

Research on Coupling and Coordinated Development of Energy Industry in Anhui Province, China, Based on the TOPSIS Model

Liu Xiao Qian^{1,2}, Benjamin Chan Yin Fah¹

¹ Universiti Tun Abdul Razak (UNIRAZAK)

²Guangdong Baiyun University, Guangzhou, China

Abstract

The economic development and ecological status of various regions in Anhui Province from 2020 to 2022 were analyzed by using the synergetic optimization model, and the synergetic coordination among regions was analyzed by using the TOPSIS model. The analysis shows that the economic development and the coordinated scheduling of the ecosystem in Anhui province show an obvious optimization trend on the whole. The coordinated scheduling is mainly between 0.282 and 0.654, which is a better or worse coordinated coordinated scheduling on the whole. The ecological status indicators of each region are significantly higher than that of other regions. The degree of coupling and coordination between the provincial capital cities and the south of the Yangtze River is higher than that between the Huaihe River and the north of the Huaihe River. Through improvement, the coordinated management of economy and environment can be improved, and the emission of "three wastes", environmental quality and environmental pollution control capacity can be improved.

Keywords: Coupling model; Ecological environment; Economics; Coordinated development

1) Introduction

The rapid economic development and the serious degradation of the ecological environment are a huge contrast. When resources are exhausted, ecological deterioration and environmental deterioration, Anhui Province's economic results are not as pleasant as before^[1]. This is also the ecological environment issue that China government pay close attention to. Therefore, in the process of developing and protecting ecology, there must be a scientific and efficient cooperative relationship to ensure the sustainable development of society^[2].

2) Literature review

The harmonious development of ecology and economy has always been the focus of international and regional scholars. Meadows and other economists jointly published a book called "Limits to Growth", which simulates the relationship between economy and ecology through a systematic dynamic model. Grossman and Kruger proposed the Kuznets curve. They believe that when the economy develops, the quality of the environment will change from bad to good^[3].

Costanza Robert pointed out that in order to achieve the harmonious relationship between economy and ecology, we should not only rely on the development of environmental technology, but also pay attention to the measurement of social development. In China, Chen Zuhai divided the coordinated development of ecology and economy into three stages: primitive, modern and modern. Jiang Hongli and others advocated that the harmonious development of economy and ecology is a process of mutual promotion, coupling and coordinated development^[4].

Dong Huizhong pointed out that the pressure mechanism of regional economy on ecosystem has two positive and negative interactions. In recent years, the harmonious development of China's ecology and economy has achieved relatively fruitful results. Previous studies have mostly focused on a single system, rarely involving the interaction and synergy between the two systems and the evaluation, and lack a model that can explain the coupling relationship between the two systems. For this reason, the article starts from Qingdao and uses the coupling model of physics to conduct an empirical analysis of the harmonious development of ecology and society in China, with a view to helping the development of other regions^[5].

3) Methodology

The research data are mainly from the statistical yearbook of Anhui Province, the bulletin of water resources, the bulletin of environmental quality and the statistical bulletin of national economic and social development of cities from 2020 to 2022. The interpolation method or extrapolation method is used to supplement and improve individual missing data.

3.1 Weighting by entropy method

The objective weight is determined by the subjective weighting method and the objective weighting method. This study uses the entropy method in the objective weighting method to calculate, which can avoid the purposefulness of weight setting. The objective weighting method calculates the weight of each index, and calculates the economic development index and ecological environment index of each city through the linear weighting method.

Formula (1) is the forward indicator standardization, and formula (2) is the reverse indicator standardization. The formula is as follows:

$$X_{ij} = \frac{a_{ij} - \min\{a_{ij}\}}{\max\{a_{ij}\} - \min\{a_{ij}\}} \quad (1)$$

$$i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

$$X_{ij} = \frac{\max\{a_{ij}\} - a_{ij}}{\max\{a_{ij}\} - \min\{a_{ij}\}} \quad (2)$$

$$i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

In order to ensure the accuracy of the results, dimensionless treatment is required, and the result is 0.001, that is, Z_{ij} is the index after dimensionless treatment.

Calculate the proportion of the i th index under the j th index, and the formula is as follows.

$$P_{ij} = \frac{Z_{ij}}{\sum_{i=1}^m Z_{ij}} \quad (3)$$

Calculate the entropy value of the j th index, and the formula is as follows.

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^m P_{ij} \ln P_{ij} \quad (4)$$

Calculate the difference coefficient g_i of the j th index, and the formula is as follows.

$$g_i = 1 - e_i \quad (5)$$

Calculate the weight w_j of the j th index, and the formula is as follows.

$$W_j = \frac{g_i}{\sum_{j=1}^m g_i} \quad (6)$$

3.2 Coupling model of economic development and ecological environment

Build a coupling model of economic development and ecological environment, and the formula is:

$$C = \left\{ \frac{U_1 \times U_2}{[0.5 \times (U_1 + U_2)]^2} \right\}^k \quad (7)$$

$$T = aU_1 + bU_2 \quad (8)$$

$$D = \sqrt{C \times T} \quad (9)$$

Where, C represents the coupling degree, U_1 represents the economic development index, and U_2 represents the ecological environment index; K is the adjustment factor, where the empirical value is 2; T is a comprehensive economic and ecological environment indicator; A and b are the protection coefficients of economic development and ecological environment, where a and b are taken as 0.5; D is the result of coordination. The coupling degree can be used to measure the degree of phase coupling in the system, but it can only reflect the interaction strength of the system, without any advantages and disadvantages. Coupled collaborative scheduling can not only reflect the mutual influence of each system, but also reflect the good degree of each system. Coupled collaborative scheduling can link the ecological environment and economic development to make it more comprehensive. The level of coupling degree and coupling coordination degree is shown in Table 1.

Table 1 Classification of coupling degree and coordination degree of economic development and ecological environment

Coupling degree (C)	Coupling stage	Coupled co-dispatch (D)	Coupling coordination degree
0.81~1.00	Highly coupled	0.7~1.0	High-quality coordinated development
0.51~0.80	Running-in coupling	0.5~0.7	Good coordinated development
0.11~0.50	Antagonistic coupling	0.4~0.5	Low-level coordinated development
0~0.10	Low coupling	0.3~0.4	Mild disorder development
		0~0.4	Serious maladjustment development

4) Results and discussion

4.1 Economic development and ecological environment index

Table 2 and Table 3 respectively calculate the economic development and ecological status indicators of various regions in Anhui Province from 2020 to 2022. Overall, the ecological status indicators of each region are significantly higher than those of other regions. The economic foundation of Anhui Province is relatively poor. Although the economic growth rate is very high in recent years, the overall development level is still very low. At the same time, Anhui province attaches great importance to the construction of the ecological environment, and the ecological conditions have been significantly improved, but on the whole, the economic development lags behind the ecological environment.

Table 2 Economic development index of different regions in Anhui Province

Regional	cities	2020	2021	2022
Between the	Hefei	0.600	0.602	0.583
Yangtze River	Chuzhou	0.116	0.134	0.213
and Huaihe	Lu'an	0.153	0.155	0.137
River	Mountain			
North of	Huaipei	0.171	0.174	0.164
Huaihe River	Suzhou	0.151	0.158	0.126

Regional	cities	2020	2021	2022
	Bengbu	0.187	0.204	0.282
	Huainan	0.255	0.252	0.238
Jiangnan along	Ma'anshan	0.441	0.451	0.458
the river	Wuhu	0.431	0.434	0.441
	Mount Huang	0.185	0.182	0.152
	Anqing	0.135	0.138	0.150
Provincial average		0.211	0.215	0.212

Table 3 Ecological environment index of different regions in Anhui Province

Regional	cities	2020	2021	2022
Between the	Hefei	0.412	0.378	0.423
Yangtze River	Chuzhou	0.567	0.542	0.580
and Huaihe	Lu'an	0.627	0.706	0.614
River	Mountain			
North of	Huaibei	0.421	0.416	0.424
Huaihe River	Suzhou	0.567	0.453	0.446
	Bengbu	0.540	0.514	0.554
	Huainan	0.257	0.281	0.324
Jiangnan along	Ma'anshan	0.171	0.211	0.220
the river	Wuhu	0.475	0.427	0.458
	Mount Huang	0.733	0.811	0.716
	Anqing	0.572	0.555	0.580
Provincial average		0.501	0.488	0.506

From the perspective of time, the economic development and ecological environment indicators of Anhui Province have shown significant changes. The development indicators of the regions along the Yangtze River, Huaihe River and the south of the Yangtze River show a fluctuating growth trend; The economic development indicators in the north of the Huaihe River have declined slightly, including the development indicators in Suzhou, Huainan and Huaibei; The ecological environment indicators in the Jianghuai River and the northern part of the Huaihe River show a fluctuating trend, while the ecological environment indicators in the southern part of the Yangtze River and the Yangtze River basin are generally stable.

From the regional point of view, the ecological and economic development indicators in the south of the Yangtze River and the Huaihe River are better than those in the north of the Huaihe River. In

recent years, the development of various regions in Anhui province has shown an unbalanced trend. In recent years, the development level of Hefei and Maanshan are both in the forefront of the country; The development indicators of Suzhou and Lu'an are lower than 0.2. In the future, more economic construction and cooperation among regions are needed to bridge the differences in economic development between regions. In terms of economic development indicators, the gap between different regions shows a decreasing trend, mainly Huangshan and Lu'an, both exceeding 0.70.

4.2 Economic development and ecological environment coupling degree and coupling coordination

See Table 4 and Table 5 for the calculation results of the coupling degree and coordination degree of economic development and ecological environment in different regions in 2020-2022.

Table 4 Coupling degree of economic development and ecological environment in different regions of Anhui Province

Regional	cities	2020	2021	2022
Between the Yangtze River and Huaihe River	Hefei	0.83	0.86	0.87
	Chuzhou	0.52	0.63	0.51
	Lu'an	0.21	0.21	0.28
	Mountain			
North of Huaihe River	Huaibei	0.73	0.71	0.70
	Suzhou	0.40	0.30	0.40
	Bengbu	0.67	0.61	0.61
	Huainan	0.81	0.75	0.87
Jiangnan along the river	Ma'anshan	0.75	0.75	0.78
	Wuhu	1.00	1.00	0.87
	Mount Huang	0.43	0.43	0.50
	Anqing	0.52	0.52	0.51
Provincial average		0.71	0.71	0.71

Table 5 Coupling and coordination degree of economic development and ecological environment in different regions of Anhui Province

Regional	cities	2020	2021	2022	mean value	Coupling co-scheduling
Between the Yangtze River and Huaihe	Hefei	0.650	0.636	0.660	0.654	Good coordination
	Chuzhou	0.405	0.421	0.508	0.413	Low level coordination
	Lu'an	0.300	0.284	0.262	0.316	Low degree

Regional	cities	2020	2021	2022	mean value	Coupling co- scheduling disorder
River	Mountain					
North of Huaihe River	Huaibei	0.466	0.470	0.461	0.461	Low level coordination
	Suzhou	0.283	0.310	0.262	0.282	Mild disorder
	Bengbu	0.483	0.501	0.477	0.457	Low level coordination
	Huainan	0.437	0.44	0.431	0.458	Low level coordination
Jiangnan along the river	Ma'anshan	0.467	0.515	0.512	0.510	Good coordination
	Wuhu	0.638	0.625	0.637	0.624	Good coordination
	Mount Huang	0.471	0.461	0.431	0.477	Low level coordination
	Anqing	0.421	0.425	0.437	0.423	Low level coordination
Provincial average		0.503	0.505	0.503	0.515	

In terms of coupling, the economic development and ecological environment of Anhui province is a "run-in" process, and the "coupling" in the south of the Yangtze River is greater than that in the north of the Yangtze River and Huaihe River. At the municipal level, the coupling process of 11 cities can be divided into three levels: ① strong coupling. Among them, Hefei, Wuhu and Huainan are all in this mode, and the coupling degree is more than 0.9, which shows that the economic development and ecological environment function in the region are the same. ② Friction connection. Maanshan, Huaibei, Bengbu, Chuzhou, Anqing and Huangshan all belong to this type, and their coupling degree varies from 0.6 to 0.9, indicating that their ecosystems cannot adapt to the pressure of development. ③ Duality. The coupling degree of Suzhou and Lu'an is between 0.3 and 0.6, which represents the overall level of economic development and ecological status of the region.

In terms of coordination, overall, the coordination of economic development and ecosystem has been significantly improved. The level of coordination in the south of the Yangtze River is better than that in the north of the Yangtze River and Huaihe River. At the urban level, the coupling adjustment rate of 11 cities is divided into three levels: ① Good coordination. Hefei, Wuhu, Maanshan. ② Low-level coordination. Huangshan, Huaibei, Huainan, Bengbu, Anqing. ③ Mild imbalance to and below. This is the case in Suzhou and Liu'an. In addition, the spatial-temporal imbalance of regional coordination is

the main reason for the imbalance of regional economic development. The level of coordinated

dispatch in cities with relatively developed economic development, such as provincial capital cities and cities along the river, is generally higher than that in less developed cities such as the northern part of the Huaihe River.

4.3 Analysis of factors affecting the coupling and coordinated development of economic development and ecological environment.

In terms of environmental assessment, the emissions of "three wastes", environmental quality and environmental pollution are the main reasons for coordinated environmental control. These indicators include: harmless treatment rate of urban domestic waste, industrial waste gas and wastewater discharge, artificial afforestation area, comprehensive utilization rate of general industrial solid waste, water quality compliance rate of urban centralized drinking water source, provincial control and above Class I~III water quality section ratio, air quality reaching and better than Class I days ratio, etc., which are closely related to collaborative management. It is proposed to further strengthen the control of industrial pollution, develop a sustainable circular economy, reduce the discharge of pollutants, improve the disposal efficiency of solid waste and domestic waste in general industries, and reduce the production of general industrial solid waste. This measure will promote the economic development and ecosystem coordination of Anhui province. At the same time, improving the water quality standard rate of urban centralized water supply, the proportion of provincial control and above Class I~III water quality sections, and the proportion of excellent days also play a positive role in improving the coordinated dispatching.

In terms of economic development, the proportion of the secondary industry using resources in GDP, regional GDP, per capita disposable income of rural residents, per capita GDP, and per capita disposable income of urban residents have a great impact on coupling coordination. The second industry is likely to cause "structural pollution" in the process of promoting economic development. From 48.3% in 2020 to 41.3% in 2022, the proportion of GDP in the tertiary industry increased from 39.6% in 2020 to 50.8% in 2022; The proportion of the secondary industry with heavy pollution and high resource consumption has also been continuously adjusted in a good way, from "two three one" to "three two one". In order to further strengthen the coordination and coordination between regions, the transformation from "heavy" to "light" has promoted the development of Anhui province.

5) Conclusion

(1) During 2020-2022, the economic development and ecological environment indicators in Anhui Province changed significantly.

(2) From 2020 to 2022, the coupling and synergy between economic development and ecological environment in Anhui Province generally showed a good trend, with the overall performance of 0.282~0.654, which was better coordinated. There is an imbalance between regions in the coordinated dispatch of urban-rural integration. The coordinated dispatch level of cities with relatively low economic development level, such as provincial capital cities and cities along the river, is generally lower than that of underdeveloped cities in the north of the Huaihe River.

(3) Anhui Province's "three wastes" emissions, environmental quality, environmental pollution control, the proportion of the output value of the secondary industry to GDP, regional gross domestic product, per capita GDP, and per capita disposable income of rural and urban residents are the key

factors restricting the economic development and environmental coordination in Anhui Province.

(4) According to the results of this study, we can get the following inspiration: at the urban level, according to the development characteristics of each region, we should reasonably promote the transformation and upgrading of industrial structure, promote industrial upgrading, continue to increase investment in ecological environment protection and pollution control, and reduce pollutant emissions. At the regional level, we should strengthen regional cooperation, make full use of the radiative driving effect of the northern Huaihe River region and the coastal Jiangnan region, shorten the economic development and ecological environment differences between urban and rural areas, and realize the benign interaction and coordinated development of various regions in the province.

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