Coupling and Coordination Development Between Urbanization and Eco-environment in National New Areas

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Abstract. Taking 22 prefecture-level cities from national new areas as the research objects, based on entropy weight method and coupling coordination model, we analyzed the coordination degree's temporal and spatial dynamic evolution between urbanization and ecological environment from 2003 to 2018. The results show that: (1) The level of urbanization and eco-environment subsystems of national new areas are continuously improving, with the eco-environment levels being lower than the urbanization levels, they are classified as "lagging ecological environment" cities; (2) The coupled coordination relationship between urbanization and ecological environment has completed the transformation from imbalance to intermediate coordination, the overall trend is toward a healthy development. (3) Cities in midwestern regions have great potential for development, their urbanization levels, ecological environment levels and coupling coordination levels are lower than those of the eastern regions.

Keywords: Urbanization · Eco-environment · Coupling and Coordination Degree · National New Areas

1 Introduction

National new areas are approved, established and built by The State Council, whose main task is to implement the major development strategies and economic reform policies. From 1992 to 2017, 19 national new areas have been established, which are widely distributed in the eastern and midwestern regions of China. Studies mainly focuses on the following aspects: (1) The functional positioning and strategic orientation of national new areas. Li et al. proposed an index system for evaluating the development potential of national new areas covering 18 indicators [1]. (2) Management system of national new areas. Bo sorted out the dilemmas and shortcomings of national new areas [2]. (3) Comparative study of national new areas. Hao believes that national new areas are the latest stage of the development of China's special economic zones, which are established to implement special policies and management means within a certain spatial area [3].

While urbanization brings positive effects such as population agglomeration, industrial structure optimization and rapid economic growth, it inevitably aggravates environmental pollution and resource waste in cities. Eco-environment is also becoming a

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major factor limiting the development of urbanization. The coordinated development of urbanization and ecological environment has been studied focusing on the following aspects: (1) Basic theory and variation law. Bandyipadhyay et al. proposed the environmental Kuznets curve, which suggested that urban economic development and ecological environment quality show an inverted "U" shape evolution [4]. (2) Evaluation of the development of coupling and coordination. A number of domestic scholars have conducted empirical studies on the coupling of urbanization and eco-environment in southwest China, Beijing-Tianjin-Hebei Region, Central Plains City Cluster, as well as Yangtze River Delta [5–8]. (3) The path of coordinated development. Pei believes that optimizing industrial structure, saving resources and improving physical fitness are important measures to promote the coordinated development [9].

In summary, researchers have paid little attention to the coordinated development of urbanization and eco-environment in national new areas. The dynamic comparison is mostly based on time-series analysis, while the spatio-temporal pattern evolution is relatively insufficient. Therefore, this paper selects 22 cities of the national new areas as research objects, quantitatively analyses the evolution characteristics of coordinated development of urbanization and eco-environment from time and space based on the entropy weight and coupling coordination model, to provide a reliable basis for the formulation of coordinated development policies of the national new areas.

2 Research Methods

2.1 Index Selection and Evaluation System Construction

On the basis of relevant research [10, 11], 23 indicators are selected to construct the urbanization and eco-environment index system, and the entropy method [12] is used to calculate the weight, as shown in Table 1.

2.2 Research Area and Data Sources

Established as early as 1993 in Pudong New Area, Shanghai was endowed with many preferential policies, in order to assure the comparability of cities, this paper excludes Shanghai and selects other 22 cities to collect and sort out the coordinated development status from 2003 to 2018. All indicators are obtained from the China City Statistical Yearbook and provincial yearbooks, few missing values were supplemented by the annual statistical bulletin of each city.

2.3 Entropy Weight Method

Compared with subjective assignment methods such as hierarchical analysis and expert evaluation, the entropy weighting method can avoid bias caused by human factors and reflect the relative importance of indicators more objectively. In order to unify the positive and negative indicators, and to facilitate the vertical time difference analysis of the data and the horizontal spatial and temporal comparison of the city data, the data should be dimensionless, and the calculation formula are as follows:

$$\text{Positive indicators}: x_{ij} = (X_{ij} - minX_{ij})/(maxX_{ij} - minX_{ij}) \quad (1)$$

Table 1. The index system and weights of urbanization and eco-environment..

Item	First grade indexes	Second grade indexes	Weights
The integration value of urbanization	Demographic urbanization	Urbanization rate	0.1038
		Proportion of secondary industry employees	0.0517
		Proportion of tertiary industry employees	0.0608
	Economic urbanization	GDP per capita	0.0896
		Total retail sales of consumer goods per capita	0.0717
		Per capita RMB savings deposits	0.0798
		Proportion of the added value of secondary industry	0.0639
		Proportion of the added value of tertiary industry	0.0705
	Social urbanization	The number of college students per 10,000 people	0.1334
		Post and telecommunications business per capita	0.0445
		Public libraries contain books for every hundred people	0.0315
		Number of doctors per 10,000 people	0.0652
	Spatial urbanization	Administrative area of land	0.1117
		Urban road area per capita	0.0218
The integration value of eco-environment	Ecological pressure factor	Discharged volume of industrial dust per capita	0.0970
		Discharged volume of industrial wastewater per capita	0.0576
		Discharged volume of industrial SO_2 per capita	0.0650
	Ecological endowment factor	Percentage of vegetation with green areas	0.0582

(*continued*)

Table 1. (*continued*)

Item	First grade indexes	Second grade indexes	Weights
	Ecological response factor	Comprehensive utilization rate of general industrial solid waste	0.1087
		Rate of centralized treatment of sewage treatment plants	0.1715
		Harmless disposal rate of domestic garbage	0.1166
	Resource factor	Gas supply per capita	0.1783
		Liquefied petroleum gas supply per capita	0.1471

$$\text{Negative indicators}: x_{ij} = (maxX_{ij} - X_{ij})/(maxX_{ij} - minX_{ij}) \tag{2}$$

Where, x_{ij} is the data obtained after the normalization process; X_{ij} is the original data of the index; $maxX_{ij}$ and $minX_{ij}$ are the two levels of the original data, respectively. After obtaining the dimensionless data, select translation amplitude ω=1 and the calculation process are as follows:

$$x'_{ij} = x_{ij} + \omega \tag{3}$$

$$P_{ij} = x'_{ij}(\sum_{i=1}^{n} x'_{ij})^{-1} \tag{4}$$

$$e_{ij} = (-\ln n)^{-1}\sum_{i=1}^{n} P_{ij}\ln P_{ij} \tag{5}$$

$$W_j = (1 - e_{ij})(n - \sum_{i=1}^{n} e_{ij})^{-1} \tag{6}$$

Where, P_{ij} is the share of the jth indicator in ith city; e_{ij} is the entropy of the jth indicator; W_j is the weight of jth indicator.

2.4 Coupling Degree Model

The comprehensive efficiency $U(x)$ and $E(y)$ of urbanization and eco-environment system are calculated according to the weights and data obtained above. a and b are the indexes of two systems respectively, and the calculation formula are as follows:

$$U(x) = \sum_{i=1}^{a} W_j x_{ij} E(y) = \sum_{i=1}^{b} W_j y_{ij} \tag{7}$$

Table 2. The division criteria of coupling coordination degree.

Rank	D	Coordination stage	Rank	D	Coordination stage
1	0.00 ≤ D < 0.09	Extreme imbalance	6	0.50 ≤ D < 0.59	Barely coordination
2	0.10 ≤ D < 0.19	Serious imbalance	7	0.60 ≤ D < 0.69	Primary coordination
3	0.20 ≤ D < 0.29	Moderate imbalance	8	0.70 ≤ D < 0.79	Intermediate coordination
4	0.29 ≤ D < 0.39	Mild imbalance	9	0.80 ≤ D < 0.89	Good coordination
5	0.30 ≤ D < 0.49	On the verge of imbalance	10	0.90 ≤ D < 1.00	High quality coordination

Coupling usually refers to the interaction and influence of two or more systems [13]. Due to the synergistic action of disordered parameters in each system, the system changes from disordered to ordered. For a binary system, the coupling degree is calculated as follows:

$$C = 2\left[\frac{U(x) \times E(y)}{(U(X) + E(y))^2}\right]^{1/2} \tag{8}$$

Coupling degree $C \in [0, 1]$, with the increase of C, the two systems promote each other and the degree of coordination is higher, the system develops from disorder to order.

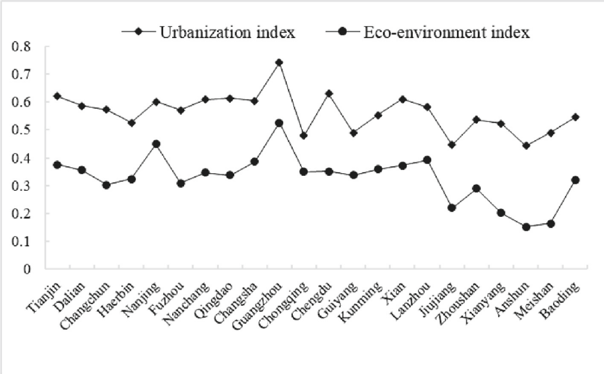
2.5 Coupling Coordination Degree Model

Coupling degree maps the degree of mutual interaction between urbanization and ecological environment, while it may be difficult to precisely reflect the degree of synergistic development, thus the coupling coordination degree model [14] is used to measure the degree of coupled and coordinated development between different subsystems, and the calculation formula is as follows:

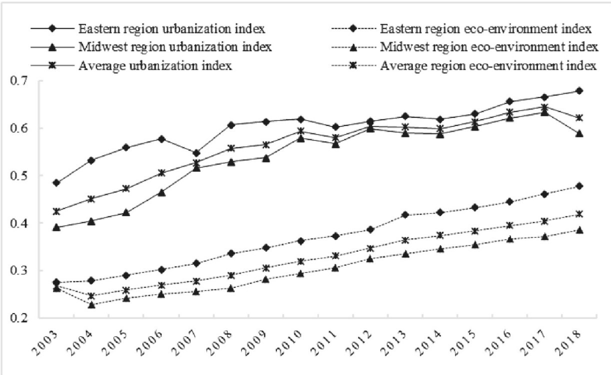
$$T = \alpha U(x) + \beta E(y) \tag{9}$$

$$D = \sqrt{C \times T} \tag{10}$$

Where, D is coupling coordination degree; T is the comprehensive coordinated development index between them; α and β are undetermined coefficients, $\alpha + \beta = 1$. This paper holds that urbanization and ecological environment are equally important to urban development, so $\alpha = \beta = 0.5$. Referring to relevant studies [15], the specific partitioning criteria are shown in Table 2:



a. Indexes of different cities



b. Indexes of different regions

Fig. 1. Urbanization and eco-environment index in national new areas

3 Analysis of Results

3.1 Analysis of the Urbanization System and Ecological Environment System

Based on the indicators of urbanization and ecological environment evaluation system of national new areas, the weight of each indicator was calculated by using the entropy weight method (see Table 1). The weights were put into formula (7) to calculate and the comprehensive index of urban urbanization system and eco-environment system. Figure 1 show the results of the urbanization and eco-environment index of different cities and different regions respectively.

From the city level, as shown in Fig. 1(a), among the 22 cities, Guangzhou has strong development momentum and its urbanization index and ecological environment index are the highest, with an average urbanization index of 0.7410 and an average eco-environment index of 0.5258; while some cities with relatively backward economic development, such as Anshun, has the lowest urbanization index and ecological environment index, with an average urbanization index of only 0.4425, while the ecological environment development index is only 0.1526.

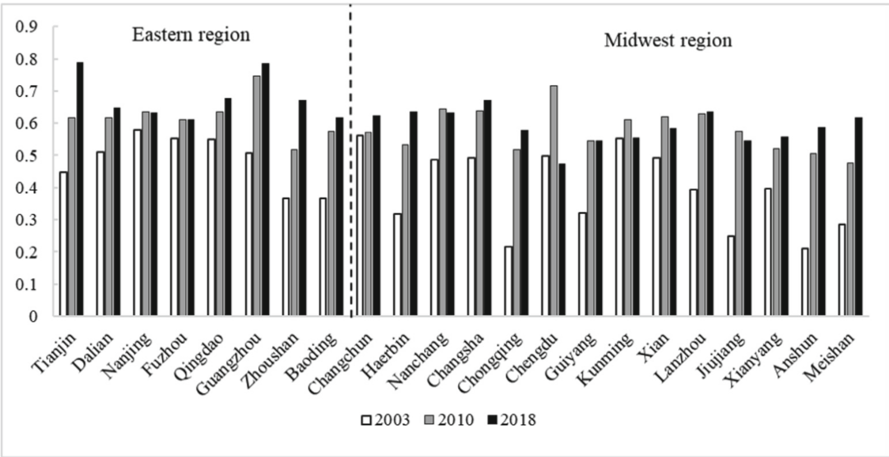


Fig. 2. Evolution of urbanization level

From the temporal level, as shown in Fig. 1(b), both the urbanization index and the eco-environment index have steadily increased during the period of 2003–2018. The average urbanization index increased from 0.4254 to 0.6211; the eco-environment index increased from 0.2670 to 0.4186, while there is a big gap between them, indicating there is an urgent need for high-quality development. In terms of regions, the eastern region continues to lead in the level of urbanization and eco-environment by virtue of its good economic foundation, strong geographical advantages, and abundant human capital.

3.1.1 Evolution of Urbanization Level

Figure 2 selects the urbanization index of each city at three time points of 2003, 2010 and 2018. The urbanization index of the eastern region is much higher than that of the central and western regions in 2003. By 2018, the urbanization level of the central and western regions has increased significantly, and the gap with the eastern region has narrowed greatly, which also alleviates the spatial polarization of urbanization. Tianjin and Guangzhou occupy a leading position. Although the urbanization level of Chongqing, Anshun and Meishan is low, their urbanization indexes have increased rapidly, which has great development potential.

3.1.2 Evolution of Eco-environment Level

As shown in Fig. 3, compared with the urbanization index, the ecological environment evaluation index is generally low, but due to the substantial increase in the green coverage rate of the built-up area, and vigorously strengthen the protection of environmental resources, the harmless treatment rate of all kinds of domestic waste and industrial waste has increased, and the eco-environment index has also increased. Similar to the development of urbanization, Tianjin, Nanjing and Guangzhou have increased rapidly and are much higher than other cities, while Jiujiang, Anshun and Meishan have a small growth rate and far behind other regions. In general, the awareness of ecological and

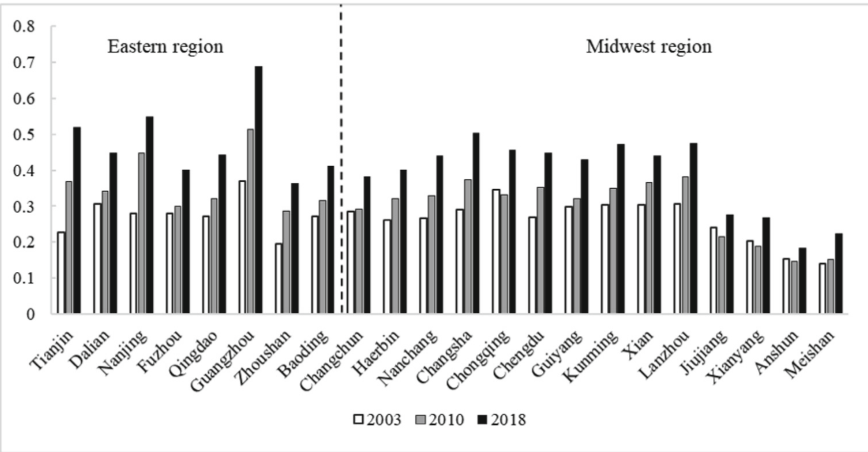


Fig. 3. Evolution of eco-environment level

environmental protection in each city has increased gradually, the ability of resource and environmental protection has been continuously enhanced, and the level of ecological environment has steadily improved.

3.2 Analysis of the Coupling and Coordination Degree in National New Areas

The weight and comprehensive index value of the two system indexes of urbanization and ecological environment have been calculated based on the entropy method above, we further calculated the coupling coordination degree D. Referring to the classification standard of coupling coordination degree (Table 2), the coupling coordination degree of urbanization and eco-environment of national new areas is divided. The results show that the coupling coordination degree of the urbanization level and the eco-environment development level from 2003 to 2018 is mainly distributed in the range of 0.4088–0.8571, which includes five coordination levels: on the verge of imbalance, barely coordination, primary coordination, intermediate coordination and good coordination.

In order to further analyse the different spatial conditions of national new areas in China, we use the ArcGIS software to visualize the coupling coordination degree of three important time nodes in 2003, 2010 and 2018 as well as the annual average (Figs. 4, 5, 6 and 7), which can intuitively observe the change of coupling coordination degree with time and the development gap of different cities. In 2003 (Fig. 4), the overall development level was relatively low, most of which were in a state of barely coordination, and there were even cities, such as Jiujiang and Meishan, on the verge of imbalance. By 2010 (Fig. 5), most of the cities had gradually developed into the primary coordination level. By 2018 (Fig. 6), most of national new areas were in a state of intermediate coordination, and Guangzhou City had even reached a good coordination stage. Figure 7 shows that the coupling development level of the average value is closest to that of 2010. In summary, the urbanization and eco-environment of national new areas have basically achieved coordinated development, but there is still a big gap from achieving high-quality coordinated development.

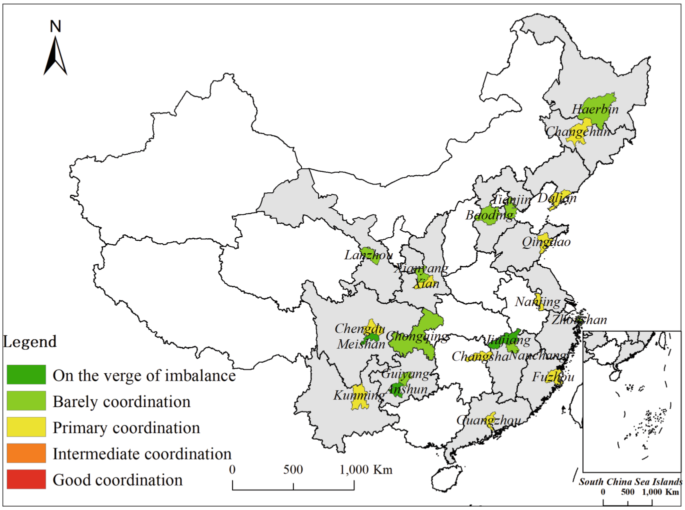


Fig. 4. Coupling coordination degree in 2003

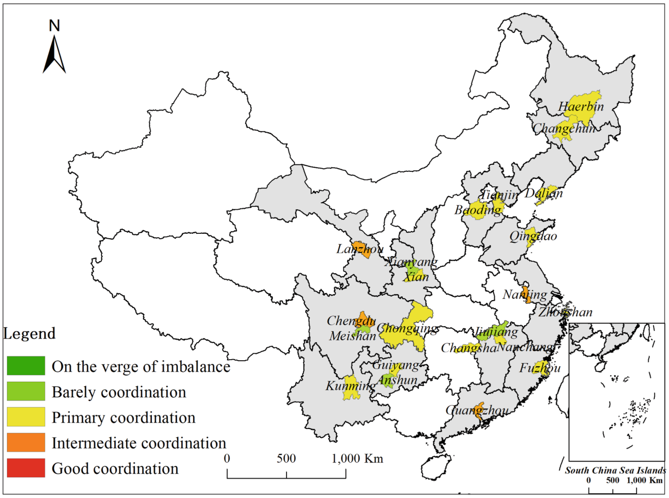


Fig. 5. Coupling coordination degree in 2010

Figure 8 depicts the changes of the coupling and coordination degree of urbanization development and eco-environment development in the national new areas by means of line graphs, Fig. 8(a) shows the average value of the coupling and coordination degree of the eastern and midwestern regions in the national new areas over time. In Fig. 8(b), the average coupling degree is almost the same as the coupling degree in 2010, which show that the coupling degree of each city is steadily increasing year by year, but with large differences. Some resource-based cities have relatively diversified industrial structures, abundant alternative industries, and can use ecological and environmental resources

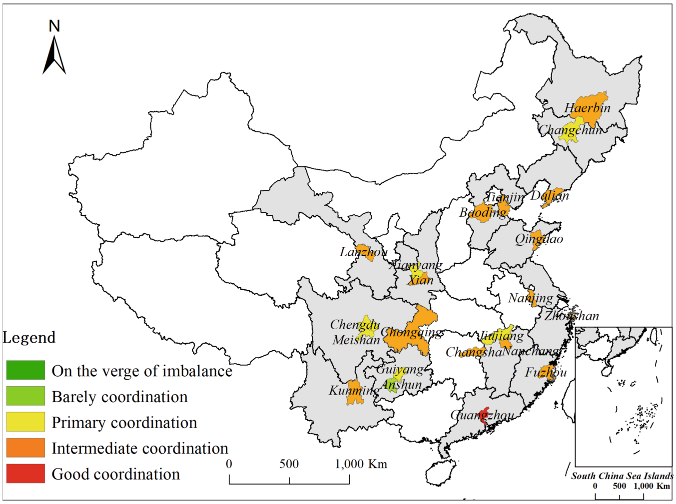


Fig. 6. Coupling coordination degree in 2018

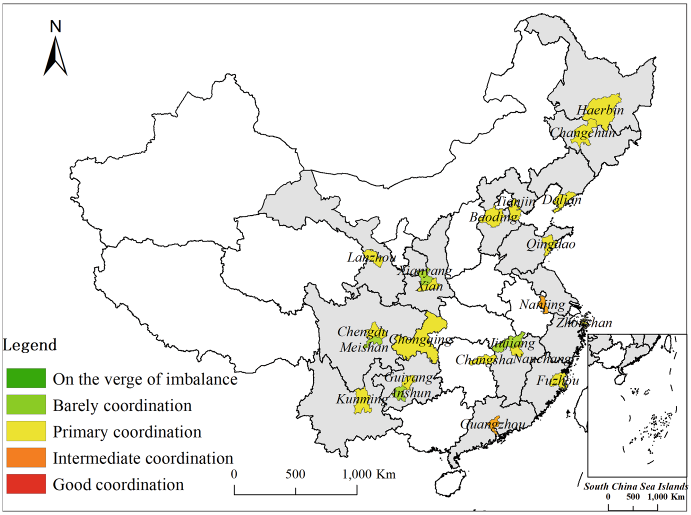
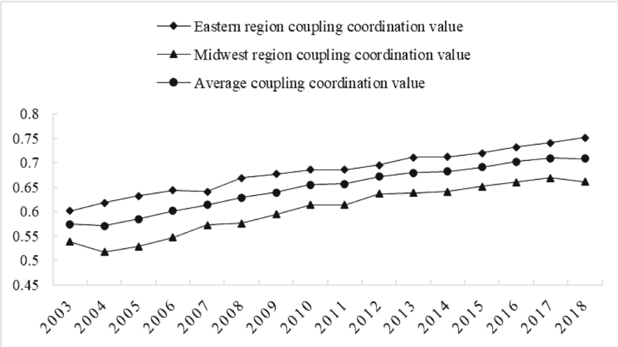
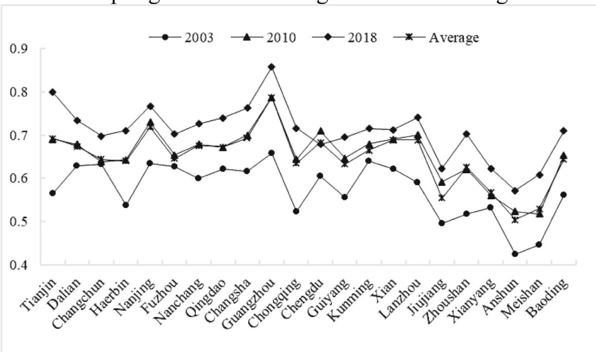


Fig. 7. The average coupling coordination degree

more efficiently in the urbanization process, thus the coupling coordination degree is also higher. In other regions, the urbanization of population and economic urbanization are relatively backward, and the development and utilization of ecological resources are sloppy and inefficient, resulting in a low degree of coupling and coordination.



a. Coupling coordination degree in different regions



b. Coupling coordination degree in different years

Fig. 8. The coupling and coordination degree in national new areas

4 Conclusions and Recommendations

From the view of interaction between urbanization and eco-environment, coupling coordination degree model is used to measure the spatial interaction of national new areas, the conclusions are drawn: (1) The urbanization system and ecological environment system of the national new area have maintained an upward trend in the past two decades, and the urbanization development is pioneering, while the eco-environment development reflects lagging. In terms of spatial distribution, the high value areas of both systems are concentrated in developed cities in the eastern region, such as Guangzhou, Tianjin, Nanjing and Fuzhou, while the low value areas are concentrated in smaller cities in the midwestern regions, such as Anshun, Meishan, Xianyang and Jiujiang. (2) The coupled coordination relationship between urbanization and eco-environment has transformed from near disorder to primary coordination to intermediate coordination, indicating that the two systems are developing in a benign and orderly direction. By 2018 Guangzhou's urbanization and ecological environment development have stepped into a harmonious right track, while the development of cities in Midwest regions such as Anshun and Meishan remains lagging behind. (3) The national new areas in midwestern regions have a lot of room for development, whose urbanization levels, eco-environment levels and coupling coordination levels are lower than those of the eastern regions.

Based on this, in order to solve the problem of the interactive development of urbanization and eco-environment, suggestions are proposed as follows: (1) National new areas are "lagging ecological environment" cities, they should focus on improving the quality of urbanization in the future, pay more attention to the efficient use of eco-environment, improve the protection system of water environment, air environment and soil environment, strictly control the emission of three wastes, and further use environmental protection to force the transformation and upgrading of industries to achieve the transformation of old and new dynamics. Transforming the previous crude urbanization development model that simply attaches importance to scale expansion and population number agglomeration, and adhere to the connotative urbanization development that is driven by industry, takes eco-environmental protection as the premise, and realizes coordinated development of society, economy, resources and environment as the ultimate goal. (2) Cities with a low level of urbanization should absorb more people in accordance with the carrying capacity of local resources and environment, accelerate the process of population, space, economic and social urbanization, and comprehensively improve the quality of urbanization. In the selection of industries, we should make use of the advantages of eco-environment, expand and strengthen the competitive industries, develop circular economy, and unswervingly take the road of green, low-carbon and sustainable development. In terms of social development, the level of public services such as medical care and education should be accelerated. Leading the integrated development of urban and rural areas with the strategy of rural revitalization, and speeding up the construction of institutional mechanisms for integrated development of urban and rural areas.

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