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Research on the Coordinated Development of Resources, Environment, and Economy in the Yellow River Basin¹

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Abstract

Background: The high-quality development in the Yellow River Basin has to be fostered by the coordination of resources, environment, and economy. Therefore, conducting an analysis on the coupling level of resources, environment, and economy in the Yellow River Basin is of major significance to the research on its high-quality development path.

Methods: Based on the data of the nine provinces in the Yellow River Basin from 2004 to 2017, a coupling development model is constructed for an analysis of the coupling level in this area and a modeling prediction. A comprehensive evaluation of the development level of Resources-Environment-Economy system and the subsystems in the Yellow River Basin is performed by combining the range change method and entropy weight method.

Results: The result shows that despite the rising coupling level of resources, environment, and economy in the Yellow River Basin, the comprehensive evaluation value of the environment subsystem is low, which was merely 0.109 in 2017 and has remained unchanged between 2009 and 2017, resulting in a low coupling coordination degree of Resources-Environment-Economy. In 2017, the coupling coordination degree was only 0.454. The development was on the verge of imbalance and the high-quality coordinated development of the Yellow River Basin has been restricted. The simulated prediction indicates that the coordinated development of Resources-Environment-Economy in the Yellow River Basin can only be realized by overcoming the disadvantages of the ecological and economic systems.

Conclusions: When the comprehensive evaluation value of environmental subsystem increases by 0.2 and that of economic subsystem increases by 0.1, all the systems are just coordinated; when the comprehensive evaluation value of each subsystem reaches 0.65, the development of the systems of Resources-Environment-Economy in the Yellow River Basin are well coordinated.

Key words: The Yellow River Basin; High-quality development; Resources-Environment-Economy; Coupling; Simulation and prediction

1 Introduction

Since ancient times, the Yellow River Basin has been the center of China's political, economic and cultural development. Its total population accounts for more than 30% of the total population of China, and its regional GDP accounts for more than 26% of China^[1]. With the concept of cultural self-confidence and the great rejuvenation of the Chinese nation put forward, the value of resources, economy, society, culture and ecological civilization in the Yellow River Basin is unprecedentedly prominent. In this context, Xi Jinping presided over the symposium on ecological protection and high-quality development of the Yellow River Basin in 2019, which promoted the ecological protection and high-quality development of the Yellow River Basin as a major national strategy^[2].

As an important ecological functional area in China, the Yellow River Basin is also an ecologically fragile area, and the importance of ecological protection is more prominent^[3]. The distribution of water resources in the Yellow River Basin is extremely unbalanced, the development in the basin is unbalanced and insufficient, the extensive exploitation and processing of energy, minerals and other resources, and the economic and social problems beyond the carrying capacity of the ecosystem seriously restrict the high-quality development of the Yellow River Basin. Therefore, a comprehensive investigation of the evolution and development trend of Resources-Environment-Economy development in the Yellow River Basin is not only a beneficial

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exploration of the concept of sustainable and high-quality development, but also has certain guiding significance for formulating basin development strategies.

With the concept of high-quality development deeply rooted in people's hearts, scholars at home and abroad have made more and more extensive research on Resources-Environment-Economy(REE), and many scholars have made some achievements. Tian Bingbing ^[4] took Hangzhou as the research object, constructed a comprehensive evaluation index system of Resources-Environment-Economic development level in Hangzhou, calculated the coordination value of Hangzhou from 2008 to 2017, and put forward countermeasures and suggestions for the sustainable development of Hangzhou; WANG ^[5] evaluated the economic-energy-environment system of Shandong Province from 2004 to 2012. Cao Yan ^[6] selected the data of forest resources, economic development level and environmental conditions in Fujian Province from 2007 to 2017, constructed the dynamic evaluation index system of forest Resources-Economy-Environment system in Fujian Province, and put forward suggestions on the focus of ecological development in Fujian Province; In the study of the Yellow River Basin, Zhao Jianji ^[7] constructed a coupling coordination model of new urbanization and environment, analyzed the coupling coordination relationship between new urbanization and ecological environment in the Yellow River Basin from 2005 to 2016, and made development suggestions; Li Yue ^[8] studied the coupling degree of cultural industry and tourism industry in the Yellow River Basin and its influencing factors based on the data from 2006 to 2018, and put forward the strategy of promoting the development of core urban agglomerations to strengthen the radiation-driven effect; Liu Linyi ^[9] used the panel VAR model to quantitatively investigate the interactive response relationship between ecological protection and high-quality development in the Yellow River Basin; Jay Song ^[10] constructed the evaluation index system of population-economy-environment system, and based on the coupling coordination degree model, explored the spatial and temporal characteristics of the coupling coordination degree of population-economy-environment system in nine provinces of the Yellow River Basin in recent years, and further explored its influencing factors. Zhao Liangshi ^[11] took the Yellow River Basin water-energy-food security system as the core, and calculated and simulated the coupling coordination degree of the Yellow River Basin water-energy-food security system from 2007 to 2017 by using the coupling coordination degree model.

It can be seen that the previous studies mostly focused on the coupling and coordinated development between the two subsystems, focused on the analysis of the development situation in previous years, and made little research on the future development, and lacked the research on the coupling and coordinated development between the three subsystems and Resources-Environment-Economy. In view of this, on the basis of previous studies, taking nine provinces in the Yellow River Basin as objects, this paper constructs a comprehensive evaluation index system of Resources-Environment-Economy in the Yellow River Basin. Based on the range change method, entropy weight method and coupling coordination degree model, it evaluates and simulates the REE composite system and its coupling coordination characteristics, aiming at providing guidance for realizing high-quality development of the Yellow River Basin.

2 Coupling coordination mechanism and index system construction of Resources-Environment-Economy in the Yellow River Basin

1.1 Coupling coordination mechanism of Resources-Environment-Economy in the Yellow River Basin

As shown in Figure 1, in order to achieve the high-quality development of the Yellow River Basin, it is inseparable from the scientific development of resources, effective environmental protection, rapid economic development, and the coordination and interaction among resources, environment and economy in the basin.

Figure. 1 Coupling coordination mechanism of industrial Resources-Environment-Economy system in the Yellow River Basin

Between resources and economic system, the mineral resources that the high-quality development of the Yellow River Basin depends on can increase employment opportunities, residents' income and industrial output value, and provide raw materials for economic development. Accordingly, economic development can promote the development of resources in the Yellow River Basin through investment in technology and equipment, and provide strong support for resource development. Between economic and environmental systems, economic development has increased the development of natural resources and ecological environment, causing environmental pressure, but at the same time, economic development will also increase the pursuit of better ecological environment quality, thus increasing the investment in capital and technology for ecological environment governance, so that the ecological environment has improved ^[12]; Between environment and resource system, the unreasonable exploitation of resources in the Yellow River Basin will inevitably cause damage to the ecological environment, such as the destruction of land resources and geological disasters, thus affecting the agricultural production environment. The harsh ecological environment limits the exploitation of resources. On the contrary, a good ecological environment will increase the economic benefits of resource development enterprises, reduce safety accidents and improve the living environment quality of people in resource development areas.

1.2 Construction of Resource-Environment-Economy Index System in Yellow River Basin

Resource-environment-economy is a complex and multi-level open system. According to the availability of data, the principles of scientificity, operability, universality and completeness of index selection, and the current situation of Resources-Environment-Economy development in the Yellow River Basin, this paper constructs a three-layer index system, which consists of general target level, sub-target level and index level. According to the promotion or inhibition of each specific index on the development of three subsystems, the indicators are divided into positive (promotion) negative (inhibition) types, and the specific classification is shown in Table 1.1.

Table.1 Resource-environment-economic evaluation index system

Total target layer	Subsystem	Index layer	Unit	Type
General system of Resources-Environment-Economy	Resources	C1 Per capita cultivated land area	Ha/Person	+
		C2 Average per capita water resources	Cubic Meters/person	+
		C3 Percentage of forest cover	%	+
		C4 Electric energy production	Billion kWh	+
		C5 Proportion of industrial water to total water consumption	%	-
		C6 Total energy consumption	Ten thousand tons of standard coal	-
		C7 Energy consumption per unit of gdp	Ten thousand tons/one hundred million yuan	-
		C8 Water consumption per unit GDP	100 million cubic meters/100 million yuan	-
	Environment	C9 Industrial wastewater discharge	Ten thousand tons	-
		C10 Industrial exhaust emissions	Ten thousand tons	-
		C11 Output of industrial solid waste	Ten thousand tons	-
		C12 Comprehensive utilization of industrial solid waste	Ten thousand tons	+
		C13 Complete investment in industrial pollution control	One hundred million yuan	+

	C14 Proportion of energy conservation and environmental protection expenditure to GDP	%	+
Economy	C15 GDP growth rate	%	+
	C16 Per capita GDP	RMB/person	+
	C17 Total investment in fixed assets	One hundred million yuan	+
	C18 Total retail sales of social consumer goods	One hundred million yuan	+
	C19 Proportion of primary industry	%	-
	C20 Proportion of secondary industry	%	-
	C21 Proportion of tertiary industry	%	+

The index data in the index system constructed by this study are all from the statistical yearbooks of all provinces and the whole country from 2004 to 2017.

3 Development Model of Coupling Coordination Degree of Resources-Environment-Economy in Yellow River Basin

Coupling coordination degree describes the degree of interaction and synergy between subsystems in the development process, which is an effective method to measure the degree of coordinated development among various parts of the system. In order to objectively and effectively analyze the coupling coordination characteristics of the composite system, firstly, the evaluation values of resources, environment and economic subsystems in the Yellow River Basin are calculated by the range change method and entropy weight method, and on this basis, the coupling coordination degree model is introduced to evaluate the interactive coupling and coordinated development among various systems.

2.1 Comprehensive evaluation value of Resources-Environment-Economy subsystem in the Yellow River Basin

In this section, the original data of 21 research indicators in nine provinces of the Yellow River from 2004 to 2017 are standardized by using the range change method to obtain standardized data. The entropy weight method is used to calculate the weight of each indicator, and then the comprehensive score of each indicator is obtained. Combined with the three subsystems of resources, environment and economy, the comprehensive evaluation value of each subsystem is calculated. The calculation steps are as follows ^[13].

- 1、Construct evaluation matrix. Combined with table 1, the evaluation index life is recorded as m, which is from 2004 to 2017; The evaluation index is n, with a total of 21 (see table 1); A data matrix can be obtained as shown in formula (1):

$$X = (X_{ij})_{m \times n} \quad (1)$$

X_{ij} (i=1, 2, ..., m; j=1, 2, ..., n) is the value of the nth evaluation index in the m-th year.

- 2、Standardization of initial data matrix. In order to eliminate the influence of different dimensions of each index on the evaluation results, the range transformation method is often used to deal with each index. The calculation is shown in Formula (2) and Formula (3):

$$X'_j = \frac{X_j - \min\{X_j\}}{\max\{X_j\} - \min\{X_j\}} \quad (\text{Applicable to "+" indicators}) \quad (2)$$

$$X'_j = \frac{\max\{X_j\} - X_j}{\max\{X_j\} - \min\{X_j\}} \quad (\text{Applicable to "-" indicators}) \quad (3)$$

- 3、Calculate the specific gravity matrix Y, $Y_j = \frac{X'_j}{\sum X'_j}$, see formula (4) for the specific gravity matrix obtained

$$Y = (Y_1, Y_2, \dots, Y_n) \quad (4)$$

- 4、Calculate the value of information entropy of the J index as e_j

$$e_j = -K \sum_{i=1}^m Y_j \ln Y_j \quad (j=1, 2, \dots, n) \quad (5)$$

$k = \frac{1}{\ln m}$ is a non-negative constant and $0 \leq e_j \leq 1$

- 5、Calculate the weight ω_j of the j index, see formula (6), and get the weight ω_j as shown in Table 2.

$$\omega_j = \frac{1 - e_j}{n - \sum_{j=1}^n e_j} \quad (j=1, 2, \dots, n) \quad (6)$$

6、 Calculate the weighting matrix, as shown in Formula (7).

$$Z = (z_{ij})_{mn} = \begin{matrix} & \omega_1 X'_{11} & \cdots & \omega_n X'_{1n} \\ & \cdots & & \cdots \\ \omega_1 X'_{m1} & & \cdots & \omega_n X'_{mn} \end{matrix} \quad (7)$$

$\omega_n X'_{mn}$ is the comprehensive score of the nth evaluation index in the m-th year.

7、 Add the comprehensive scores of the three subsystems of resources, environment and economy to get the comprehensive score value of resources, environment and economy subsystem in the m-th year, as shown in formula (8)

$$\begin{cases} \text{Resource: } U_1 = \sum_{i=1}^8 \omega_i X'_{mi} \\ \text{Environment: } U_2 = \sum_{i=9}^{14} \omega_i X'_{mi} \\ \text{Economy: } U_3 = \sum_{i=15}^{21} \omega_i X'_{mi} \end{cases} \quad (8)$$

According to the above steps, the comprehensive evaluation values of resources, environment and economic subsystems can be obtained, and the results are shown in Table 3.3.

2.2 Coupling coordination degree model of Resources-Environment-Economy in the Yellow River Basin

Combined with the coupling coordination relationship of the three subsystems studied in this paper and the coupling coefficient model in existing physics, the coupling degree model of interaction between two elements and three elements is generalized, as shown in formulas (9) and (10).

$$C = \left\{ \frac{U_1 \times U_2}{\left[\frac{(U_1 + U_2)}{2} \right]^2} \right\}^{\frac{1}{2}} \quad (9)$$

$$C = \left\{ \frac{U_1 \times U_2 \times U_3}{\left[\frac{(U_1 + U_2 + U_3)}{3} \right]^3} \right\}^{\frac{1}{3}} \quad (10)$$

C is the coupling degree; U_1 , U_2 and U_3 are the comprehensive evaluation values of resources, environment and economy in the Yellow River Basin.

According to the above coupling degree model, we can calculate the coupling degree of nine provinces in the Yellow River Basin and the overall coupling degree level of the Yellow River Basin from 2004 to 2017. The value of C reflects the correlation between subsystems. The greater the value of C, the stronger the correlation. Coupling degree can only show the strength of the correlation among the systems, but can not reflect the comprehensive coordination level among the three subsystems. In order to truly express the level of coordinated development of the system, the coupling coordination degree formula is defined as shown in Formula (11) and Formula (12).

$$D = \sqrt{C \times T} \quad (11)$$

$$T = \alpha U_1 + \beta U_2 + \gamma U_3 \quad (12)$$

D stands for coupling coordination; C is the coupling degree; T represents the comprehensive evaluation index of the development level of the three subsystems in the region; U_1 , U_2 and U_3 are the comprehensive scores of each subsystem (see table 3); α , β and γ are the weight coefficients of the three subsystems, that is, their respective importance. In this paper, the equivalent method is used to give weight, so that $\alpha = \beta = \gamma = 1/3$. When studying the relationship between pairs, take $\alpha = \beta = \gamma = 1/2$.

4 Results and analysis

3.1 Analysis of comprehensive development level

According to the above research, the weight of each evaluation index of the Resources-Environment-Economy system of the Yellow River Basin is shown in Table 2, the comprehensive evaluation value is shown in Table 3, and the time series change analysis of the comprehensive evaluation value is shown in Figure 2.

Table 2. Weight of evaluation index

Resources	Weight	Environment	Weight	Economy	Weight
C1	0.0703	C9	0.0400	C15	0.0392
C2	0.0481	C10	0.0230	C16	0.0429
C3	0.0686	C11	0.0445	C17	0.0531
C4	0.0396	C12	0.0441	C18	0.0488

C5	0.0402	C13	0.0499	C19	0.0576
C6	0.0340	C14	0.0363	C20	0.0301
C7	0.0642	---	---	C21	0.0457
C8	0.0795	---	---	---	---
Total	0.4445	---	0.2378	---	0.3174

Table.3 Comprehensive score table of river basin Resources-Environment-Economy subsystem

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
U ₁	0.130	0.169	0.167	0.156	0.164	0.241	0.253	0.287	0.286	0.307	0.294	0.285	0.296	0.311
U ₂	0.101	0.097	0.108	0.118	0.124	0.127	0.113	0.104	0.099	0.114	0.115	0.101	0.121	0.109
U ₃	0.059	0.079	0.088	0.108	0.105	0.124	0.138	0.142	0.159	0.167	0.191	0.217	0.249	0.259
REE	0.097	0.115	0.121	0.127	0.131	0.164	0.168	0.178	0.181	0.196	0.200	0.201	0.222	0.226

Figure.2 Time sequence diagram of comprehensive evaluation value of Resources-Environment-Economy system in river basin

It can be seen from Figure 2 that the comprehensive score value of the resource-environment-economy composite system composed of three subsystems: resources, environment and economy is on the rise. Before 2008, the increase was slow, and after 2009, the increase was increased, with the largest increase in 2008-2009. The comprehensive score of resource system is the highest, showing a fluctuating upward trend on the whole, followed by economic subsystem, while the pressure of environmental system is greater and the overall score is lower. Before 2009, the score of environmental subsystem was higher than that of economic subsystem because of the low level of economic development and less pollution to the environment. After 2009, the score of environmental subsystem was affected by environmental pollution brought by industrial development, showing a fluctuating downward trend.

On the whole, the comprehensive score of resources subsystem in the Yellow River Basin increased from 0.13 in 2004 to 0.311 in 2017. During 2013-2015, due to the high score of economic development, after 2015-2016, due to the influence of policies such as energy reduction and emission reduction, the resource consumption driven by economic growth will be lower, and the pressure on the resource subsystem will be reduced, so the score of the resource subsystem will increase. The score of environmental subsystem increased from 0.0996 in 2004 to 0.109 in 2017, and the overall score was low, showing a slow upward trend. The scores of economic subsystems in nine provinces increased from 0.059 in 2004 to 0.259 in 2017. The scores of economic subsystems declined from 2007 to 2008 under the influence of international financial crisis, and increased rapidly from 2013 to 2016 under the influence of the 12th Five-Year Economic Development Plan.

3.2 Analysis of Coupling Coordination Degree

According to the coupling coordination model. With reference to a large number of relevant research results, it is divided into 10 grades according to the numerical value of coupling coordination

degree, as shown in Table 4. According to formula (9-12), the coupling coordination degrees of resources-environment, resources-economy, environment-economy and resources-environment-economy are calculated, as shown in Table 5. Summarizing the above coupling coordination results, the development trend of coordination level in the Yellow River Basin is shown in Figure 3.

Table.4 Classification standard of coupling coordination level

Coordination degree value	[0.0-0.1)	[0.1-0.2)	[0.2-0.3)	[0.3-0.4)	[0.4-0.5)	[0.5-0.6)	[0.6-0.7)	[0.7-0.8)	[0.8-0.9)	[0.9-1.0)
Degree of coordination	(1) Extreme maladjustment	(2) Severe maladjustment	(3) Moderate maladjustment	(4) Mild maladjustment	(5) Close to maladjustment	(6) Forced coordination	(7) Primary coordination	(8) Intermediate coordination	(9) Good coordination	(10) High-quality coordination

Table.5 Analysis Table of Coupling Coordination Degree of Resources-Environment-Economy in Yellow River Basin

	Resources-Environment	Coordination status	Environment-Economy	Coordination status	Resources-Economy	Coordination status	REE	Coordination status
2004	0.338	(4)	0.278	(3)	0.296	(3)	0.303	(4)
2005	0.358	(4)	0.296	(3)	0.340	(4)	0.330	(4)
2006	0.366	(4)	0.312	(4)	0.348	(4)	0.342	(4)
2007	0.368	(4)	0.336	(4)	0.360	(4)	0.354	(4)
2008	0.378	(4)	0.338	(4)	0.362	(4)	0.359	(4)
2009	0.418	(5)	0.354	(4)	0.416	(5)	0.395	(4)
2010	0.411	(5)	0.353	(4)	0.432	(5)	0.397	(4)
2011	0.416	(5)	0.349	(4)	0.450	(5)	0.403	(5)
2012	0.410	(5)	0.354	(4)	0.462	(5)	0.406	(5)
2013	0.433	(5)	0.372	(4)	0.476	(5)	0.425	(5)
2014	0.429	(5)	0.385	(4)	0.487	(5)	0.432	(5)
2015	0.411	(5)	0.384	(4)	0.499	(5)	0.429	(5)
2016	0.435	(5)	0.417	(5)	0.521	(6)	0.455	(5)
2017	0.429	(5)	0.410	(5)	0.532	(6)	0.454	(5)

Figure. 3 Development trend of coupling coordination level of Resources-Environment-Economy system

As far as the environment-economy system is concerned, the trend of coupling coordination degree of this system is roughly the same as that of REE system. Although the trend of environment-economy coordination degree is gentle from 2009 to 2012, it also shows an overall upward trend. Under the background of building a resource-saving and environment-friendly society, ensuring green development and upgrading of industrial structure in the Yellow River Basin is an important measure for high-quality development. It can be seen from Figure 2 that the stagnation of

environmental comprehensive evaluation index in recent years is one of the reasons for the low degree of coupling coordination between environment and economy, and it can be seen that the environmental protection pressure in the Yellow River Basin is huge.

As far as the resource-environment system is concerned, the coupling and coordination degree of the two systems shows a gentle trend and is on the verge of imbalance, which is mainly due to the unreasonable exploitation of resources in the Yellow River Basin in recent years, which has caused some damage to the environment. The comprehensive evaluation value of resource system is on the rise, while the comprehensive evaluation value of environment system is low, which is the direct reason for the gentle coupling degree of resource-environment system.

The coupling and coordination degree of resource-economy system is the highest, and it shows a good upward trend after 2008, and has entered a stage of barely coordination. This is mainly due to the rapid economic growth due to the increased exploitation of resources in the Yellow River Basin in recent years. Accordingly, economic development will further increase the demand for resources, thus increasing technical investment and capital support for resource development and exploration, and providing economic support for resource development.

On the whole, the value of the overall coupling coordination degree shows a fluctuating upward trend with the increase of years, which indicates that the coordinated development level of the three subsystems is developing to a good situation, and the system has achieved a good transition from mild maladjustment to near maladjustment. However, at present, the coupling coordination degree of Resources-Environment-Economy in the Yellow River Basin is still very low, which is basically in the stage of imbalance, and the resources and environment pressure of economic development is still very great. Specifically, the growth rate of the comprehensive coupling coordination degree in this basin is characterized by stages. From 2004 to 2008, the growth rate was relatively moderate, because under the condition of a certain abundance of resources, the development between environment and economy was still in a benign and coordinated development stage; The growth rate in 2008-2009 was fast, because the economic development did not exceed the carrying capacity of resources and environment due to the impact of the economic crisis, and resources were fully protected and utilized in these two years; From 2009 to 2012, the growth rate slowed down. In these four years, the scores of resources and economy were rising, but the coordination values of resources-environment and environment-economy coupling degree were declining, which was one of the reasons for the slowdown of the growth rate of coupling coordination of composite systems. From 2012 to 2017, the growth rate has returned to the original speed. This stage may be mainly affected by the economic system. Advanced technology and sufficient funds provide preconditions for efficient use of resources and investment in environmental protection.

5 Simulation and Prediction Based on the Coupling Coordinated Development Model of Resources-Environment-Economy in the Yellow River Basin

4.1 Simulated scenario setting

Based on the data of 2017, the comprehensive evaluation values of resources, environment and economic system are $U_1=0.311$, $U_2=0.109$ and $U_3=0.259$ respectively. Based on the control variable method, six development paths of SE1~SE6 are established (see Table 6), and the coupling coordination degree is predicted and analyzed. Among them, SE1 means that the comprehensive evaluation values of the three subsystems each increase by 0.1; SE2 means that the comprehensive evaluation value of resource system increases by 0.3; SE3 means that the comprehensive evaluation value of environmental system increases by 0.3; SE4 means that the comprehensive evaluation value of economic system rises by 0.3; In order to make up for the shortcomings of the environment and economic system in 2017, SE5 increased the comprehensive evaluation value of the environmental system by 0.2 and the comprehensive evaluation value of the economic system by 0.1; SE6 is set so that the comprehensive evaluation value of each subsystem rises to 0.65.

Table.6 Setting of simulated development path

	SE0		SE1		SE2		SE3		SE4		SE5		SE6
	2017		change	result	change	result	change	result	change	result	change	result	result
Resources	U_1	0.311	$U_1+0.1$	0.411	$U_1+0.3$	0.611	U_1	0.311	U_1	0.311	U_1	0.311	0.65
Environment	U_2	0.109	$U_2+0.1$	0.209	U_2	0.109	$U_2+0.3$	0.409	U_2	0.109	$U_2+0.2$	0.309	0.65
Economy	U_3	0.259	$U_3+0.1$	0.359	U_3	0.259	U_3	0.259	$U_3+0.3$	0.559	$U_3+0.1$	0.359	0.65

4.2 Simulation results and analysis

The prediction object is the coupling coordination degree value among the systems, and the results are shown in Table 7 and Figure 4.

Table.7 Prediction results of coupling coordination degree under different development paths

	SE0	SE1	SE2	SE3	SE4	SE5	SE6
Resources-Environment	0.429	0.541	0.508	0.597	0.429	0.556	0.806
Environment-economy	0.410	0.523	0.410	0.570	0.497	0.577	0.806
Resources-economy	0.532	0.620	0.630	0.532	0.645	0.578	0.806
REE	0.454	0.560	0.508	0.566	0.516	0.570	0.806

Figure. 4 Prediction results of coupling coordination degree under different development paths

It can be seen from figure. 4 that under the SE1 path, when the comprehensive evaluation value of each subsystem rises by 0.1, the coupling coordination degree also rises, and the rising range is roughly the same, and all of them achieve barely coordination, among which the coupling coordination degree of resources and economy achieves primary coordination; Under the SE2 path, the comprehensive evaluation value of resource system is greatly improved, and the coupling coordination degree of environment and economy is low, and the overall development is unbalanced; Under SE3 path, only the comprehensive evaluation value of environmental system is improved, and the coupling coordination level is better than SE2. Under SE4 path, the comprehensive evaluation value of economic system is greatly improved, and the coupling coordination degree of resources and environment is low, which is similar to SE2 path, which restricts the coordinated development of the whole system; Under the SE5 path, the shortcomings of the environment and economic system are complemented, the coordination level has been better improved, and the coordination degree of resource-environment-economy coupling has also increased; Under SE6 scenario, the comprehensive evaluation value of each subsystem reaches 0.65, and the coupling coordination degree among each system can reach a good coordination level, approaching the high-quality development trend.

It can be seen from the above that if the Yellow River Basin is to achieve high-quality coordinated development, the problem of low comprehensive evaluation value of environmental and economic systems should be solved first, and the shortcomings of the coupled coordinated development model of the Yellow River Basin should be supplemented. The comprehensive evaluation value of environmental system is the lowest, which is only 0.109 in 2017. It can be seen from the weight distribution in Table 2 that the weight of environmental system itself is lower than that of resource system and economic system, only 0.2378. Increasing investment in industrial pollution control, improving the comprehensive utilization of industrial solid waste and reducing the output of industrial solid waste are the most effective methods. Although the weight of reducing industrial wastewater and waste gas emissions and increasing the proportion of energy conservation and environmental protection expenditure in GDP is small, it should not be underestimated. In view of the low comprehensive evaluation value of environmental system, the indicators of environmental system should be fully exerted to make up the shortcomings. According to the economic system, it is the most effective way to

improve the comprehensive evaluation value of the economic system by focusing on improving the proportion of the primary industry, the total investment in fixed assets and the total retail sales of social consumer goods.

6 Conclusions and suggestions

5.1 Conclusions

(1) From the comprehensive evaluation value, the comprehensive score value of the resource-environment-economy composite system is on the rise. The comprehensive score of resource system is the highest, showing a fluctuating upward trend on the whole, followed by economic subsystem, showing an upward trend on the whole, while the environmental system is under greater pressure and has a lower overall score.

(2) From the perspective of the level of coupled and coordinated development, the coupled and coordinated state of Resources-Environment-Economy in the Yellow River Basin has been continuously improved, and the level of coordination of Resources-Environment-Economy in the basin is still very low. The constraints of resources and environment on economic development and the uncoordinated problems among them are prominent, and there is a long way to go to achieve regional sustainable development, which also reflects the great potential of coordinated development in the Yellow River Basin.

(3) From the simulation and prediction results, if the Yellow River Basin achieves high-quality coordinated development, the comprehensive evaluation value of environment and economic system should be supplemented first. When the comprehensive evaluation value of environmental system increases by 0.2, that of economic system increases by 0.1, or that of environmental system increases by 0.3, each system can reach the level of barely coordinated development. When the comprehensive evaluation value of each system reaches 0.65, each system can achieve a good coordinated development level and present a high-quality development trend.

(4) It is the most effective way to make up the shortcomings of environmental system development, increase investment in industrial pollution control, improve the comprehensive utilization of industrial solid waste and reduce the output of industrial solid waste; It is the most effective way to improve the comprehensive evaluation value of economic system by making up the shortcomings of economic system and increasing the proportion of primary industry, total investment in fixed assets and total retail sales of social consumer goods.

5.2 Suggestions

There is no doubt that the high-quality development of the Yellow River Basin plays an important role in China's economy. In order to realize the high-quality development of the Yellow River Basin, this paper puts forward the following suggestions by analyzing and combining the actual situation of the Yellow River Basin.

(1) Adhere to the concept of giving priority to ecological protection and promote ecological environmental protection. The comprehensive environmental assessment value of the Yellow River Basin is the lowest and stagnant, which seriously restricts the coordinated development of the basin. The urgent task to realize the high-quality development of the Yellow River Basin is to improve the comprehensive evaluation value of the environmental system, that is, to increase the investment in industrial pollution control, improve the comprehensive utilization of industrial solid waste, reduce the output of industrial solid waste, reduce the discharge of industrial wastewater and waste gas, and increase the proportion of energy conservation and environmental protection expenditure to GDP.

(2) Improve the comprehensive evaluation value of economic system. According to the characteristics of each basin section of the Yellow River, it is necessary to proceed from reality, adjust measures to local conditions and make scientific policy ^[14], that is, to rationally position different economic development models in different regions, and to drive various elements such as organization, market and government to deepen reform, mainly to increase the proportion of primary industry, the total investment in fixed assets and the total retail sales of social consumer goods, and to make specific plans and arrangements, instead of hastily introducing and implementing construction projects, so as to avoid detours.

(3) In the process of realizing the high-quality development of the Yellow River Basin, we should control the "three pairs of relations", that is, deal with the relations between resource development and environmental protection, economic development and environmental carrying capacity, economic development and resource development, sum up the development experience from 2004 to 2017, find out the shortcomings of environment and economic subsystems, and make up the shortcomings of development to enhance the level of coupled and coordinated development.

(4) It is extremely urgent to improve the ecological development level of nine provinces in the

Yellow River Basin. When the comprehensive evaluation value of ecological and economic subsystems is equal to that of resource subsystems, the coupling and coordinated development can be realized. When the comprehensive evaluation value of each subsystem reaches 0.65, the coupling and coordination degree among each system can reach 0.806, achieving a good coordinated development level.

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Figures

Figure 1
Coupling coordination mechanism of industrial Resources-Environment-Economy system in the Yellow River Basin

Figure 2
Time sequence diagram of comprehensive evaluation value of Resources-Environment-Economy system in river basin

Figure 3

Development trend of coupling coordination level of Resources-Environment-Economy system

Figure 4

Prediction results of coupling coordination degree under different development paths