Study on the coupling and coordinated development of industrial optimization and upgrading and ecological civilization construction in the Yellow River Basin

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Keywords: industry optimization and upgrading; construction of ecological civilization; coupling coordination degree

Abstract: The ecological protection and high-quality development of the Yellow River Basin has become a major national strategy today. In the context of supply-side structural reforms, it is of great significance to study the coupling and coordinated development of industrial optimization and upgrading and ecological civilization construction in the Yellow River Basin. By constructing an industrial structure comprehensive evaluation system that includes industrial structure advancement and industrial structure rationalization, and an ecological environment comprehensive evaluation system that includes ecological human settlement, green economy and environmental governance, we use the entropy method to objectively evaluate the industries optimization and upgrading and ecological civilization construction in the Yellow River Basin. Further we use the coupling coordination model to quantitatively analyze the coupling coordination degree between the industrial optimization and upgrading and ecological civilization construction in the Yellow River Basin from 2011 to 2017. The study finds that the level of industrial optimization and upgrading in the Yellow River Basin is lower than the national average, mainly due to its low level of industrial structure advancement; the level of ecological civilization construction in the Yellow River Basin is slightly lower than the national average, and provinces along the Yellow River Basin differ in their performance in terms of ecological human settlement, green economy and environmental governance. The degree of coupling coordination between the optimization and upgrading of industrial structure and the construction of ecological civilization in the Yellow River Basin has been on the rise in recent years, from moderate disorder and mild disorder to low coordination and moderate coordination.

1. Introduction

Since the Five-point Strategy was proposed in 2012, China's ecological civilization construction has entered a new stage. In recent years, China has promoted the process of ecological civilization construction by continuously promoting the optimization and upgrading of the industrial structure. The industrial structure of a region plays a decisive role in the regional resources and environment (Zhao Xisan, 2010) [1]. In the process of improving the advanced industrial structure, China has vigorously developed strategic emerging industries, effectively improving the efficiency of resource utilization and achieving sustainable development. Meanwhile, improving the coordination ability and correlation level between different industries and realizing harmonious development between different systems is not only a requirement for improving the level of rationalization of the industrial structure, but also the focus of ecological civilization construction (Wang Mingliang, 2008) [2].

The construction of ecological civilization in a region can lead to further optimization and upgrading of the industrial structure. In the overall layout of China's "five-point strategy", the construction of ecological civilization is in a prominent position, and its core is to establish an ecological economic system (Yu Zhenguo, 2013) [3]. The construction of ecological civilization needs to be based on the resource and environmental carrying capacity of the region (Zhu Tan, 2015) [4]. As the shortage of energy and resources has become a major challenge facing China's economic development, it’s an opportunity to cultivate new economic growth points and promote the upgrading of industrial structure by taking the promotion of ecological civilization construction.

At the same time, the construction of ecological civilization aims at the harmony between man and nature, which facilitates the rational allocation of production factors among various industries.

Industrial structure and ecological environment are two systems that influence each other. Many scholars have conducted researches on the coupling coordinated relationship between China's industrial structure and ecological environment, involving many regions such as the Beijing-Tianjin-Hebei region and the Yangtze River Economic Belt [5,6,7]. China has written the "Outline of the Yellow River Basin Ecological Protection and High-quality Development Plan" into the government work report in 2020. As the Yellow River Basin is an important ecological barrier and also an important economic zone in China, it's necessary to study the coupling coordinated relationship of industrial optimization and upgrading and ecological civilization construction in the Yellow River Basin in the context of supply-side structural reforms. On the one hand, promoting the upgrading of industrial structure can improve the quality of the ecological environment; on the other hand, regional ecological civilization construction can also lead to industrial optimization and upgrading. Only when the two form a coupled interaction relationship, can a win-win situation of ecological protection and economic development be truly realized. Based on this, this paper constructs a comprehensive evaluation index system for industrial optimization and upgrading and ecological civilization construction, uses the coupling coordination degree model to analyze coupling coordination degree of the Yellow River Basin and the provinces along the route from 2011 to 2017 and propose targeted suggestions.

2. Data and Methodology

2.1 Sample Data

Considering the availability, representativeness, and scientific nature of data, this paper measures industrial structure from two dimensions of *industrial structure advancement* and *industrial structure rationalization*, and measures ecological environment from three dimensions of *ecological human settlement*, *green economy* and *environmental governance*.

Industrial structure advancement is measured by the ratio of the output value of the tertiary industry to the output value of the secondary industry. The larger the ratio, the more advanced the industrial structure.

Industrial structure rationalization is measured by Theil coefficient, namely:

$$TL = \sum_{i=1}^{n} (\frac{Y_i}{Y}) \ln(\frac{Y_i/Y}{L_i/L})$$

Y represents GDP, and Y_i represents the added value of the three industries ($i = 1,2,3$). L represents the sum of employment in the three industries, and L_i represents the employment in the three industries ($i = 1,2,3$). The smaller the Theil coefficient, the smaller the degree of deviation of the industrial structure from equilibrium and the more reasonable the industrial structure.

The *ecological human settlement* includes four three-level indicators: per capita park green area, built-up area green coverage, rural sanitary toilet penetration, and urban buses per 10,000 people; the *green economy* includes five three-level indicators: pesticide use and fertilizer application per unit of agricultural output, and wastewater discharge, sulfur dioxide emissions and solid waste generation per unit of industrial added value; the *environmental governance* includes six three-level indicators: the harmlessness rate of domestic garbage, urban sewage treatment rate, the proportion of environmental governance investment in GDP, the proportion of the number of days with good API in provincial capitals, the concentration of inhalable particulate matter in provincial capitals, and the sound effect of environmental noise levels in provincial capitals.

The relevant data come from the 2012-2018 China Statistical Yearbook, China Environmental Statistical Yearbook and various regional statistical yearbooks. Since the three indicators including the number of days with good API only have relevant data for major cities across the country, for the comparability of the data and the integrity of the system construction, the provincial capital city data is used instead of the province. Due to the serious lack of data on ecological civilization

construction in Tibet, the scope of this data only includes 30 provinces except Tibet, Hong Kong, Macao and Taiwan.

2.2 Comprehensive Evaluation Index System

1) Dimensionless and normalized processing of data. In order to eliminate the dimensional differences between the variables, the range method is used to standardize the data of each index. *i*, *j* and *k* denote years, provinces and indexes respectively. Among them, the constant *c* is to avoid the value 0 appears.

$$\text{Positive Index} \quad X'_k(i,j) = \frac{X_k(i,j) - X_k(\min) + c}{X_k(\max) - X_k(\min)}$$

$$\text{Negative Index} \quad X'_k(i,j) = \frac{X_k(\max) - X_k(i,j) + c}{X_k(\max) - X_k(\min)}$$

2) Determine the index weight and calculate the comprehensive score. We use the entropy method to calculate the index weight, and calculates the comprehensive score of industrial structure and ecological environment.

(a) Calculate the sample's weight under each index. $p_k(i,j) = X'_k(i,j) / \sum X'_k(i,j)$

(b) Calculate the entropy value of the index. $e_k = -K \sum p_k(i,j) \cdot lnp_k(i,j)$.

$K = 1/lnT$. T is the number of samples under each index, in this paper $T = i \cdot j$.

(c) Calculate the difference coefficient of each index. $h_k = 1 - e_k$.

(d) Determine the weight of each index. $\omega_k = h_k / \sum h_k$.

(e) Calculate the overall score. $\mu(i,j) = \sum \omega_k \cdot X'_k(i,j)$.

2.3 Coupling Coordination Model

We use the coupling coordination model to describe the coordinated development level of the two systems at different time and space levels. The specific model of coupling coordination is as follows: $D = \sqrt{C \cdot T}$. *D* denotes the degree of coupling coordination, and its value is between 0 and 1. The larger the value of *D*, the better the degree of coupling and coordination between the two. $C = 2\sqrt{\mu_1 \cdot \mu_2}/(\mu_1 + \mu_2)$. The value range of *C* is between 0 and 1, indicating the coupling relationship between the two systems. The closer C is to 1, the stronger the coupling relationship between industrial optimization and upgrading and ecological civilization construction. $T = \alpha\mu_1 + \beta\mu_2$. Among them, α and β are undetermined coefficients, and satisfy $\alpha + \beta = 1$. Since the two systems are equally important in this paper, $\alpha = \beta = 0.5$.

Based on the performance of the research objects in this paper, we divide them into 6 categories according to the value range of the coupling coordination degree. At the same time, we analyze the synchronization relationship between the two. The classification and synchronization relationship are shown in Table 1.

Table 1 Coupling and Coordination Types and Grades

D	Types	Grades	$\mu_1(i,j) < \mu_2(i,j)$	$\mu_1(i,j) > \mu_2(i,j)$
$0.0 \le D < 0.3$	serious disorder	F	Industrial optimization and upgrading lag behind	Ecological civilization construction lag behind
$0.3 \le D < 0.4$	moderate disorder	E		
$0.4 \le D < 0.5$	mild disorder	D		
$0.5 \le D < 0.6$	low coordination	C		
$0.6 \le D < 0.7$	moderate coordination	B		
$0.7 \le D < 1.0$	highly coordination	A		

3. Main Results

3.1 Current Status of Industry Optimization and Upgrading

Table 2 shows the evaluation results of the industrial structure in different regions from 2011 to

2017. The upper reaches of the Yellow River include Qinghai, Sichuan, Gansu, Ningxia, and Inner Mongolia. The middle reaches of the Yellow River include Shaanxi and Shanxi. And the lower reaches of the Yellow River include Henan and Shandong. The comprehensive scores of the industrial structure of various regions basically show an upward trend, and the comprehensive scores of the Yellow River Basin have been lower than those outside the Yellow River Basin in recent years. In 2011, the score of the upper reaches of the Yellow River was far lower than that of the middle and lower reaches, but the growth rate was relatively fast in seven years. The scores of the middle and lower reaches are basically the same.

We further analyze the evaluation results and rankings of the industrial structure of the provinces along the Yellow River Basin, and find that most of the provinces rank at the lower middle level in the country. Shanxi's results score the highest. Gansu shows an upward trend year by year, and Ningxia and Shaanxi show a downward trend. Other provinces fluctuate slightly but remain stable overall.

Table 2 Evaluation Results of Industrial Structure in each Regions

	2011	2012	2013	2014	2015	2016	2017
China	0.1664	0.1776	0.1894	0.2152	0.2505	0.2749	0.2904
Yellow River Basin	0.1032	0.1093	0.1198	0.1473	0.1882	0.2092	0.2272
Outside the YRB	0.1935	0.2069	0.2192	0.2443	0.2772	0.3031	0.3174
The upper reaches	0.0884	0.0994	0.1088	0.1368	0.1750	0.1997	0.2417
The middle reaches	0.1284	0.1154	0.1262	0.1538	0.2196	0.2430	0.2096
The lower reaches	0.1151	0.1279	0.1412	0.1671	0.1899	0.1994	0.2084

3.2 Current Status of Ecological Civilization Construction

Table 3 shows the evaluation results of the ecological environment in different regions from 2011 to 2017. The evaluation results of ecological environment in various regions show an overall upward trend, and the results of the Yellow River Basin are slightly lower than those outside the Yellow River Basin. The comprehensive score of the upper reaches has increased rapidly year by year. In 2011, it was basically the same as the middle reaches, and by 2017 it was much higher than that. The performance of the lower reaches is slightly better than the performance of the upper and middle.

We further analyze the evaluation results and rankings of the ecological environment of the provinces along the Yellow River Basin. We can see that there are large gaps in the performance, and there is no obvious trend of changes with geographical locations. Shandong score the highest, while Gansu and Henan score lower among China. There is a big gap in the performance of various provinces in different aspects, and they need to focus on different aspects to improve.

Table 3 Evaluation Results of Ecological Environment in each Regions

	2011	2012	2013	2014	2015	2016	2017
China	0.4588	0.4904	0.4995	0.5072	0.5141	0.5348	0.5427
Yellow River Basin	0.4342	0.4636	0.4803	0.4949	0.4947	0.5323	0.5273
Outside the YRB	0.4694	0.5020	0.5078	0.5125	0.5224	0.5359	0.5493
The upper reaches	0.4259	0.4559	0.4865	0.5017	0.5089	0.5395	0.5446
The middle reaches	0.4278	0.4587	0.4695	0.4771	0.4674	0.5294	0.4637
The lower reaches	0.4613	0.4878	0.4754	0.4955	0.4862	0.5171	0.5477

3.3 Coupling and Coordination Analysis

Table 4 shows the scores of coupling coordination degree in each region from 2011 to 2017. The scores of coupling coordination degree in all regions show an upward trend, and the coupling

coordination degree of the Yellow River Basin is lower than that of regions outside the Yellow River Basin. The evaluation type of the coupling coordination degree of the Yellow River Basin is mild disorder from 2011 to 2013, and it is low coordination from 2014 to 2018.

Table 4 Score of the Coupling Coordination Degree in each region

	2011	2012	2013	2014	2015	2016	2017
China	0.5087	0.5266	0.5391	0.5600	0.5847	0.6051	0.6173
Yellow River Basin	0.4553	0.4683	0.4846	0.5147	0.5454	0.5715	0.5840
Outside the YRB	0.5316	0.5516	0.5625	0.5793	0.6015	0.6196	0.6316
The upper reaches	0.4360	0.4581	0.4773	0.5099	0.5409	0.5676	0.5992
The middle reaches	0.4824	0.4658	0.4817	0.5078	0.5528	0.5877	0.5500
The lower reaches	0.4763	0.4961	0.5057	0.5338	0.5493	0.5649	0.5800

From the perspective of the coupling coordination degree, the industrial structure and ecological environment system of the provinces in the Yellow River Basin from 2011 to 2017 basically showed a state of mild disorder to low coordination, or even moderate coordination. From the perspective of synchronization, all provinces in the Yellow River Basin show that the construction of ecological civilization is ahead of the construction of industrial optimization and upgrading. Among them, the industrial structure of Inner Mongolia, Ningxia and Shandong is more backward than the other provinces, and the process of industrial optimization and upgrading needs to be paid attention in the future.

Table 5 Coupling and Coordination Types of provinces in the YRB

	2011	2012	2013	2014	2015	2016	2017
Qinghai	D	D	D	D	C	C	C
Sichuan	D	D	D	C	C	C	B
Gansu	E	D	D	C	C	C	B
Ningxia	D	D	C	C	C	C	C
Inner Mongolia	D	D	D	C	C	C	B
Shaanxi	D	E	D	D	D	C	C
Shanxi	D	C	C	C	B	B	C
Henan	D	D	D	D	C	C	C
Shandong	C	C	C	C	C	B	B

4. Conclusion

During the sample period, the evaluation results of the industrial structure and the ecological environment of the Yellow River Basin are lower than the national average, and there are large differences between provinces. The level of *industrial structure advancement* in the Yellow River Basin, the *ecological human settlement* and the *green economy* in the Yellow River Basin are the main reasons for the lower evaluation results.

The coupling coordination degree of industrial optimization and upgrading and ecological civilization construction in the Yellow River Basin is lower than the national level, but it shows a growing trend. The coupling coordination degree has been upgraded from mild disorder, even moderate disorder to low coordination and moderate coordination. The study finds that the construction of ecological civilization in the provinces of the Yellow River Basin is ahead of the industrial optimization and upgrading, which is the main influencing factor for the lower coupling and coordination of the Yellow River Basin.

The provinces along the Yellow River Basin need to base on their locality, give full play to their advantages in local resources, and transform their economic growth patterns. At the same time, the governments need to increase the proportion of funds invested in ecological environment

improvement, give full play to the dual role of policy and publicity guidance, and promote the green development of the industry. Localities need to improve the shortcomings in the process of their own industrial optimization and upgrading and ecological civilization construction, and use the spillover effects of the optimization of industrial structure and ecological civilization construction to promote the coupling and coordinated development in the Yellow River Basin.

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