

A Study on the Coupling of High Quality Economic Development and Ecological Protection in the Yellow River Basin

Xie Changqing^{1,a,*}, Chen Jiajia^{2,b}, Zhao Xinyue^{3,c}

¹School of Economics and Management, Foshan University of Science and Technology, Foshan, China

²School of Economics and Management, Foshan University of Science and Technology, Foshan, China

³School of Economics and Management, Foshan University of Science and Technology, Foshan, China

^a15919096466@163.com, ^b2236059810@qq.com, ^c244910845@qq.com

*Corresponding author

Abstract: The Yellow River Basin is an important ecological barrier and economic zone in China. Studying the high-quality development of the Yellow River Basin economy is of great significance for the sustainable development and ecological security of China's economy and society. Based on the perspective of economic development and ecological protection in provinces along the Yellow River Basin, an indicator system is constructed from two dimensions: economic development and ecological protection. The entropy weight method is used to calculate the weights of each indicator, and the weight results are used for coupling analysis. The ecological and economic coupling and coordinated development in the lower reaches of the Yellow River is relatively good, while the coupling and coordination degree in the upper reaches is relatively average, except for Shanxi, which is on the rise overall. Suggest provinces with good coordination to increase support; In provinces with poor coordination, the government plays a guiding role in seeking breakthroughs in economic transformation. In addition, it is necessary to establish an effective ecological protection network to promote the development of the ecological economy.

Keywords: The Yellow River Basin; Economic growth; Ecological protection; Coupling coordination

1. Introduction

In 2019, with the proposal of the major strategy for ecological protection and high-quality development in the Yellow River Basin, the coordinated development of the economy and ecology in the Yellow River Basin has become an important goal for China's green development in the new era. The Yellow River Basin, as an important economic zone and ecological barrier in China, is related to the ecological security and social development of the northern region. High quality economic development requires economic growth not to sacrifice the ecological environment. The extensive economic growth model in the past cannot match it, and the economic growth model has gradually shifted from high-speed growth to high-quality development. However, due to natural geographical environmental factors and long-term high-intensity industrial production and development, the ecological environment of the Yellow River Basin is currently facing significant pressure. The lack of coordination between ecological environment protection and productivity layout, as well as the mismatch between industrial scale and resource and environmental carrying capacity, are obvious issues. Therefore, scientific analysis of the high-quality economic development and ecological protection level in the Yellow River Basin can better handle and coordinate the relationship between high-quality economic development and ecological protection, and also contribute to the better implementation of the strategic requirements of "jointly focusing on large-scale protection and promoting large-scale governance".

The current academic research mainly focuses on the connotation and measurement of high-quality economic development, ecological protection evaluation system, and analysis of the coupling relationship indicator system between the two. For high-quality economic development, Yuan Xiaoling et al. [1] believe that high-quality economic development places more emphasis on the rational allocation of resources, which is a coordinated development in the dimensions of quantity and quality. Zhang Yuesheng et al. [2] believe that high-quality economic development pays more attention to issues such as ecological environment and technological innovation in its direction. Sun Xuetao et al. [3] pointed out

that innovation in production technology and optimization of industrial structure are important connotations of high-quality economic development. Zhao Haoxiang et al.^[4] believe that high-quality economic development is a model that focuses more on the distribution of tertiary achievements based on the existing economic scale. Gelin^[5] believes that high-quality development needs to be coordinated with ecological environment protection and improve green output in economic production. At present, research on the ecological protection evaluation system mainly focuses on calculating through the construction of mathematical models, such as the PSR framework model that combines ecological pressure with environmental status and human response^[6], or selecting relevant indicators for ecological environment system development evaluation through entropy method^[7], or using data envelopment analysis methods to calculate environmental governance efficiency and climate Constructing an ecological service system assessment from the perspective of soil and other ecological service categories^[8]. Early research on the relationship between ecological environment and high-quality economic development mostly focused on the EKC curve, which suggests an inverted U-shaped relationship between ecological environment and economic development level.

Based on existing research, this article constructs an economic high-quality development index and an ecological protection index to measure the economic high-quality development and ecological protection status of various provinces and regions in the Yellow River Basin, and dynamically analyzes the coordination and coupling relationship between the two. Furthermore, from the perspective of spatial correlation, the evolution process of their coupling and coordination scheduling is explored, clarifying the situation and differences of economic high-quality development and ecological protection in various provinces and regions of the Yellow River Basin, This has certain theoretical value and practical significance in promoting high-quality economic development and ecological environment governance in the Yellow River Basin.

2. Research method

2.1 Indicator weight calculation

Based on the analysis of the above impact mechanisms, a coupled coordination degree model is selected to measure the level of high-quality economic development and ecological protection in the nine provinces and regions of the Yellow River Basin. The coupling coordination degree model is commonly used to analyze the level of coordinated development between systems. Coupling degree can reflect the magnitude of mutual influence between two or more systems, while co scheduling can reflect the degree of coupling relationship, that is, the level of coordination. Following the approach of Jia Haifa et al. ^[7], a coupled coordination model C is constructed as follows:

$$C = \frac{\sqrt{Env(x)Eco(y)}}{(Env(x) + Eco(y))} \quad (1)$$

In the formula, $Env(x)$ and $Eco(y)$ respectively represent the ecological protection level index and the high-quality economic development level index. Furthermore, construct the coupling coordination function T between the two systems, where: α and β The weights for the coordinated development of each system are respectively. According to past practice, assign a value of $\alpha = \beta = 0.5$

$$T = \alpha Env(x) + \beta Eco(y) \quad (2)$$

$$D = \sqrt{C \times T} = \frac{\sqrt{2}}{2} (Env(x)Eco(y))^{\frac{1}{4}} \quad (3)$$

Among them, D is the coupling coordination scheduling. Drawing on the practice of existing literature^[8], the coupling coordination degree is divided into 10 levels, as shown in Table 1:

Table 1: Classification criteria for coupling co scheduling levels.

coupling coordination degree	Coordination level	Coupling coordination degree	coupling coordination degree	Coordination level	Coupling coordination degree
(0.0~0.1)	1	Extreme imbalance	[0.5~0.6)	6	Barely coordinate
[0.1~0.2)	2	Severe imbalance	[0.6~0.7)	7	Primary coordination
[0.2~0.3)	3	Moderate imbalance	[0.7~0.8)	8	Intermediate coordination
[0.3~0.4)	4	Mild imbalance	[0.8~0.9)	9	Good coordination
[0.4~0.5)	5	Near imbalance	[0.9~1.0)	10	High quality coordination

2.2 Construction of evaluation index system

This article is based on the coupling analysis of high-quality economic development level and ecological protection construction in nine provinces along the Yellow River, revealing the changes in the economic and ecological spatiotemporal pattern of the Yellow River Basin in recent years. In order to scientifically quantify the actual situation of the economic and ecological dimensions, this article starts with two primary indicators of high-quality economic development and ecological protection, and divides the primary indicators into several secondary and tertiary indicators. The selection of high-quality economic development indicators refers to the 5-dimensional high-quality economic development indicators constructed by Lu Xintong^[9], including five secondary indicators: economic development level, innovative development, economic structure, economic development efficiency, and economic openness level. The economic development level includes gross domestic product, per capita GDP, and GDP growth rate, reflecting the macroeconomic development status of the nine provinces; Innovative development includes R&D funding, technology market transactions, and the number of domestic invention patent applications, reflecting the sustainability of high-quality economic development; The economic structure includes the proportion of the primary, secondary, and tertiary industries in the current year, reflecting the changes in the industrial structure of each province; The efficiency of economic development includes the value of GDP, the income gap between urban and rural residents, and the number of healthcare professionals per 10000 people; The level of economic openness includes total import and export volume and foreign direct investment. Ecological protection refers to some indicators in the "Assessment Target System for Ecological Civilization Construction" issued by the National Development and Reform Commission, and measures the ecological protection status along the Yellow River Basin from three secondary indicators: ecological greening, environmental pollution, and pollution control. Ecological greening includes the total area of afforestation, the area of natural reserves, and forest coverage, reflecting the degree of local greening; Environmental pollution includes wastewater discharge, annual emissions of polluting gases, and energy consumption per unit of GDP, reflecting the water resources situation in the Yellow River Basin; Pollution control includes the comprehensive utilization of general industrial waste, sewage treatment rate, and harmless treatment rate of household waste. Specific indicators are shown in Table 2 below.

Table 2: Index System for Urban Economic Development and Ecological Protection.

First-grade indexes	Secondary indexes	Third level indexes	weight
High quality economic development	Level of economic development	Gross Domestic Product	7.65%
		Per capita GDP	2.55%
		GDP growth rate	1.85%
	Innovation-driven development	R&D funding	15.05%
		Technology market transaction volume	15.98%
		Number of domestic invention patent applications	12.45%
	Structural optimization	The proportion of the secondary industry	1.68%
		The proportion of the tertiary industry	2.15%
		Advanced industrial structure	2.18%
	Economic development efficiency	GDP Gold Content	2.04%
		Income gap between urban and rural residents	3.40%
		Number of health technicians per unit population	2.07%
	Economic openness level	Total import and export volume	16.16%
		foreign direct investment	14.80%
Ecological protection	Ecological greening	Total afforestation area	16.68%
		Nature Reserve Area	14.36%
		Forest coverage rate	35.65%
	environmental pollution	Industrial wastewater discharge	5.22%
		Industrial sulfur dioxide emissions	5.83%
		Energy consumption per unit GDP	2.17%
	Pollution control	Energy consumption per unit GDP	13.43%
		Sewage treatment rate	2.73%
		Harmless treatment rate of household waste	3.93%

2.3 Data sources

The article selects nine provinces along the Yellow River Basin, including Qinghai Province, Sichuan Province, Gansu Province, Ningxia Hui Autonomous Region, Shaanxi Province, Inner Mongolia Autonomous Region, Henan Province, Shanxi Province, and Shandong Province, as the research objects. The research data mainly comes from the statistical yearbooks published by the National Bureau of Statistics and the local statistical bureaus of nine provinces from 2010 to 2019, as well as the Environmental Quality Bulletin published by each province. Interpolation method is used to supplement some missing values.

3. Analysis of Economic Development and Ecological Protection Results in the Yellow River Basin

3.1 Comprehensive evaluation of economic development

Based on the previous indicator weight calculation, a comprehensive evaluation of the economic development of each province over the years can be made, and it can be seen that the economic conditions of each province are different.

As shown in Table 3, it can be seen that economic growth is of an overall upward trend, which can

be divided into fast growing and slow growing types. The fast-growing provinces include Henan, Shaanxi, Sichuan, and Shandong. Among them, Shandong, Sichuan, and Shaanxi have strong economic development momentum, with Sichuan Province having the fastest economic development, while Henan Province's economic development is slightly lagging behind; The economic size of Shandong Province far exceeds that of other provinces; Slow growing provinces include Inner Mongolia Autonomous Region, Qinghai, Ningxia, Gansu, and Shanxi. The economic development trends of Qinghai and Ningxia almost overlap, while the development trends of Gansu Province are relatively similar to those of Qinghai and Ningxia. The economic development of the three provinces is at the end of the nine provinces; Shanxi Province has the largest fluctuation in the upward trend, decreasing in 2015 and continuing to rise thereafter. This may be due to a decrease in indicators with relatively high weights such as total import and export volume, R&D funding, and technology market, which affected the comprehensive evaluation index of Shanxi Province in 2015. Overall, Shandong Province has the best economic development, followed by Sichuan Province, followed by Shaanxi and Henan. Shandong Province is far ahead of other provinces in terms of both economic output and various indicators of economic development, which may be closely related to its coastal geographical location, excellent strategic position, and policy support for the leading role of the Yellow River Economic Belt; The development momentum of Shaanxi, Sichuan, and Henan provinces should not be underestimated, gradually narrowing the gap with Shandong; The worst among them are Ningxia Hui Autonomous Region and Qinghai Province, indicating that the upper reaches of the Yellow River Basin still need to vigorously promote the strategy of high-quality economic development.

Table 3: Comprehensive Evaluation Index of Economic Development from 2010 to 2019.

	Qinghai	Sichuan	Gansu	Ningxia	Neimenggu	Shaanxi	Shanxi	Henan	Shandong
2010	0.1158	0.1927	0.1345	0.1231	0.1602	0.1591	0.1518	0.1578	0.4319
2011	0.1259	0.2286	0.1464	0.1284	0.1788	0.1877	0.1630	0.1951	0.5101
2012	0.1325	0.2566	0.1563	0.1363	0.1913	0.2172	0.1735	0.2374	0.5507
2013	0.1457	0.2727	0.1615	0.1422	0.1901	0.2602	0.1919	0.2594	0.6200
2014	0.1517	0.2986	0.1647	0.1489	0.1966	0.2845	0.1869	0.2883	0.6653
2015	0.1567	0.3088	0.1653	0.1536	0.2033	0.2916	0.1768	0.3145	0.6726
2016	0.1627	0.3419	0.1732	0.1613	0.2109	0.3190	0.1918	0.3316	0.6810
2017	0.1706	0.4067	0.1731	0.1742	0.2081	0.3845	0.2091	0.3656	0.7086
2018	0.1804	0.4849	0.1914	0.1828	0.2257	0.4172	0.2274	0.4026	0.7547
2019	0.2016	0.5181	0.2039	0.1931	0.2381	0.4583	0.2321	0.4052	0.7479

3.2 Comprehensive evaluation of ecological protection

Table 4: Ecological Protection Comprehensive Evaluation Index from 2010 to 2019.

	Qinghai	Sichuan	Gansu	Ningxia	Neimenggu	Shaanxi	Shanxi	Henan	Shandong
2010	0.4862	0.4577	0.2862	0.1818	0.5764	0.3573	0.2952	0.2472	0.2628
2011	0.5562	0.4404	0.2847	0.1779	0.6236	0.3607	0.3190	0.2612	0.2727
2012	0.5514	0.4176	0.2905	0.1861	0.6270	0.3691	0.3476	0.2692	0.2649
2013	0.5544	0.4227	0.3000	0.2008	0.6322	0.3842	0.3496	0.2766	0.2744
2014	0.5584	0.4176	0.3556	0.2111	0.5857	0.3941	0.3621	0.2929	0.2868
2015	0.5635	0.4902	0.3905	0.2038	0.6193	0.4066	0.3556	0.2845	0.2819
2016	0.6140	0.5367	0.4114	0.2312	0.6140	0.4105	0.3705	0.2967	0.3340
2017	0.6169	0.5727	0.4138	0.2168	0.6269	0.4105	0.3794	0.3126	0.3510
2018	0.6123	0.5305	0.4291	0.2304	0.5947	0.4131	0.3946	0.3164	0.3548
2019	0.6285	0.5292	0.4315	0.2334	0.6409	0.4118	0.4066	0.3246	0.3672

According to Table 4, the comprehensive evaluation of ecological protection in the nine provinces can be basically divided into two types: fluctuating upward and overall leveling. Inner Mongolia, Sichuan Province, Qinghai Province, and Gansu Province have a fluctuating upward trend. The fluctuation amplitude of Inner Mongolia and Sichuan is relatively obvious, and they all showed a downward trend from 2011 to 2014, which may be related to the significant decrease in the total afforestation area and nature reserve area of the two provinces during this period; Qinghai and Gansu have seen a significant increase, with a rapid development trend in ecological protection. There are Ningxia, Shanxi, Henan, Shaanxi, and Shandong with an overall trend towards leveling. Among them, Ningxia has the lowest comprehensive evaluation index, while Shanxi, Henan, and Shandong have similar ecological protection, which may be related to significant indicators such as total afforestation

area, forest coverage, and nature reserve area; Shaanxi has the highest comprehensive evaluation of ecological protection. From a comprehensive perspective of the nine provinces, Inner Mongolia, Qinghai, and Sichuan have the best ecological protection, while other provinces still need to strengthen their environmental protection efforts. Although the overall ecological situation of the Yellow River Basin is improving, provinces such as Ningxia should pay special attention to it.

3.3 Coupling coordination analysis

Table 5: Coupling Coordination Degree D Values from 2010 to 2019.

	Qinghai	Sichuan	Gansu	Ningxia	Neimenggu	Shaanxi	Shanxi	Henan	Shandong
2010	0.1	0.227	0.119	0.167	0.1	0.1	0.1	0.1	0.1
2011	0.511	0.367	0.205	0.17	0.649	0.292	0.423	0.414	0.4
2012	0.565	0.213	0.352	0.416	0.748	0.457	0.6	0.553	0.324
2013	0.658	0.321	0.457	0.582	0.759	0.637	0.703	0.63	0.513
2014	0.697	0.24	0.678	0.686	0.516	0.725	0.716	0.746	0.641
2015	0.732	0.641	0.751	0.672	0.777	0.79	0.642	0.743	0.612
2016	0.837	0.769	0.831	0.848	0.783	0.843	0.761	0.816	0.849
2017	0.873	0.897	0.834	0.843	0.831	0.917	0.854	0.914	0.919
2018	0.899	0.896	0.943	0.943	0.7	0.959	0.953	0.965	0.964
2019	0.995	0.917	0.995	0.995	0.995	0.99	0.995	0.995	0.99

Table 6: Coupling Coordination Results from 2010 to 2019.

	Qinghai	Sichuan	Gansu	Ningxia	Neimenggu
2010	Extreme imbalance	Moderate imbalance	Extreme imbalance	Extreme imbalance	Extreme imbalance
2011	Barely coordinate	Mild imbalance	Moderate imbalance	Severe imbalance	Primary coordination
2012	Barely coordinate	Moderate imbalance	Mild imbalance	Near imbalance	Intermediate coordination
2013	Primary coordination	Mild imbalance	Near imbalance	Barely coordinate	Intermediate coordination
2014	Primary coordination	Moderate imbalance	Primary coordination	Primary coordination	Barely coordinate
2015	Intermediate coordination	Primary coordination	Intermediate coordination	Primary coordination	Intermediate coordination
2016	Good coordination	Intermediate coordination	Good coordination	Good coordination	Intermediate coordination
2017	Good coordination	Good coordination	Good coordination	Good coordination	Good coordination
2018	Good coordination	Good coordination	High quality coordination	High quality coordination	Intermediate coordination
2019	High quality coordination	High quality coordination	High quality coordination	High quality coordination	High quality coordination

Combining Table 2 and the coupling coordination model, the coupling results of Tables 5,6 and 7 can be obtained. From Table 5, it can be seen that the coupling coordination results of the nine provinces in the Yellow River Basin from 2010 to 2019 have all developed towards a good trend. In 2010, almost all provinces were severely imbalanced, but by 2019, all provinces achieved high-quality coordination. Shaanxi, Shandong, and Henan have achieved high-quality coordination for three consecutive years. Among these three provinces, Shandong Province has experienced a tortuous rise over the past decade, with a slight decline in both 2012 and 2015. It is speculated that during these two years, Shandong's economy has developed rapidly, and ecological protection has not kept up, resulting in an imbalance in coupling coordination; The coordination between Henan and Shaanxi has steadily increased. Qinghai Province, Inner Mongolia, and Sichuan Province achieved high-quality coordination for the first time in 2019. The coordination degree between Sichuan Province and Inner Mongolia fluctuated more violently, with Sichuan Province rapidly increasing from 2014 to 2019, Inner Mongolia experiencing significant fluctuations over the past decade, and Qinghai Province steadily rising. The development trends of Gansu, Ningxia, and Shanxi provinces are similar, all showing a stable upward trend. Among them, Shanxi province experienced a decline in 2015 and then continued to rise. It is

speculated that this may be influenced by ecological indicators such as the utilization of general industrial waste and the total area of afforestation.

Table 7: Coupling Coordination Results from 2010 to 2019.

	Shaanxi	Shanxi	Henan	Shandong
2010	Extreme imbalance	Extreme imbalance	Extreme imbalance	Extreme imbalance
2011	Moderate imbalance	Near imbalance	Near imbalance	Near imbalance
2012	Near imbalance	Barely coordinate	Barely coordinate	Mild imbalance
2013	Primary coordination	Intermediate coordination	Primary coordination	Barely coordinate
2014	Intermediate coordination	Intermediate coordination	Intermediate coordination	Primary coordination
2015	Intermediate coordination	Primary coordination	Intermediate coordination	Primary coordination
2016	Good coordination	Intermediate coordination	Good coordination	Good coordination
2017	High quality coordination	Good coordination	High quality coordination	High quality coordination
2018	High quality coordination	High quality coordination	High quality coordination	High quality coordination
2019	High quality coordination	High quality coordination	High quality coordination	High quality coordination

4. Research conclusions and policy recommendations

Based on the above results, this study found that: (1) economic growth is of an overall upward trend, which can be divided into fast growth and slow growth types. Fast growing provinces include Henan, Shaanxi, Sichuan, and Shandong, with strong economic development momentum in Shandong, Sichuan, and Shaanxi. Slow growing provinces include Inner Mongolia Autonomous Region, Qinghai, Ningxia, Gansu, and Shanxi, with almost overlapping economic development trends in Qinghai and Ningxia, and similar development trends in Gansu Province, Qinghai, and Ningxia. Overall, Shandong Province has the best economic development, followed by Sichuan Province, followed by Shaanxi and Henan. Shandong needs to play a leading role in the Yellow River Economic Belt; (2) The comprehensive evaluation of ecological protection in the nine provinces can be basically divided into two types: fluctuating upward and overall leveling. The fluctuating upward type includes Inner Mongolia, Sichuan Province, Qinghai Province, and Gansu Province. The fluctuation amplitude of Inner Mongolia and Sichuan is relatively obvious, while Qinghai and Gansu have a larger increase. The overall leveling type includes Ningxia, Shanxi, Henan, Shaanxi, and Shandong, with Ningxia having the lowest comprehensive evaluation index and Shaanxi having the highest comprehensive evaluation of ecological protection; (3) The coupling coordination results indicate that the overall trend is good, with Shaanxi, Shandong, and Henan achieving high-quality coordination for three consecutive years, Qinghai Province, Inner Mongolia, and Sichuan Province achieving high-quality coordination for the first time in 2019, and Gansu, Ningxia, and Shanxi provinces showing similar development trends, all steadily increasing.

For provinces with continuous high-quality coordination, the government cannot relax its vigilance and should increase support for their economic development, summarize experience, improve the level of economic development, and promote economic growth; For provinces that have just achieved high-quality coordination, the government should strengthen guidance on their economic development, increase attention, reduce the possibility of future economic and ecological imbalances, and maintain a stable economic development trend. In addition, it is necessary to strengthen the ecological protection of the Yellow River Basin, especially to improve the level of ecological protection in Ningxia Province. At the same time, strengthen ecological protection cooperation between adjacent provinces, establish an effective ecological protection network, and form a benign ecological protection environment. In addition to strengthening laws and regulations on ecological protection, it is also necessary to establish a sound ecological protection system, strictly enforce ecological protection regulations, and increase punishment for illegal activities. In response to the situation where the nine provinces in the Yellow

River Basin have achieved high-quality coordination, it is necessary to strengthen the management of ecological and economic coupling coordination in these nine provinces, continue to maintain a high-quality coordination state, promote the development of national ecological and economic coupling coordination, establish a positive image for other river and lake economic belts in China, fully implement the new development concept, deeply implement the innovation driven development strategy, and vigorously promote the high-quality development of the Yellow River Basin economy.

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