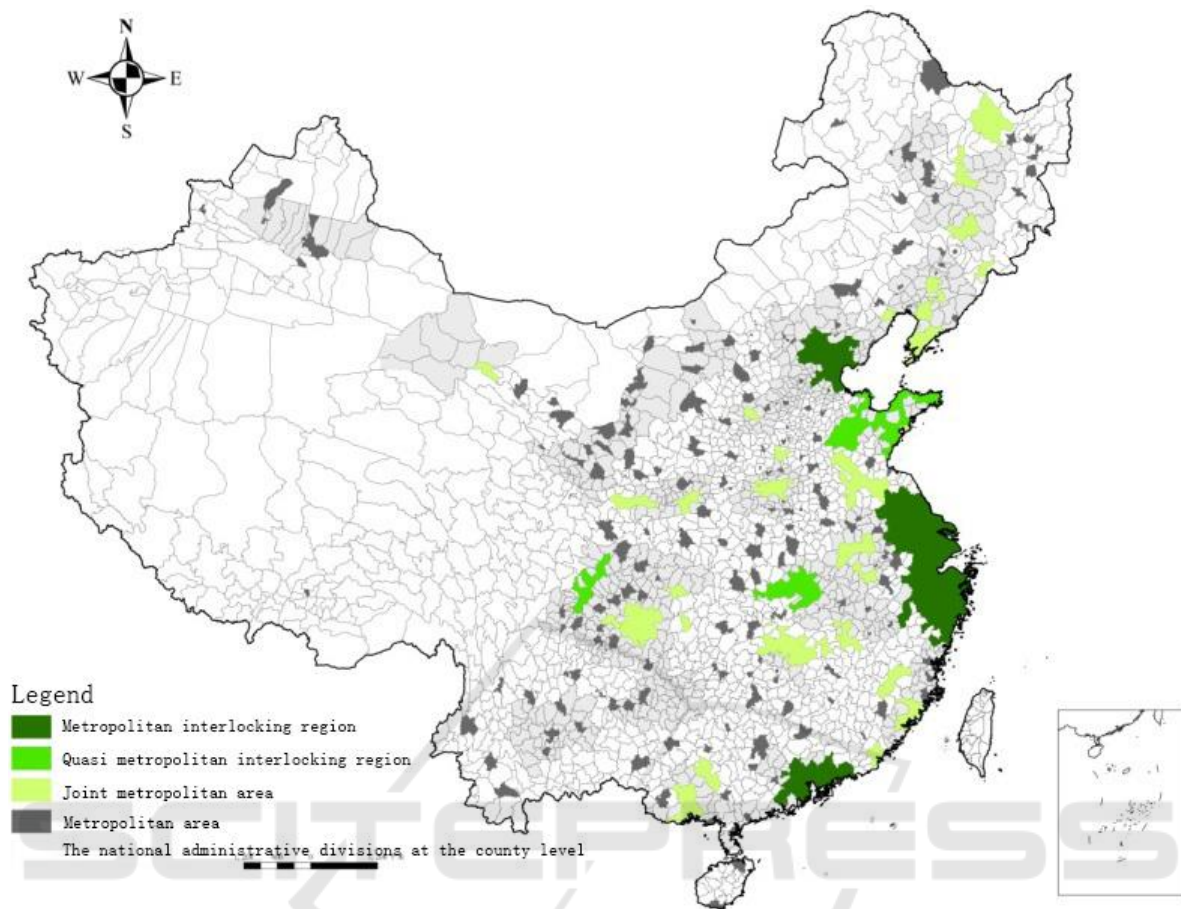


Figure 2. The developmental pattern of urban agglomerations in 2010.

4. Prospects

The strategic spatial pattern of economic development in China experienced the evolution trend from T-shaped structure, π -shaped structure and finally to three-vertical axes and two-horizontal axes structure, which in turn played a guiding role in the evolution of urban agglomerations' developmental pattern. The evolution track of metropolitan area in 2000-2010 has verified that the development axes are the important battle field and the most concentrated area for growth and development. Accordingly, on the basis of spatial strategic structure confirmed by Major Function-Oriented Zone Planning, this paper establishes a pattern for growth and evolution of urban agglomerations taking transportation corridor of Europe-Asia and Yangtze River as two horizontal axes and Coastal railway, Beijing-Harbin, Beijing-Guangzhou and Baotou-Kunming railway as three vertical axes. On the T-shaped development axis constituted by coastal line and Yangtze River, one giant metropolitan interlocking region, two large-scale metropolitan interlocking regions, three metropolitan interlocking regions and one quasi metropolitan interlocking region are to evolve and grow step by step. More specifically, they are major Yangtze River Delta giant metropolitan interlocking region, southeast coastal large-scale metropolitan interlocking region, Beijing-Tianjin-Hebei large-scale metropolitan interlocking region, middle reaches of Yangtze River metropolitan interlocking region, central and southern Liaoning metropolitan interlocking region, Chengdu-Chongqing metropolitan interlocking region and Beibu Gulf quasi metropolitan interlocking region.

On the economic development axis of Gansu-Lianyungang Port-Lanzhou-Xinjiang Land Bridge, one metropolitan interlocking region and two quasi metropolitan interlocking regions are to evolve and grow step by step. On the development axis of Baotou-Kunming, two quasi metropolitan interlocking regions are to evolve and grow. They are Hohhot-Baotou-Erdos quasi metropolitan interlocking region and central Yunnan quasi metropolitan interlocking region. In Northeast region, Changchun-Jilin-Tumenjiang belt-shaped quasi metropolitan interlocking region and Harbin-daqing-Suifenhe belt-shaped quasi metropolitan interlocking region are to evolve and grow around the Changchun-Jilin-Tumenjiang transportation corridor and Harbin-Daqing transportation corridor. Consequently, the developmental pattern for growth and evolution of urban agglomeration will be formed by 15 key urban agglomerations in the future, i.e. one giant metropolitan interlocking region, two large-scale metropolitan interlocking regions, five metropolitan interlocking regions and seven quasi metropolitan interlocking region.

Hefei and Xuzhou metropolises will integrate into Yangtze River Delta metropolitan interlocking region together, hopefully turning into the biggest giant metropolitan interlocking region in China and even in the world. It's speculated that Changsha-Zhuzhou-Xiangtan joint metropolitan area and Wanjiang metropolis will grow continuously before integrating into the Wuhan quasi metropolitan interlocking region, which will be expected to be the biggest middle reaches of Yangtze River metropolitan interlocking region in the central region. It's expected that Pearl River Delta will grow continuously with Xiamen-Zhangzhou-Quanzhou joint metropolitan area and Fuzhou metropolis in West-Straits Economic Area along the coastal channel, gradually turning into the large-scale metropolitan interlocking region in southeast coastal region. Stretching and growing along the Bohai Gulf comprehensive transportation channel both southwards and northwards and Beijing-Shijiazhuang transportation corridor southwards, Beijing-Tianjin-Hebei will mainly center its focus on Beijing, Tianjin, Tangshan, Langfang and Baoding, forming Beijing-Tianjin-Hebei metropolitan interlocking region. Dalian and Shenyang metropolis will grow continuously to become central and south Liaoning metropolitan interlocking region. Chengdu-Deyang-Mianyang-Guangyuan metropolis will come into being and interconnect and communicate with Chongqing quasi metropolitan interlocking region so as to become the biggest metropolitan interlocking region in the west region. As for joint metropolitan areas like Tianshui-Baoji, Central Plains and Zhengzhou-Kaifeng-Luoyang, they are likely to connect with each other through the Eurasian Continental Bridge, thus becoming the belt-shaped metropolitan interlocking region in the middle reaches of Yellow River.

5. Conclusions and discussion

To sum up, setting county-level administrative division as basic analysis unit and metropolitan area as basic component unit to identify the growth boundary of urban agglomeration brings about advantages like more accurate results, better comparability and dynamics. However, any method has its own limitations. The identification method based on growth boundary of urban agglomeration is vulnerable to interference of administrative division adjustment and misleading of statistical caliber, which may lead to the erroneous judgements like rapid growth momentum in some areas with frequent and intensive transition from county to district or city. In addition, the specific standards in classifying urban agglomerations are committed to certain degree of subjectivity because they are mainly determined by expert advice and related research parameters, causing lack of compatibility in relevant researches with different standards. Aiming at the existing drawbacks, the follow-up study is intended to focus on two key points. For one thing, it's better to seek the critical point of key indicators through the empirical analysis as the specific standards in classifying urban agglomerations. For another, from the perspective of transportation accessibility, cities' connection degree and construction degree, multi-dimension integration method and depiction of regional distribution degree and connection degree will be adopted to identify the growth boundary of urban

agglomeration based on data mining in nighttime light data, land use, traffic network and urban commuting data.

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