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Evaluation of the Coupling and Coordination Relationships between Economic Growth and the Ecological Environment in Qinghai Province

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Abstract: ***Qinghai Province shoulders the important task of maintaining national ecological security. To promote the construction of an "ecological civilization pilot zone", it is necessary to coordinate the economic growth and ecological environment of the province. This paper uses panel data from 2008--2018 to construct an indicator system from the two dimensions of economic growth and ecological protection and uses the entropy method and coupling coordination model to measure and evaluate the development level of Qinghai Province's economy and ecological protection. The results show that (1) from 2008–2018, the changes in the coupling degree and coupling coordination degree of the two systems of economic growth and ecological protection in Qinghai Province basically showed a steady upward trend. (2) From 2008--2015, the degree of economic–eco-ecological coupling was in the antagonistic stage, and the degree of coupling coordination tended to change from moderate to mild. (3) From 2016 to 2018, the degree of coupling was in the running-in stage, the degree of coupling coordination was stable under mild imbalance, and there was a trend toward near-disharmony and coordinated development, indicating that the coordinated development level of the economy and ecology has moved toward coordinated development.***

Keywords: Entropy method; Coupling coordination model; Economic growth; Ecological protection; Qinghai Province.

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1. Introduction

As an important ecological barrier in China, Qinghai Province shoulders the important task of maintaining national ecological security. To build an "ecological civilization pilot zone", the coordinated development of economic growth and ecological protection is extremely important. Rachel Carson (1962) first proposed the issue of coordination between economic development and the environment [1]. Liu, H., et al [2] incorporated environmental factors into the economic growth theory model to study the relationship between the economy and ecology. Gao Hongxia et al. [3] used panel data from various provinces to conduct an empirical analysis of the environmental Kuznets curve of the relationship between economic growth and environmental pollution. In studies of the level of coordinated development of economic growth and the ecological environment, scholars have mostly measured and evaluated the degree of coordination at the river basin level and provincial level.

At the basin level, scholars have paid more attention to the degree of coupling coordination between economic growth and ecological protection in the Yellow River Basin. Zhang Rongtian et al. [4] took the Pan-Yangtze River administrative region as an example, used the entropy method to analyze the coupling coordination between economic development and the ecological environment and its evolution rules, and conducted a score ranking. Wang Wei [5] analyzed the ecological protection quality and economic development level of the Yangtze River Economic Belt on the basis of a comprehensive evaluation model and used the coupled coordination degree model to analyze its spatiotemporal evolution rules. Ren Baoping [6] is based on three factors: economic growth, industrial development and the ecological environment. The dimensions are used to evaluate and analyze the

degree of coupling coordination and its driving factors in the Yellow River Basin, and the GM prediction model is used to predict the degree of short-term coupling coordination. Zhang Xiaoyu et al. [7] constructed an indicator system from two dimensions: economic growth and the ecological environment. An analysis of the coupling and coordination of economic growth and environmental protection in nine provinces where the Yellow River flows revealed that, except for Qinghai Province, the degree of coupling and coordination in the other provinces has gradually increased. At the provincial level, Guofeng et al. [8] used the entropy method to conduct a coupling study of economic integration and sustainable development of the ecological environment in the three northeastern provinces and observed their temporal changes. Xie Qiang et al. [9] conducted research and analysis on the ecological environment and economic development of Gansu Province by constructing a coupling model and a coupling coordination model between the quality of the ecological environment and the economic development level. Xue Jing et al. [10] analyzed the coupling coordination degree of Gansu Province and its 14 municipalities in terms of time and space and reported that the comprehensive development level is increasing annually.

There are few studies on the coupling coordination between economic growth and the ecological environment in Qinghai Province. Zhao Yingyan et al. [11] used a modified ecological footprint model to study and analyze the ecological and economic coordination in Qinghai Province. The results revealed that the ecological environment was extremely unsafe and that economic and ecological coordination was very poor. Hu Xiwu et al. [12] used the coupling coordination model and VAR model to study and analyze the coordination between economic development and ecological protection in Qinghai Province and the influencing factors by industry. Jia Haifa et al. [13] used the entropy method and the coupling coordination model to evaluate and analyze the comprehensive development level of the ecological civilization in Qinghai Province from the three dimensions of economic development, social progress and ecological environment protection. This paper uses the entropy method and the coupling coordination model to establish two systems of economic growth and the ecological environment; establishes six subsystems, namely, economic level, economic structure, economic vitality and ecological foundation, environmental pressure and environmental governance; and conducts a comprehensive analysis and evaluation of the coordinated development level of economic growth and the ecological environment.

2. Overview of the Study Area

Qinghai is located between 31°36′ and 39°19′ north latitude and 89°35′ and 103°04′ east longitude. It borders Gansu in the north and east, Xinjiang in the northwest, Tibet in the south and southwest, and Sichuan in the southeast. It is located northeast of the Qinghai–Tibet Plateau and has an average altitude of more than 3,000 m and an average annual temperature of -5.1–9.0°C. It is named after the largest inland saltwater lake in the country, Qinghai Lake. Qinghai Province is divided into agricultural and pastoral areas with the Sun and Moon Mountains as the natural dividing line. Since four-fifths of the area is a plateau, the pastoral area is the main area. Qinghai Province has Sanjiangyuan National Park, Qilian Mountain National Park and Qinghai Lake National Nature Reserve and is a national highland for the construction of an ecological civilization.

3. Data Sources and Research Methods

3.1 Data Sources

The data used in this study are from the China Statistical Yearbook and the Qinghai Statistical Yearbook. The selected data range is from 2008--2018. The missing data in some years are calculated appropriately via arithmetic means and other methods. The data processing process was performed via Excel and Stata 16.0 software.

3.2 Entropy Weight Method

3.2.1 Data standardization

To eliminate the impact of the differences in the dimensions and magnitudes of the indicators, the indicators are first normalized to the minimum and maximum values. This paper refers to the approach of Zhang Xiaoyu et al. [7] and performs a 0.001 shift on the data.

$$\text{Positive indicator: } H_{ij}=\frac{X_{ij}-min(X_{ij})}{max(X_{ij})-min(X_{ij})}+0.001 \quad (1)$$

$$\text{Negative indicator: } H_{ij}=\frac{max(X_{ij})-X_{ij}}{max(X_{ij})-min(X_{ij})}+0.001 \quad (2)$$

where Xij is the jth indicator under the i-th system, H_{ij} is the value after normalization, and n is the number of indicators. Since there are 11 indicators, the value range of n is 1–19.

3.2.2 Use the entropy weight method to calculate the eigenvalue proportion P_{ij} of the j-th indicator in the i-th year

$$P_{ij}=\frac{H_{ij}}{\sum_{i=1}^{n} H_{ij}} \quad (0\leq P_{ij}\leq 1) \quad (3)$$

3.2.3 E_j of the index according to the entropy calculation formula.

$$E_j=-k\sum_{i=1}^{n} P_{ij} lnP_{ij} \quad (0\leq E_j \leq 1) \quad (4)$$

where k > 0, ln is the natural logarithm, the constant k is related to the sample number n, and k = 1/lnn.

3.2.4 Calculating the difference coefficient D_j of the j-th indicator on the basis of information entropy

$$D_j=1-E_j \quad (5)$$

3.2.5 Use the difference coefficient to calculate the weight W_j of the j-th indicator

$$W_j=\frac{D_j}{\sum_{i=1}^{n} D_j} \quad (6)$$

Among them? $\sum_{=1}$ □□, =1.

3.2.6 Weighted summation to calculate the comprehensive evaluation score

$$U_i=\sum_{i=1}^{n} Y_{ij} W_j \quad (7)$$

The higher the U value is, the higher the comprehensive score and the more favorable the evaluation result. Finally, the evaluation results are compared on the basis of all U values.

3.3 Coupling Coordination Model

$$C = 2 \times \left[\frac{U_1 U_2}{(U_1+U_2)2}\right]^{\frac{1}{2}} \quad (8)$$

$$T = \alpha U_1 + \beta U_2 \quad (9)$$

$$D = \sqrt{C \times T} \quad (10)$$

where C is the coupling degree of the two systems, reflecting the intensity of the interaction between the systems; T is the comprehensive coordination index of the two systems; and α and β are the weights of the two systems. Since both are equally important in the coordinated development of economy and ecology, α = β = 0.5 is taken, and D is the coupling coordination degree of the two systems. The higher the D value is, the higher the coupling coordination level, and vice versa.

4. Construction of the evaluation index system

4.1 Construction of the economic growth evaluation index system

This paper draws on existing research results [7-10] and, on the basis of the principles of indicator selection, reflects economic growth in three dimensions—economic level, economic structure, and economic vitality—and reflects the ecological environment in three dimensions—ecological foundation, environmental pressure, and environmental governance—as shown in Table 1.

(1) Economic level: GDP per capita, local fiscal general budget revenue, and total retail sales of consumer goods.
(2) Economic structure: the proportion of secondary industry, the proportion of tertiary industry, and the difference in per capita disposable income of urban and rural residents.

(3) Economic vitality: Growth rate of fixed asset investment, total import and export volume of foreign-invested enterprises, and total export volume.

4.2 Construction of the Ecological Environment Evaluation Index System

This paper draws on existing research results [11-13] and reflects the ecological environment in three dimensions, namely, the ecological foundation, environmental pressure, and environmental governance, on the basis of the principle of indicator selection, as shown in Table 1.

(1) Ecological basis: forest coverage, per capita water resources, and per capita cultivated land area.

(2) Environmental pressure: Sulfur dioxide emissions, smoke (dust) emissions, and total wastewater emissions.

(3) Environmental governance: Completed investment in industrial pollution control, daily urban sewage treatment capacity, and the harmless treatment rate of domestic waste.

Table 1: Index system and weights of economic growth and ecological environment protection in Qinghai Province

System Layer	Criteria Layer	Serial number	Indicator layer	Indicator Type	Weights
Economic Growth	economic level	1	per capita (yuan/person)	+	0.0507
		2	Local fiscal general budget revenue (100 million yuan)	+	0.0467
		3	Total retail sales of consumer goods (100 million yuan)	+	0.0499
		4	Industrial added value (100 million yuan)	+	0.0516
	economic structure	1	Proportion of secondary industry (%)	+	0.0441
		2	The proportion of the tertiary industry	+	0.0489
		3	Difference in per capita disposable income between urban and rural residents (yuan)	+	0.0507
	Economic vitality	1	Fixed asset investment growth rate (%)	+	0.0567
		2	Total import and export volume of foreign-invested enterprises (thousand US dollars)	+	0.0712
		3	Total export value (10,000 USD)	+	0.0528
ecosystem	Ecological foundation	1	Forest cover rate(%)	+	0.0384
		2	Per capita water resources (cubic meters/person)	+	0.0487
		3	Per capita cultivated land area (hectares/10,000 people)	-	0.0528
	Environmental pressure	1	Sulfur dioxide emissions (10,000 tons)	-	0.0775
		2	Smoke (dust) emissions (10,000 tons)	-	0.0561
		3	Total wastewater discharge (10,000 tons)	-	0.0449
	Environmental governance	1	Completed investment in industrial pollution control (10,000 yuan)	+	0.0610
		2	Daily urban sewage treatment capacity (10,000 cubic meters)	+	0.0521
		3	Harmless treatment rate of domestic waste (%)	+	0.0454

5. Results and Analysis

5.1 Comprehensive Measurement and Result Evaluation of Economic Growth and Ecological Protection in Qinghai Province

According to the various indicators of Qinghai Province from 2008--2018, the entropy method was used to calculate the weight coefficients of various indicators in the evaluation system of economic growth and ecological protection in Qinghai Province. The results are listed in Table 1. The comprehensive evaluation values of the three subsystems of economic growth and ecological protection were calculated via formulas (1) - (7), as shown in Tables 2 and 3. Table 2 and Figure 1 show that the comprehensive evaluation values of each subsystem of Qinghai Province's economic level, economic structure and economic vitality increased from 2008--2018, and the level of economic growth also showed an increasing trend, indicating that Qinghai Province's economy has been growing continuously from 2008--2018 and that its economic level, economic structure and economic vitality have improved to a certain extent.

Table 2: Comprehensive evaluation values of economic growth in different years

years	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
economic level	0.0002	0.0085	0.0289	0.0587	0.0811	0.1044	0.1203	0.1352	0.1495	0.1710	0.1990
economic structure	0.0375	0.0450	0.0426	0.0576	0.0601	0.0551	0.0600	0.0809	0.0966	0.1085	0.1139
Economic vitality	0.0914	0.0911	0.0653	0.0823	0.0616	0.0730	0.0586	0.0617	0.0425	0.0099	0.0118
Economic growth level	0.1291	0.1446	0.1368	0.1985	0.2028	0.2325	0.2389	0.2778	0.2885	0.2894	0.3247

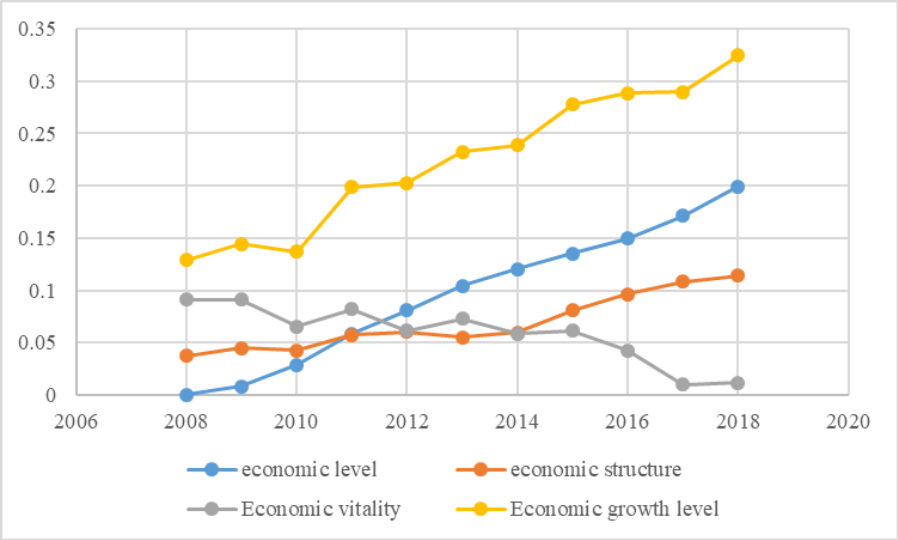

Figure 1: Trends in comprehensive evaluation values of each subsystem of economic growth in Qinghai Province from 2008--2018

Table 3 shows that the ecological foundation of Qinghai Province in 2008--2018 was evaluated at a high level in 2009, 2010 and 2018: the environmental pressure evaluation value has been decreasing since 2008, and it has not gradually increased until 2016, indicating that the environmental pressure is gradually decreasing; the environmental governance evaluation value has fluctuated each year, indicating that the governance of the environment is unstable. The ecological environment development level fluctuated in the early stage and rose slowly in the later stage, indicating that the ecological environment has gradually improved and developed in recent years.

Table 3: Comprehensive evaluation values of the ecological environment in different years

years	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Ecological foundation	0.0573	0.1265	0.1104	0.0555	0.0813	0.0457	0.0819	0.0506	0.0585	0.0854	0.1100
Environmental pressure	0.0908	0.0825	0.0717	0.0594	0.0541	0.0464	0.0245	0.0238	0.0821	0.0772	0.1225
Environmental governance	0.0159	0.0141	0.0064	0.0704	0.0657	0.0584	0.1019	0.0972	0.1587	0.0881	0.1006
Ecological environment development level	0.1640	0.2231	0.1885	0.1852	0.2011	0.1505	0.2083	0.1716	0.2993	0.2506	0.3331

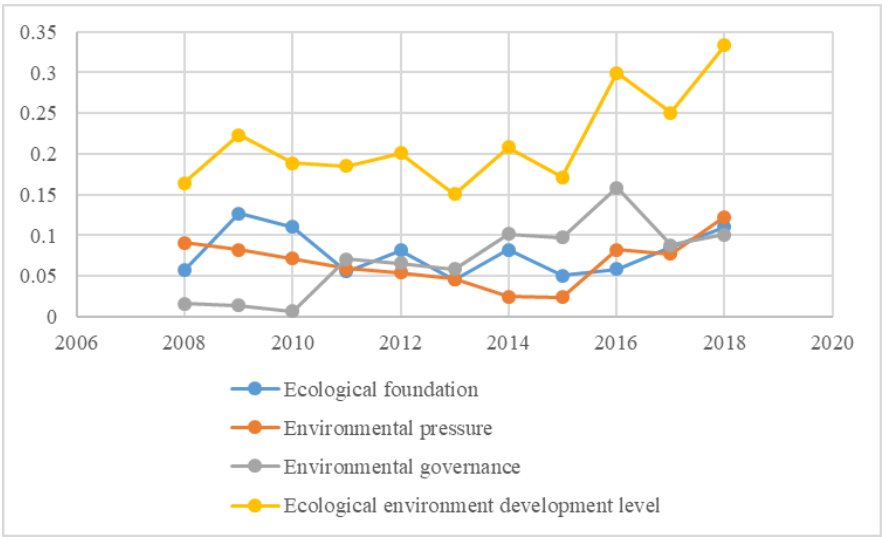

Figure 2: Trends in comprehensive evaluation values of ecological environment subsystems in Qinghai Province from 2008--2018

5.2 Coupling Coordination Analysis

This paper refers to the coupling degree and coupling coordination degree classification of Hu Xiwu et al. [12]

and divides the coupling degree into 4 levels and the coupling coordination degree into 10 levels, as shown in Table 4. On the basis of the comprehensive evaluation value of economic growth and ecological protection in Qinghai Province from 2008--2018, the coupling degree and coupling coordination degree of economic growth and ecological protection are calculated via formulas (8)–(10), as shown in Table 5, and its development trend is shown in Figure 3.

Table 4: Classification of the degree of coupling and degree of coupling coordination

C	Coupling level	D	Coordination level	D	Coordination level
[0.0-0.3]	Low level coupling stage	[0.0-0.1)	Extremely disordered	[0.5-0.6)	Barely coordinated
[0.3-0.5)	Antagonistic phase	[0.1-0.2)	Serious disorder	[0.6-0.7)	Primary Coordination
[0.5-0.8)	Running-in phase	[0.2-0.3)	Moderate Disorder	[0.7-0.8)	Intermediate Coordination
[0.8-1.0]	High level coupling stage	[0.3-0.4)	Mild disorder	[0.8-0.9)	Good coordination
		[0.4-0.5)	On the verge of disorder	0.9-1.0)	High-quality coordination

As shown in Table 5, the degree of coupling between economic growth and ecological protection in Qinghai Province remained between 0.3 and 0.5 from 2008--2015, which was in the antagonistic stage. It reached the running-in stage after 2016, indicating that the degree of coupling between the economy and ecology in Qinghai Province was relatively low and needs to be further improved. The coupling coordination degree gradually shifted from moderate imbalance to mild imbalance and then reached the verge of imbalance. The trend chart also steadily increases, which means that the coordination level of the economy and ecology in Qinghai Province is constantly improving and that the construction of an ecological civilization is playing a role.

Table 5: Types of coordination between economic growth and the ecological environment in Qinghai Province from 2008--2018

years	Coupling	Coordination Phase	Coupling coordination	Coordination Type
2008	0.3800	Antagonistic phase	0.2360	Moderate Disorder
2009	0.4188		0.2775	
2010	0.3982		0.2545	
2011	0.4378		0.2898	Mild disorder
2012	0.4494		0.3012	Moderate Disorder
2013	0.4275		0.2862	
2014	0.4717		0.3247	Mild disorder
2015	0.4606		0.3217	
2016	0.5421	Running-in phase	0.3992	
2017	0.5183		0.3741	On the verge of disorder
2018	0.5734		0.4343	

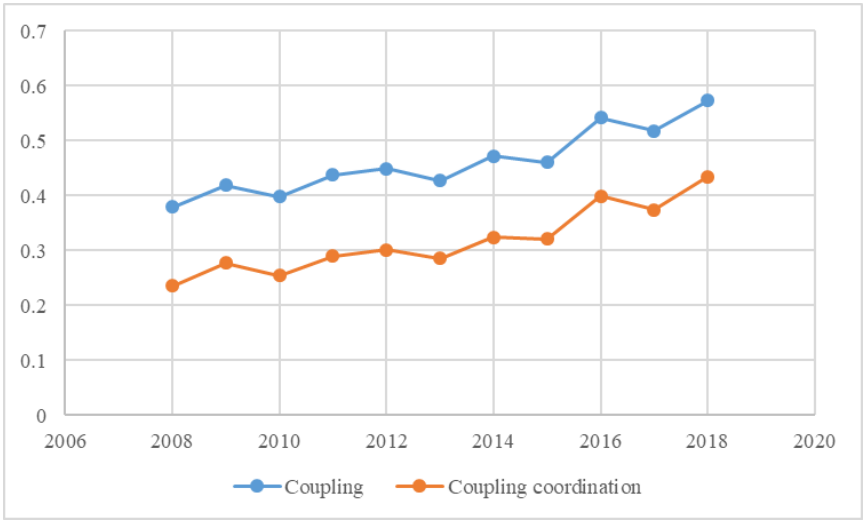

Figure 3: Trend of coordination between economic growth and ecological protection in Qinghai Province from 2008--2018

6. Conclusion and Discussion

6.1 Conclusion

From the two dimensions of economic growth and ecological protection, this paper established six subsystems, namely, economic level, economic structure, economic vitality and an ecological foundation, environmental pressure, and environmental governance. A total of 19 indicator factors were selected. The entropy method was

used to comprehensively evaluate the coordinated development level of economic growth and ecological protection in Qinghai Province from 2008--2018. The coupling degree and coupling coordination degree model were used to evaluate the comprehensive value and measure the coordination level. The conclusions are as follows:

(1) From 2008–2018, the economic growth and development level of Qinghai Province made great progress, and the economic level, economic structure and economic vitality steadily improved, which is conducive to the further development of Qinghai's economy in the future. The ecological environment is also constantly improving, especially the rapid development of the ecological foundation, and the environmental pressure and environmental governance level are also gradually improving and developing, which is of great help to Qinghai Province in further building an "ecological civilization highland". However, the comprehensive evaluation value of economic growth and the ecological environment is relatively low. Therefore, in future ecological civilization construction, we should continue to increase the governance of the ecological environment, improve people's living environment, and improve the level of Qinghai's economic development.

(2) From 2008–2018, the changes in the degree of coupling and degree of coupling coordination of the two systems of economic growth and ecological protection in Qinghai Province basically showed a steady upward trend. From 2008–2015, the degree of economic–ecological coupling was in the antagonistic stage, and the degree of coupling coordination tended to change from moderate coordination to mild coordination. From 2016–2018, the degree of coupling was in the running-in stage, the degree of coupling coordination was stable in mild imbalance, and there was a trend toward near-disharmony and coordinated development, indicating that the coordinated development level of the economy and ecology had moved toward coordinated development.

6.2 Discuss

Scholars have conducted many evaluations and measurements of the coordinated development level of economic growth and the ecological environment in various river basins and provinces. However, as a major province in terms of ecological civilization construction, Qinghai Province has few research results, and the existing research lacks a detailed division of subsystems. This paper uses the coupling coordination model to measure the coupling coordination level of economic development and ecological protection in Qinghai Province, which can provide a reference for the measurement of economic and ecological levels in other regions in the future. However, owing to the difficulty in obtaining data and the imperfection of the construction of a certain indicator system, further improvements can be made in the future to conduct in-depth research on the coordinated development level of economic growth and the ecological environment in Qinghai Province.

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