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Research on Synergy Degree Evaluation of Green Ecology and Regional Economy in Western China

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Abstract: *19 indicators of the two systems—ecological environment and economic development in western China are selected to measure the synergy level of green ecology and regional economic development in western China from 2014 to 2019 and accelerate the pace of high-quality economic development. The entropy method and the composite system synergy model are employed to carry out the comprehensive evaluation. The results show that western China's ecological environment and economic development generally perform an N-type development trend with alternating increases and decreases. At the same time, the synergy degree is low. The evaluation highlights the clear differences between the southwest and northwest regions. Western China should adhere to sustainable development and lay more emphasis on the protection and restoration of the ecological environment in future economic development.*

Keywords: *Western China, Green Ecology, Regional Economy, Synergy Degree*

1. Introduction

In recent years, the economy in western China has developed rapidly. The GDP of the 12 provinces (cities, districts) in western China increased from 1.5 trillion yuan in 1999 to 20.5 trillion yuan in 2019, with an average annual growth of about 10.9%, which is higher than the national average. However, owing to the continuously advanced western development strategies, both the industrialization-oriented economic construction and the more unappreciated ecological environment have made western China be confronted with a more rigorous ecological test, including the three wastes pollution caused by rapid industrialization, the resource crisis caused by excessive development, the destruction of the industrial structure imbalance on the environment, etc. (Zhu, 2016) [1] Consequently, for realizing the synchronization of ecologic and economic development to further promote the economic development in a high-quality way, it is of great significance to study the synergy degree between green ecology and regional economy in western China.

The American economist Kuznetz first proposes the inverted U-shaped curve between income distribution and economic development, and then Grossman Krueger et al. propose the Environmental Kuznets Curve. [2] With the continuous enrichment of theories and the gradual optimization of research methods, more scholars have elaborated on the relationship between ecological environment and economic development from diverse perspectives. David A.Savage applies Behavioral Economics to analyze main environmental problems in economic development and concludes that they would lead to suboptimal results. [3] Zhang et al. analyze relationships among economic growth, energy consumption, air emissions and air environmental protection investment in China from 2000 to 2007, indicating that the rapid growth of the Chinese economy was accompanied by a rise in energy consumption and a decline in energy efficiency and environmental load intensity and that the rate of improvement was much slower than that of economic growth. [4]

Recently, domestic scholars mainly studied economic development and the ecological environment by coupling coordination degree model, cluster analysis and hierarchical analysis. For example, Tong chooses the coupling coordination degree model to measure the coupling coordination degree between economic development and ecological environment in western China and classifies 12 western regions by cluster analysis. (2019) [5] Liu et al. utilizes the analytic hierarchy process (AHP) to construct a comprehensive index for water ecology-economy synergistic development of Lanzhou-Xining urban agglomeration and carries out spatial and temporal evaluation. (2021) [6] Ning et al. measure the synergy

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degree of ecological protection and economic development in the Yellow River Basin, noting a strong consistency and a clear cyclicality between them. [7]

The collaborative development of green ecology and regional economy is a significant action to promote the formation of a new pattern in western China, which is also an inevitable requirement to promote high-quality economic development. Hence, based on the index system of existing related research, this paper establishes a comprehensive index system of green ecology and regional economy, and then applies the entropy method and composite synergy degree model to measure the synergy degree of ecological environment and economic development in western China from 2014 to 2019, which is conducive to actively seeking the coordinated development of ecology and economy. On the other hand, it has a certain reference significance for promoting the sustainable development of the economy in Western China.

2. Green Ecology and Regional Synergy Model in Western China

2.1. Determine Order Parameters of Green Ecology and Regional Economic System

Based on synergy theory, this paper divides the composite system into two independent subsystems with different attributes—green ecology and regional economy. Considering the principles of scientific, systematic, representative and feasible selection of indicators, the order parameters of the two subsystems are determined after analyzing the ecological construction and economic development in western China based on the relevant indicator systems of Tong and Liu, etc. [5] The green ecological subsystem consists of 9 order parameters reflecting energy consumption, pollution emissions and environmental governance, while the regional economic subsystem consists of 10 order parameters presenting regional economic scale, economic vitality and residents ' lives. The detailed composition of the order parameters of each subsystem is shown in Table 1.

Table 1: Order parameters of green ecology subsystem and regional economy subsystem

Subsystems	Primary indexes	Secondary indexes	Unit	Type
Green ecology	Energy Consumption	Coal	million tons	Negative
		Petroleum	million tons	Negative
		Liquefied petroleum gas	million tons	Negative
	Pollution Emission	Industrial wastewater emissions	billion tons	Negative
		Industrial sulfur dioxide emissions	million tons	Negative
		Industrial solid waste production	million tons	Negative
	Environmental Governance	Industrial pollution treatment investment	million yuan	Positive
		Urban sewage treatment rate	%	Positive
		Greening coverage rate of urban built-up area	%	Positive
Regional economy	Economic Scale	Per capita GDP	yuan	Positive
		General public budget revenue	billion yuan	Positive
		Total imports and exports	billion dollars	Positive
	Economic Vitality	Value Added of Tertiary Industry in GDP	%	Positive
		R & D Expenditure of Industrial Enterprises above Scale	million yuan	Positive
		Education funds	billion yuan	Positive
	Residents ' Life	Total retail sales of social consumer goods	billion yuan	Positive
		Unemployment rate	%	Negative
		Consumer price index	-	Negative
		Per capita disposable income of residents	yuan	Positive

2.2. Subsystem Order Degree Model

According to the synergy theory, this paper abstracts the composite system as $S = \{S_1, S_2\}$, where S_1 and S_2 represent the two subsystems of green ecology and regional economy, respectively. It is assumed that the order parameter of each subsystem is $e_j = (e_{j1}, e_{j2,} \dots, e_{jn})$, where $n \geqslant 1$, $\beta_{ji} \leqslant e_{ji} \leqslant \alpha_{ji}$, $i = 1,2 \dots n, \alpha_{ji}$ and β_{ji} are the maximum and minimum values of the order parameter e_{ji} in each system. It is assumed that $e_{j1,} e_{j2,} \dots, e_{jl}$ are positive indicators, and each value is positively correlated with the degree of order. On the contrary, $e_{jl+1}, e_{jl+1}, \dots e_{jn}$ are negative indexes, and each value is

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negatively correlated with the order degree. So the order degree model of the order parameter component of the subsystem is as follows:

$$U_j(e_{ji})\begin{cases}\dfrac{e_{ji}-\beta_{ji}}{\alpha_{ji}-\beta_{ji}} & (i\in[1,l])\\ \dfrac{\alpha_{ji}-e_{ji}}{\alpha_{ji}-\beta_{ji}} & (i\in[l+1,\mathrm{n}\end{cases} \tag{1}$$

In this paper, the contribution of the order parameter variable e_j to the order degree $u_j(e_j)$ of the system is calculated by the linear weighting method:

$$u_j(e_j)=\sum_{j=1}^{n} w_j u_j(e_{ji}), w_j \geqslant 0, \sum_{j=1}^{n} w_j = 1 \tag{2}$$

Where w_j is the weight of each order parameter, which is determined by the entropy method. The basic principle of the entropy method is as follows: Normalize the data and calculate the weight of the indicator a_{ij}:

$$u_{ij} = a_{ij}/\sum a_{ij} \tag{3}$$

Calculate the entropy value:

$$e_j = -k\sum u_{ij}\ln u_{ij}, \qquad \mathrm{k} = 1/\ln m \tag{4}$$

Calculate the difference coefficient :

$$g_j = 1 - e_j \tag{5}$$

Calculate the weight of the indicator a_{ij}:

$$w_j = g_j/\sum g_j, (j = 1,2,\dots,n) \tag{6}$$

2.3. Construct Synergy Model

In this paper, the synergy degree between green ecology and regional economy is measured by the composite system synergy model with the initial time point of the time series as the benchmark. The formula of composite system synergy degree is as follows

$$\mathrm{U}_{(t)} = \mathrm{sig}(.)\sqrt{|U_1(t)-U_1(t-1)|\cdot|U_2(t)-U_2(t-1)|} \tag{7}$$

$$\mathrm{sig}(\cdot) = \begin{cases}1, \mathrm{U}_1(\mathrm{t})-\mathrm{U}_1(\mathrm{t}-1)\geqslant 0\ and\ \mathrm{U}_2(\mathrm{t})-\mathrm{U}_2(\mathrm{t}-1)\geqslant 0\\ -1, \text{else}\end{cases} \tag{8}$$

Where $U_1(t)$ and $U_2(t)$ denote the order degree of the two subsystems at time t, respectively. $\mathrm{U}_{(t)} \in [-1,1]$, the larger the value is, the better the synergistic development of the composite system is. It can be seen that only when the order degree of the green ecology subsystem and the regional economy subsystem is improved, the order degree of the system as a whole can rapidly increase. In other words, the effective synergistic development among the subsystems or their internal elements is realized.

3. Analysis of the Synergy Degree between Green Ecology and Regional Economy

3.1. Analysis of Order Degree of Subsystems

The formula (1) and (2) is used to calculate the changes of order degree of green ecology subsystem and regional economy subsystem in southwest and northwest China, respectively. The results are as shown in Figure 1 and Figure 2.

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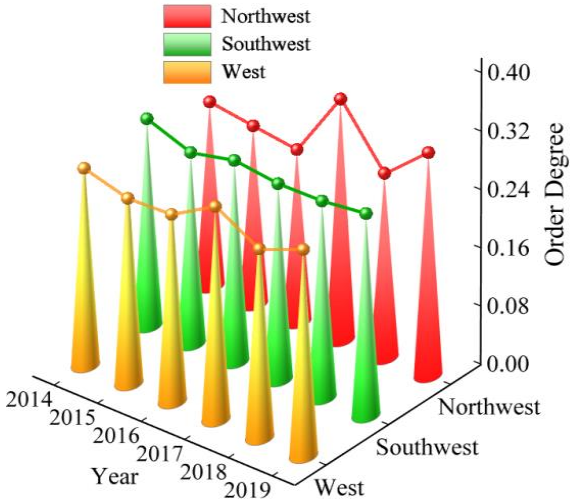

Figure 1: Order degree of green ecology subsystem in Northwest, Southwest and West China

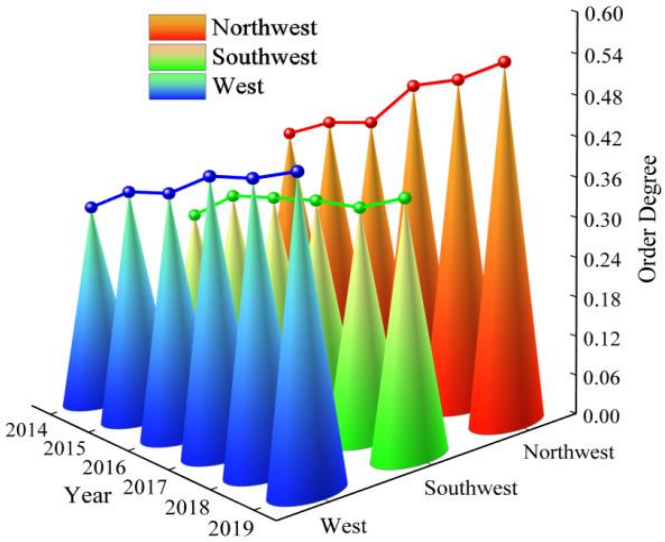

Figure 2: Order Degree of Regional Economy Subsystem in Northwest, Southwest and West China

From Figure 1, we can find that the order degree of the green ecology subsystem shows a fluctuating upward trend in general, with a small decrease in 14- 16 years and a significant increase in 17 years, reaching a maximum value of 0.292 before falling back to 0.282 in 19 years. It is said that Western China has gradually paid more attention to the construction and development of green ecology and achieved certain results. Compared to the slight change in Northwest China, Southwest China fluctuated more dramatically, achieving a significant rebound in 2017 after initially being in a weak position and then gradually declining to narrow the difference with Northwest China. It can be concluded that there are regional differences in the construction and protection of ecology in western China, with more stable development in northwest China and dynamic but volatile development in southwest China.

From Figure 2, we can notice that the order degree of the regional economy subsystem generally has a continuous upward trend, gradually increasing from 0.299 in 2014 to 0.460 in 2019. Therefore, it can indicate that China's western region has experienced rapid economic development and good economic construction in recent years. The order degree of southwest China has always been higher than that of the Northwest. It has a clear growth trend and is expanding its lead year by year after 2016. It is mainly due to the continuous economic policy of developing western China. Moreover, southwestern cities such as Chengdu and Kunming have developed better than other northwestern cities, effectively driving the overall economic development of southwestern China and further widening regional differences.

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3.2. Analysis of Synergy Degree of the Composite System

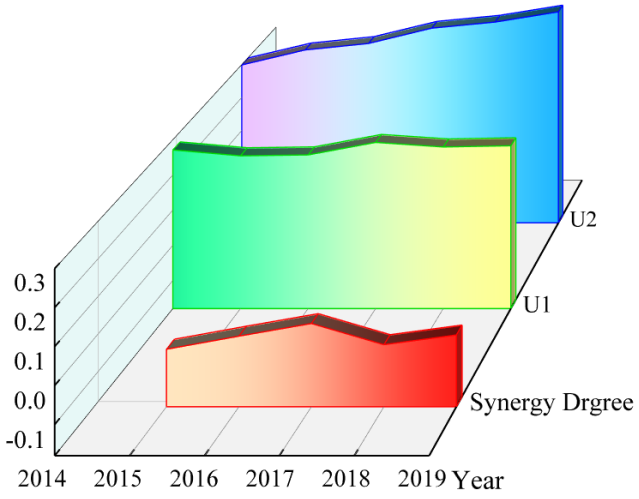

Figure 3: Synergy Degree of the Composite System in Western China

The synergy degree of the green ecology and regional economy composite system in western China was calculated based on each subsystem's order degree using the formula (7) and (8) as shown in Figure 3. As shown from the above Figures, the synergy between green ecology and regional economy in western China shows an N-type development trend of alternating increase and decrease and is generally at a low level of synergy. It is worth noting that the order degree of the regional economy subsystem is significantly higher than that of the green ecology subsystem, indicating that the economic development helps promote the green ecology and plays a supporting and boosting role.

The synergy degree of the composite system varies from time to time. From 2014 to 2015, the order degree of the green ecology subsystem decreases, while the order degree of the regional economic subsystem increases significantly. At this time, the synergy degree of the composite system is negative, and there is an incoordination phenomenon, indicating that the western region of China is at the expense of the environment to promote better economic activities. Then, in 2015-2017, the order degree of the two subsystems began to grow synchronously, and the synergy degree of the composite system changed from negative to positive, which suggests that the two are in a synergistic state and the development trend is good. After that, with the continuous growth of the order degree of the regional economy subsystem, the order degree of the green ecology subsystem has declined slightly, and the composite system has again shown an uncoordinated state.

4. Conclusions

(1) From the perspective of system analysis, selecting nineteen indicators and applying the entropy value method and the composite system synergy model to comprehensively measure the level of synergistic development of green ecology and regional economy in western China. A comparative analysis is conducted for the southwest and northwest regions regarding the subsystem order degree and an overall analysis of the composite system synergy degree.

(2) The synergy degree of the composite system in Western China generally presents an n-type development trend of increasing and decreasing alternately, which is in a low-level synergy state. Rapid economic development plays a supporting and promoting role in the construction and protection of the ecological environment. There are obvious differences between regions, with a steadier green ecological development in the northwest and a more dynamic economic development in the southwest.

(3) Western China should take the efficient recycling of resources as the core, persist in the sustainable development strategy, and maximize the conservation of resources and environmental protection. Give full play to the potential and advantages of central cities, deepen economic and trade cooperation and industrial cooperation with surrounding cities and regions, strengthen the exchange of cleaner production technology, and jointly promote the comprehensive harnessing of the ecological environment.

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