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Spatial and Temporal Dynamics of Coupled Coordination in Rural Economic, Social, and Environmental Development: A Case Study of Chinese Provinces within the Rural Revitalization Context

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Abstract: The interplay between the economy, society and environment has evolved throughout human history, following to specific laws. The theory and mechanism of coupled coordination theory mechanism bear crucial guiding significance for advancing synchronized rural development. After the release of the rural revitalization policy, there has been a trend of rapid development in rural areas. This article takes rural areas across the country as the overall research object and integrates the coupling coordination theory into the interaction between China's rural economy, society, and environment. This research applies the coupled coordination theory and model to the rural economic, social and environmental system. It establishes an index system tailored for contemporary Chinese rural areas and uses the entropy value method and coupled coordination model to gauge the degree of coupled coordination in each province of China from 2012 to 2024. The results of the survey show that the rural areas in eastern China are more developed than the rural areas in central China, which in turn outperforms the rural areas in western and northeastern China. In conclusion, the coordinated development of rural areas in China varies from place to place, highlighting the differences in development.

Keywords: Coupled coordination, entropy value, rural revitalization, rural economy-society-environment.

1. Introduction

The revitalization of the nation hinges on the rejuvenation of its rural landscapes." The 20th National Congress of the Communist Party of China proposed a comprehensive initiative for rural revitalization. Throughout the 13th Five-Year Plan period, China placed significant emphasis on rural concerns and achieved noteworthy advancements in diverse facets of rural development. In the 14th Five-Year Plan period, China aims to comprehensively promote rural revitalization and expedite the progress of rural areas, ultimately enhancing the well-being and contentment of farmers. Economic development, social security, and environmental protection are integral elements of green and sustainable development, their interdependent and balance being paramount. Only through collaborative development within the context of rural revitalization can modern rural areas fulfill the expectations of the Chinese populace.

Numerous contemporary experts and scholars have delved into the coupling coordination model. As early as 1995, a group of American scholars proposed the renowned Environmental Kuznets Curve (EKC curve), demonstrating that, under optimal conditions, there exists an "inverted U-shaped" relationship between the level of economic development and environmental quality [1]. In recent years, Chinese experts and scholars have increasingly utilized the coupled coordination model, predominantly exploring the correlation between economic development and environmental protection. Additionally, they have extended this model to encompass coupled coordination relationships involving water resources, tourism, and other research domains, often within the context of urban or urban-rural integration.

Based on the coupled coordination theory and model, scholars such as Sun [2], Zhang [3], Gao [4] and Ma [5] have focused on the Yellow River Basin as their research object, investigating the coupling coordination degree between the economy and environment or other systems in the region. Kuang [6] conducted an inquiry into the time and space evolution pattern and driving factors of coupling coordination degree between 2005 and 2020. Wang [7] scrutinized and evaluated the coupling and coordinated development status of water resources, economy, society and ecological environment in the Beijing-Tianjin-Hebei region from 2006 to 2019, analyzing the primary influencing factors using grey correlation.

The previous literature provides valuable insights; however, there are notable deficiencies in terms of research depth and scope: 1) the research predominantly concentrates on regional, provincial, and city levels, with a limited focus on a national scale; 2) the research mostly adopts an urban or urban-rural interface perspective, overlooking the coordination dynamics within rural areas. Therefore, this paper integrates the coupling coordination theory into the interplay among China's rural economy, society, and environment. It begins with a comprehensive exploration of rural revitalization, establishing an exhaustive evaluation index system for China's rural economy, society, and environment. Utilizing the entropy value method and coupling coordination model, the paper assesses the coordination status within China's rural economy, society, and environment. The objective is to provide recommendations for China's rural modernization and comprehensive development.

2. Indicator System, Data Sources, Research Methods

2.1. Introduction to the Economy-Society-Environment (ESE) System

The development of the economy, society, and environment follows certain patterns. According to the coupling coordination development theory, over a long period and across a substantial spatial scale, the interaction among the economy, society, and environment will show dynamic changes in time and space. Guided by this principle, the theoretical understanding of the evolution laws governing China's rural economy, society, and environment becomes possible. This theoretical understanding contributes to improve the current state of rural areas, fostering comprehensive rural development, and further realizing rural revitalization.

The ESE system emerges from the integration of the economic, social, and environmental subsystems, forming a complex, diverse, and dynamic framework. The economic subsystem functions as a cornerstone for material well-being, encompassing all essential goods for daily life that satisfy both material and spiritual needs. The social subsystem involves the organization of people based on their developmental context, playing a key role in harmonizing the development of the three subsystems. The environmental subsystem is composed of the natural living environment, serving as the foundation of human life. However, the carrying capacity of the environment is finite, and exceeding this capacity can lead to system deterioration. The operational dynamics among the economy, society, and the environment are influenced not only by their internal interactions but also by various external factors, as shown in Fig. 1.

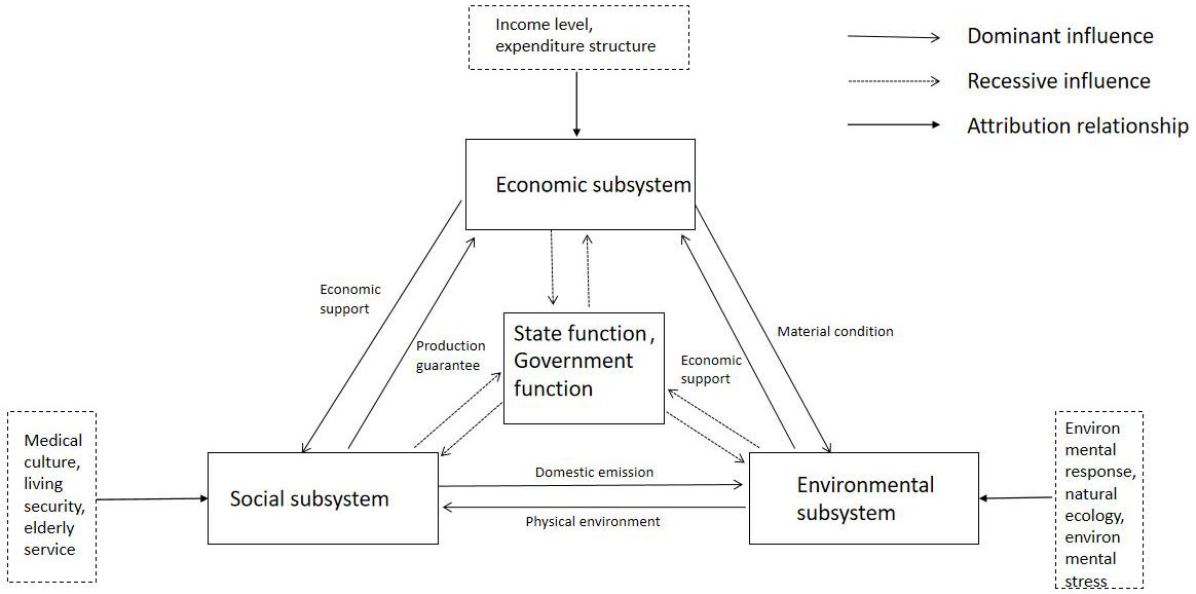


Figure 1. Interaction between ESE systems

2.2. Building an Indicator System

The foundation and key element for evaluating the coupling and coordination among the economic, social, and environmental subsystems in the ESE system lie in measuring the development levels of these subsystems. Yet, the complexities and uncertainties inherent in the ESE system's dynamics make it impractical to rely on a single indicator for a comprehensive assessment. Consequently, this paper adopts a multi-indicator evaluation system, integrating diverse indicators into a comprehensive index structured hierarchically. Adhering to principles such as scientific rigor, representativeness, and data availability, and drawing insights from a substantial body of literature and scholars' frameworks, 18 indicators across the main categories of economy, society, and environment were selected to delineate the coupling and coordination relationships among the three subsystems (Table I).

Economic indicators are categorized into income levels and consumption structures, with six third-level indicators selected from research papers by Peng [8], Zhao [9], Lu [10], Qin [11], and others. Social indicators encompass medical culture, livelihood security, and elderly care services at the second level, with six third-level indicators selected based on research papers by Wang [12], He [13], Shi [14], Zhao [9], and others. Environmental indicators are divided into environmental response, natural ecology, and environmental pressure at the second level, with six third-level indicators selected from the works of experts and scholars such as Zhang [15], Sun [16], and Lu [10].

Table 1. Comprehensive economic-social-environmental index system in rural China

First-order index	Secondary index	Three-level index	comment	Weight/%
economics	income level	Rural per capita disposable income/(Yuan)		5.36
		Rural-urban income ratio	inverse indicator	1.68
		Total output value of agriculture, forestry, animal husbandry and fishery/(100 million yuan)		7.3
	consumption structure	Engel coefficient/(%)	inverse indicator	1.37
		Per capita Entertainment consumption in rural areas/(Yuan)		6.77
		Rural per capita consumption expenditure/(Yuan)		5.5
community	medical culture	Number of Rural Cultural Stations/(each)		7.3
		Number of rural clinics/(each)		10.6
		Number of village health workers per 1,000 people/(1)		5.1
	living security	Proportion of people living on subsistence allowance/(%)	inverse indicator	1.67
		Rural minimum living security fund/(Yuan)		9.0
	system of elderly care service	Number of rural pension institutions/(PCS)		12.5
environment	environmental response	Penetration rate of sanitary latrines/(%)		5.2
		Domestic sewage treatment rate/(%)		5.27
		Safe drinking water coverage/(%)		2.65
		Per capita road area/(m2/ person)		6.44
	natural ecological	Vegetation coverage rate/(%)		5.14
	environmental stress	Fertilizer application intensity/(kg/hm2)	inverse indicator	1.19

2.3. Data Sources

This study focuses on rural areas across 31 provinces in China, spanning the period from 2012 to 2024. Data sources encompass the "China Statistical Yearbook," "China Rural Statistical Yearbook," "China Urban-Rural Construction Statistical Yearbook" and EPS databases, in addition to statistical reports from both the national level and each province. In instances of missing data, interpolation techniques were applied. Data gaps were identified for Beijing, Shanghai, and Tibet; consequently, this investigation concentrates on the remaining 28 provinces. Per capita road area denotes the available road area per person in rural areas, while fertilizer use intensity is calculated by dividing the amount of fertilizer used by the cultivated land area.

2.4. Research Method

1) Data Processing and Weight Determination

Before conducting a comprehensive evaluation of the rural economy-society-environment, it is essential to determine the weights of each indicator. In this study, the entropy method of objective weighting was selected for this purpose.

Given the diverse dimensions and units of each indicator, direct data analysis is not feasible. Therefore, the raw data undergoes normalization using the following equations:

Positive indicator:

$$x'_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

Negative indicator:

$$x'_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (2)$$

In equations (1) and (2), is the minimum value of the j-th indicator, is the maximum value of the j-th indicator, and is the normalized data of each indicator.

To calculate the entropy value using the entropy weighting method, we first calculate the information entropy of the j-th indicator:

$$e_j = -K \sum_{i=1}^{m} y_{ij} \ln y_{ij} \quad (3)$$

In equation (3), is a constant, and $K = \frac{1}{\ln m}$

Next, calculate the entropy weight:

$$W_j = \frac{1 - e_j}{\sum_{i=1}^{m} (1 - e_j)} \quad (4)$$

Finally, for the comprehensive evaluation of the economy, society, and environment, the comprehensive evaluation index is determined by the sum of the product of the standard values of each tertiary indicator and their corresponding weights. The equation is as follows:

$$U_i = \sum_{j=1}^{m} W_j * x'_{ij} \quad (5)$$

In equation (5), represents the comprehensive score of the economy, society, and environment, is the weight of each indicator obtained by the entropy weighting method, and is the value of each indicator data after standardization.

2) Coupling Coordination Degree Model

Coupling, based on the physical concept, involves the interaction and influence between two or more systems. The coupling coordination degree model is employed to measure the degree of coordinated development among these entities. Therefore, using the coupling coordination model to analyze the overall level of coordinated development in rural areas provides a clearer view of whether rural development is coordinated. Therefore, this study utilizes a coupling degree model of three subsystems, as shown below:

$$C = \frac{3 * (U_1 * U_2 * U_3)^{1/3}}{U_1 + U_2 + U_3} \quad (6)$$

In equation (6), C represents the degree of coupling, U_1, U_2, U_3 represents the comprehensive evaluation index of the economy, society, and environment, which are obtained by equation (5).

However, the coupling degree model only indicates the strength of the coupling degree between entities and cannot represent the level of coordinated development among the

three entities. Therefore, the coupling coordination degree model is introduced as follows:

$$D = \sqrt{C * T} \quad (7)$$

$$T = \alpha U_1 + \beta U_2 + \theta U_3 \quad (8)$$

In equation (8), D represents the degree of coupling coordination, and T represents the comprehensive evaluation index of the economy, society, and environment. As this study considers the equal importance of the economy, society, and environment, the undetermined coefficients are set to $\alpha = \beta = \theta = {}^{1}/_{3}$.

Table 2. Evaluation basis and classification criteria of coupling coordination

First level	D	Second level	Third level (primitive types)
Third level (primitive types)	0.90≤D≤1.00	Effective coordination	If a, then it is a lagging type. If so, it is an economic-socio-environment synchronous type.
	0.80≤D≤0.89	Good coordination	
	0.70≤D≤0.79	Intermediate coordination	
	0.60≤D≤0.69	Basic coordination	
intermediate category	0.50≤D≤0.59	preliminary coordination	
	0.40≤D≤0.49	on the brink of disarray	
maladaptive decline class	0.30≤D≤0.39	mild dysfunction	
	0.20≤D≤0.29	moderate dysfunction	
	0.10≤D≤0.19	severe dysfunction	
	0.00≤D≤0.09	extreme dysfunction	

Table 3. Combined economic-social-environmental index of rural areas in China by province

Region		2012			2015			2018			2021			2024		
		U_1	U_2	U_3	U_1	U_1	U_2	U_3	U_2	U_3	U_1	U_2	U_3	U_1	U_2	U_3
Eastern Region	Tianjin	0.18	0.11	0.32	0.29	0.14	0.35	0.33	0.28	0.39	0.38	0.26	0.50	0.56	0.32	0.58
	Hebei	0.21	0.48	0.28	0.30	0.38	0.33	0.35	0.41	0.38	0.44	0.44	0.45	0.56	0.47	0.54
	Jiangsu	0.30	0.31	0.43	0.40	0.29	0.51	0.47	0.34	0.56	0.56	0.35	0.66	0.75	0.35	0.69
	Zhejiang	0.27	0.31	0.40	0.37	0.27	0.53	0.45	0.31	0.52	0.56	0.38	0.63	0.81	0.42	0.75
	Fujian	0.17	0.22	0.25	0.28	0.17	0.35	0.35	0.22	0.40	0.45	0.26	0.46	0.62	0.30	0.57
	Shandong	0.28	0.45	0.45	0.38	0.41	0.49	0.43	0.41	0.61	0.53	0.45	0.71	0.70	0.50	0.71
	Guangdong	0.19	0.36	0.42	0.29	0.29	0.53	0.39	0.33	0.60	0.51	0.38	0.67	0.70	0.38	0.83
	Hainan	0.07	0.08	0.33	0.17	0.08	0.35	0.24	0.11	0.40	0.33	0.15	0.54	0.43	0.20	0.60
	Mean value	0.21	0.33	0.36	0.31	0.29	0.43	0.38	0.34	0.48	0.47	0.38	0.58	0.64	0.42	0.66
Central Region	Shanxi	0.11	0.25	0.32	0.19	0.24	0.35	0.22	0.25	0.39	0.27	0.29	0.49	0.39	0.30	0.56
	Anhui	0.16	0.32	0.25	0.25	0.21	0.28	0.32	0.27	0.42	0.44	0.38	0.51	0.54	0.41	0.57
	Jiangxi	0.13	0.33	0.19	0.22	0.31	0.26	0.28	0.33	0.39	0.39	0.40	0.44	0.52	0.41	0.54
	Henan	0.23	0.53	0.24	0.33	0.37	0.24	0.39	0.41	0.39	0.51	0.53	0.47	0.61	0.56	0.49
	Hubei	0.20	0.34	0.19	0.32	0.30	0.26	0.40	0.32	0.46	0.50	0.36	0.53	0.66	0.35	0.55
	Hunan	0.18	0.50	0.21	0.30	0.41	0.26	0.36	0.40	0.36	0.49	0.48	0.44	0.64	0.43	0.55
	Mean value	0.17	0.38	0.23	0.27	0.31	0.27	0.33	0.33	0.40	0.43	0.41	0.48	0.56	0.41	0.54
Western Region	Heilongjiang	0.15	0.18	0.09	0.29	0.18	0.20	0.36	0.19	0.25	0.37	0.22	0.25	0.51	0.24	0.39
	Guangxi	0.11	0.26	0.10	0.22	0.17	0.15	0.31	0.19	0.26	0.42	0.23	0.36	0.54	0.23	0.37
	Chongqing	0.10	0.30	0.23	0.19	0.15	0.28	0.26	0.21	0.40	0.34	0.26	0.42	0.48	0.30	0.50
	Sichuan	0.17	0.66	0.19	0.27	0.59	0.24	0.35	0.57	0.39	0.46	0.58	0.48	0.60	0.51	0.46
	Guizhou	0.04	0.22	0.11	0.16	0.21	0.16	0.24	0.25	0.31	0.32	0.31	0.43	0.42	0.32	0.44
	Yunnan	0.07	0.17	0.13	0.18	0.15	0.17	0.25	0.20	0.29	0.35	0.27	0.36	0.46	0.30	0.36
	Shanxi	0.12	0.27	0.11	0.21	0.25	0.17	0.26	0.29	0.26	0.32	0.32	0.39	0.45	0.33	0.42
	Gansu	0.06	0.16	0.16	0.14	0.14	0.19	0.19	0.16	0.26	0.24	0.22	0.30	0.33	0.25	0.37
	Qinghai	0.07	0.07	0.16	0.14	0.08	0.20	0.17	0.12	0.26	0.23	0.17	0.36	0.29	0.20	0.40
	Ningxia	0.07	0.04	0.16	0.17	0.06	0.25	0.22	0.11	0.35	0.26	0.13	0.41	0.37	0.16	0.43
	Xinjiang	0.12	0.15	0.28	0.18	0.16	0.29	0.25	0.16	0.41	0.35	0.19	0.45	0.42	0.25	0.53
	Mean value	0.10	0.22	0.16	0.20	0.19	0.21	0.26	0.22	0.31	0.33	0.26	0.38	0.44	0.28	0.43
Northeast Region	Liaoning	0.19	0.24	0.40	0.29	0.21	0.44	0.32	0.21	0.56	0.40	0.23	0.72	0.51	0.27	0.64
	Jilin	0.17	0.17	0.26	0.25	0.18	0.30	0.28	0.19	0.41	0.35	0.24	0.51	0.44	0.26	0.59
	Heilongjiang	0.20	0.16	0.32	0.30	0.15	0.35	0.36	0.15	0.45	0.43	0.18	0.46	0.51	0.20	0.60
	Mean value	0.19	0.19	0.33	0.28	0.18	0.36	0.32	0.19	0.47	0.39	0.22	0.56	0.49	0.24	0.61

This study refers to and draws from previous research results, dividing the level of system coupling coordination into 10 levels. The specific classification and evaluation criteria for the degree of coupling coordination are shown in Table II.

3. Empirical Analysis

Due to the similarity in index values across certain years, this paper presents the comprehensive indices of rural economy, society, and environment in each province of China for the years 2012, 2015, 2018, 2021and 2024. The regions are divided into eastern, central, western, and northeastern regions, as detailed in Table III.

3.1. Evolution Characteristics of Subsystem Composite Index

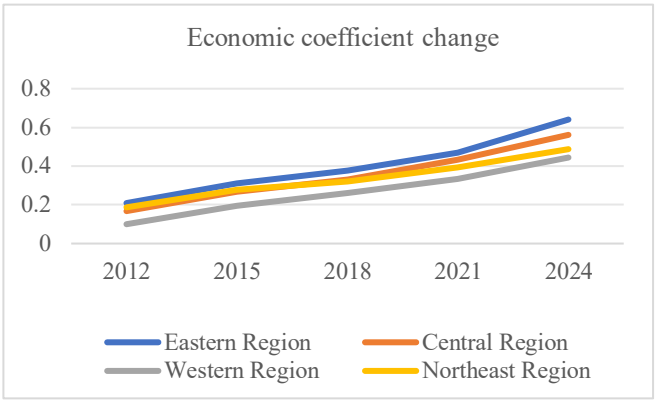
1) Evolutionary Characteristics of the Economic Composite Index

As shown in Table III and Fig. 2 (a), the economic index of rural areas in each province showed an overall upward trend from 2012 to 2024. Most provinces experienced an increase of 0.01 to 0.67 from 2018 to 2024. The eastern rural area had the highest economic growth rate, while the northeastern rural area exhibited slower but stable growth in recent years. The economic composite index of the eastern rural area remained stable, hovering between 0.6 and 0.7 in 2024. Both the eastern and central rural areas have economic composite indices exceeding 0.5. Sichuan, Inner Mongolia and Guangxi in the western rural areas, as well as Heilongjiang and Liaoling in the northeastern rural areas, reached or surpassed the 0.5 threshold. Other regions displayed smaller economic indices, suggesting that economic development in the eastern and central rural areas is stronger, while that in the western and northeastern rural areas is comparatively weaker.

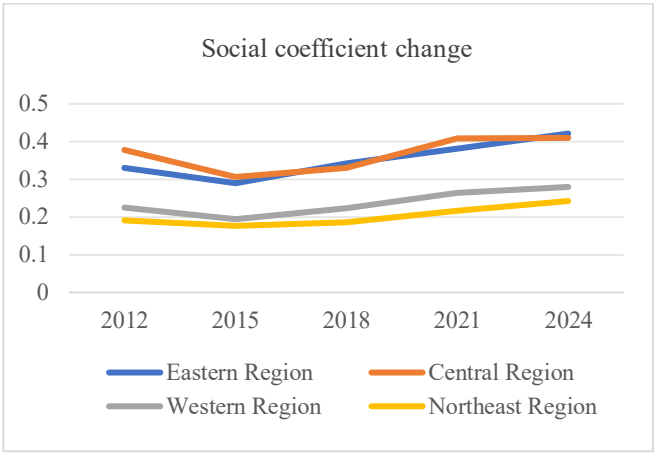
Regionally, the pace of economic development varies significantly among provinces. In 2012, Zhejiang, Jiangsu, and Shandong, geographically close to rural areas, led the nation in forefront rural economic development. Over the past decade, provinces such as Gansu, Qinghai, Ningxia, and Guizhou have steadily caught up, experiencing accelerated growth, particularly after the enactment of the rural revitalization policy. Provinces including Hebei, Hunan, Guangdong, Chongqing, Henan, Anhui, Hubei, Guangxi, Fujian, Shaanxi, Guizhou, Sichuan, Yunnan, Xinjiang, Heilongjiang, and others have consistently shown an upward trajectory in rural economic development over the past decade. This is similar to the overall economic development level of each province, and also reflects the degree of economic development of each province from some perspectives.

Zhejiang, Jiangsu, Guangdong and Fujian other provinces witnessed rapid rural economic development from 2012 to 2024. During the study period, the rural economic development pattern of provinces and cities has significant regional differences, and they are all in the stage of sustainable development with different development speeds.

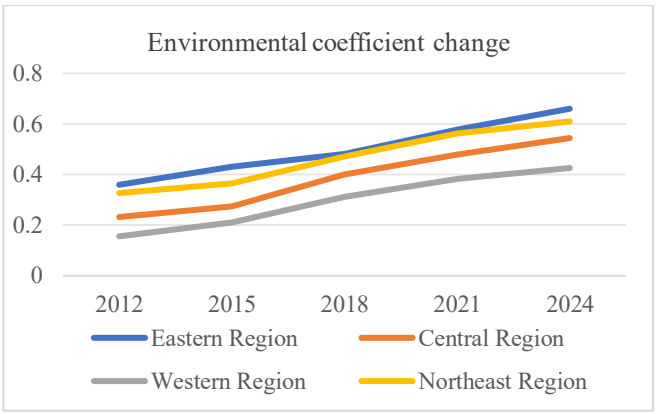
Zhao [9]'s research found that in areas with a relatively good economic foundation or a high level of economic development, rural areas are more likely to achieve development, and the development speed is faster; However, due to the poor economic foundation, although the western region has abundant resources, its level of economic development is relatively lagging behind. This is partially similar to the research findings of this article, which also found that between 2018 and 2021, the development speed of rural areas in the central regions was higher than that in the eastern rural areas, and there was a trend of accelerated development of the national rural economy after the release of the rural revitalization policy.



(a) Economic coefficient change



(b) Social coefficient change



(c) Environmental coefficient change

Figure 2. Economic, social and environmental changes over time

2) Evolutionary Characteristics of Rural Social Composite Index

As depicted in Table III and Fig. 2 (b), the rural social composite index across various regions of China displayed minimal changes from 2012 to 2024. There was a gradual increase in the index for various rural areas, with the highest average index observed in central rural areas. Conversely, the social composite index was lowest in western and northeastern rural areas.

Within each region, provinces such as Hebei, Jiangsu, Guangdong, Shandong, Anhui, Jiangxi, Henan, and Sichuan

recorded a social composite index exceeding 0.33 in 2024, surpassing the national average level. The social comprehensive index of other provinces is lower than the national average level. During the study period, the social composite index of Tianjin exhibited a consistently slow upward trend. In contrast, while the environmental composite index of the other provinces showed a decline in isolated years, it generally followed a slow upward trajectory without significant fluctuations. Research data show that only a small part of rural areas has good social development, and most rural areas have stagnated social development and have not achieved a large degree of development and change. The social comprehensive index varies slightly among different regions, and they are all in a stage of temporary development.

Wang [12]'s research data shows that the overall level of rural social elderly care service supply in 28 provincial-level administrative regions in China is relatively low. There are provinces and cities with good or bad development in the eastern, central, and western regions. The research data in this article shows that social security in rural areas in central China has developed well, which is slightly different from Wang's research conclusion; The social security in most rural areas of China is still in a stage of development.

3) Evolutionary Characteristics of Environmental Composite Index

As delineated in Table III and Fig. 2 (c), throughout the research period, the overall environmental composite index exhibited an upward trajectory, with a particularly swift ascent in recent years. The eastern rural region led the other three regions with a score of 0.66, while the western rural region lagged behind the national average with a score of 0.43.

From a regional standpoint, the provinces of Henan, Sichuan, Shandong and Hunan surpassed others with significantly higher environmental composite indices in 2024. There is a large gap in the development degree of rural environmental protection across the country, withHenan, Sichuan and Shandong leading the country in the degree of development, while Hainan, Heilongjiang, Ningxia and Qinghai, which have poor development at the present stage, lag behind in the development of the study period. From 2012to 2015, the environmental composite index ultimately rose in Xinjiang, Tianjin, Qinghai, Ningxia, Jilin, Hainan, and Inner Mongolia, whereas form 2018 to 2024, it ultimately fell in Tianjin, Sichuan, Hunan, Hubei, and Guangxi. The low comprehensive environmental index in the western region can be attributed to two main factors: geographical conditions, where the predominance of mountainous and plateau terrain, combined with arid conditions and a fragile ecological environment, results in a scarce water resource base. This makes it difficult to improve the coverage rate of safe drinking water and leads to high costs for constructing rural sewage collection networks. Moreover, due to the constraints of the natural landscape, the difficulty of developing infrastructure such as rural greening and per capita road area is significantly higher than in the eastern plains; and industrial facilities, as the western region serves as a national base for energy and heavy chemical industries, hosting numerous resource-intensive sectors, it bears a substantial load from industrial waste gas, wastewater, and solid residues. Coupled with high fertilizer application intensity driven by the pursuit of higher agricultural yields in some areas, the region's fragile ecological carrying capacity means that investments in environmental governance struggle to fully offset the compounded pressures of pollution emissions and geographic constraints.

The above phenomenon shows that environmental protection in China's rural areas has attracted more attention in recent years, and the environmental protection problem has been preliminarily solved, and the environment is generally in a trend of improvement.

3.2. Evolutionary Characteristics of Coupling and Coordination among Rural Economy, Society, and Environment

As indicated in Table IV, from a national perspective, the coupling coordination degree of rural areas across various regions of China has been steadily increasing. This trend indicates that the overall coordination among rural economy, society, and environment is improving. Regionally, the coupling coordination degree across provincial rural areas varied considerably in 2012, with substantial and uneven disparities. However, by 2024, most provinces maintained a similar level of coupling coordination, with little disparity. The eastern region achieved the highest coupling coordination degree, with four provinces surpassing 0.75, all located in the eastern region. The coupling coordination degree of rural development in the western and northeastern regions lags behind that of the eastern and central regions. Most rural areas in the eastern region have reached the basic to intermediate coordination stage, while most provinces in the central region are at the basic coordinated to intermediate coordination stage. Rural areas in the western and northeastern regions are on the verge of preliminary to the basic coordinated stage.

Further analysis, combined with Table III, identifies different types of economic, social, and environmental lags within each region, as outlined in Table IV. This analysis sheds light on the primary hindrance factors in different regions at the current stage.

Table 4. Coupled economic-social-environmental coordination in rural China by province

Region		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Eastern Region	Tianjin	0.43	0.44	0.48	0.49	0.55	0.55	0.57	0.58	0.58	0.61	0.64	0.66	0.69
	Hebei	0.55	0.56	0.58	0.58	0.60	0.60	0.62	0.63	0.64	0.67	0.68	0.70	0.72
	Jiangsu	0.58	0.59	0.60	0.62	0.65	0.66	0.67	0.69	0.69	0.71	0.73	0.73	0.75
	Zhejiang	0.57	0.59	0.60	0.61	0.64	0.63	0.65	0.68	0.69	0.71	0.77	0.79	0.80
	Fujian	0.46	0.49	0.48	0.51	0.52	0.54	0.56	0.58	0.60	0.62	0.65	0.68	0.69
	Shandong	0.62	0.64	0.64	0.65	0.69	0.68	0.69	0.70	0.72	0.74	0.77	0.77	0.79
	Guangdong	0.55	0.56	0.58	0.59	0.63	0.64	0.65	0.68	0.70	0.71	0.76	0.77	0.78
	Hainan	0.35	0.37	0.41	0.41	0.43	0.43	0.47	0.49	0.50	0.54	0.58	0.59	0.61
Central Region	Shanxi	0.45	0.46	0.48	0.50	0.52	0.52	0.53	0.55	0.56	0.58	0.59	0.62	0.63
	Anhui	0.49	0.49	0.47	0.49	0.53	0.54	0.58	0.60	0.64	0.67	0.69	0.69	0.71
	Jiangxi	0.45	0.47	0.50	0.51	0.53	0.55	0.58	0.61	0.63	0.64	0.66	0.69	0.70
	Henan	0.55	0.57	0.58	0.55	0.59	0.59	0.63	0.66	0.68	0.71	0.72	0.73	0.74
	Hubei	0.48	0.49	0.52	0.54	0.56	0.59	0.62	0.64	0.65	0.68	0.71	0.70	0.71
	Hunan	0.43	0.44	0.48	0.49	0.55	0.55	0.57	0.58	0.58	0.61	0.64	0.66	0.69
Western Region	Inner mongolia	0.37	0.40	0.45	0.47	0.49	0.51	0.51	0.51	0.52	0.52	0.57	0.58	0.60
	Guangxi	0.52	0.52	0.54	0.57	0.61	0.61	0.61	0.66	0.66	0.69	0.71	0.70	0.73
	Chongqing	0.37	0.41	0.40	0.42	0.44	0.46	0.50	0.51	0.54	0.57	0.58	0.59	0.60
	Sichuan	0.44	0.43	0.43	0.45	0.47	0.49	0.53	0.54	0.55	0.58	0.61	0.64	0.64
	Guizhou	0.53	0.54	0.59	0.58	0.60	0.62	0.65	0.68	0.70	0.71	0.72	0.73	0.72
	Yunnan	0.31	0.35	0.38	0.42	0.45	0.47	0.52	0.54	0.56	0.59	0.60	0.63	0.62
	Shaanxi	0.34	0.36	0.39	0.40	0.44	0.45	0.50	0.54	0.54	0.57	0.57	0.60	0.61
	Gansu	0.39	0.40	0.44	0.45	0.48	0.50	0.52	0.56	0.57	0.58	0.60	0.62	0.63
	Qinghai	0.34	0.36	0.38	0.39	0.42	0.41	0.44	0.48	0.49	0.50	0.53	0.56	0.56
	Ningxia	0.30	0.33	0.35	0.36	0.38	0.38	0.42	0.44	0.46	0.49	0.49	0.51	0.53
	Xinjiang	0.28	0.31	0.35	0.37	0.40	0.42	0.45	0.46	0.47	0.49	0.53	0.53	0.54
Northeast Region	Liaoning	0.42	0.43	0.44	0.45	0.48	0.47	0.50	0.52	0.54	0.56	0.61	0.59	0.62
	Jilin	0.51	0.53	0.54	0.55	0.57	0.56	0.58	0.59	0.60	0.64	0.64	0.67	0.66
	Heilongjiang	0.45	0.44	0.48	0.49	0.51	0.51	0.53	0.55	0.55	0.59	0.60	0.62	0.64

4. Conclusion and recommendation

This paper conducts an in-depth examination of the relationship between the economy, society and environment in rural China. By analyzing the economy, society and environment of rural areas across various provinces and cities in China from 2012 to 2024, the following conclusions are drawn by using the coupled coordination model and the constructed index system.

Table 5. Advantages and disadvantages of regional development

Region	Advantage	Inferior Position
Eastern region	Economy Environment	Society
Central region	Economy Society	Environment
Western region		Economy Society Environment
Northeast region		Economy Society Environment

Table 6. Lag type by region

	Economic lag	Social lag	Environmental lag
District	Hebei, Jiangxi, Shanxi, Guizhou,	Tianjin, Jiangsu, Anhui Zhejiang, Fujian, Hainan, Shandong, Hubei, Guangdong, Guangxi, Chongqing, Yunnan, Qinghai, Ningxia, Xinjiang, Shaanxi, Gansu, Jilin, Heilongjiang, Liaoling	Henan, Hunan, Shanxi, Sichuan, Inner Mongolia

Firstly, while rural areas in China are continuing to progress, there remains a noticeable development gap between the eastern and western regions. Research results of Lu [10] show that: from 2014 to 2019, the level of rural economic development in all parts of China has significantly improved, showing "higher in the east, middle in the middle, and lower in the west". The eastern rural areas, particularly those in Jiangsu and Zhejiang, stand out as leaders in the country. Despite the overall development trend in the eastern region is positive, there are still variations in the development levels among different sub-regions. Some rural areas in the central region have similar levels of rural development to those in the eastern region, while others, such as Shanxi and Jiangxi, as well as rural areas in Tianjin and Hainan in the east, remain relatively underdeveloped and need to intensify efforts to promote economic growth. While rural areas in western Sichuan demonstrate relatively good economic development, there is room for improvement in the economic development of rural areas in western and northeastern China. Strategies adapted to the specific conditions of each region should be developed to promote the development of the rural economy. Provinces can be in the agricultural industry,

finance, talent and other fields. According to the actual situation of the provinces, adjust the rural industrial structure, develop industries suitable for the local climate and resource conditions, and promote the industrialization and modernization of agriculture, through the introduction of advanced technology and management experience, improve the quality and output of agricultural products, strengthen the brand building of agricultural products, and increase the added value of agricultural products; We will strengthen rural financial services, provide loans and financial instruments to support farmers' production and operation activities, and encourage farmers to develop diversified operations in planting, breeding and processing. We will strengthen the mechanism for training rural personnel, improve the quality of the rural labor force, guide and support skilled personnel to return to their hometowns to start businesses, and promotesustainable economic and social development in rural areas.

Secondly, the social composite index of rural areas in China remains generally low, with no significant change observed during the study period. Zhao [9] finds that the best rural social infrastructure construction is in Tianjin, Shandong, Shaanxi, Shanxi and Hebei, and the lower five provinces are Xizang, Fujian, Hainan, Guangdong and Yunnan. This is slightly different from the results of this study. Notably, Sichuan Province stands out with the highest social composite index in rural areas, significantly surpassing other provinces. However, the overall social score of rural areas in most provinces remain low, protection efforts t the social level development of rural areas in China is relatively lacking at this stage, and more attention should be paid to strengthening the rural social security system and improving the social security capacity in the future, so as to improve the overall development level of rural society and conform to the rural revitalization policy. With the deepening of China's aging degree, more attention should be paid to the construction and improvement of rural social security and medical and health systems in rural areas of all provinces. According to the results of empirical analysis, the improvement of social system has become the number one problem in most provinces. How to strengthen the allocation of rural education resources, strengthen the construction of rural medical and health service system, establish and improve the rural social security system and rural governance issues need to be comprehensively analyzed in each province according to the actual situation.

Furthermore, environmental developments exhibit significant regional disparities. The eastern provinces of Jiangsu, Zhejiang, and Guangdong, achieve high scores for the overall rural environmental quality, leading the nation in environmental protection efforts. Conversely, economically disadvantaged areas such as Hebei in the east, Jining and Heilongjiang in the northeast, and rural areas in Qinghai in the west scored poorly on environmental indicators. These regions should intensify their environmental protection efforts to achieve green and sustainable development. The environmental foundation of rural areas is better than that of urban areas, and all provinces and cities need to introduce environmental protection policies in line with the actual situation of rural areas at the present stage, mainly to solve environmental problems in rural production and life.

Economic, social and environmental relations are mutually reinforcing and can never focus on development of one or the other. At present, there are different degrees of unbalanced development in all provinces, and we should pay attention to the common progress in other aspects when the development is insufficient. At this stage, the situation of each province is different in all aspects, and it is necessary to combine its own actual situation, historical background, realistic advantages and disadvantages, follow the leadership of the party, strive to develop, and strive to follow the trend of The Times.

In conclusion, the development of China's economic-social-environmental system is currently uneven. The coupling coordination degree of economy, society and environment in eastern rural areas is higher than that in western rural areas, central rural areas and northeast rural areas, and it is getting closer and closer with time. The degree of coupling coordination in the central region is slightlybehind that in the eastern region, and most provinces are in the stage of basic coordinated to Intermediate coordination stage. In the western region, the majority of provinces exhibit a relatively low level of rural coupling coordination. According to the empirical research in this paper, the development of rural areas should pay attention to their own advantages and disadvantages in various aspects, actively respond to China's policies, keep up with the trend of facts, and formulate a unique style in line with their own development.

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