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Evaluation of urban competitiveness based on factor analysis—Taking 35 key cities in China as an example

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Abstract

Key cities represent the strongest competitiveness level of each province and city. At present, the problem of unbalanced development level of key cities in China is more prominent. Improving urban competitiveness has become an urgent problem for urban governments. In order to study the competitiveness of 35 key cities in China, this paper formulates a total of 27 indicators from the five levels of economic development, social undertakings, public infrastructure, ecological environment and technological innovation, and uses measurement software to draw the advantages and disadvantages of relevant urban development. The results show that the top cities in the comprehensive competitiveness of 35 key cities in China include Beijing, Shanghai, Shenzhen and Guangzhou, and the differences among key cities are more prominent in all dimensions. The relative level of competitiveness development of key cities corresponds to the level of regional economic development and technological innovation to a certain extent.

Keywords: Urban competitiveness; key cities; factor analysis

1. Introduction

Urban competitiveness refers to the ability of a city to optimize the allocation of resources in its subordinate large area for its own development, so as to obtain the sustainable growth of urban economy, which is created and maintained under the comprehensive action of many factors such as society, economic structure, values, culture, system and policy[1]. Key cities are often the pioneers and main force of national policies[2], representing the strongest competitiveness level of provinces and cities. In 2020, the gross domestic product of 35 key cities accounts

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for about 39 % of China's gross domestic product, and the average per capita GDP of key cities is 27474.43 yuan higher than the Per capita GRP; In terms of the gap between key cities, the maximum difference in GDP is 37590.3 billion yuan, and the difference between the highest per capita GDP and the lowest per capita GDP is about 111897 yuan. It can be seen from this that the economic level gap between cities in China is relatively large, and the urban development is not balanced, especially the unbalanced development of key cities is more prominent. Therefore, it is urgent to evaluate the competitiveness of key cities, find out the competitive advantages and shortcomings of each city, and coordinate regional economic development.

Firstly, this paper analyzes the current situation and problems of urban competitiveness research at home and abroad. Secondly, taking 35 key cities as research samples, a total of 27 indicators were formulated from the five levels of economic development, social undertakings, public infrastructure, ecological environment and scientific and technological innovation, and then the advantages and disadvantages of relevant urban development were obtained by using measurement software. Finally, it provides countermeasures and suggestions for improving the competitiveness of key cities and narrowing the gap between cities.

2. literature review

Urban competitiveness is an important part of regional competitiveness[3]. Scholars at home and abroad have carried out a lot of research on the theoretical model, evaluation method, geographical category and index system of urban competitiveness from the theoretical and empirical perspectives.Some scholars have constructed a certain theoretical model for urban competitiveness. Pengfei Ni has constructed a bowstring arrow model and a flywheel model. The urban value chain model proposed by Beijing Institute of International Urban Development; Dennis proposed the " 3 + 1 " theoretical model to study the international competitiveness of metropolitan areas[4]. Begg proposed the ' maze ' model [5]and so on. There are many studies on the evaluation of urban competitiveness by Chinese scholars. Some scholars have used different methods to evaluate urban competitiveness, such as principal component analysis[6], factor analysis[7], TOPSIS method[8], entropy weight method[9], complex network analysis[10]and so on. Some scholars have studied the urban competitiveness from different geographical categories. For example, Shaohua Wu and Yujia Li evaluated the urban competitiveness of western China[6]; Shuping Zhang studied the competitiveness evaluation of international consumption center cities in the Yangtze River Delta urban agglomeration[11]; Youcai Gao and Kai Tang measured the competitiveness of 70 sample node cities on the three routes of the Silk Road Economic Belt[12]; Zhiqiang Guo and Bin Lv studied the competitiveness of national central cities[13]; some scholars have studied the urban competitiveness of different provinces such as Jiangsu[14], Hubei[6][7], Sichuan[15]and so on. Some scholars have created different urban competitiveness evaluation systems to study urban competitiveness from different dimensions. For example, Shaohua Wu and Yujia Li take western cities as the research object to establish an evaluation system of urban comprehensive competitiveness from six aspects: economic strength, infrastructure, social security, resources and environment, scientific and technological innovation and opening up[6]; China 's GUCP (Global Urban Competitiveness Research-City and Competitiveness Research Center of the Chinese Academy of Social Sciences) published the 2020 China Urban Competitiveness Report from the dimensions of urban sustainability, urban local factors, urban living environment, urban economic vitality and scientific and technological innovation. Some scholars have pointed out that there are still many shortcomings in the study of urban competitiveness, such as the interpretation of the connotation of urban competitiveness has not yet reached a consensus ; the influencing factors of urban competitiveness In different periods, backgrounds and perspectives, some specific factors will become the core elements affecting urban competitiveness, and a truly authoritative and objective evaluation index system for urban competitiveness has not yet been formed[16].

Although the research on urban competitiveness at home and abroad has gradually improved, most foreign scholars focus on national competitiveness, and there are relatively few studies on urban competitiveness, especially empirical research. Domestic scholars ' research started late, and there are relatively few studies on the competitiveness of key cities in China. This paper takes 35 key cities as research samples, constructs the evaluation index system of urban competitiveness, evaluates the urban competitiveness of key cities based on factor analysis, and analyzes the competitive shortcomings and competitive advantages of key cities in China, in order to provide countermeasures and suggestions for the development of key cities.

3. Key city competitiveness index systems

Based on the previous research results, following the principles of purpose, scientificity, operability, representativeness and practicability, a total of 27 variables from five levels of economic development, social undertakings, public infrastructure, ecological environment and technological innovation are selected to form the evaluation index system of urban competitiveness, as shown in Table 1.

Table 1. Evaluation index system of key city competitiveness.

Functional layer	Indicator layer
Economic development	Gross Regional Product(X_1), Per Capita GRP(X_2), General public budget revenue(X_3), General Public Budget Expenditure(X_4),The added value of the tertiary industry(X_5),Urban per-capita disposable income(X_6),Total Retail Sales of Consumer Goods(X_7), Deposits of Financial Institutions at Year-end(X_8), The average wage of on-the-job workers in urban non-private units(X_9)
Social undertaking	Number of Hospitals(X_{10}), Number of Licensed (Assistant) Doctors (X_{11}), Number of school staff(X_{12}),Number of Museums(X_{13})
Public infrastructure	Built-up Area(X_{14}), Total Gas Supply(X_{15}),Highway Freight Traffic(X_{16}),Total Mileage of Domestic Roads(X_{17}),Length of Urban Sewage Pipes(X_{18})
Ecological environment	Area of Green Land(X_{19}),Volume of Industrial Particulate Emission(X_{20}),Volume of Sulphur Dioxide Emission(X_{21}),Volume of Nitrogen Dioxide Emission(X_{22}),Annual Mean Concentration of PM2.5(X_{23}),Ratio of Waste Water Centralized Treated of Sewage Work(X_{24})
Scientific and technological innovation	Number of Patent Authorizations (X_{25}), Number of Invention(X_{26}), Science and technology expenditure (X_{27})

4. Data Sources and treatments

4.1. Data sources

This paper defines the cities under the jurisdiction of prefecture-level cities, provincial capitals and sub-provincial cities as key cities, and selects relevant data of 35 key cities for empirical research. Lhasa is not included due to lack of data. The data are derived from the ' China City Yearbook ' in 2021, the statistical bulletins of national economic and social development in various cities in 2021, etc. The missing data in the data are replaced with medians.

4.2. Data treatment

KMO statistics value > 0.5, Bartlett spherical test results < 0.05, the data of 5 groups of variables are fully applicable to factor analysis. The principal component analysis method is adopted, the eigenvalue is set to be greater than 1, and the maximum variance method is used for rotation. The cumulative contribution rate of the number of principal component factors should be higher than 85 %. The results show that:

(1)The original 9 variables of ' economic development ' variable group extracted a principal component factor of ' economic development '. The variance percentage of this factor is 89.197 %, which has certain explanatory power.

(2)The original four items of the ' social cause ' variable group extracted the principal component factor of ' social cause level ', and the variance percentage of this factor was 86.719 %, which had certain explanatory power.

(3)The original five items of the ' public infrastructure ' variable group extracted two principal component factors of ' area, gas supply and drainage ' and ' road transportation '. The variance percentages of the two were 48.727 % and 36.956 respectively, and the cumulative variance contribution rate was 85.683 %, which had certain explanatory power.

(4)The original five items of the ' ecological environment ' variable group extracted three principal component factors of ' industrial emission and particle concentration ', ' sewage treatment ' and ' green area '. The variance percentages of the two were 49.240 %, 20.717 % and 18.819 respectively, and the cumulative variance contribution rate was 88.776 %, which had certain explanatory power.

(5)The original three variables in the ' technological innovation ' variable group extracted a principal component factor of ' technological innovation level '. The variance percentage of this factor was 89.364 %, which had certain explanatory power.

According to the factor score coefficient matrix, the scores of each factor are calculated, and the comprehensive factor scores of each variable group can be calculated by substituting the variance contribution rate of each factor. Then use the analytic hierarchy process weight to calculate the score F, as shown in Table 2.

Table 2. Competitiveness score of key cities.

	Economic development		Social undertaking		Public infrastructure		Ecological environment		Scientific and technological innovation		Score	
Key cities	F1	Rank	F2	Rank	F3	Rank	F4	Rank	F5	Rank	F	Rank
Beijing	3.21	1	2.8	1	1.57	2	0.46	6	3.37	1	2.570	1
Shanghai	3.21	1	1.53	4	1.16	4	-0.23	24	2.12	3	1.987	2
Shenzhen	1.54	3	-0.08	16	0.45	6	-0.14	16	2.66	2	1.344	3
Guangzhou	1.12	4	0.73	6	1.49	3	-0.43	30	1.37	4	0.879	4
Hangzhou	0.61	6	0.46	9	0.13	9	0.67	5	0.72	6	0.612	5
Chongqing	0.85	5	2.72	2	2.5	1	-0.27	25	-0.01	12	0.606	6
Wuhan	0.27	10	0.51	8	0.24	8	-0.14	16	0.99	5	0.398	7
Nanjing	0.53	7	0.15	12	0.05	10	0.24	7	0.4	7	0.382	8
Chengdu	0.39	8	1.85	3	0.28	7	-0.2	21	0.24	8	0.308	9
Tianjin	0.3	9	0.59	7	0.6	5	-0.55	34	0.18	9	0.133	10
Ningbo	0.07	11	-0.23	19	-0.22	20	0.06	9	0.06	11	0.029	11
Jinan	-0.14	15	0.16	11	0.04	11	0.82	4	-0.35	17	0.024	12
Qingdao	0.07	11	0.1	13	-0.01	13	-0.35	27	-0.09	13	-0.062	13
Nanning	-0.7	29	-0.52	24	-0.31	23	2.32	1	-0.72	32	-0.063	14
Hefei	-0.22	17	-0.29	20	-0.04	14	-0.14	16	0.15	10	-0.094	15
Zhengzhou	-0.12	14	0.34	10	-0.21	19	-0.06	11	-0.19	14	-0.106	16
Xi 'an	-0.18	16	0.76	5	-0.06	15	-0.21	22	-0.19	14	-0.126	17
Changsha	-0.04	13	-0.15	18	-0.19	18	-0.37	29	-0.28	16	-0.188	18
Changchun	-0.57	23	-0.32	21	-0.26	22	0.95	3	-0.61	25	-0.241	19
Guiyang	-0.66	26	-0.72	28	0.03	12	1.11	2	-0.66	31	-0.263	20
Fuzhou	-0.25	18	-0.5	23	-0.53	30	-0.22	23	-0.47	19	-0.337	21
Kunming	-0.46	22	-0.09	17	-0.15	16	-0.01	10	-0.65	29	-0.380	22
Dalian	-0.45	21	-0.58	25	-0.33	24	0.11	8	-0.61	25	-0.381	23
Xiamen	-0.37	19	-1.1	32	-0.47	28	-0.43	30	-0.46	18	-0.456	24
Shenyang	-0.41	20	-0.34	22	-0.24	21	-0.56	35	-0.57	23	-0.469	25
Shijiazhuang	-0.62	25	0.07	14	-0.17	17	-0.19	19	-0.65	29	-0.472	26
Harbin	-0.68	27	-0.06	15	-0.46	27	-0.19	19	-0.64	28	-0.520	27
Taiyuan	-0.69	28	-0.65	26	-0.45	25	-0.06	11	-0.63	27	-0.529	28
Nanchang	-0.58	24	-0.69	27	-0.56	31	-0.32	26	-0.59	24	-0.536	29
Urumqi	-0.71	30	-0.99	31	-0.45	25	-0.11	15	-0.81	34	-0.616	30
Lanzhou	-0.79	31	-0.86	29	-0.64	32	-0.09	13	-0.77	33	-0.638	31
Yinchuan	-0.84	33	-1.23	35	-0.51	29	-0.36	28	-0.49	20	-0.648	32
Hohhot	-0.82	32	-0.98	30	-0.66	33	-0.47	32	-0.5	21	-0.661	33
Haikou	-0.92	34	-1.18	33	-0.79	34	-0.09	13	-0.83	35	-0.735	34

Xining	-0.94	35	-1.2	34	-0.82	35	-0.53	33	-0.51	22	-0.747	35

The results of cluster analysis of total scores were analysed by using measurement software, in which K-means cluster analysis was set, and the number of classifications was 2. The number of cities in the first category is 4 , including Beijing, Shanghai, Shenzhen and Guangzhou, and the remaining 31 cities are in the second category.

5. Empirical Analysis of Competitiveness Evaluation of Key Cities

From the scores of table 2 and their clustering, it can be seen that Beijing, Shanghai, Shenzhen and Guangzhou have the strongest urban economic competitiveness and technological innovation competitiveness ;Beijing, Chongqing, Chengdu and Shanghai rank top in the competitiveness of urban social undertakings; Chongqing, Beijing, Guangzhou and Shanghai rank top in the competitiveness of urban public infrastructure ;Nanning, Guiyang, Changchun, Jinan and Hangzhou have the highest level of urban ecological environment competitiveness. Overall, the top four cities in urban competitiveness include Beijing, Shanghai, Shenzhen and Guangzhou.

5.1. Competitiveness analysis of economic development

The results show that the economic development level scores of Beijing and Shanghai are 3.21, which are far ahead of the key cities. Shenzhen and Guangzhou scored 1.54 and 1.12 respectively. These four cities are called first-tier cities, and their economic development level is far higher than that of other key cities. The comprehensive strength and competitiveness of cities in mainland China are relatively at the most advanced level. Cities with an average level of economic development (comprehensive factor score of economic development is greater than 0) also include Chongqing, Hangzhou, Nanjing, Chengdu, Tianjin, Wuhan, Ningbo and Qingdao, which are at a higher level among the 35 key cities. The cities whose comprehensive factor score is higher than-0.5 include Changsha, Zhengzhou, Jinan, Xi 'an, Hefei, Fuzhou, Xiamen, Shenyang, Dalian, Kunming and other cities whose economic development level is in the middle level. In the sample, the comprehensive factor scores of Changchun, Nanchang, Shijiazhuang, Guiyang, Harbin, Taiyuan, Nanning, Urumqi, Lanzhou, Hohhot, Yinchuan, Haikou, Xining and other 13 cities are below-0.5, which belongs to the city with low level of economic development. Through the analysis of the observed indicators, it is found that Beijing, Shanghai, Guangzhou and Shenzhen have a huge economic aggregate and are in the forefront of the city's GDP, per capita GDP and other indicators. For example, in terms of GDP indicators, Shanghai, Beijing, Shenzhen, Chongqing and Guangzhou are among the best, and Chongqing ranks fourth over Guangzhou, but the gap between the two is not large. In the per capita GDP index, Beijing, Nanjing, Shenzhen, Shanghai, Hangzhou, Guangzhou exceeded 135,000 yuan, in the forefront of the country. In general, China's urban economic development is not balanced, and the economic development level of 35 important cities in China has obvious stratification.

5.2. Competitiveness analysis of social undertakings

The results show that the scores of social undertakings in Beijing and Chongqing are 2.8 and 2.72 respectively, which are in the leading position in China. The score of Chengdu is 1.85, and the score of Shanghai is 1.53. From the perspective of indicators, whether it is education, health care, or culture, it is ranked top. The cities with an average level of social undertakings (factor score greater than 0) are Xi 'an, Guangzhou, Tianjin, Wuhan, Hangzhou, Zhengzhou, Jinan, Nanjing, Qingdao and Shijiazhuang, which are at a higher level in 35 cities. The cities with scores between-0.5 and 0 are Harbin, Shenzhen, Kunming, Changsha, Ningbo, Hefei, Changchun, Shenyang and Fuzhou, and the level of social undertakings in the nine cities is at the middle level. The comprehensive factor scores of Nanning, Dalian, Taiyuan, Nanchang, Guiyang, Lanzhou, Hohhot, Urumqi, Xiamen, Haikou, Xining and Yinchuan in the sample are all below-0.5, which belongs to the city with low level of social development. The analysis of the observation indicators shows that Beijing and Chongqing, as municipalities directly under the central government, have the highest number of health institutions, health practitioners and school staff among the 35 key cities, indicating that these two cities attach more importance to medical care and education. From the number of museums, Beijing ranks first, Chengdu, Shanghai and Xi 'an exceed Chongqing, and there are more than 100

museums in five cities, indicating that these five cities attach great importance to the development and dissemination of culture. In general, there are obvious differences in the competitiveness of social undertakings among key cities.

5.3. Competitiveness analysis of public infrastructure

The results show that the comprehensive factor score of Chongqing's public infrastructure is 2.5, and Chongqing is far ahead of the 35 cities, followed by Beijing, Guangzhou and Shanghai, with scores of 1.57, 1.49 and 1.16, respectively. These four are far higher than other key cities in terms of public infrastructure. The cities with a comprehensive factor score of public infrastructure above the average level (factor score greater than 0) are Tianjin, Shenzhen, Chengdu, Wuhan, Hangzhou, Nanjing, Jinan and Guiyang, which have higher levels of public infrastructure. The cities with scores between-0.5 and 0 in the sample are Qingdao, Hefei, Xi 'an, Kunming, Shijiazhuang, Changsha, Zhengzhou, Ningbo, Shenyang, Changchun, Nanning, Dalian, Taiyuan, Urumqi, Harbin and Xiamen. The level of public infrastructure in these cities is in the middle level. Cities with scores below-0.5 include Yinchuan, Fuzhou, Nanchang, Lanzhou, Hohhot, Haikou and Xining. These cities have low levels of public infrastructure. Through the analysis of the observation indicators, it is found that Chongqing is on the top of the list of indicators. From the perspective of built-up area and drainage pipeline length, Beijing, Chongqing, Guangzhou and Shanghai are in the forefront. From the perspective of total gas supply, Beijing, Shanghai, Guangzhou, Shenzhen and Chongqing are in the forefront; in terms of transportation indicators, Chongqing is far higher than other key cities. In general, the comprehensive factor scores of public infrastructure among 35 key cities are significantly different.

5.4. Competitiveness analysis of ecological environment

The results show that Nanning ranks first in ecological environment, with a score of 2.32. The second is Guiyang, with a score of 1.11. The ecological environment level of these two cities is the highest. The cities with the ecological environment comprehensive factor score above the average level are Changchun, Jinan, Hangzhou, Beijing, Nanjing, Dalian and Ningbo. The calculation results of Kunming, Zhengzhou, Taiyuan, Lanzhou, Haikou, Urumqi, Shenzhen, Wuhan, Hefei, Shijiazhuang, Harbin, Chengdu, Xi 'an, Fuzhou, Shanghai and Chongqing are between-0.3 and 0, and the ecological environment level is medium. Nanchang, Qingdao, Yinchuan, Changsha, Guangzhou, Xiamen, Hohhot, Xining, Tianjin and Shenyang scored lower in the comprehensive ecological environment factor. Through the analysis of the observation indicators, it is found that Shanghai, Guangzhou, Shenzhen, Nanjing and Beijing have a large area of green space, indicating that these cities attach great importance to greening. From the perspective of industrial particulate matter emissions, industrial sulfur dioxide emissions, industrial nitrogen oxide emissions and annual average concentration of fine particulate matter, Shenzhen, Xiamen and Haikou are the least, indicating that these cities attach importance to emission reduction in ecological environment protection measures; the centralized treatment rate of sewage treatment plants in 35 key cities is higher than 90 %, and Haikou is as high as 100 %. In general, the scores of ecological environment comprehensive factors among 35 key cities are still significantly different. Under the background of ecological civilization construction in China, it is very important to strengthen the improvement of environmental quality in domestic cities, especially key cities.

5.5. Competitiveness analysis of science and technology innovation

The results show that Beijing, Shenzhen, Shanghai and Guangzhou rank the top four in scientific and technological innovation, with scores of 3.37, 2.66, 2.12 and 1.49 respectively, which is similar to the ranking of economic development level. It can be seen that the relationship between scientific and technological innovation and economic development is mutually reinforcing and complementary. Wuhan, Hangzhou, Nanjing, Chengdu, Tianjin, Hefei and Ningbo also scored above the average level of science and technology innovation comprehensive factor. These cities are at a higher level among the 35 key cities. The calculation results of Chongqing, Qingdao, Zhengzhou, Xi 'an, Changsha, Jinan, Xiamen, Fuzhou, Yinchuan and Hohhot are between-0.5 and 0, and the level of scientific and technological innovation in 35 key cities is medium. Xining, Shenyang, Nanchang, Changchun,

Dalian, Taiyuan, Harbin, Kunming, Shijiazhuang, Guiyang, Nanning, Lanzhou, Urumqi and Haikou have a low level of scientific and technological innovation among the 35 key cities. Through the analysis of the observation indicators, it is found that the number of patent authorizations in Beijing, Shanghai, Shenzhen and Guangzhou is more than 130,000, which is much higher than that in other key cities. The expenditure of science and technology in these four cities is also higher than that in other key cities, indicating that the governments of these cities attach importance to scientific and technological innovation. From the number of inventions, in addition to the above four cities, the inventions of Wuhan and Hangzhou are also in the forefront. In general, there is a significant gap in the comprehensive factor scores of scientific and technological innovation among 35 key cities in China.

6. Countermeasures and suggestions

Through empirical research, it is found that the competitiveness of 35 key cities in mainland China shows significant inter-city differences among various dimensions, and the stratification is serious. Based on the analysis results, the following countermeasures and suggestions are put forward.

(1) Consolidate the economic foundation of the development of key cities and build a regional innovation system. At present, the development of key cities is not balanced. The relative level of comprehensive competitiveness of 35 key cities in China corresponds to the level of regional economic development and technological innovation to a certain extent. Promote urbanization and highlight the role of radiation ; build a regional innovation system, increase urban cohesion, attract and retain foreign funds, talents and technology ; establish a resource sharing mechanism and a talent flow mechanism, enjoy rich educational resources through cooperation between cities or the introduction of talent technology, and make up for the lack of educational resources in some cities ; increase investment in scientific and technological innovation and education, and provide policy and financial support for scientific research and innovation.

(2) Improve the public service system and enhance the competitiveness of social undertakings and public infrastructure in key cities. Provide more financial support for urban public service construction, improve the public infrastructure construction of each city, and provide strong support for the construction of new urbanization. Build a transportation network to meet the needs of residents ' travel and transportation; improve medical, educational and cultural services to meet the needs of residents. Develop planning and resource sharing in the construction of urban public service competitiveness. Improve the rating and supervision mechanism of urban public service construction, purchase service mechanism, improve the service quality and efficiency of public service products, and improve residents ' satisfaction with public services.

(3) Strengthen environmental protection and improve the competitiveness of the ecological environment. Strengthen the publicity of environmental protection, enhance the awareness of ecological environmental protection of the whole people, and develop low-carbon, environmentally friendly and green production and lifestyle. Encourage residents to green consumption; strengthen the supervision of the government, improve the legal system and supervision system of ecological environment protection ; increase urban greening area, save resources and reduce emissions ; encourage enterprises to carry out green production, and vigorously promote the use of green clean energy.

(4) Play their respective advantages, clear city positioning. Clear the city 's respective urban function positioning, play the leading role of the first-tier cities, rely on their own advantages, make up for the shortcomings, enhance public service capacity, municipal construction level and environmental competitiveness, create a competitive situation to optimize the division of labor in the urban system, and coordinate regional balanced development. While maintaining their own advantages, cities should also strengthen cooperation with other cities to promote common progress.

(5) According to local conditions, formulate development plans that meet their own conditions. Most of the cities with low competitiveness in key cities are geographically inland, and their transportation is not as developed as coastal areas. Cities should take a road that is in line with their own characteristics. According to their own location differences and resource advantages, they should seize their own characteristic industries, optimize the industrial structure, build a characteristic industrial system, and improve the current situation of unbalanced development to improve urban competitiveness.

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