Study on spatiotemporal evolution of urbanization coupling coordination in Shandong Province

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Keywords: urbanization; coupling coordination; spatiotemporal evolution

Abstract: Taking 16 prefecture level cities in Shandong Province as the research objects, this paper studies the coupling coordination degree of urbanization in Shandong Province. From the time dimension, this paper analyzes the dynamic change of urbanization coupling coordination degree in Shandong Province from 2010 to 2018; from the spatial dimension, through the variation coefficient and Theil index, this paper studies the dynamic difference degree between regions. Based on the four dimensions of economy, society, population and landscape, this paper selects 24 indicators to construct the index system of urbanization coupling coordination level. According to the entropy method, calculate the index weights, obtain the scores of the four subsystems, and study the coupling coordination degrees between them. The results show that: from 2010 to 2018, the urbanization coupling coordination degrees of the whole Shandong Province and its all cities are on the rise, and the urbanization coupling coordination levels of all cities have been improved. Qingdao, Jinan, Yantai and Weifang are among the top cities in Shandong Province, while Zaozhuang and Rizhao are lower in Shandong Province. The variation coefficient and Theil index of urbanization coupling coordinated development in Shandong Province are both decreasing, which indicates that the dispersion degree of coupling coordinated development among different regions in Shandong Province is decreasing.

1. Introduction

Since the reform and opening up, China's urbanization process has been continuously promoted. For the description of urbanization, many scholars [1] [2] put forward different opinions. The interpretation of the concept of urbanization, from the simple increase in urban population, rural landscape change, to many in-depth substantive revealed. Some scholars put forward that urbanization is not only the change of landscape and population structure, but also the change of production and life style and people's ideas. At present, China's urbanization is entering a new period of transformation and development [3]. To explore and grasp the rule of urbanization can promote the high-quality development of urbanization [4].

To evaluate the economic development of a province, we should not only pay attention to the overall economic aggregate, but also pay close attention to whether the development of different regions in a province is balanced and whether the development of different subsystems such as economy, society, population and urban construction in a region is coordinated. Therefore, the establishment of a representative and universal index system and the research on the coupling and coordinated development of urbanization in a province can be used as an important reference for the quality of economic development study. On this basis, it is necessary to build an index system which can reflect the coupling coordination of urbanization.

As an eastern coastal province, Shandong's GDP ranks among the top three in China, which is obviously at a disadvantage compared with Guangdong. The coupling and coordinated development of urbanization can provide a new perspective to look at the development differences and mutual coordination between different regions and within regions. As a big economic province, Shandong Province has developed rapidly since the reform and opening up, and has made remarkable progress

in all aspects. The calculation and analysis of urbanization coupling coordination in Shandong Province can also provide reference for other provinces.

This study selects the panel data of 2010, 2014 and 2018 in Shandong Province, and takes 16 prefecture level cities in Shandong Province (excluding Laiwu City) as the research objects. From the perspective of urbanization coupling coordination, through the coefficient of variation and Theil index, this paper explores the temporal and spatial development changes of cities in Shandong Province, so as to provide support for coordinated urbanization development.

2. Overview and data sources of the study area

2.1 Overview of the study area

Shandong Province, located in East China, is a coastal province. It borders Hebei, Henan, Anhui and Jiangsu from north to south. Shandong is mountainous and hilly, with Shandong Peninsula in the East, North and West on the North China Plain, and mountains and hills in the middle and south. The geomorphic plain and basin crisscross, and the mountains and hills as a skeleton. The climate is warm temperate monsoon climate. The unique natural geographical conditions make Shandong Province an important agricultural province, which lays a good foundation for the development of the secondary and tertiary industries.

Shandong Province governs 16 prefecture level cities including Jinan City, Qingdao City, Zibo City, Zaozhuang City, Dongying City, Yantai city, Weifang City and soon, with a total of 136 county-level administrative regions. By the end of 2019, Shandong Province has a permanent population of 100.0721 million, with a per capita GDP of 70653 yuan and a GDP of 7106.75 billion yuan.

2.2 Data sources

The data in this paper comes from the statistical yearbook of Chinese cities, Shandong statistical yearbook, statistical yearbooks of cities in Shandong Province from 2011 to 2019, and statistical communiques of national economic and social development of cities from 2010 to 2018.

3. Research methods

3.1 Index System Construction and Data processing

This paper constructs the index system from four dimensions of economic urbanization, social urbanization, population urbanization and landscape urbanization. Among them, the level of Economic Urbanization reflects the good situation of all economic subjects in the whole society, which can be reflected in the production situation of all industries in the whole society, the development situation of major industries in the society, the consumption situation of residents, and the financial situation of the government. Social urbanization can reflect the overall living standard of social residents, which can be reflected in the improvement of social public infrastructure, medical and health level, residents' living convenience and the improvement of urban wastewater and waste treatment system. Population urbanization reflects the urbanization of population quantity and quality, which is reflected in the increase of the number and proportion of urban population, and the better guarantee and improvement of the employment and education quality of urban population. Landscape urbanization can directly reflect the visual changes of a city, including the changes of land use types and features. Landscape urbanization can provide a place for economic, social and population urbanization.

Therefore, for the whole system of urbanization, this paper establishes the subsystems of economy, society, population and landscape from the above four levels, so as to study the coordinated development of the interaction among the four subsystems in the whole system of new urbanization. The selection of indicators should follow the principles of scientificity and operability, and consider the actual situation of social and economic development in Shandong Province. On the basis of

reading a large number of references [5] [6], the selection and classification of indicators are carried out. See Table 1 for details.

Because the units of each index are not consistent, so after obtaining a large number of data in the statistical yearbook, it is necessary to further carry out dimensionless data processing. In this paper, the method of normalization is used to normalize the required data. The formula is as follows.

$$X_{norm} = \frac{X - X_{\min}}{X_{\max} - X_{\min}}$$

Table 1 Index system and weights of urbanization coupling coordination research

First level indicators	Secondary indicators	Attribute	Weights
Economic Urbanization	GDP	+	12.36%
	Added value of 2nd industry	+	10.68%
	Added value of tertiary industry	+	16.85%
	Total output value of agriculture, forestry, animal husbandry and fishery	+	10.22%
	Industrial output	+	10.54%
	Consumption expenditure of urban residents	+	8.46%
	Total retail sales of consumer goods	+	13.75%
	Government revenue	+	17.14%
Social urbanization	Natural gas supply	+	14.58%
	Central heating area	+	15.20%
	Number of health institutions	+	12.03%
	Number of medical beds	+	9.42%
	Number of public vehicles in operation	+	18.51%
	Sewage treatment capacity	+	12.84%
	Harmless treatment capacity of domestic waste	+	17.42%
Population urbanization	Urban population	+	31.19%
	Urbanization rate of permanent population	+	14.45%
	Disposable income of urban residents	+	24.91%
	Number of senior high school graduates	+	29.45%
Landscape Urbanization	Road length	+	37.61%
	Urban Road area per capita	+	9.93%
	Green coverage rate of built up area	+	7.53%
	Green space area	+	29.03%
	Per capita park green area	+	15.90%

3.2 Determination of index weights and subsystem scores

In this paper, entropy method is used to determine the weight of each research index in each subsystem. The weight results are shown in Table 1.

3.2.1 Calculate the proportion of the indicator j: P_{ij}

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}}$$

3.2.2 Calculate the information entropy of the index j: e_j

$$e_j = -k\sum_{i=1}^{m}\left(P_{ij} \times \ln P_{ij}\right)$$

Where, $e_j \in [0,1]$ and the constant $k = 1/\ln m$ ($k>0$, m is the number of evaluation units.)

3.2.3 Calculate the redundancy of the index j: d_j

$$d_j = 1 - e_j$$

3.2.4 Calculate the weight value of the indicator j: W_j

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

3.2.5 Determine the score of each subsystem

The P_{ij} and W_j are obtained from the above steps. At this time, the linear weighting method is used to determine the score of each subsystem.

$$F_i = \sum_{j=1}^{m} X_{ij} \bullet W_j$$

$$(i = 1,2,3,\ldots,m;\ j = 1,2,3,\ldots,n)$$

3.3 Coupling coordination degree

3.3.1 Coupling degree model

According to the scores of each subsystem of urbanization, the coupling coordination degree model is established. Referring to the relevant literature of other scholars, the coupling coordination degree model is established.

$$C = \left\{ \frac{U_1 \times U_2 \times U_3 \times U_4}{\left[\left(U_1 + U_2 + U_3 + U_4\right)/4\right]^4} \right\}^{\frac{1}{4}}$$

$U_1 \sim U_4$ are the scores of each subsystem of urbanization; C is the coupling degree, the closer it tends to be 1, the more coordinated it is among subsystems; if it tends to be 0 , the more unbalanced it is among subsystems.

3.3.2 Coupling coordination degree model

In order to find out whether the system coupling coordination degree is at a lower or higher level of coordination, a coupling coordination development degree model is established to reflect the coordinated development level among systems. The formula is as follows.

$$D = \sqrt{CT}$$

$$T = \frac{U_1 + U_2 + U_3 + U_4}{4}$$

T is the comprehensive coordination index of each subsystem of urbanization and D is the coupling coordination degree of each subsystem of urbanization. The larger the value is, the better the coupling coordination effect is.

3.4 Coefficient of variation and Theil index

Through the calculation of coefficient of variation and Theil index, the degree of spatial dispersion and dynamic change of data are obtained.

4. Results analysis

4.1 Dynamic evolution of dispersion degree of urbanization coupling coordination in Shandong Province

The coefficient of variation and Theil index can be used to study the regional dynamic differences [7]. According to the coefficient of variation and Theil index, we can observe the dispersion degree of urbanization coupling coordination in Shandong Province. From 2010 to 2018, the coefficient of variation and Theil index of urbanization coupling co scheduling showed a downward trend, and the coefficient of variation decreased significantly from 0.327 in 2010 to 0.229 in 2014, and then to 0.227 in 2018 (Figure 1). It shows that the degree of dispersion of coupling and coordinated development of urbanization in Shandong Province is decreasing, and the regional difference is decreasing to a certain extent.

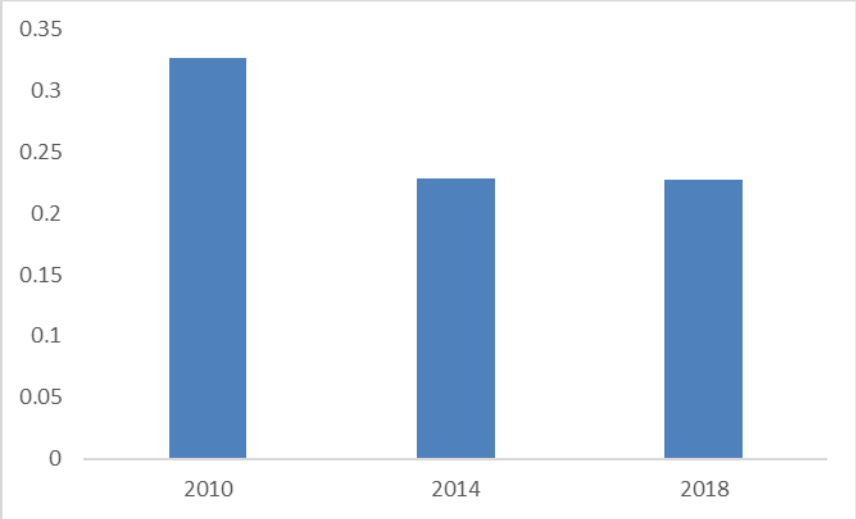

Fig. 1 Trend of variation coefficient of urbanization coupling coordination from 2010 to 2018

4.2 Spatiotemporal differentiation of urbanization coupling coordination

After calculation, there are temporal and spatial differences in urbanization coupling coordination among prefecture level cities in Shandong Province, as shown in Figure 2. From the perspective of time dimension, from 2010 to 2018, the urbanization coupling coordination degree of all cities in Shandong Province showed an upward trend, indicating that the overall urbanization coupling coordination degree of Shandong Province was on the rise. Among them, Qingdao and Heze have the largest increase in urbanization coupling coordination score in 8 years, with Qingdao increasing by 0.277 and Heze increasing by 0.262, as shown in Figure 3. In terms of spatial distribution, Qingdao, Jinan, Yantai, Weifang and Linyi City have the highest level of urbanization coupling coordination among prefecture level cities in Shandong Province. Qingdao has the highest level of urbanization coupling coordination, reaching 0.942 in 2018, while Zaozhuang and Rizhao have the lowest level. In general, Rizhao has the lowest level of urbanization coupling coordination, with a score of only 0.214 in 2010.

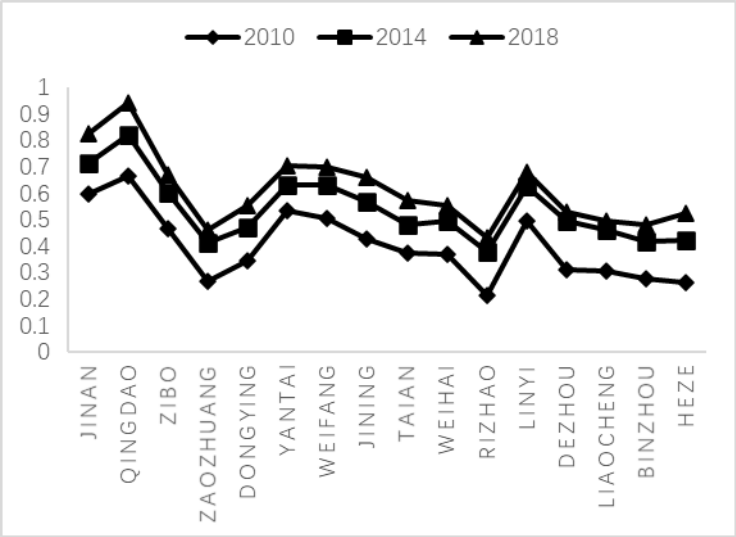

Fig. 2 Comparison of urbanization coupling coordination levels among cities in Shandong Province from 2010 to 2018

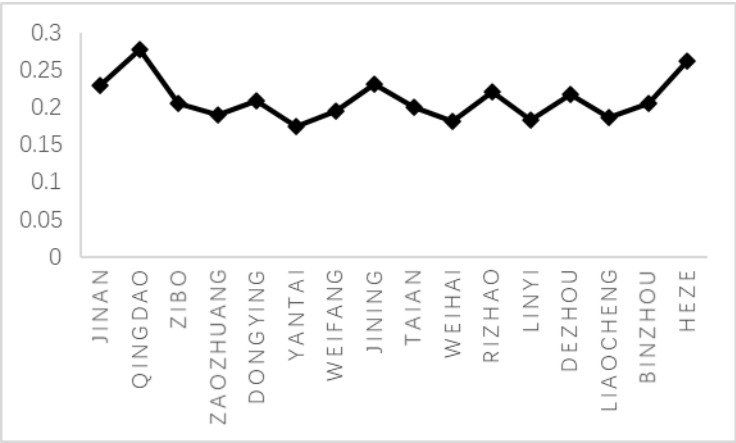

Figure 3 Development range of urbanization coupling coordination score of Shandong Province from 2010 to 2018

In addition, referring to the relevant literatures [8] [9], the paper introduces the urbanization coupling coordination scheduling classification theory, and determines the coordinated development level of each subsystem of urbanization according to the actual situation of each system, as shown in Table 2. Through the analysis, the coupling coordination degree of each city in 2010-2018 is constantly improving, which shows that the coupling coordination degree of urbanization in Shandong Province is rising on the whole, and different cities have appropriately improved their

initial values. After data processing, based on the development of urbanization in 2010-2018, the data in 2018 can be used as the main reference to divide the coupling coordination degree of cities in Shandong Province. The results are shown in Table 3.

Table 2 Classification standard of coupling coordination degree

D-value interval of coupling coordination degree	Coordination level	Coupling coordination degree
(0.0~0.1)	1	Extreme maladjustment
[0.1~0.2)	2	Serious maladjustment
[0.2~0.3)	3	Moderate maladjustment
[0.3~0.4)	4	Mild maladjustment
[0.4~0.5)	5	On the verge of maladjustment
[0.5~0.6)	6	Level-basic coordination
[0.6~0.7)	7	Primary coordination
[0.7~0.8)	8	Intermediate coordination
[0.8~0.9)	9	Good coordination
[0.9~1.0)	10	High quality coordination

Table 3 Coupling coordination degree classification of cities in Shandong Province

Coupling coordination degree	Coordination level	City
On the verge of maladjustment	5	Zaozhuang, Rizhao, Liaocheng, Binzhou
Level-basic coordination	6	Dongying, Tai'an, Weihai, Dezhou, Heze
Primary coordination	7	Zibo, Weifang, Jining, Linyi
Intermediate coordination	8	Yantai
Good coordination	9	Jinan
High quality coordination	10	Qingdao

5. Conclusions

This paper analyzes the spatial comparison of urbanization coupling coordination degrees of 16 prefecture level cities in Shandong Province, discusses the differences of urbanization coupling coordination level among different regions in Shandong Province, and discusses the spatiotemporal dynamic evolution. The main conclusions are as follows.

(1) From 2010 to 2018, the coupling coordination degree of urbanization in Shandong Province is on the rise, and the coupling coordination level of urbanization in all cities has been improved. In 2018, the coupling coordination degree of cities in Shandong Province has reached the coordination level. It includes four cities on the verge of imbalance, five barely coordinated cities, four primary coordinated cities, and one intermediate, one good and one high-quality coordinated city.

(2)Among them, Qingdao, Jinan, Yantai and Weifang are among the top cities in Shandong Province, while Zaozhuang and Rizhao are slightly deficient in the level of urbanization coupling coordination in Shandong Province, and there is still a broad space for development.

(3) From 2010 to 2018, the coefficient of variation and Theil index of coupling and coordinated development of urbanization in Shandong Province continue to decline, which shows that the dispersion degree of coupling and coordinated development among different regions in Shandong province continues to decline, and the regional differences show a decreasing trend to a certain extent.

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