Analysis on the Evolution of Urban Spatial Patten in Bohai Rim Region in the Context of Regional Integration

Wang Mingli
Dai Hongweia
School of Economics of the Central University of Finance and Economics
Beijing, 100081

Wang Jue
Anhui Institute of Economic Research
Hefei, 230091

Abstract

Based on the previous studies on the evolution of urban spatial pattern using population indicators, this paper estimates the regional primacy and Zipf index of Beijing by combining several indicators such as economy (GDP), population (permanent population) and land (built-up area), and makes a comparative analysis on the changes of urban spatial pattern in the Bohai Rim region from 2002 to 2017 from different perspectives. It is found that in the process of regional integration in the Bohai Rim region, the population mobility is close to Zipf's law; however, the economic size tends to be concentrated in top cities and urban land area tends to be scattered, showing two contrary relative population mobility trends. Accordingly, this paper puts forward policy suggestions on promoting the coordination of economic factors, land area and population mobility, so as to enhance the efficiency of economic development.

Key words: Bohai Rim region, urban spatial pattern, urban primacy, Zipf index

I. Research Background and Practical Significance

Bohai Rim region refers to the vast economic region encompassing all the coastal areas surrounding the Bohai Sea and part of the Yellow Sea. In a narrow sense, the Bohai Rim region includes Beijing, Tianjin, Hebei, Liaoning and Shandong and can also be divided into Beijing-Tianjin-Hebei region, Shandong Peninsula and Liaodong Peninsula. In a broad sense, the Bohai Rim region extends to Shanxi and Inner Mongolia. In order to improve the direct relevance of regional samples, this study mainly focuses on the narrow Bohai Rim region. The Bohai Rim region has unparalleled advantage in geographical location. It is adjacent to the North Korea, South Korea and Japan in the east, borders the central and western regions in the west and the Yangtze River delta in the south, echoes Guangdong, Hongkong and Macao, and is close to Harbin-Changchun megalopolis, Mongolia and Russian Far East in the north, playing a unique role in connecting the East and the West and linking the North and the South. Over the past four decades of reform and opening-up, the Bohai Rim region has seen a sustained increase in regional GDP, a marked improvement in people's living standards, and increasingly growing development strength and foundation, with its advantages of superior geographical location, abundant human resources and perfect infrastructure. Because of its importance in economic, political and social development, the Bohai Rim region has always attracted much attention in the national regional patten. In 1986, the former State Development Planning Commission defined seven economic regions nationwide, one of which is the Bohai Rim region. In retrospect, the economic cooperation and development history of the Bohai Rim region can be roughly divided into the following four stages:

Exploration stage (1986—1991). In 1986, the former State Development Planning Commission defined seven economic regions nationwide, and the Bohai Rim region is one of them. In the same year, Tianjin, together with 15 coastal cities in the Bohai Rim region, established a regional economic cooperation organization—Mayors' Joint Meeting for Bohai Rim Regional Economic Cooperation. The related issues of the Bohai Rim region gradually became a topic of academic research. In 1987, Economic Outlook the Bohai Sea started its publication, becoming an important field for research on the economic development in the Bohai Rim region. During this period, there were lots of theoretical explorations, while few practices that really promoted the development of the Bohai Rim region.

Preliminary development stage (1992—2002). In 1992, the report of the 14th National Congress of the Communist Party of China set a goal of "developing and opening up the Bohai Rim region", and formally defined the concept of "Bohai Economic Rim", and the Ninth Five-Year Plan proposed to build the

Bohai Economic Rim centered on Liaodong Peninsula, Shandong Peninsula and Beijing-Tianjin-Hebei region, thus further enhancing the position and role of the Bohai Rim region in the nationwide regional layout. With the deepening of the reform of socialist market economy, the laws of market economy had played an increasingly important role in regional economic cooperation, and the market integration in the Bohai Rim region had been also greatly advanced. Meanwhile, the theoretical research system of the Bohai Rim was gradually formed. For example, Cao analyzed the formation and development of the Bohai Economic Rim[1]; Du and Li believed that the research on the Bohai Rim region should be strengthened from the aspects of industrial structure adjustment, infrastructure improvement, cooperation and coordination enhancement, etc.[2]; land use, industrial development and port system became research hotspots[3][4][5].

Accelerated development stage (2003—2015). In this stage, the Mayors' Joint Meeting for Bohai Rim Regional Economic Cooperation played an important role in regional cooperation, reached several consensuses, e.g., "Langfang Consensus" in 2004 and "Tianjin Initiative" in 2006, deepened the exchange and cooperation in key areas such as regional infrastructure construction, industrial cooperation planning and ecological environment protection, and greatly raised the level of cooperative development in the Bohai Rim region. Besides, the research on the Bohai Rim gradually increased and deepened. According to CNKI, the number of papers containing "Bohai Rim" in the title increased from 44 in 2003 to 155 in 2015, covering environmental governance, port transportation, economic cooperation and many other fields.

New normal stage (2015—). In October 2015, the National Development and Reform Commission issued the *Outline for the Cooperative Development of the Bohai Rim Region*, proposing to build the Bohai Rim region into a new engine for China's economic growth, transformation and upgrading, a demonstration zone for regional coordinated development innovation and ecological civilization construction, and an all-round open gateway for the Asia-Pacific region. At the same time, the Beijing-Tianjin-Hebei region, as the core of the Bohai Rim, has attracted lots of attention, and the coordinated development of the Beijing-Tianjin-Hebei region has become a major regional strategy of China. In March 2015, the Central Government reviewed and approved the *Outline for the Coordinated Development of the Beijing-Tianjin-Hebei Region*, formulated and implemented the "1+N" policy, and made a series of major moves to free Beijing from non-capital functions and promote the coordinated development of the three places, which effectively promoted the economic cooperation in the Beijing-Tianjin-Hebei region and accelerated the regional economic integration. As a result, substantial progress has been made in regional economic cooperation, reflected in close cooperation in many economic fields such as environmental protection, energy development and infrastructure, and regional development has entered a new stage. The Beijing-Tianjin-Hebei region is the core of economic and social development in northern China, and the key to the economic take-off in the Bohai Rim region. Therefore, it will be a growth pole in the future development of the Bohai Rim region. In the development of the three major economic growth poles of China, it will be of great strategic significance to accelerate the in-depth cooperation and promote the integrated development in the Bohai Rim region on the basis of the coordinated development of the Beijing-Tianjin-Hebei region, no matter from the perspective of economic volume, regional connection or practical need to promote the coordinated economic development of the northern and southern China.

II. Literature Review

The regional spatial distribution has never been balanced, from the central cities and suburban and rural areas in Thunnen's Isolated State Theory to the multi-level central place in Chris Taylor's Central Place Theory. The reason lies in the regional unbalanced growth.

(I) Unbalanced growth: a driver for regional development

Perroux, a French economist, proposed the growth pole theory, which holds that innovative enterprises gather in central cities and establish close cooperation relationship, so that central cities attract the production factors in the surrounding areas like "magnetic poles" and promote the economic growth of themself and other regions. Myrdal[8][9] proposed the circular cumulative causation theory, and believed that there are three effects in gradient development, namely polarization effect, spread effect and backwash effect, which together restrict the concentration and decentralization of regional production distribution. Besides, Myrdal held that economies of scale are an important advantage for the development of growth poles. On the whole, central cities at different ranks and in different sizes will eventually form in a region. However, because of the free mobility of factors among cities, the marginal output (price) of labor, capital and other factors among different cities should tend to be the same.

(II) Evolution model of regional spatial pattern

The evolution of regional spatial pattern is a point-line-plane process.

Sun[11] believed that a growth pole can speed up regional development and strengthen its influence with its polarization effect, and spread its influence to the whole region with the multiplier effect and spread effect, thus driving the development of the whole region. This is a point-centered growth pole model, which features point-point and point-plane echoing and finally forms the "point-axis-plane" development trend. Lu[12] found that in traditional landlocked countries like China, regional central cities were often established earlier, while port cities mostly emerged after port opening in modern times, and proposed a "center-port" dual-core development structure which leads regional economic development. This structure is particularly prevalent in the Bohai Rim region, such as Beijing-Tianjin, Changchun-Dalian, Jinan-Qingdao, Shijiazhuang-Cangzhou, etc. With the further regional economic development, "point-axis" will develop into "point-axis-cluster". Japan and western countries, which have earlier developed cities and mature urban systems, have seen various metropolitan interlocking regions such as urban agglomerations and megalopolises. According to Gottman[13], a metropolitan interlocking region is a region where city blocks are connected without obvious landscape differences between cities and villages, and in a metropolitan interlocking region, there should be at least 25 million urban population who live a modern urban life. According to the city light map, the core area of the Yangtze River Delta urban agglomeration in China has gradually developed into a metropolitan interlocking region, but the Bohai Rim region is still in the stage of "point-axis" driven development.

(III) City size distribution

The state of regional spatial pattern evolution is reflected in the size difference among central cities at different ranks. Specifically, primate cities, i.e., central cities at the highest level, usually have a variety of comprehensive and unique functions such as driving economic growth and exercising political functions, thus holding prominent position. In 1939, Mark Jefferson proposed the law of primate city[14], that is, the largest city in a country is always much larger than the second largest one, or even equivalent to the combination of several other cities. The relative size of the primate city is only a part of city size distribution. Auerbach believed that the city size distribution is very similar to Pareto distribution[15], and Zipf pointed out that the Pareto index of city size distribution should be equal to 1 according to Zipf's law[16], which was hailed as one of the most striking laws of new economic geography by Krugman[17]. Rosen, Gabaix, Eaton et al. proved the validity of Zipf's law by taking the urban distribution in the United States, France, Japan, Turkey and other countries as samples[18][19][20]. However, some scholars, such as Duranton and Eeckhout, held different views. They believed that there is a certain degree of deviation between the actual city size distribution and Zipf'slaw[21][22]. In the face of rapid urbanization in China, many Chinese scholars have also studied the law of city distribution. Chen et al. analyzed the law of city size distribution from the mathematical point of view, and found that city size distribution is a fractal[23]. In the empirical research in China, scholars come to different conclusions due to the changes of statistical caliber and city size. Song found that the data of Chinese cities in 1991 and 1998 fitted well with Zipf'slaw[24]. A study by Schaffar et al. showed that the city size distribution in China from 1984 to 2004 followed Zipf's law and the city size presented a divergent growth, while the growth of big cities slowed down, affected by the development policy of "controlling big cities"[25].

Anderson et al. pointed out that the city size distribution in China better fits with lognormal distribution, and urban growth shows an obvious convergent trend[26]. Xu et al. analyzed the dynamic evolution of China's city size distribution from 1990 to 2000, and found that the Zipf index deviated positively from 1, and the city size distribution tended to be even.[27] Based on Zipf's law, Liu et al. believed that the permanent population and GDP of the Yangtze River Delta urban agglomeration and the permanent population of the Pearl River Delta urban agglomeration have showed a diamond-shaped city hierarchy structure; the GDP of the Pearl River Delta urban agglomeration has showed a pyramid-shaped city hierarchy structure, nearly conforming to Zipf distribution and implying that the Pearl River Delta urban agglomeration has achieved Pareto efficiency in the spatial allocation of resources. The difference in industrialization stage is the cause for different Zipf index values of urban population between two major urban agglomerations, and the difference in marketization level is a key factor that determines the difference in economic size distribution between two major urban agglomerations[28]. So far, there have been many studies on the city size distribution of Beijing-Tianjin-Hebei region, Shandong Peninsula and other regions in the Bohai Rim[29][30][31], but few on the Bohai Rim as a whole, especially the comparative analysis on the changes in city size distribution before and after the integrated development policy of the Bohai Rim region was put forward.

III. Measurement Methods and Data Sources

(I) Measurement methods

1. Zipf index

Auerbach first found that the city size in five European countries and the United States is similar to Pareto distribution, and accordingly set its expression as follows:

$R_i=KP_i^{-q}$ (1)

Take the log of the both sides of the equation and convert the equation into:

$\log R_i=\log K-q\log P_i$ (2)

Where, P_i is the size of the city ranking i^{th}(ranking in descending order); R_i is the rank of the i^{th} city; K is a constant; q is the Zipf index. $q\rightarrow 1$ implies that the city size distribution is close to the Zipf's law, that is, the size of the largest city in a country is twice that of the second largest city, three times that of the third largest city, and so on; $0 < q < 1$ represents concentrated city size distribution, that is, high-ranking big cities are prominent, while small and medium-sized cities are underdeveloped. $q>1$ represents scattered city size distribution, that is, high-ranking cities are not prominent, and small and medium-sized cities are well developed.

Zipf index q is obtained using the ordinary least squares (OLS) estimation equation (2). The results of OLS estimation in a small sample size are biased. Besides, the city size ranking and regression may lead to autocorrelation among error terms, thus resulting in deviation of the standard error estimate of q. To solve this problem, Gabaix proposed a method to eliminate the deviation, that is, change the logarithm of the dependent variable R into the logarithm of (R-1/2). Empirical research shows that 1/2 is the optimal displacement, which can minimize the estimation deviation:

$\text{Log}(R_i-1/2)= \log K - q\log P_i$(3)

Add c to both sides of the equation (3) to get:

$\text{Log}(R_i-1/2)+ \log P_i= \log K -(q-1)\log P_i$(4)

Equation (4) can be used to test whether q significantly deviates from 1.

2. Primacy

The size of high-ranking cities, especially the primate city, is most important to the city distribution system. To this end, Jefferson proposed the "two-city" index, that is, the ratio of the population of the primate city to the second largest city is S=P1/P2. Despite its ease of understanding and calculation, the "two-city" index is not comprehensive enough. As a result, the "four-city" index S4=P1/(P2+P3+P4) and the "eleven-city" index $S_{11}=2P_1/(P_2+P_3+\ldots+P_{11})$ were later proposed. According to Zipf's law, the two-city index should be 2, and the four-city index and eleven-city index should be 1. For the convenience of comparison, we calculated the two-city index according to $S=P_1/(P_1+P_2)$ in this study, so that the theoretical expected values of the two-city index, four-city index and eleven-city index are all 1. If the actual value is less than 1, the primate city is relatively small in size; otherwise; the primate city is relatively large in size.

(II) Data sources

This paper represents the actual city size with the main indicators (regional GDP, year-end total population and built-up area) of the municipal districts in prefecture-level cities of Beijing, Tianjin, Hebei, Shandong and Liaoning (namely the Bohai Rim region in a narrow sense) in 2002, 2007, 2012 and 2017, estimates the degree in which Zipf's law fits with the actual city size with the modified model, and analyzes the impact of primacy change on the process of regional integration by comparing the changes of Beijing's primacy and Zipf index in the four stages. The indicators used in this paper come from *China City Statistical Yearbook* and *China Urban Construction Statistical Yearbook* of corresponding years.

IV. Empirical Analysis

(I) Analysis on changes of city size

In the period of 2002-2017, the year-end total population of municipal districts in the Bohai Rim region increased from 72.5061 million to 103.8865 million, a total increase of 43.28% in the whole period and an increase of 6.36% and 6.26% in 2012-2007 and 2007-2012 respectively, showing a stable growth. In the period of 2012-2017, population gathering in regional central cities accelerated, with a growth rate of 26.77%, thus speeding up the formation of a new urban spatial pattern. In order to visually describe the statistical characteristics of city size changes, this paper makes statistics on the city size changes in the Bohai Rim region from 2002 to 2017 (as shown in Table 1) and the urban population size distribution in 2017 (as shown in Table 2) by measuring the year-end total population, according to the requirements of urban population size in the *Notice of the State Council on Adjusting the Standards for Categorizing City Size* (G.F. No. 51 [2014]).

In the period of 2002-2017, small and medium-sized cities with a population of less than 1 million saw a decline in both the number of cities and the proportion of population, and there had been no small cities with a population of less than 500 thousand by 2017; type II big cities with a population of 1-3 million saw an increase in the number of cities, while a decline in the proportion of population; type I big cities (with a population of over 3 million), supercities (with a population of over 5 million) and megacities (with a population of over 10 million) saw a rise in both the number of cities and the proportion of population. More than 50% of the population gathered in about 20% of the cities. On the whole, the Bohai Rim region showed the following features in the period of 2002-2017: (1) With the advancement of urbanization, the population gathering in central cities accelerated, and city size increased to varying degrees; (2) The degree of population gathering in big cities, especially in supercities and megacities, was greater than that in small and medium-sized cities, and the formation of urban spatial distribution accelerated.

According to the spatial city size distribution in 2017, the high-ranking cities in Beijing-Tianjin-Hebei region developed well, encompassing two megacities (Beijing and Tianjin) and three type I big cities (Shijiazhuang, Tangshan and Handan in Hebei). By contrast, there was only one supercity (Shenyang) and one type I big city (Dalian) in Liaodong Peninsula, and only one supercity (Qingdao) and one type I big city (Jinan) in Shandong Peninsula. In terms of low-ranking cities, the population of cities in Shandong Peninsula all exceeded 1 million, and there were still 5 and 8 medium-sized cities with a year-end population of 0.5-1 million in Liaodong Peninsula and Beijing-Tianjin-Hebei region respectively. On the whole, these three regions all developed in the dual-core model integrating regional centers (Beijing, Shenyang and Jinan) and port cities (Tianjin, Dalian and Qingdao). By comparison, the south (Beijing-Tianjin-Hebei region and Shandong Peninsula) developed better than the north (Liaodong Peninsula), and the middle developed better than the two wings (Shandong Peninsula and Liaodong Peninsula).

Table 1 Changes of City Size in Bohai Rim Region (2002-2017)

		Megacity	Supercity	Type I big city	Type II big city	Medium-sized city	Small city
2002	Number of cities	1	1	2	17	18	5
	Proportion of population (%)	14.7	10.4	11.3	41.9	18.6	3.1
2007	Number of cities	1	2	2	18	19	2
	Proportion of population (%)	14.8	16.7	8.5	40.7	18.1	1.2
2012	Number of cities	1	2	3	17	20	1
	Proportion of population (%)	15.0	16.3	12.7	36.8	18.7	0.5
2017	Number of cities	2	2	5	22	13	0
	Proportion of population (%)	23.2	10.6	19.4	36.6	10.3	0

Table 2 City Size Distribution in Bohai Rim Region in 2017

	Qty.	Cities
Megacity	2	Beijing and Tianjin
Supercity	2	Liaoning (1): Shenyang Shandong (1): Qingdao
Type I big city	5	Hebei (3): Shijiazhuang, Tangshan and Handan Liaoning (1): Dalian Shandong (1): Jinan
Type II big city	22	Hebei (3): Zhangjiakou, Qinhuangdao and Baoding Liaoning (4): Anshan, Fushun, Panjin and Tieling Shandong (15): Zibo, Zaozhuang, Dongying, Yantai, Weifang, Jining, Tai'an, Weihai, Rizhao, Laiwu, Linyi, Dezhou, Liaocheng, Binzhou and Heze
Medium-sized city	13	Hebei (5): Chengde, Langfang, Cangzhou, Hengshui and Xingtai Liaoning (8): Benxi, Dandong, Jinzhou, Yingkou, Fuxin, Liaoyang, Chaoyang and Huludao

(II) Analysis on correlation of main economic indicators

From 2002 to 2017, the year-end total population (P), built-up area (S) and regional GDP (Y) of cities at and above the prefecture level in the Bohai Rim region grew rapidly (as shown in Table 2), with a growth rate of

(nominal growth rate, the same below) 2.43%, 4.9% and 14.2% respectively. The growth rate of year-end population was relatively close to that of built-up area, and the year-end population per square kilometer of built-up area decreased from 14,700 to 10,300, implying an increasingly reasonable population density. The growth of GDP was greater than the increase of population and land, and the regional GDP per 10,000 people and per square kilometer of land rose, which, despite the influence of inflation, showed that urban expansion was accompanied by the improvement of economic development quality, rather than simple low-level agglomeration. It should be noted that due to the general economic decline in northeast China in recent years, reflected in the fact that the GDP of 10 cities in Liaoning Province in 2017 was lower than that in 2012, the minimum GDP of cities in the Bohai Rim region dropped significantly in 2017.

According to Pearson correlation coefficient, the main economic indicators of cities such as population, land and output in different periods are closely related, with the correlation coefficients all over 95%. Specifically, the correlation between population and output gradually rose from 2002 to 2012, and the correlation between output and land gradually declined after 2007, indicating that the contribution of population to city appearance (built-up area) and economic output increased, while the contribution of land to economic growth decreased. As the negative impacts on economy, population and land are not synchronous, the correlation between year-end total population and regional GDP and between year-end total population and built-up area caused by the economic slowdown of Liaodong Peninsula decreased by 2.3% and 1% respectively in 2017.

Table 3 Changes of Main Economic Indicators of Cities in Bohai Rim Region (2002-2017)

Year	Main indicators (mean-[minimum, maximum])				
	Regional GDP (RMB 100 million, current price)		Build-up area (km^2)		Year-end total population (10,000)
2002	361.7-[37.5, 3124.5]		112.1-[26.7,1043.5]		164.8-[43.1,1067.0]
2007	907.9-[100.7, 9207.6]		147.8-[32.0,1289.3]		175.3-[44.5,1142.5]
2012	1800.2-[214.9,17617.0]		179.8-[40.0,1261.1]		186.3-[44.1,1226.5]
2017	2650.9-[129.6,28014.9]		229.7-[59.0,1445.5]		236.1-[57.0,1359.0]

Table 4 Pearson Correlation Coefficient of Main Economic Indicators in Bohai Rim Region

	P~Y	P~S	Y~S
2002	0.970576	0.946115	0.965003
2007	0.970757	0.962366	0.988021
2012	0.977	0.980112	0.985278
2017	0.954113	0.969798	0.982175

(III) Analysis on primacy of central cities

In the period of 2002-2017, Beijing was always the primate city in the Bohai Rim region in terms of population, built-up area and regional GDP. In this study, the "two-city", "four-city" and "eleven-city" primacy of Beijing and the proportion of Beijing in the Bohai Rim region in 2002, 2007, 2012 and 2017 were measured with these three indicators (Table 5). It is found that from 2002 to 2017, the land and population growth in Beijing was lower than that in other regions, and the "two-city" primacy, "four-city" primacy and "eleven-city" primacy of Beijing all declined. Besides, the proportion of Beijing's population in the total population of the Bohai Rim region had no significant change, the proportion of Beijing's GDP in the total GDP of the Bohai Rim region increased by 4.4%, and the proportion of Beijing's built-up area in the total build-up area of the Bohai Rim region decreased by nearly 3.6%, implying limited urban space expansion in Beijing. In the context of accelerated population migration to big cities, especially megacities and supercities, the proportion and primacy of population in Beijing did not rise but decreased during 2012-2017, mainly because Beijing restricted population inflow and land expansion. In this period, Tianjin, the city ranking second, partially replaced Beijing in receiving population and investment. The built-up area, year-end total population and regional GDP of Tianjin grew at an annual average rate of 6%, 2.25% and 16.74% respectively, which were 3.8%, 0.6% and 1% higher than those of Beijing. The two-city primacy of Beijing declined significantly.

Table 5 Changes of Primacy Indicators in Bohai Rim Region (2002-2017)

		S_2	S_4	S_{11}	S_{ALL}
2002	Build-up area	2.299	1.098	1.060	0.212
	Year-end total population	1.418	0.680	0.657	0.147
	Regional GDP	1.717	0.764	0.748	0.196
2007	Build-up area	2.256	1.045	0.962	0.198
	Year-end total population	1.453	0.695	0.664	0.148
	Regional GDP	1.962	0.937	0.913	0.230
2012	Build-up area	1.746	0.802	0.725	0.159
	Year-end total population	1.510	0.722	0.667	0.150
	Regional GDP	1.480	0.804	0.847	0.222
2017	Build-up area	1.329	0.634	0.640	0.143
	Year-end total population	1.294	0.633	0.574	0.131
	Regional GDP	1.510	0.838	0.932	0.240

Note: S_{ALL} represents the proportion of Beijing (as the primate city) in the Bohai Rim region (%).

(IV) City rank-size regression analysis

The logarithm scatterplots of the built-up area (S), year-end total population (P), regional GDP (Y) and rank of cities in different periods show that in the period of 2002-2017, the rank-size distribution of population and built-up area tended to be linear, and the tail gradually became flat. Meanwhile, the scatter distribution of the two indexes tended to be consistent, and the distribution of land index got closer to that of population index. The distribution of regional GDP deviated to the upper right and the tail drooped obviously, implying discrete economic size distribution. The position of Tianjin, the second largest city, was higher than the line connecting the primate city and the third largest city, indicating that the size of Tianjin was indeed higher than the theoretical expectation.

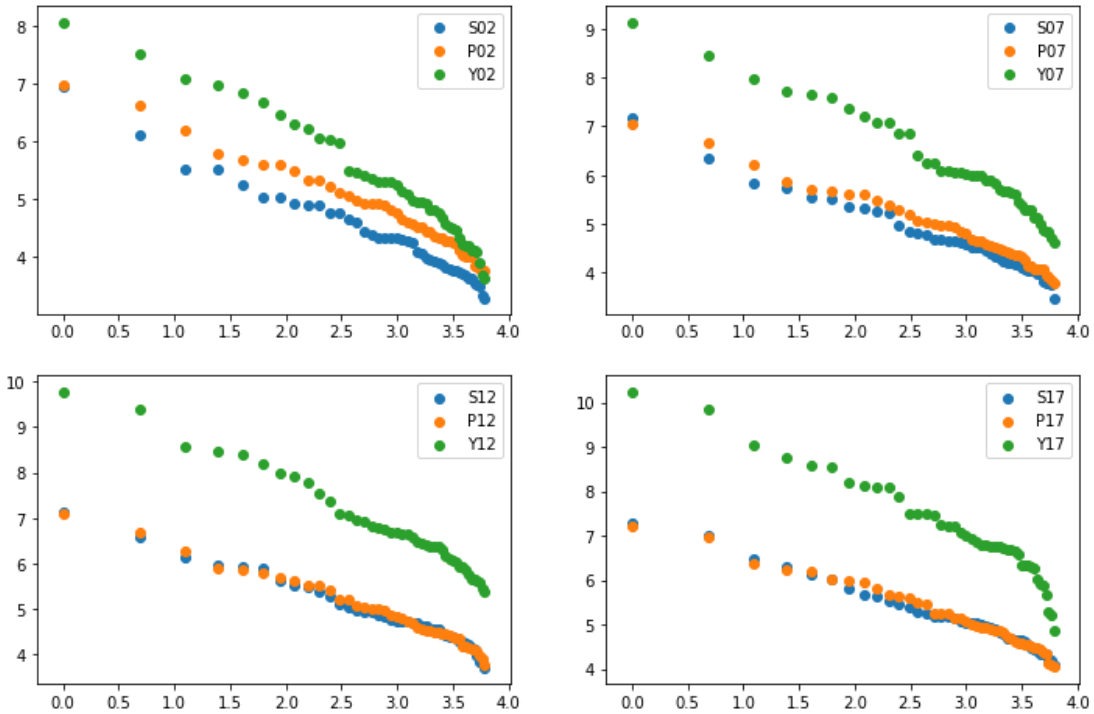

Fig. 1 City Rank (X)-Size (Y) Loglog Scatterplot

According to the modified regression equation of Zipf's law, i.e. equation (3), we regressed the rank R with three indicators, namely regional GDP (Y), built-up area (S) and permanent population (P), and got the estimated values (as shown in Table 6). It can be seen that the coefficients of determination (adj R^2) of the model are all greater than 0.9, which well explains the rank-size relationship in an urban agglomeration. The estimated values of q are all close to 1, and the rank-size distribution of regional GDP is less than 1, indicating that the economic size is biased towards big cities, that is, the economic size of high-ranking cities is prominent, while that of small and medium-sized cities is inadequate. The rank-size distribution of land and population is greater than 1, implying scattered city size distribution, that is, the size of high-ranking cities is not prominent, and there are relatively more land and population in small and medium-sized cities. The estimated values of q-1 are significantly different from 0, that is, the hypothesis of q=1 is denied, which represents a significant deviation from the rank-size rule. By comparison, the estimated q value of economic size declines, which indicates that the economic status of high-ranking cities (especially the primate city) rises; the estimated q value of land size increases, which indicates that the land expansion of small and medium-sized cities is faster than that of high-ranking cities. The estimated q value of population is greater than 1, but approaches to 1, which shows that the population flow between cities makes the city size distribution more reasonable. On the whole, (1) the economic development deviates from the rank-size distribution of population and land, which indicates that the intra-regional economic growth gap, especially the growth gap between the primate city/high-ranking cities and other cities, is widening. High-ranking cities have enhanced the constraints on population and land expansion; however, there is still no smooth way for elements and public services to flow to other big cities or small and medium-sized cities. (2) The built-up area is scattered and also expanding, while the population mobility tends to be close to Zipf distribution, indicating that the inter-city distribution of newly-added construction land in the region cannot fully reflect the changes of population mobility.

Table 6 Estimation of Q in Rank-Size Regression

		cons_	q	q-1	adjR^2
2002	S	8.301600*** (.126126)	1.272392*** (.028704)	0.272392*** (.028704)	0.978574
	P	8.798184*** (.175721)	1.262511*** (.036489)	0.262511*** (.036489)	0.965298
	Y	7.490916*** (.183246)	0.895653*** (.034261)	-0.104347*** (.034261)	0.940722
2007	S	8.799291*** (.136273)	1.297983*** (.029083)	0.297983*** (.029083)	0.978858
	P	8.965784*** (.171296)	1.279588*** (.035094)	0.279588*** (.035094)	0.968646
	Y	8.332530*** (.193389)	0.903080*** (.031080)	-0.096920*** (.031080)	0.951482
2012	S	9.048759*** (.180786)	1.289604*** (.036846)	0.289604*** (.036846)	0.966062
	P	9.032673*** (.174140)	1.277514*** (.035246)	0.277514*** (.035246)	0.968283
	Y	9.005262*** (.182436)	0.914153*** (.026538)	-0.085847*** (.026538)	0.965002
2017	S	9.560384*** (.167550)	1.325296*** (.032491)	0.325296*** (.032491)	0.974793
	P	9.339327*** (.217893)	1.274240*** (.041977)	0.274240*** (.041977)	0.955369
	Y	8.580408*** (.262954)	0.815062*** (.036566)	-0.184938*** (.036566)	0.920201

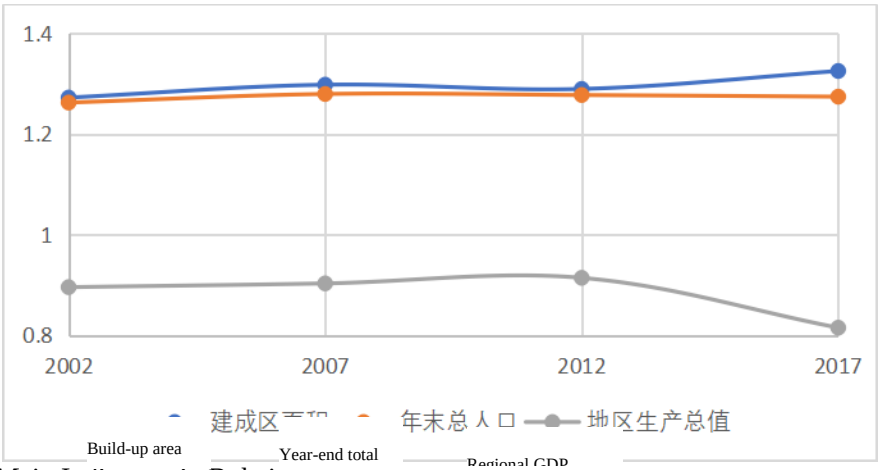

Fig. 2 Zipf Index of Main Indicators in Bohai Rim Region

V. Conclusions and Suggestions

To sum up, we draw the following conclusions: during 2002-2017, (1) the population gathering in central cities (especially big cities, supercities and megacities) in the Bohai Rim region accelerated; (2) the primacy of Beijing dropped significantly, and Tianjin partially replaced Beijing as the leader in population gathering; (3) the economic development deviated from the spatial distribution of population and land. The economic size increasingly gathered in high-ranking cities, the population distribution tended towards Zipf's law, and the land distribution tended to be scattered.

From the perspective of population flow, Zipf's law is indeed an inescapable law in the regional integration of the Bohai Rim region. Both the economic size distribution and land distribution should match with the law of population flow. However, this is not the case in the Bohai Rim region. To this end, we put forward the following suggestions.

(1) Vigorously promote the coordinated development of Beijing, Tianjin and Hebei. Implement the coordinated development strategy of Beijing-Tianjin-Hebei region and the *Outline for the Cooperative Development of the Bohai Rim Region*; focus on freeing Beijing from non-capital functions, speeding up the construction of Xiong'an New Area in Hebei, and enhancing the leading role of Tianjin Binhai New Area by taking advantage of the valuable opportunities brought by such national strategies as the "Belt and Road Initiative" and coordinated development of Beijing-Tianjin-Hebei region; spur the close cooperation among Liaoning, Shandong and Beijing-Tianjin-Hebei region; partially take over Beijing's population, industries and functions in a targeted manner; strengthen the integration of ports and promote the "port-industry-city" integrated development in the Bohai Rim region; give full play to the leading role of Beijing, Tianjin, Shenyang, Dalian, Shijiazhuang, Qingdao, Jinan and other top cities; foster regional growth poles by relying on national-level new districts and coastal port cities, strengthen the East-West and South-North links and cooperation, and promote the overall competitiveness of the Bohai Rim region.

(2) Deepen the institutional innovation and reform. Resolutely break down the institutional barriers to the decisive role of the market in resource allocation, strengthen the macro-guidance function of the government, accelerate the improvement of a unified, open, competitive and orderly market system, and create a new pattern of regional collaborative opening; constantly explore new cooperation ideas, innovate cooperation concepts, improve cooperation mechanisms and systems, and strive to create a new situation of cooperation and development; speed up the establishment of a new construction land allocation mechanism in line with the trend of population flow; appropriately increase the construction land in big cities, supercities and megacities, improve the efficiency of urban stock construction land, increase the redevelopment and reuse of stock land, and avoid low-density expansion.

(3) Optimize the spatial distribution of regional industries. Promote the formation of a new pattern of cooperative development that features internal optimization, external expansion, coordination and interaction with the support of important transportation belts, by taking advantages of the development foundation, location conditions and transportation convenience and relying on major urban agglomerations, e.g., Beijing-Tianjin-Hebei region, Southeast Liaoning and Shandong Peninsula; accelerate the industrial gradient transfer, give full play to the advantages of the Bohai Rim region with highly complementary resource endowments and obvious industrial gradients, strengthen regional industrial cooperation, encourage Tianjin and Hebei to take over the non-capital functions of Beijing, actively integrate Liaoning and Shandong into the integrated development of Beijing-Tianjin-Hebei region, promote the rational allocation of various production factors, and optimize the industrial agglomeration in the region.

(4) Build a regional market integration system. Break down administrative barriers, set unified standards, and establish a regional coordination and consultation mechanism; improve market rules and systems, and establish a unified, sound and open commodity market; break through institutional barriers, establish an open market for labor services, finance, property rights, real estate and technical factors, and promote the free mobility and optimal allocation of regional factor resources.

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