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Measurement of the Level of Coupling and Coordination Between Eco-environment and High-Quality Economic Development in Hunan Province and Its Spatial Differences

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Abstract: The coordinated development of the ecological environment and high-quality economy is of great significance for maintaining ecological balance. Select 14 cities and states in Hunan Province as the research objects, establish a comprehensive evaluation index of ecological environment and high-quality economic development, use the weighted method to calculate the evaluation index of each city and state index from 2010 to 2021, and use the coupling coordination degree model to evaluate the ecological environment of Hunan Province. The spatiotemporal evolution law of coupling degree and coupling coordination degree with economic high quality is analyzed. (1) From 2010 to 2021, the economic development speed of the cities and states in Hunan Province was faster than the ecological environment development speed. (2) From the perspective of the Spatio-temporal evolution trend of the coupling degree of the high-quality development of the ecological environment and economy, the coupling degree of most cities and states have increased, but it stays at the low level of the antagonistic stage, and the interaction between the ecological environment and the high-quality development of the economy needs to be strengthened. (3) From the perspective of the overall Spatio-temporal evolution trend of the coupling and coordination degree of high-quality development of ecological environment and economy, the level of the coupling and coordination degree of most cities and states has improved during the study period, but the coupling and coordination degree of each city and state are mainly between the moderate imbalance and the mild imbalance, and the overall level is low; The spatial scale of the development of the coupling coordination degree of cities and states is not balanced. (4) Based on the analysis of the formation mechanism of the space-time evolution of the coupling coordination degree of eco-environment and high-quality economic development with the main line of element function structure, it is found that the coupling of element, function, and structure is the three main performance levels of the coupling coordination of the two.

Keywords: Economy, Ecological Environment, Degree of Coupling Coordination, Degree of Coupling

1. Introduction

The regional economy has entered the stage of high-quality development, and the interaction between high-quality economic development and the ecological environment has a great correlation and coupling consistency. The economy and environment are interdependent and promote each other all the time. The high-quality development of the economy needs the support of an excellent ecological environment. Moreover, high-quality economic development can effectively promote the construction of ecological civilization and ecological

environment protection. Under such circumstances, high-quality and efficient integration of the ecological environment and economic development has become an important part of ecological civilization construction, playing an important role in ecological protection and economic growth. To put it simply, the ecological environment provides primitive resources for the economy, which is the basic guarantee for the smooth development of high-quality economic activities. The economy can provide financial support for ecological and environmental protection. This makes the ecological environment and high-quality economic development mutually dependent, and the effective integration of the two has become an effective way to promote economic growth and protect the living environment. So far, many domestic scholars have studied the ecological environment and high-quality economic development.

In the coupling of ecological and economic coordination development theory research, Yang Wensan [1] to mutual influence relationship between ecological environment protection and economic development in Anhui province as the research object, found in different countries, the ecological, economic and social development in different areas of the evolution path of overall coordination of the coupling degree is similar, but different countries or regions the evolution speed, The main reason is that the degree of coordination between ecological environmental protection and economic development policy intervention is not the same. The uncoordinated ecological environment evolution process even leads to the collapse of the social economy. Gu Guofeng and Wang Jiankang [2] studied the coordination relationship between the ecological economy and social development in Northeast China, and the results showed that the coordination region of the ecological economy and social development in Northeast China gradually expanded from south to north in spatial dimension, and the coordination relationship gradually improved from south to north in the time dimension. Given this, the report of the 19th CPC National Congress points out that it is necessary to continuously strengthen the construction of ecological civilization and actively promote the harmonious coexistence between man and nature. Therefore, it is the key link to realize the sustainable development of both sides to check the integration trend and balance the development relationship between the ecological environment and high-quality economic development.

In terms of the evaluation index system of the coupled and coordinated development of ecology and economy, Li Yong analyzed the relationship between the economic development level of Guangdong Province, Xiangtan Province, and Shaanxi province, representing the eastern, central and western regions of China respectively, and the ecological environment status during 1999-2003. The evaluation system of the comprehensive index (coordination degree between ecological environment and economic development) and five single indexes (water consumption intensity, energy intensity, transportation, environmental protection investment intensity, sulfur dioxide, and carbon dioxide emission intensity) was established [3]. Cao Yuanping analyzed the construction

principles of the regional environmental economic index system and completed the construction of the regional environmental economic index system from four aspects: scale, structure, efficiency, and development [4]. Huang Xiaoyong and Yin Jidong [5] constructed the comprehensive evaluation index system of the ecosystem, economic system, and social system, conducted empirical analysis and comprehensive evaluation of the economic development level of Jiangxi Province, and evaluated the coordinated development of the ecological economy in a single region. Yan Shanshan and Zhuang Yun [6] constructed the economic and social-ecological evaluation index system of 9 prefecture-level cities in Fujian Province and used the entropy weight method and coupled coordination evaluation model to analyze the coupled and coordinated development of ecology, economy, and society from the space-time dimension. Qin Xiangdong, hong-mei duan [7] the combination of qualitative and quantitative methods, from the level of ecological function, social and economic development, and resource environmental bearing capacity index system of three levels of profit-making economic regionalization is studied, to profit-making economic zone as the research object, is divided into prohibited development zones, restricted development zones, restricted development zone, and key development zone 4 ecological economic zone, According to the characteristics of ecological economic zones, the development direction of industrial structure in different ecological economic zones is put forward. Chen Ruiqing and He Ling et al. [8], referring to the domestic and foreign index systems of sustainable development, comprehensive development, coordinated development, and ecological civilization construction, initially selected the comprehensive analysis index system of urban ecology, society, and economy, and constructed the basic index system of urban comprehensive analysis based on the principle of index design.

In terms of the study of the coupled and coordinated development model of ecology and economy, Li Shantong and Liu Yong [9] put forward the economic analysis of ecological and economic development through the study of the coordinated development model of environment and economy. Wu Yueming et al. [10] established an evaluation model of the degree of coordinated development by applying the principle of synergetics. Ma Huimin, Ding Yang, and Yang Qing [11] established a mathematical model to measure the coordination among ecological, social, and economic subsystems in the development process of a region, to evaluate the sustainability of the entire regional development. Liu Yaobin et al. [12] proposed the coupling degree model of ecological environment and economic development by measuring the coupling degree of the ecosystem and economic system in different periods. Wang Weiguo [13] used the fuzzy mathematics method to calculate the degree of coordinated development and studied the coordinated development of the regional economy, society, and ecological environment. Fan Na, Fu Bin, and Wang Zhiping [14] constructed an evaluation index system for the coupled and coordinated development of the economy, ecology, and

society in Gansu Province from the perspective of targeted poverty alleviation based on the statistical data of economic development, ecological construction and social development in Gansu Province from 2000 to 2015. The coefficient of variation of economy, ecology, and society, and the coupling coordination degree model were used to calculate and analyze the coupling degree, coupling coordination degree, and its comprehensive evaluation index. Based on measuring the coupling degree and coordination degree between economy, society, and ecology, Feng Yali [15] innovatively used a kernel density curve to describe and analyze it. Liu Yuan and Zhou Yong et al. [16] analyzed the Spatio-temporal variation characteristics of the ecosystem and economic development in the Yangtze River Economic Belt with the grey prediction model. Su Jinbao [17] used a multi-level grey method to study the coupling development potential of the ecological economy and local social development in the Greater Khingan Mountains. Zhou Zhengzhou [18] studied the coordinated development degree of the economy and society in the Yangtze River Economic Belt under the framework of the pressure-state-response model and coupling-coordination degree model. Rao Qinghua, Lin Xiuzhu, Li Jiabing, et al. [19] established a three-system coupling coordination evaluation index system based on eco-economic and social coupling, used the entropy weight method to determine the weight, and evaluated the coordination degree of different regions in Minjiang River Basin in recent 10 years. Based on the panel data analysis of 11 prefecture-level cities in Jiangxi Province from 2009 to 2013, Sun Buzhong and Fan Heng et al. [20] constructed a comprehensive index evaluation system from the aspects of ecology, economy, society, and resources, and used the grey system entropy weight method to evaluate the dynamic development and change process of comprehensive ecological and economic indicators in Jiangxi Province. Mu Xianzhong et al. [21] studied Changsha City from the perspective of the coupling of ecology, economy, and society, and used the dissipative structure model to study the ecological and economic transformation of Changsha city. Tong Peishan and Shi Shengxu [22] built the evaluation index system of ecological environment and economic development based on the PSR model and GCQ model respectively and used the entropy weight method and coupling coordination degree to measure the coupling coordination relationship between ecological environment and economic development of Xiamen Zhangquan urban agglomeration from 2010 to 2015.

Through the review of the above relevant literature, domestic scholars have achieved rich research results in the aspects of ecological economic and social systems, constructed a large number of models and indicators for the coordinated development of ecological and economic systems, and provided rich theoretical support and practical guidance. Many research results show that there is a certain correlation between the ecosystem, economic system, and social system. However, foreign scholars on the relationship between the ecological economic and social system have carried on the deepening and reflection, added a variety of variables, integrates the research methods of economics, expanded the research scope, and all kinds of research methods and research perspectives gradually mature and rich, the corresponding research contents and focus on analyzing the elements of the economy, the ecological degree of coupling. However, specific studies on the coupling and coordination between ecological environment and high-quality economic development are still lacking, and no evaluation index system with internal logic has been formed. Some evaluation indicators may be repeated, while some necessary indicators may be missing, which will affect the accuracy of the final results. The interaction mechanism between eco-economic systems has not been studied in depth, so the conclusion obtained is relatively general. In addition, economic development and ecological environment cover a wide range. Economic development involves natural resources, industrial scale, entrepreneurship and employment, and residents' income, while the ecological environment involves three dimensions: ecological resources, ecological governance, and ecological pollution. It can be said that the coupling and coordination of economic development and ecological environment is a necessary prerequisite to ensure the efficient development of the regional economy. Taking Hunan Province as the research object, this study studies the coupling and coordinated development relationship between the two, and puts forward corresponding optimization suggestions, aiming at solving the core contradiction between ecological environment and economic development, and supplementing the deficiencies in the symbiotic development of ecology and economy.

2. Materials and Methods

2.1. Index System

Constructing the corresponding evaluation index system is a necessary basis for studying the coordinated development of the coupling degree of ecological environment and high-quality economic development. Therefore, based on relevant research achievements of Tang Peixian et al. [23] and following the principles of systematism, scientificity, availability, regularity, comprehensiveness, timing, and objectivity, an evaluation index system of a total of 20 indicators for the high-quality development of ecological environment and economy in Hunan Province was constructed. Among them, the indicators of the economic system mainly start from the subsystems of economic resources, economic scale, economic employment, and economic income, and are selected based on supply and demand. The indicators of the ecological environment system are mainly selected from the subsystems of ecological resources, ecological governance, and ecological pollution, and are guided by environmental governance. In terms of indicator nature, "+" is a positive indicator, and "-" is a negative indicator. The larger the value of the former, the better, while the smaller the value of the latter, the better. The final selected indicators are shown in Table 1.

Table 1. *Table of indicator systems.*

Elements layer	Index layer	unit	Index properties
	Per capita GDP (A_1)	yuan	+
High Quality	Density of economic development (A_2)	Ten thousand yuan/square kilometer	+
Economic	Value added density of Primary industry (A_3)	Ten thousand yuan/square kilometer	+
Development Index	Value Added Density of Secondary Industry (A_4)	Ten thousand yuan/square kilometer	+
(A)	Value Added Density of the Tertiary Industry (A_5)	Ten thousand yuan/square kilometer	+
	Growth rate of fixed investment (A_6)	%	+
	Forest coverage rate (V_1)	%	+
Ecological	Green space per capita (V_2)	Square meters	+
Environment Index	Wastewater discharge per unit of GDP (V_3)	Tons/ten thousand yuan	-
(V)	Sulphide emissions per unit of industry (V_4)	Tons/ten thousand yuan	-
	Energy consumption per unit GDP (V_5)	Ton standard coal/ten thousand yuan	-
	Urbanization rate (V_6)	%	+

2.2. Research Methods

Coupling refers to a kind of continuous cooperation phenomenon produced by the interaction and response between different systems or different elements of the same system. The coupling degree is used to express the degree of mutual influence and interaction between various elements of the target system. The strength of this state is expressed with the coupling degree, coupling degree is high, then this kind of action is strong, the coupling degree is low, then this kind of action is weak. The interaction between different systems needs to be coordinated to achieve good and harmonious development between systems. The degree of system harmonization is measured by the degree of coordination. A high degree of coordination can promote coordination between different systems, and the degree of coordination can make the discussion of the coupling degree between multiple systems more perfect. Coupling coordination refers to the interaction between coupling and coordination, and its strength is expressed by coupling coordination degree, which is expressed as the state of harmonious, unified, and orderly change of interaction and influence between systems. The coupling coordination degree can be calculated at the same time as the coupling degree, to understand the degree of coupling state between different systems and judge whether the systems coexist harmoniously. In terms of this study, according to the current situation of Hunan Province, the harmony degree between the ecological and economic systems of Hunan Province can be inferred from the "coupling coordination degree", and the coupling coordination degree between the two systems can be optimized to make the two systems more properly coordinated and develop benignly.

2.2.1. Standardized Processing of Data

To make each index comparable, this paper uses the data normalization processing method to make each sub-index data. This method can change the dimensionless value into a dimensionless value. Because of its simple processing method, it can be used to solve complex problems and is widely used in various disciplines. The value ranges from 0 to 1 and is indicative only. A larger value indicates better content. The value has no actual meaning. The index normalization formula can be divided into two parts. The positive normalization formula is selected for the type with a higher value and better value, and the negative normalization formula is selected for the type with a smaller value and better value. Since all the sub-indexes selected in this paper are of the better type with higher values, the forward normalization formula is selected [24].

Forward normalization formula:

$$N_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \tag{1}$$

Negative normalization formula:

$$N_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \tag{2}$$

Where: x is the value of each indicator variable, N_{ij} is the normalized value of the indicator, i is the city and state, and j is the indicator class.

2.2.2. Index Calculation Method

Ecological environment and high-quality economic development are the comprehensive reflections of the above-selected sub-indicators. Therefore, the arithmetic average of each sub-indicator is used to obtain the ecological environment index and high-quality economic development and revitalization index. The calculation formula is as follows.

Formula of ecological environment index:

$$A_i = \sum_{j=1}^{6} N_{ij}/6 \tag{3}$$

The formula of high-quality economic development index:

$$V_i = \sum_{j=1}^{6} N_{ij}/6 \tag{4}$$

Where A represents the ecological environment index, V represents the high-quality economic development index, i represents the city and state, and j represents the indicator category.

After calculation, the ecological environment index and the high-quality economic development index are still normalized indexes, which are within the range of [0,1], just like the normalized sub-indexes, and have only indicative significance without specific meaning. The higher the value is, the higher the degree of ecological environment protection or high-quality economic development.

2.3. Design of Coupling Coordination Degree Model

The coupling coordination model can analyze the relationship between the two systems more comprehensively. This model adds the coordination analysis based on the coupling degree calculation, that is, it becomes the coupling coordination model. The degree of coordination is an index to measure whether the development of several systems is consistent. If the degree of coordination is high, it indicates that the relationship between each group of the system is harmonious and properly coordinated, which can promote the overall development of the system, and vice versa. Development degree reflects the comprehensive development of two or more systems, the relationship between ecological environment and high-quality economic development, and both development and coordination. It is the essential requirement of development that ecological environment and high-quality economic development cooperate and promote each other, so this study adopts the development degree model to participate in the calculation. The degree of coupling is obtained according to the degree of coordination and development, indicating the degree of interaction between several systems and the degree of closeness. The greater the coupling degree, the stronger the mutual influence between the systems and the greater the interdependence [25]. These three values are correlated with each other, but different from each other. They complement each other and can more comprehensively explain the relationship between high-quality economic development and rural cultural revitalization.

2.3.1. Coordination Degree

The calculation formula of coordination degree is as follows.

$$C = \left[\frac{A \times V}{(0.5A + 0.5V)^2}\right]^2 \tag{5}$$

2.3.2. Development Degree

The development degree calculation formula is as follows.

$$T = 0.5(A + V) \tag{6}$$

2.3.3. Coupling Coordination Degree

The coupling coordination degree is used to reflect the coupling and coordination development level of the ecological environment and high-quality economic development. Based on the relevant research of Wang Chongling et al., a coupling co-scheduling model is built [26]. The coupling degree calculation formula is as follows.

$$D = \sqrt{C \times T} \tag{7}$$

In Equation (7), D represents the coupling coordination level of ecological environment and high-quality economic development, C represents the coordination degree of ecological environment and high-quality economic development, and T refers to the development degree of ecological environment and high-quality economic development.

2.3.4. Classification and Phase Characteristics of Coupling Degree

In addition, to more accurately classify the coupling coordination degree of ecological environment and high-quality economic development in Hunan Province, the classification setting method of Fu Lian et al. [27] was further consulted, and the classification grade standard as shown in Table 2 was set.

Table 2. *Classification and stage characteristics of coupling degree between ecological environment and high-quality economic development in Hunan Province.*

Classification stage	C	Characteristics of
the Disordered coupling stage	0	The system is in an unordered development state and has no impact on each other
Low coupling stage	0~0.3	The damage degree of ecological environment is low, and it basically carries economic development
Antagonism phase	0.3~0.5	The damage degree of ecological environment becomes stronger, and the capacity of carrying economic development becomes weaker
Running-in stage	0.5~0.8	Economic development gradually restores the ecological environment and the system enters a benign coupling period
High coupling stage	0.8~1	The system is in the state of orderly development and closely related to each other

Table 3. *Hunan Province ecological environment and high-quality economic development coupling coordination degree classification level standards.*

Grade standard D	High quality coordination	Good coordination	Intermediate coordinate	Primary coordination	Critical coordination
	0.9~1.0	0.8~0.9	0.7~0.8	0.6~0.7	0.5~0.6
Grade standard D	On the verge of maladjustment	Mild maladjustment	Moderate maladjustment	Severe maladjustment	Extreme maladjustment
	0.4~0.5	0.3~0.4	0.2~0.3	0.1~0.2	0~0.1

3. Classification and Stage Characteristics of Coupling Coordination Degree

3.1. Data Sources

The index data of the economic system and ecological environment system selected in this study mainly come from the Statistical Yearbook of Hunan Province and the statistical yearbook of various cities and states. At the same time, the interpolation method is used to fill the missing data of some cities and states with the data of similar cities and states. To select the research period more rationally and scientifically, the literature on the economy and ecological environment in the recent 10 years was sorted out, and the research period was selected as 2019-2020.

3.2. Normalization of Original Data

Table 4. *Standardized numerical table of eco-economic evaluation indicators in Hunan Province from 2009 to 2020.*

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
A_1	0.00001	0.05477	0.52714	0.63284	0.70000	0.78469	0.87351	0.93672	0.99543	1.00000	0.93059	0.96425
A_2	0.00001	0.12648	0.28536	0.39257	0.49249	0.60088	0.68595	0.77948	0.92189	1.00000	0.67330	0.70335
A_3	0.00001	0.21494	0.44410	0.60136	0.65658	0.68541	0.79167	0.93513	1.00000	0.64751	0.62971	0.66243
A_4	0.00001	0.18599	0.41528	0.55000	0.66526	0.77522	0.82920	0.85492	0.96489	1.00000	0.55047	0.57634
A_5	0.00001	0.07129	0.16885	0.24723	0.33845	0.45107	0.54970	0.67646	0.84323	1.00000	0.62528	0.65685
A_6	0.00001	0.07940	0.13957	0.25708	0.39923	0.53259	0.68217	0.74697	0.88295	1.00000	0.61264	0.64028
V_1	0.00001	0.25858	0.29024	0.34565	0.39314	0.93404	0.93404	0.95251	0.96306	1.00000	0.52131	0.55315
V_2	0.00001	0.00001	0.00001	0.33333	0.33333	1.00000	1.00000	0.66667	0.33333	0.33333	1.00000	0.66667
V_3	0.01222	0.02429	0.00001	0.00098	0.07453	0.22769	0.30981	0.73991	0.95226	1.00000	0.57719	0.60865
V_4	0.00001	0.04281	0.02572	0.10907	0.11811	0.17491	0.25968	0.70768	0.97127	1.00000	0.60110	0.63198
V_5	0.00001	0.05477	0.52714	0.63284	0.70000	0.78469	0.87351	0.93672	0.99543	1.00000	0.54997	0.58029
V_6	0.97600	0.97600	0.97500	0.97400	0.97300	0.97200	0.97000	0.97000	0.97000	0.96900	0.97972	0.97925

3.3. Analysis on Coordinated Evolution Types of Coupling Degree Between High-Quality Development of Ecological Environment and Economy in Hunan Province

According to the synchronization difference between the development level of eco-environment and high-quality economic development in Hunan Province, and referring to the research of existing scholars, the coupling coordination evolution types are divided into the following three types: the economic development index is higher than the eco-environment development index, and the amplitude is more than 10%, which is the eco-environment lag type; The deviation between the economic development index and the ecological environment development index is within 10%, which is synchronous. The eco-environment development index is higher than the economic development index, and the excess is more than 10%, which is the economic lag type. According to the evaluation index system constructed above, the high-quality development and development indexes of the ecological environment and economy of each city and state are calculated, and the coupling and coordinated evolution types are obtained, as shown in Table 5.

Table 5. *Coordinated evolution of the coupling and coordinated evolution of ecological environment and high-quality economic development in Hunan Province from 2009 to 2020.*

	2010		2012		2014		2016		2018		2020	
	C	D	C	D	C	D	C	D	C	D	C	D
index	0.398	0.415	0.438	0.467	0.511	0.567	0.283	0.305	0.327	0.341	0.311	0.335

* D represents the coupling coordination level of ecological environment and high-quality economic development, C represents the coordination degree of ecological environment and high-quality economic developmen.

As can be seen from Table 5, the coupling degree index between the ecological environment and high-quality economic development in various places from 2009 to 2021 is basically between 0.3 and 0.6, and the overall transition from the low coupling degree stage to the run-in stage. From the perspective of coupling degree types, from 2009 to 2021, the coupling degree types of cities and states are mainly concentrated in the antagonistic stage, that is, the interaction between the ecological environment and high-quality economic development is limited, and their respective development is relatively independent. This result indicates that the development of high-quality industries in the Hunan economy is in extensive mode, and the cross-influence between the economy and the ecological environment is weak. The reason may be that in the development process of the two, the government's overall planning of the economy, environment, and service is weak, resulting in a low contribution rate of integration between economic development and the ecological environment. From the point of view of the development trend, this phenomenon has gradually improved. Especially after 2017, Hunan Province entered the run-in stage from the antagonistic stage. It can be predicted that with the gradual progress of ecological civilization construction, the relationship between the ecological environment and high-quality economic development will be closed in the future.

Table 6. *Coupling degree and coupling coordination index of ecological environment and high-quality economic development in Hunan Province from 2009 to 2020.*

Year	2009	2010	2011	2012	2013	2014
Type	Economic lag type	Economic lag type	Economic lag type	Basic synchronous type	Basic synchronous type	Basic synchronous type

Year	2015	2016	2017	2018	2019	2020
Type	Basic synchronous type	Basic synchronous type	Basic synchronous type	Ecological environment lag type	Ecological environment lag type	Ecological environment lag type

4. Analysis on the Regional Characteristics of the Coupling Coordination Degree

4.1. Data Sources

The index data of the economic system and ecological environment system selected in this study are mainly from the Statistical Yearbook of Hunan Province 2021 and the statistical yearbook of various cities and cities. The selected research areas are divided into Central Hunan, including Changsha, Zhuzhou, Xiangtan, and Loudi; Xiangxi region, including Huaihua, Shaoyang, Zhangjiajie, Xiangxi; Southern Hunan region, including Hengyang, Chenzhou, Yongzhou; In northern Hunan, including Yueyang, Changde and Yiyang, the data of 14 cities and states in the province were selected for the study.

4.2. Normalized Analysis of Sub-indexes

The specific data of each index are processed by normalization formula, and Table 7 is obtained. Then, according to the calculation method of the comprehensive level index of each sub-index, the sub-index of each city is calculated, and the coupling degree is finally obtained (Table 8).

Table 7. *Standardized numerical table of eco-economic evaluation indicators of 14 cities and prefectures in Hunan Province in 2020.*

Prefecture level cities	A_1	A_2	A_3	A_4	A_5	A_6	V_1	V_2	V_3	V_4	V_5	V_6
Changsha	1.0000	1.0000	1.0000	1.0000	1.0000	0.0541	0.0541	0.5574	0.4856	0.8818	0.0000	1.0000
Zhuzhou	0.5363	0.2337	0.4729	0.2658	0.0788	1.0000	1.0000	1.0000	0.4099	1.0000	0.1473	0.6338
Xiangtan	0.6033	0.4299	0.8708	0.4773	0.1249	0.5946	0.5946	0.6221	0.5489	0.8895	0.4793	0.5049
Hengyang	0.2493	0.1869	0.6816	0.1615	0.1499	0.9189	0.9189	0.8382	0.1687	0.7537	0.1462	0.2257
Shaoyang	0.0531	0.0654	0.2882	0.1825	0.0000	0.7027	0.7027	0.8632	0.6238	0.6693	0.1204	0.0324
Yueyang	0.5285	0.2337	0.9863	0.2442	0.2825	0.7568	0.7568	0.6221	0.2925	0.5568	0.3640	0.3600
Chang de	0.4397	0.1589	0.6265	0.1625	0.0596	0.9730	0.9730	0.9309	0.1468	0.5269	0.1474	0.2106
Zhangjiajie	0.0812	0.0094	0.0577	0.0093	0.0545	0.0000	0.0000	0.0000	1.0000	0.1575	0.0037	0.0858
Yiyang	0.1987	0.1028	0.4992	0.0810	0.0936	0.8378	0.8378	0.3029	0.0000	0.3934	0.2485	0.1628
Chenzhou	0.2602	0.0841	0.3128	0.0729	0.1342	0.6757	0.6757	0.8324	0.1164	0.2512	0.2518	0.2606
Yongzhou	0.1146	0.0467	0.2026	0.0705	0.1259	0.6757	0.6757	0.5515	0.6480	0.3323	0.0889	0.0990
Huaihua	0.0775	0.0187	0.0500	0.0277	0.1096	0.8649	0.8649	0.1074	0.9577	0.2079	0.0939	0.0402
Loudi	0.1576	0.1682	0.4659	0.0715	0.1075	0.7027	0.7027	0.2721	0.7160	0.2657	1.0000	0.0472
Xiangxi	0.0000	0.0000	0.0000	0.0000	0.1174	0.0270	0.0270	0.4177	0.6260	0.0000	0.0650	0.0000

4.3. Calculation Results of Coupling Coordination Degree

Table 8. *Synthesis index and coupling coordination degree table.*

Prefecture level cities	Comprehensive indicators of high-quality economic development	Comprehensive index of ecological environment	Coordination degree	Development degree	Coupling degree
Changsha	0.5394	0.6955	0.6028	0.6175	0.6101
Zhuzhou	0.4752	0.3888	0.4256	0.4320	0.4288
Xiangtan	0.6665	0.4462	0.5243	0.5563	0.5401
Hengyang	0.4560	0.2816	0.3388	0.3688	0.3535
Shaoyang	0.1996	0.1172	0.1429	0.1584	0.1504
Yueyang	0.5439	0.2216	0.2903	0.3827	0.3333
Chang de	0.6295	0.1515	0.2084	0.3905	0.2853
Zhangjiajie	0.0595	0.1368	0.0771	0.0981	0.0870
Yiyang	0.4202	0.2263	0.2818	0.3233	0.3018
Chenzhou	0.2478	0.2131	0.2285	0.2305	0.2295
Yongzhou	0.8826	0.6327	0.7272	0.7577	0.7423
Huaihua	0.1347	0.2534	0.1682	0.1941	0.1807
Loudi	0.1008	0.2496	0.1322	0.1752	0.1522
Xiangxi	0.3504	0.0911	0.1247	0.2207	0.1659

The coordination degree of high-quality economic development and ecological environment in Hunan Province is relatively high as a whole. Except for Zhangjiajie, which is 0.0771, the other cities (prefectures) are all above 0.12, among which Yongzhou, Changsha, and Xiangtan are above 0.5, accounting for 20% of the province's cities (prefectures). These data indicate that the development of these two systems is relatively coordinated.

From the data on the development degree of each city (state), it can be found that the development potential of these cities (states) is basically at a medium level. The eastern region is a high-value area, while the western region is a low-value area. Among them, in Changsha and Xiangtan city development degree is relatively high, the three cities (states) both in terms of ecological environment facilities, or in economic development in the high-quality comprehensive index is higher, so the city (state) is better, the basis of the ecological environment of the service facilities agriculture modernization foundation was also at a higher level, There is a lot of room for growth. However, the development potential of Zhangjiajie, Shaoyang, Loudi, and Zhangjiajie is not very good, with development degrees below 0.20. It is quite

difficult for them to cooperate, especially since the development degree of Zhangjiajie is less than 0.10. This is mainly because the location of these four cities (states) is not very good, and the land and climate conditions are relatively poor for agricultural production.

From the level of coupling degree, the coupling degree of each city (state) in Hunan is basically in the middle, among which Yongzhou City's coupling degree is 0.7423, ranked in the first place, ranked in the last place Zhangjiajie city, only 0.0870. Taken as a whole, it doesn't make a big difference. From the distribution of the situation, some of the better economic development of the city (state), including Xiangtan city, Hengyang city, etc., this city (state) coupling degree is relatively high. And some cities (states) in the western region, including Huaihua City and Zhangjiajie city, etc., the coupling degree of these cities (states) is at a relatively low level. By analyzing the coupling degree of each city (prefecture) in Hunan, it can be found that the higher the coupling degree, the greater the mutual influence between the two systems. As the driving force of economic development, the ecological environment industry plays an obvious role in promoting high-quality economic development. As an important means and symbol of agricultural economic growth, high-quality economic development creates demand for the development of the ecological environment industry. From the perspective of spatial distribution, the spatial distribution of coupling degree also has a strong spatial correlation. Except for Yongzhou, the distribution of other cities (states are in line with the law of high-value aggregation in the north and low-value aggregation in the southwest, which is consistent with the spatial distribution law of development degree, coordination degree, and ecological environment index.

To sum up, every city in Hunan province (state) in the coupling conditions are relatively good, but in the aspects of ecological environment and economic development coordination degree high quality but performance is lacking, it also represents the ecological environment and economic development in high quality, no more sound coupling mechanism has been set up in Hunan, so, in the future development of the process, We must accelerate the improvement of the coupling development mechanism of ecological environment and high-quality economic development, to realize the mutual promotion and mutual promotion of high-quality economic development and rural ecological environment.

This paper mainly uses the coordinated coupling model, takes 14 cities and prefectures in Hunan Province as the research object, and conducts a quantitative analysis of the relationship between high-quality economic development and the ecological environment. The five indicators selected are all indicators closely related to the high-quality economic development and ecological environment of Hunan Province in 2020. These indicators are used to calculate the comprehensive index of ecological environment and high-quality economic development, and then the coordination degree and coupling degree of these two aspects are calculated respectively. The following are the results of the quantitative analysis of these two indicators:

(1) The coordination degree of eco-environment and high-quality economic development indexes of all cities in Hunan Province is maintained at a relatively high level, with all values exceeding 0.06, among which Changsha, Changde, Zhangjiajie, and Yongzhou are above 0.5, accounting for 28.67% of the whole province. This data indicates that the coordination degree is still very high. This means that there is a very close relationship between the two systems. The rural ecological environment plays a key role in the process of high-quality economic development and development, and high-quality economic development can also provide economic support for the development of the ecological environment.

(2) The comprehensive index of high-quality economic development in Hunan Province is generally low, which is reflected in the imbalance in all aspects of high-quality economic development. There is no city (prefecture) that is outstanding in all aspects. Among them, Shaoyang city, Huaihua city, and Zhangjiajie's economic development level is low, with high-quality development of 0.2 the following, this three city economic development level is low quality, in addition to the natural conditions, overall economic activity the basic reason, mainly because the public service facilities, the infrastructure construction level is low.

(3) From the perspective of development degree, low-value cluster areas are formed in the west, and high-value cluster areas are formed in the east. Yongzhou, Changsha, and Xiangtan cities with high development degrees are equipped with relatively good economic and high-quality development foundation and ecological environment facility service foundation, which have great advantages for future development. Among them, Shaoyang City and Loudi City have relatively small advantages. In terms of ecological environment protection and high-quality economic development, these two cities have a low level, and it is difficult to develop in the future.

(4) The comprehensive index of high-quality economic development, ecological environment index, development degree, coordination degree, and coupling degree can show a trend of high concentration in the south and low concentration in the north in terms of spatial distribution. At the same time, among the cities, Yongzhou City with the highest comprehensive index of high-quality economic development is 0.8826, but the comprehensive index of ecological environment in Yongzhou city is 0.6327, the overall gap is not big, indicating that the development degree, coupling degree and coordination degree of the two systems are maintained at a relatively high level, and the space for development is relatively large. In particular, Changsha, Xiangtan, Zhuzhou and Hengyang, and other cities (states) have all kinds of indexes that are at a high level, but also have a lot of space for development.

High-quality economic development plays a very important role in the rural revitalization of Hunan. As the economy of Hunan is in a state of rapid development, Hunan's economy is gradually moving from tradition to modernization. High-quality economic development is closely related to a sound ecological environment. Hunan province as the research object, analyzing the city of the province's 14 (state) with high quality and economic development and ecological environment the coupling coordination between the two systems, the analysis results show that in high quality and economic development of Hunan province this aspect also has the very big development space, especially in the west, southern areas of less developed areas, need to invest more resources in the ecological environment, Promote the development of ecological economics, but also pay attention to the coordination of regional development.

5. Discussion

5.1. Coupling Mechanism of Ecological Environment and High-Quality Economic Development

The coupling of ecological environment and high-quality economic development requires the joint efforts of social, economic, environmental, and other factors. Among them, the ecological environment is a prerequisite for the sound and sustainable development of the economy. Economic development can effectively bring into play the economic benefits of ecological resources, and its rational development can provide sustainable power for ecological environmental protection. Therefore, the coupling effect between ecological environment and high-quality economic development will directly determine their development. Combined with the above analysis and viewed from the system theory principle, elements, functions and structures are the key mainlines supporting the coupling of ecological environment and high-quality economic development.

(1) Factor coupling. The orderly flow of all elements of the ecological environment and high-quality economic development is the basis of their coupling. In the process of high-quality development of the ecological environment and economy, the economy takes advantage of economic benefits to provide more solid technical and financial support for ecological environmental protection; with the advantage of resource endowment, the ecological environment provides the necessary development space for a sustainable economy. The combination of the two promotes the high-quality development of the ecological environment and economy and the full utilization and orderly flow of all resource advantages. At present, the coupling and coordinated development of the ecological environment and high-quality economic development in Hunan presents the spatial and temporal evolution characteristics of "high in the east and low in the west, and middle in the middle", which is largely caused by the failure of scientific and

reasonable allocation of factors on both sides. Therefore, the advantages of economic effect and ecological environment resource endowment should be brought into play to optimize the overall internal factor structure of the system.

(2) Functional coupling. The differentiated development strategy makes Hunan's social and economic development present a diversified trend and has different functions in different regions and at different times. As an experiential economic system, the economy's functions are in continuous change and development, such as management, service, coordination, and innovation. As a bearing economic system, the function of the ecological environment is to continuously help economic functions to achieve efficient output and multi-level utilization, and resource benefits can be systematically developed and continuously utilized. In recent years, with the rapid development of a high-quality economy, the economy has also shown a more dynamic and diverse character. At this time, high economic quality promotes the equivalence of the economy and the ecological environment through the circulation of the economic high-quality chain, aiming to achieve the "win-win" of economic and ecological benefits.

(3) Structural coupling. High-quality development of the ecological environment and economy reflects the relationship between economy and ecology to a certain extent. All along, the strategy of giving priority to economic development in Hunan Province has not placed the ecological environment in an equal position with the economy, so various ecological problems are highlighted. In terms of the continuous coupling of ecological environment and high-quality economic development, it is an inherent requirement for the long-term sustainable development of economy and ecology to constantly coordinate the relationship between man and nature. Therefore, since the 19th National Congress of the CPC put forward the concept of "harmonious coexistence between man and nature", economic development has been based more on the carrying range of the ecological environment and paid attention to the positive interaction between the two. In this context, the ecological environment and high-quality economic development have jointly reformed the traditional impression of development, and effectively promoted the steady development and orderly coordination of the "economy-ecological environment".

5.2. Coordination Mechanism Between Ecological Environment and High-Quality Economic Development

The key to high-quality development coordination between the ecological environment and economy is to rely on a good ecology, stimulate the vitality of the ecological economy, and realize harmony between man and nature. Driven by this

coordination concept, it is not only necessary to consider the feasibility of development, such as material resources, manpower, financial resources, time, and other supporting factors, but also the transformation of industrial structure and regional space. Based on the large ecological development pattern of Hunan Province, the patio-temporal coordination mechanism of high-quality development of the ecological environment and economy is mainly reflected in the mutual support and promotion of the two.

The economy has a promotion effect on the ecological environment, which is the ecological environment protection exogenous power. Sustainable economic development can greatly increase the financial support for ecological environmental protection and maintain the balance between regional ecology and development. In this way, the income generated by economic development will inevitably be used in ecological governance and protection, such as restoration of ecological communities, special greening, environmental sanitation, and feeding back the ecological environment. At the same time, the process of economic feedback to the ecological environment will also stimulate the motivation of economic workers to participate in ecological environmental protection, and force relevant departments and enterprises to invest more energy to carry out comprehensive ecological environmental protection and remediation. For example, the coordination degree of the central Hunan region is better than that of other regions, the key lies in the stronger back feeding effect of its financial support. In this process, the balance between economic development and ecological environmental protection can be jointly promoted coordination, which improves endogenous development ability.

The ecological environment promotes economic development and construction, which is the source guarantee for sustainable economic development. Generally speaking, there is a positive correlation between regional natural endowment and resource acquisition for economic development. In other words, areas with rich resources and good ecological environment quality are naturally more attractive to economic workers, which can better promote economic development. Based on this aspect, the ecological environment becomes a kind of public good, which is distributed to all levels of economic functional departments or enterprises, implementation management, development, and use. In this case, a good ecological environment can promote economic large-scale and industrial management, create a unique economic IP, provide diversified economic experience for economic workers, and consolidate the base of the ecological economic system.

6. Conclusion

By analyzing the index data of high-quality development and development of ecological environment and economy in 30 cities and prefectures in China in 2009, 2013, 2017, and 2020, the coupling degree and coupling coordination degree of the two were calculated, and the development rules were analyzed from the two dimensions of horizontal spatial differentiation and vertical time evolution. The main conclusions are as follows:

(1) From the comprehensive situation of the ecological environment and high-quality economic development of 14 cities and prefectures in Hunan Province, the economic development speed of each city and prefecture is stronger than the ecological environment development speed from 2009 to 2020, as many as 7 cities and prefectures changed from the economic lag type to the ecological environment lag type.

(2) From the perspective of the spatial and temporal evolution of the coupling degree between ecological environment and high-quality economic development, most cities and states in 2009, 2013, 2017, and 2020 were at a low level of antagonism, and the interaction between the two systems needs to be further strengthened. In terms of development trends, the coupling degree between the ecological environment and high-quality economic development has increased in most cities and states. The spatial difference results show that the coupling degree of cities and states in central Hunan is relatively high. The top three cities and states in the level of coupling degree are Changsha, Zhuzhou, and Xiangtan, which are all experimental areas of Hunan's two-type society.

(3) From the perspective of the overall Spatio-temporal evolution of the coupling coordination degree between ecological environment and high-quality economic development, the coupling coordination degree of most cities and states in Hunan in 2009, 2013, 2017, and 2020 was between moderate and mild dysregulation, and the overall coupling coordination level was low. In terms of the development trend, the coupling coordination degree of most cities and states has been improved, and as many as 12 cities and states have achieved an upward jump in the coupling coordination degree. The results of spatial differences showed that the coupling coordination degree of eco-environment and high-quality economic development in central Hunan was higher on the whole, and the cities and states above the primary imbalance level were all from central Hunan. In contrast, the coupling coordination level of city and state in western Hunan is mostly in the moderate maladjustment stage, and there is a big gap with central Hunan.

(4) From the perspective of the formation mechanism of the coupling and coordinated Spatio-temporal evolution of the ecological environment and high-quality economic development, the two play a mutually supportive and promoting role. From the perspective of system theory, the three expression levels of elements, functions, and structures are the key mainlines supporting the coupling and coordination of the Spatio-temporal evolution of the ecological environment and high-quality economic development. With the help of this main line, the economy has become the exogenous power of ecological environmental protection. The ecological

environment is also the source of sustainable economic development.

7. Recommendations

(1) We will improve our capacity for economic, ecological, and environmental governance in various ways. The government should actively exert its macro-control effect on the economy, earnestly formulate relevant high-quality economic strategies, make a harmonious development plan between the ecological environment and high-quality economic development, and continuously improve the ecological compensation for economic development. Based on fully complying with relevant ecological economic development plans, enterprises can develop and implement more abundant ecological economic projects to more strictly comply with ecological protection and restoration measures. With the joint efforts of the government and enterprises, we will build a systematic positioning plan for the sustainable development of the economy and the ecological environment, and realize the sustainable development of the ecological economy while focusing on effective management and control.

(2) Fully grasp the concept of ecological economic innovation. In the new era, high-quality economic development requires that a high-quality economy become an important way of sustainable utilization of economic resources. Given this, for the coordinated development of a high-quality ecological environment and economic development in Hunan Province, it is necessary to fully combine the ecological environment and economic resources, and thoroughly implement the concept of green sustainable coordinated development. For example, for the vast rural areas with rich economic resources, relevant units can strongly support the rural economic construction, and effectively establish a new trend of ecological and sustainable economic civilization by implementing the corresponding "economic trunk" demonstration project. Thus, while giving play to economic advantages, it can also take into account the ecological environment, and ultimately achieve a win-win situation of economy and ecology.

(3) Develop and create economic high-quality projects. Based on the concept of ecological environment protection, the economy needs to constantly innovate relevant types of economic products and services, such as establishing ecological economic projects. Based on the existence of ecological barriers, promote the integration of the economy and the ecological environment from multiple angles and directions. Not only that, cities and prefectures can also make full use of the complementary advantages of resources, establish a high standard and high-level ecological economy demonstration areas, form the linkage effect of economic resources, and truly realize the equal development of ecological environment and high-quality economic development. In addition, for regions with rich distinctive economic resources, based on ensuring the survival of the ecological barrier, it is also necessary to develop and cultivate high-quality economic pilot projects while tapping the demand of the economic market to continuously enrich relevant economic projects.

8. Limitations

Limited by the research conditions and capacity, there are still some deficiencies in this study. The objective evaluation of the ecological environment and high-quality economic development needs comprehensive consideration from multiple dimensions, and more indicators should be included to improve the reliability of the research results. In subsequent studies, we can try to analyze the level of high-quality development of the ecological environment and economy from more dimensions, to improve the extensiveness and effectiveness of the index system.

Data Availability Statement

http://tjj.hunan.gov.cn/tjsj/tjnj/(accessed on 17 May 2022).

Conflicts of Interest

The authors declare no conflict of interest.

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