Study on the coordinated development path of eco-economy of yangtze river economic belt

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Abstract: It is of great practical significance to explore the green development path of regional economy and environment. In this paper, Yangtze River Economic Belt in China was selected as the research objects, entropy method and coupling coordination degree model were used to calculate and analyse the ecological and economic changes and coordination degree. The results show that the condition of ecology and economy of the Yangtze River Economic Belt are on the rise, and the overall economy is developing rapidly. Although the economy of some regions is on the rise, it is still relatively backward. The ecological situation has been improved, the improvement range is small, and there are regional differences. Overall, the coordination degree of ecological economy has improved, but there are also spatial differences. In order to promote the coordinated development of ecological economy in the Yangtze River Economic Belt, it is suggested to strengthen the treatment of ecological environment pollution, build a modern economic system and promote green development.

Keywords: green evelopment; ecological economy; coupling co scheduling; Yangtze River Economic Belt; entropy method.

1. Introduction

Ecological economics is a subject that expounds the relationship between economy and ecosystem in the most extensive field. Since the 1960s, new concepts of pollution and environment have gradually become part of public awareness. In 1958, the protest campaign against the dangerous treatment of nuclear radiation and waste launched by Barry commoner and other scientists [1] had a profound impact on the public. The coupling method of ecological economic system has become the research focus of scholars all over the world[2].

Costanza Robert started from the value research of ecosystem service function, which laid a theoretical foundation for the coupling research of ecosystem and economic system to achieve the coordination and coupling of economy and ecosystem[3]. No matter how to achieve economic growth and the direction of science and technology development, society should adopt the most effective way to manage resources in this framework, so that all resources can be fully utilized, which is the decision whether ecological sustainable economic development can be achieved. Ostrom E, the winner of the Nobel Prize in economics, integrated the theoretical system of political science, ecology, economics and other disciplines and methods, and constructed the social ecosystem development analysis framework (SES). On the basis of empirical research, Ostrom subdivides the system optimization of the development of social ecosystem, and puts forward the system of unified market system and subdivided market system [4].

The "multi center" system arrangement of the system of government centralization and decentralization. Since then, Limburg Karin E [5], Sutton Paul C [6], villa Ferdinando [7] and other foreign scholars have conducted in-depth research on the functional value of ecosystem and its contribution to human beings based on the theory of eco-economic coupling. Tian and Sun used dynamic models to analyze the economic realization of ecosystem sustainability, measure the coupling between ecosystem and economic system from the perspective of feedback mechanism, and verify the mechanism of interaction between ecosystem and economic subsystem[8]. Braat L discussed the quantitative method of eco-economic system coordination by building a model to integrate and analyze the sub elements in the eco-economic system [9]. Common M et al. constructed an analysis model of sustainable development of ecological economy from the aspect of optimal allocation of natural resources [10]. Inge Ropke constructed the evaluation model of economic and environmental policy effects, including the economic, agricultural and environmental sub models[11].

This study attempts to explore the green development path of coordinated development of ecological economy, 11 provinces and cities along the Yangtze River economic belt are selected as the research objects, and a total of 12 research indicators of the ecological subsystem and economic subsystem in 2008-2017 are used to establish

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the evaluation index system. Entropy method and coupling coordination degree model are used to calculate and analyze the ecological and economic changes and coordination degree of the Yangtze River Economic Belt.

2. Materials and Methods

2.1 Data sources

The Yangtze River economic belt is the key area of China's economic development and ranks the first of China's river basin economy. The belt spans the eastern, central and western parts of China and covers 11 provinces as represented in Fig. 1. The energy consumption per unit of GDP, the proportion of the output value of the second industry to the GDP and the proportion of the output value of the third industry to the GDP are selected from the Statistical Yearbook of 11 provinces from 2008-2017. Per capita water resources, green coverage, forest coverage, total wastewater discharge, sulfur dioxide discharge, per capita regional GDP, total retail sales of social consumer goods and general budget revenue of local finance are selected from China National Bureau of statistics. The data of urban registered unemployment rate comes from the National economic and social development statistical bulletin from all provinces and cities.

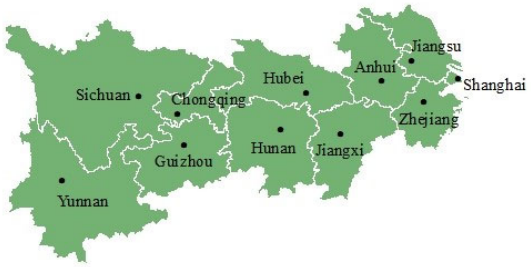

Figure 1. Territory of the Yangtze River Economic Belt in China

2.2 Entropy method

Indicators of the ecological subsystem and economic subsystem in 2008-2017 are used to establish the evaluation index system. Because the evaluation results of objective weighting method have strong mathematical theoretical basis, the calculation of weight by entropy method in objective weighting method can avoid considering the subjectivity of data. In recent years, entropy method is widely used in the study of the coordinated development of ecological economy. Therefore, entropy method is used to determine the weight of each index in the evaluation index system. The formula is as follows:

$$Y_{ij} = \frac{x_{ij}^*}{\sum_{t=1}^{r} x_{ij}^*} \quad (1)$$

In formula, Y_{ij} is the proportion of index value, x_{ij}^* is the standard value of each index, t is the number of years, t=1,2,3…r, r=10.

$$e_j = -k \sum_{i=1}^{m} \sum_{t=1}^{r} Y_{ij} \ln Y_{ij} \quad (2)$$

In formula, e_j is the information entropy of j index, $0 \leq e_j \leq 1$, k is a constant, k=1/ln(rm). For j index, the greater the difference of index value, the greater the effect on evaluation, and the smaller the entropy value.

$$d_j = 1 - e_j \quad (3)$$

In the above formula, d_j is the difference coefficient of the j-th index. The smaller the entropy is, the greater the difference coefficient is.

$$\omega_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (4)$$

In the above formula, ω_j is the weight of index J. In the ecological subsystem, j = 1,2,3 ; And in the economic subsystem, n = 6. Index weight is calculated by MATLAB (Table 1).

Table 1. Index weight of ecological subsystem and economic subsystem

Target layer	Frist-grade Indicator	Weight
Ecological subsystem	Per capita water resources	0.41
	Green coverage of built-up area	0.08
	forest coverage	0.23
	GDP energy intensity	0.07
	Total wastewater discharge	0.18
	Sulfur dioxide emissions	0.03
Economic subsystem	GDP per capita	0.21
	Total retail sales of consumer goods	0.24
	General budget revenue of local finance	0.25
	Proportion of output value of secondary industry in GDP	0.05
	Proportion of output value of tertiary industry in GDP	0.15
	The registered urban unemployment rate	0.11

Therefore, the overall evaluation value of the two subsystems can be calculated according to the index weight value. The formula is as follows:

$$f_{SE} = \sum_{j=1}^{n} \omega_{SE}\, x_{ij}^* \quad (5)$$

$$f_{EE} = \sum_{j=1}^{n} \omega_{EE}\, x_{ij}^* \quad (6)$$

Among them, f_{SE} is the overall evaluation value of the research object of social economic subsystem. The higher the value of f_{SE} is, the higher the level of social economic development is. ω_{SE} is the weight of each index of the social economic subsystem. f_{EE} is the overall evaluation value of the research object of the ecosystem. The higher the f_{EE} value is, the better the ecological quality is. ω_{EE} is the weight of each index of ecosystem.

2.3 Coupling coordination model

Coupling comes from physics, and has been widely used in ecological and socio-economic research in recent years. Coupling degree is a measure of the degree of correlation between systems, which only reflects the magnitude of interaction between systems. The coupling coordination degree can not only reflect whether each system has a good level, but also reflect the interaction between systems. Therefore, this paper uses coupling coordination

degree to study the coordinated development degree of ecology and social economy. The formula is as follows:

$$C = \left\{ \frac{f_{SE} \times f_{EE}}{\left(\frac{f_{SE}+f_{EE}}{2}\right)^2} \right\}^{1/2} \quad (7)$$

Where, $0 \leq C \leq 1$, C is the coupling degree between the ecological subsystem and the economic subsystem. The higher the value of C, the greater the interaction between the ecological subsystem and economic subsystem.

$$E = \sqrt{C \times T} \quad (8)$$

$$T = \alpha \times f_{EE} + \beta \times f_{SE} \quad (9)$$

Among them, $0 \leq E \leq 1$, E is the coupling co scheduling between the ecological subsystem and the economic subsystem. The higher e is, the higher the level of coordinated development of ecological and economic subsystems is. T is a comprehensive evaluation index for the coordinated development of ecological and socio-economic subsystems. α and β represent the contribution of ecological and economic subsystem, $\alpha + \beta = 1$. It is assumed that each subsystem is equally important for the coordinated development of ecology and social economy, $\alpha = \beta = 0.5$.

Referring to the research results of Liu et al(2018), The results of coupling coordination are divided into three categories and four subtypes(Table 2).

Table 2. Division of coordination degree of ecological and economic subsystem

Type	Classification basis	Subtype
Uncoordinated development	$0 < E \leq 0.3$	Serious disharmony
	$0.3 < E \leq 0.5$	Basically uncoordinated
Transformation development	$0.5 < E \leq 0.7$	Basic coordination
Coordinated development	$0.7 < E \leq 1.0$	Highly coordinated

3. Research results and analysis

3.1 Evaluation results and analysis of ecological subsystem

According to figure 2, it is mainly divided into three level along the Yangtze River Economic Belt: the first level is at the high ecological quality level including Jiangxi Province and Yunnan Province, with high ecological evaluation value; the second level is the medium ecological quality level including Zhejiang, Anhui, Hubei, Hunan, Chongqing, Guizhou and Sichuan, with the ecological evaluation value at the medium level; the third level is Shanghai and Yunnan The ecological evaluation value of low ecological quality layer in Jiangsu Province is low.

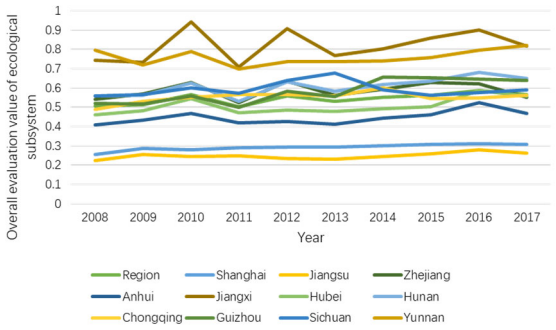

Figure 2. The general evaluation trend of ecosystem in the Yangtze River economic belt

3.2 Evaluation results and analysis of economic subsystem

As can be seen from the figure 3, the economic evaluation value of Jiangsu Province is the highest among the 11 provinces mainly because its high weight of the total retail sales of social consumer goods and the general budget revenue of local finance. And Zhejiang Province ranks second to Jiangsu in terms of per capita GDP and tertiary industry output value. Shanghai's total economic volume of financial industry ranks first in China. Moreover, Shanghai's service industry is highly developed, and it is the largest overseas tourist destination and the largest luxury cruise home port and destination in China. Shanghai's tertiary industry is also developed and its output value is very high.

The secondary industries in Anhui and Jiangxi are relatively developed. Anhui is an important agricultural production, energy, raw materials and processing and manufacturing base. And the automobile, machinery, home appliances, chemical industry, electronics, agricultural products processing and other industries occupy an important position in China. There are six pillar industries in Jiangxi, namely: Automobile aviation and precision manufacturing, characteristic metallurgy and metal products, Chinese patent medicine and biopharmaceutical, electronic information and modern home appliance industry, food industry, fine chemical industry and new building materials. All these factors contribute a high proportion of GDP. The evaluation value of the economic subsystem of Yunnan and Guizhou Province where most economy depends on tourism is the lowest, that is to say, the economic development is relatively backward, but also rising steadily along with more attention has been paid to both ecology and economy.

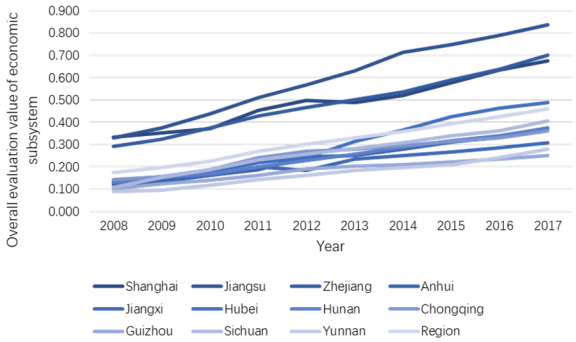

Figure 3. Development trend of evaluation value of economic subsystem in the Yangtze River economic belt

4. Discussion

The coupling coordination degree of ecological economy is calculated according to the overall evaluation value of ecological subsystem and economic subsystem. See table 3 for the results of ecological and economic coupling coordination degree of Yangtze River Economic Belt in 2008-2017. The type of coupling coordination degree has changed from "transformation development" to "coordinated development", and the subtype of coupling coordination degree has changed from "basic coordination" to "high coordination". It can be seen that the coordinated development of ecological economy in the Yangtze River economic belt is improving.

Table 3. Coordination degree and classification of regional ecological and economic coupling

Year	Coupling co scheduling	Type	Subtype
2008	0.544	Transformation development	Basic coordination
2009	0.563	Transformation development	Basic coordination
2010	0.598	Transformation development	Basic coordination
2011	0.607	Transformation development	Basic coordination
2012	0.640	Transformation development	Basic coordination
2013	0.647	Transformation development	Basic coordination
2014	0.668	Transformation development	Basic coordination
2015	0.685	Transformation development	Basic coordination
2016	0.706	Coordinated development	Highly coordinated
2017	0.714	Coordinated development	Highly coordinated

The coupling coordination degree of ecological economy is closely related to the overall evaluation value of ecological subsystem and economic subsystem. When the overall evaluation value of ecological subsystem and economic subsystem is high, the coupling coordination degree of ecology and economy is high; when the evaluation value of one subsystem is high and the evaluation value of the other subsystem is low, the coupling coordination degree of ecology and economy is low; when the overall evaluation value of both subsystems is low, the coupling coordination degree of ecology and economy is low. According to figure 4, we can observe the relationship among the overall evaluation value of the ecological subsystem, the overall evaluation value of the economic subsystem and the coupling coordination degree of the ecological economy in the Yangtze River economic belt. From the perspective of the overall trend, the evaluation value of the economic subsystem and the coupling degree of the ecological economy show a stable upward trend, and the evaluation value of the ecological subsystem is also increasing, but its fluctuation is large. The overall evaluation value of the ecological subsystem is higher than that of the economic subsystem, but the overall evaluation value of the economic subsystem grows rapidly, which tends to exceed the evaluation value of the ecological subsystem. From the perspective of fluctuation, the overall evaluation value of the economic subsystem is also in a stable rising state, and the overall evaluation value of the ecological subsystem is relatively fluctuant, with a large fluctuation range, but the ecological and economic coupling coordination degree is rising steadily, which is little affected by the ecological subsystem. The main reason is that the overall evaluation value of the economic subsystem increases too fast, and the coupling coordination degree of the ecological economy is more affected than that of the ecological subsystem.

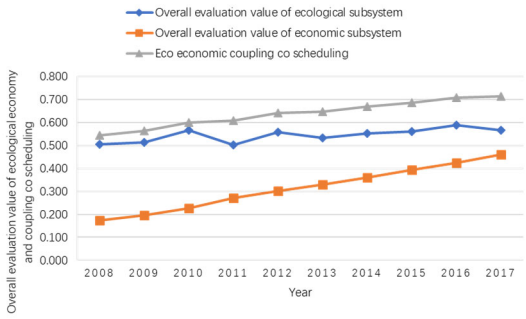

Figure 4. The overall evaluation value of regional ecosystem and economic subsystem in the Yangtze River economic belt and the change of coupling co operation

From table 4, it is observed that the eco-economic coupling co scheduling of provinces and cities along the Yangtze River Economic Belt in 2017. There are four provinces in Zhejiang, Jiangxi, Hubei and Hunan whose coupling coordination degree type reaches the type of "coordinated development", the subtype is "highly coordinated", and the other provinces and cities are in the type of "basic coordination". From table 5, we can see the change of ecological and economic coupling coordination degree of provinces and cities along the Yangtze River Economic Belt in 2008-2017. Figure5 shows the overall evaluation value of ecological and economic subsystem of Yangtze River economic belt and provinces along the belt in 2008 and 2017.

Table 4. Ecological and economic coupling coordination degree and type division of provinces and cities along the Yangtze River Economic Belt in 2017

Provinces	Coupling co scheduling	Type	Subtype
Shanghai	0.676	Transformation development	Basic coordination
Jiangsu	0.683	Transformation development	Basic coordination
Zhejiang	0.788	Coordinated development	Highly coordinated
Anhui	0.647	Transformation development	Basic coordination
Jiangxi	0.708	Coordinated development	Highly coordinated
Hubei	0.722	Coordinated development	Highly coordinated

Hunan	0.702	Coordinated development	Highly coordinated
Chongqing	0.672	Transformation development	Basic coordination
Guizhou	0.633	Transformation development	Basic coordination
Sichuan	0.699	Transformation development	Basic coordination
Yunnan	0.691	Transformation development	Basic coordination

Table 5. 2008-2017 ecological and economic coupling coordinated dispatching of provinces and cities along the Yangtze River Economic Belt

Province	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Shanghai	0.540	0.561	0.568	0.602	0.619	0.615	0.629	0.650	0.667	0.676
Jiangsu	0.522	0.556	0.572	0.596	0.605	0.615	0.645	0.663	0.686	0.683
Zhejiang	0.629	0.655	0.696	0.687	0.737	0.729	0.751	0.781	0.794	0.788
Anhui	0.472	0.489	0.525	0.529	0.568	0.568	0.594	0.615	0.646	0.647
Jiangxi	0.555	0.564	0.624	0.613	0.639	0.651	0.669	0.693	0.713	0.708
Hubei	0.501	0.523	0.557	0.566	0.585	0.622	0.652	0.681	0.722	0.722
Hunan	0.518	0.542	0.571	0.577	0.615	0.622	0.650	0.670	0.694	0.702
Chongqing	0.516	0.536	0.566	0.608	0.625	0.628	0.648	0.643	0.652	0.676
Guizhou	0.480	0.502	0.530	0.533	0.578	0.579	0.609	0.616	0.624	0.633
Sichuan	0.496	0.546	0.586	0.604	0.637	0.666	0.653	0.663	0.676	0.699
Yunnan	0.517	0.513	0.551	0.561	0.587	0.606	0.617	0.632	0.663	0.691

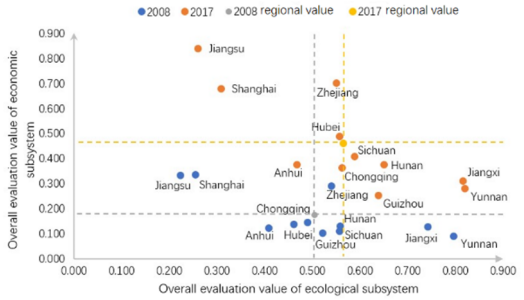

Figure 5. Overall evaluation value of ecological and economic subsystem of Yangtze River economic belt and provinces along the belt in 2008 and 2017

5. Conclusions and policy implications

(1) According to the analysis of the overall evaluation value of the ecosystem, the ecological quality of the Yangtze River economic belt has been improved, but the growth rate is very small. From the perspective of provinces and cities, the ecological evaluation values of Jiangxi and Yunnan are relatively high, while those of Shanghai and Jiangsu are relatively low. The rest of the provinces and cities are relatively concentrated, but they all have a certain increase, with a small increase. In the selected ecosystem indicators, the per capita water resources account for a large proportion, which has the greatest impact on the ecological quality, followed by forest coverage.

(2) Based on the analysis of the overall evaluation value of the economic subsystem, the economic growth of the Yangtze River economic belt is rapid. From the perspective of provinces and cities, Jiangsu, Shanghai and Zhejiang are relatively developed, while Guizhou and Yunnan are still relatively backward despite their economic growth. That is to say, the eastern part of the Yangtze River economic belt is the most developed, while the southwestern part is relatively backward.

(3) Through the analysis of the coupling coordination degree of the ecological and economic subsystem of the Yangtze River economic belt, it is concluded that the type of coupling coordination degree changes from "transformation development" to "coordinated development", and the subtype of coupling coordination degree changes from "basic coordination" to "high coordination". In terms of provinces and cities, the types of coupling coordination degree of Zhejiang, Jiangxi, Hubei and Hunan have reached the type of "coordinated development", the subtype of which is "highly coordinated", and the other provinces and cities are in the type of "basic coordination". It can be seen that there are spatial differences in the coordination degree of ecological economy coupling in the Yangtze River economic belt.

(4) Based on the analysis of the calculation results, the following development paths are proposed: strengthening the treatment of ecological environment pollution, building a modern economic system and promoting green development.

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