Research On the Synergistic Evaluation of Regional Green Finance and Regional Economy Under CRITIC Model

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Abstract. A healthy ecological environment is a crucial building block for sustainable socioeconomic development, and the green financial system can optimize industrial structure using capital and other market variables to support high-quality and environmentally friendly economic growth. This study examines the synergistic effects of local green finance and the local economy in the impoverished region, Gansu Province, China. Additionally, it introduces the Criteria Importance Through Intercrieria Correlation (CRITIC) model to unbiasedly assign weights to the assessment indicators, establishing a composite system of regional green finance subsystem and regional economy subsystem for synergistic evaluation. By examining the degree of synergy effects in Gansu Province, the findings suggest a low level of overall synergy between the economy of Gansu Province and regional green finance, with an alternating trend of decreasing-rising-decreasing. This study is helpful in lowering the subjective tendency of the assessment of green finance on economic construction and accurately carrying out targeted reforms according to the results.

Keywords: CRITIC; Green Finance; Regional Economy; Synergy Model; Underdeveloped Regions.

1. Introduction

Environmental risks such as climate crisis, extreme weather, and biodiversity reduction all pose challenges to the sustainable development of countries, and economies are gradually responding from strategic, legal, and social resource dimensions. However, government subsidies alone cannot achieve the long-term goal of innovative green development of a high-quality economy and striving to reach carbon neutrality by 2060, and the reallocation of public and social capital cannot leave the role of the financial system. In 2016, China issued the Guidance on Building a Green Financial System to promote the participation of market funds in building a green financial system, making full use of its financial functions including resource allocation, risk management and market pricing to support the construction of ecological civilization.

When it comes to the impact of green finance on economic growth, Wang [1] believes that due to limited financial resources, environmental governance investment will crowd out on productive investment in the short term, which may affect economic growth. Moreover, technological innovation often indicates the increased capital intensity of enterprises, resulting in greater financing pressure. However, Li and Xiao [2] think that green innovation is a strategic goal for enterprises to achieve sustainable development, and Gangi et al. [3] also believes that the finance system can solve the problem of micro-individuals lacking behavioral incentives. More importantly, Liu [4] empirically demonstrates that the credit decisions of financial institutions can significantly affect the quality of economic growth. Overall, in theory, a green financial system can reduce the proportion of industries with low technical barriers, high consumption and high pollution in the past, enabling enterprises to reasonably assume environmental responsibility and improving the quality of economic growth.

However, China is a so vast country that the mechanism and degree of impact of green finance construction on economic development vary for different geographical regions [5]. Tao et al [6] propose that geographical distance raises transaction costs and increases the degree of information asymmetry, and regionalizes and refines the construction of financial centers; Song and Liu [7] disprove the assumption that the growth path of the green economy is the same for all provinces and argue that the growth pattern will change over time. Meanwhile, the relationship between green finance and regional economy in different regions has also attracted extensive attention from scholars. For example, Liu and He [8] explore the impact of green finance on the economic development of six central provinces, and Chang [9] studies the role of green finance on rural economic development, but there is a lack of research targeting underdeveloped regions at the provincial level [10]. More often, most scholars use the entropy weight method to calculate the indicator weights [11], and insufficient consideration is given to the conflicting nature of indicators.

This paper analyzes the interaction between green finance and the regional economy in underdeveloped regions in a more objective and accurate way. Firstly, the CRITIC model is introduced to objectively assign weights to indicators to reduce the repetitiveness and subjective tendency of indicators. Secondly, the subsystems of regional green finance and regional economy are established by using sequential covariates, and then the internal mechanism of the composite model of green finance and regional economy can be explored by using the synergy model in the time dimension to empirically analyze the synergistic benefits of green finance and underdeveloped regional economy. Finally, taking Gansu, a province in northwest China, as the object of this study is conducive to scientifically assessing the green financial system and economic performance of underdeveloped regions, providing a reference for high-quality and sustainable economic development in Gansu Province.

2. Regional Green Finance and Regional Economy Sequential Covariate Construction

2.1. Regional Green Finance

Green finance is the financial services provided to support activities that improve the environment, address climate change, and make efficient use of natural resources. The essence of green finance is the problem of resource allocation, and the environment-friendly orientation can alleviate the environmental externality problems brought about by the excessive pursuit of economic efficiency during the development process and enhance equity. In more detail, green finance can guide the flow of resources from highly polluting and energy-intensive industries to sustainable and technologically advanced industries, create environmentally friendly and green production chains and form environmentally friendly consumption concepts while reminding financial institutions to avoid overemphasizing short-term interests and pursue sustainable investment development. Moreover, the portfolio of green financial instruments can diversify project risks and optimize the risk management system, and the price signals transmitted by the carbon emission trading market and related derivatives can assist in making economic decisions.

The assessment of green finance consists of three aspects: the first is the scale of green finance at the financial sector level which is assessed by the market value of green credit, green bonds, green investment, green development funds, green insurance, carbon finance and other related financial products. These financial products internalize the cost of external environmental pollution generated in the process of enterprise development. The second is the construction of enterprise-level green development innovation capability, represented by the number of green patents of industrial enterprises above the designated size. In theory, when the environmental performance of enterprises such as green technology innovation is better, enterprises can obtain lower-cost, longer-term and larger-scale external financing. The third are green construction facilities at the government level, represented by the proportion of green fiscal expenditure. Jiang and Wei [12] believed that direct green expenditure from finance can provide public goods such as green financial infrastructure including related laws and information platforms, and can also provide convenience or reduce costs for green projects, reducing information asymmetry and promoting the development of green finance.

2.2. Regional Economy

At present, many assessments of green finance are based on a micro perspective, such as Akomead et al [13], who measured green finance in terms of academic publications. The regional economy, on the other hand, is based on a macro perspective. This paper explores and compares the overall effect of green finance development in a spatial and temporal dimension with a regional focus, without limiting the role of green finance construction to financial institutions such as banks. The interaction relationship between regional green finance and regional economy is shown in Figure 1.

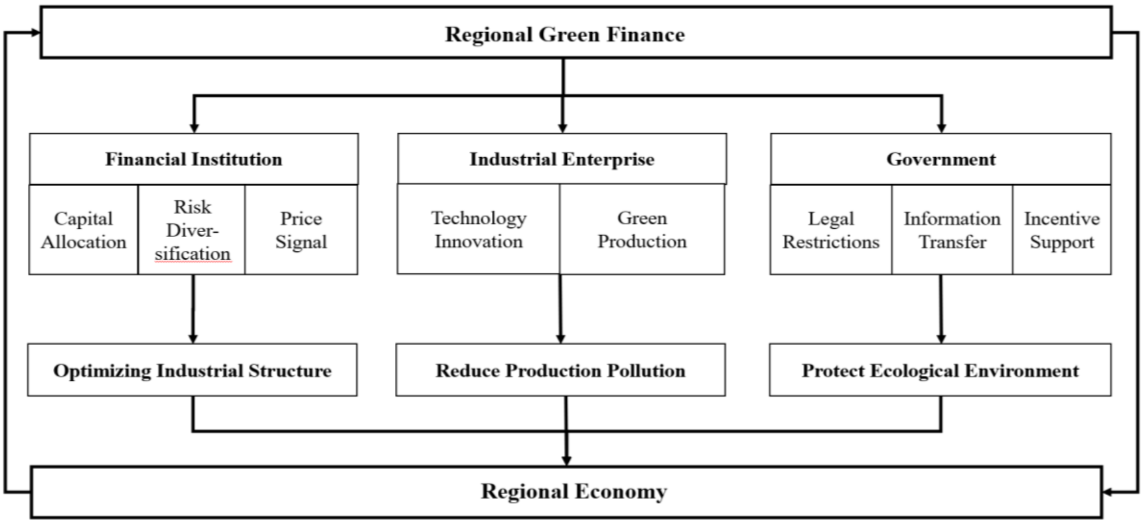

Fig. 1 Regional green finance and regional economy mechanism diagram

Regional economy evaluation indicators include not only economic structure, economic aggregate and economic efficiency, but also consider economic sustainability and economic innovation [14]. The sequential parametric index system is shown in Table 1.

Table 1 Indicators of regional green finance and regional economy system

Subsystem	Second Indexes	Third Indexes	Unit	Type
Green Finance	Scale of green finance	Green credit (X_1)	%	+
		Green bonds (X_2)	%	+
		Green investment (X_3)	%	+
		Green development funds (X_4)	%	+
		Green insurance (X_5)	%	+
		Carbon finance (X_6)	%	+
	Green innovation capability	Number of Green Patents of Industrial Enterprises above Designated Size (X_7)	UNIT	+
	Green facilities	Green fiscal expenditure (X_8)	%	+
Regional Economy	Economic structure	First industrial output (Y_1)	10^8CNY	+
		Second industrial output (Y_2)	10^8CNY	+
		Tertiary industrial output (Y_3)	10^8CNY	+
		Ratio of import and export (Y_4)	%	-
	Economic aggregate	GDP(Y_5)	10^8CNY	+
		Gross industrial product (Y_6)	10^8CNY	+
		Retail sales of social consumer goods (Y_7)	10^8CNY	+
		Resident population (Y_8)	UNIT	+
		Investment in fixed assets (Y_9)	CNY	+
	Economic efficiency	GDP per capita (Y_{10})	CNY PP	+
		Local fiscal revenue (Y_{11})	CNY	+
	Economic sustainability	Wastewater emission/GDP (Y_{12})	m^3/ CNY	-
		Sulfur dioxide emission/GDP(Y_{13})	m^3/ CNY	-
	Economic innovation	Number of valid invention patents of industrial enterprises above the scale (Y_{14})	UNIT	+

Note: ' + ' represents a positive variable and ' - ' represents a negative variable. For this paper, green credit is total credit for environmental protection projects divided by credit in Gansu; green bonds are green bonds issued divided by total bonds issued in Gansu; green investment is investment in environmental pollution control divided by GDP of Gansu; green development fund total market value of green funds divided by market value of all funds in Gansu; green insurance is environmental pollution liability insurance income divided by the total premium income in Gansu; carbon finance is carbon trading, energy use right trading, emission right trading divided by the total equity market trading in Gansu; green fiscal expenditures are fiscal environmental protection expenditures divided by the general budget expenditures in Gansu.

3. Critic Methodology

CRITIC (Criteria Importance Though Intercrieria Correlation) was proposed by Diakoulaki [15] as an objective method for assigning weights to indicators within a system. It revolves around two factors: first, contrast, represented by the standard deviation, which can reflect the degree of variation in the values of evaluation indicators; and second, contradiction, represented by the correlation coefficient, which can reflect the degree of similarity or conflict between two indicators. The advantage of the CRITIC weighting method is that it not only encourages the outstanding performance of a single indicator and increases innovation, but also eliminates the overlap between indicators and enhances the accuracy and rationality of evaluation results.

The steps of the CRITIC method are as follows:

STEP 1: Data standardization. With m research objects and n evaluation indicators, the matrix $X = (x_{ij})_{m\times n}$ is formed. To ensure that different types of indicators can be compared, the variables need to be dimensionless, and the elements of the standardized data matrix are set as x_{ij}'.

If the indicator x_j is better when it is smaller, the indicator is negative, such as the indicator wastewater emissions/GDP, which measures the economic sustainability. The smaller the value, the smaller the environmental cost needed to develop a certain level of the economy, expressed as:

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

If the indicator x_j is better when it is larger, the indicator is positive, as in the case of green bonds, where a larger value means more capital is invested in the green sector, expressed as:

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

STEP 2: Comparability construction. The standard deviation σ_j is used to express the comparability of j indicators. The standard deviation is larger if an indicator has outstanding performance relative to the mean, expressed as:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(x_{ij}' - \overline{x_j'})}{m-1}} \tag{3}$$

STEP 3: Ambivalence construction. Using f_j to denote the ambivalence between indicator j and other indicators, expressed as:

$$f_j = \sum_{k=1}^{m}(1 - r_{jk}) \tag{4}$$

Using Pearson correlation coefficient r_{jk} to express the correlation coefficient between indicator j and indicator k and the correlation between different indicators can reflect ambivalence. More exactly, when two indicators are significantly positively correlated, the value of ambivalence is small; when two indicators are significantly negatively correlated, the value of ambivalence is large.

STEP 4: Calculate the information-carrying capacity of the index. Use C_j to denote the information-carrying capacity of indicator *j*, expressed as:

$$C_j = \sigma_j f_j \tag{5}$$

STEP 5: Assign weights. Assign a greater weight to the indicator that carries more information, i.e., the weight of indicator *j* can be expressed as:

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \tag{6}$$

4. Synergy Model Construction

Regional green finance and regional economy are two subsystems with different attributes and structures. When the degree of interaction of subsystems is greater than the ability to move independently, the composite system forms an organizational structure with certain functions and achieves an orderly state, and vice versa the system is in a disorderly situation. The degree of synergy refers to the scale effect resulting from the interaction of two independent subsystems in a composite system, and the overall effect is greater than the sum of each system. In other words, the synergistic process changes the system from disorderly to orderly. We first identify the orderliness of subsystems separately, and then construct the synergy model of the composite system.

4.1. Subsystem Synergy Degree Model Construction

Denote the regional green finance and regional economy composite system by $S = \{S_1, S_2\}$, where S_1 is the regional green finance subsystem and S_2 is the regional economy subsystem, and the interaction of the two makes the composite system shift from disorder to order. Also, $x_1 = (x_{11}, x_{12}, \cdots, x_{1n})$ denotes the order parameter of the regional green finance subsystem, representing the regional green finance development status; $x_2 = (x_{21}, x_{22}, \cdots, x_{2n})$ denotes the order parameter of the regional economic subsystem, representing the regional economic development level. Moreover, when x_{ij} is a positive indicator, the larger is the better; when x_{ij} is a negative indicator, the smaller is the better. β_{ij}, α_{ij} are the upper and lower limits of x_{ij} respectively. The degree of contribution of each sequential covariate indicator to the subsystem is:

$$u_i(x_{ij}) = \begin{cases} \frac{x_{ij}-\alpha_{ij}}{\beta_{ij}-\alpha_{ij}} \\ \frac{\beta_{ij}-x_{ij}}{\beta_{ij}-\alpha_{ij}} \end{cases} \qquad i = 1,2; j = 1, \cdots, n \tag{7}$$

The contributions of the subsystem indicators to the composite system can be measured by the integration of the function $u_i(x_{ij})$ with the mathematical expression:

$$S_i = u_i(x_i) = \sum_{j=1}^{n} w_j u_i(x_{ij}) \qquad w_j \geqslant 0, \sum_{j=1}^{n} w_j = 1 \tag{8}$$

Where w_j is the weight of each indicator, $u_i(x_i)$ is the subsystem orderliness, and $u_i(x_i) \in [0,1]$.

4.2. Synergy System Model Construction

Since the composite system always evolves and develops continuously over time, dynamic measurements are required by introducing temporal order. $u_i^{t_0}(x_i)$ is the orderliness of the subsystem at the moment of t_0, and $u_i^{t_1}(x_i)$ is the orderliness of the subsystem at the moment of t_1. If $u_i^{t_1}(x_i) \geqslant u_i^{t_0}(x_i)$, it indicates that the composite system is ordered in the time period of $[t_0, t_1]$ and the two subsystems have positive synergistic effects. The comprehensive synergy degree of the operation for this composite system is expressed by the synergy degree U in the composite system of regional green finance and regional economy as:

$$U = \lambda \sqrt[n]{\prod_{i=1}^{n} \left| u_i^{t_1}(x_i) - u_i^{t_0}(x_i) \right|} \tag{9}$$

$$\lambda = \begin{cases} 1, u_i^{t_1}(e_i) \geqslant u_i^{t_0}(e_i) \\ -1, u_i^{t_1}(e_i) < u_i^{t_0}(e_i) \end{cases}$$

Where U ∈ [-1,1]. The more U tends to 1, the greater the synergy effect between regional green finance and regional economy. And the smaller U is, the lower the orderliness of the composite system and the smaller the synergy between the two subsystems.

5. Empirical Analysis

5.1. Selection of Research Objects and Data Collection

Gansu Province is located in the northwest inland of China, belonging to underdeveloped economic regions. GDP in 2021 is 3231 billion yuan (27/31), the industrial structure of the tertiary industry accounts for 53%, and the population has continued to decline since 2019. Not only that, Gansu has poor natural geography, a weak buildable environment, and an imperfect and underactive financial market system. However, Gansu Province has abundant mineral, wind energy and other energy resources, which can contribute to sustainable economic development if they can be used effectively in the process of China's vigorous development of green economy, such as the emerging construction of new energy and other green industries. This paper explores the degree of synergistic development between green finance and the regional economy in Gansu province, which can assess the effectiveness of green finance construction on the high-quality economic growth of underdeveloped regions and provide reliable suggestions for subsequent economic growth.

The data of the indicators are obtained from China Industrial Statistical Yearbook, China Financial Yearbook, China Insurance Yearbook, China Environmental Statistical Yearbook, Gansu Statistical Yearbook, wind database and public information of the Ministry of Finance from 2008 to 2021. Trends in regional green finance indicators in Gansu Province are shown in Figure 2.

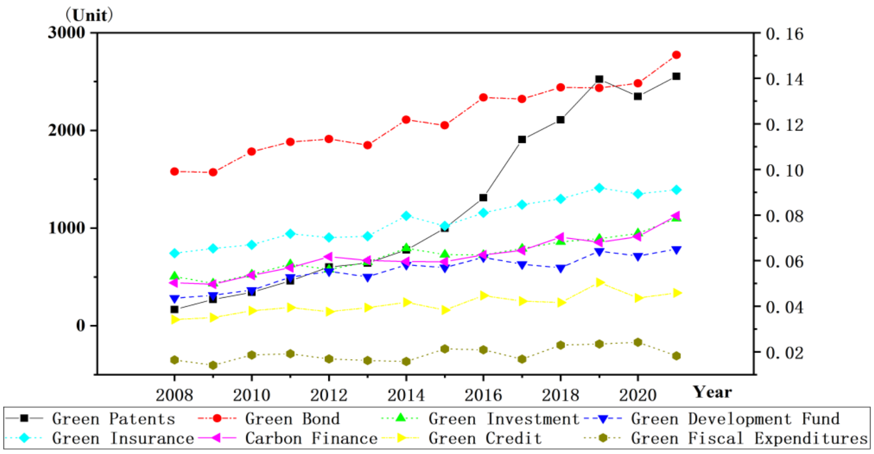

Fig. 2 Trends in regional green finance indicators from 2008 to 2021

As can be seen from Figure 2, the overall trend of all indicators of regional green finance is on the rise, showing that the construction of the green financial system in Gansu Province has been effective. Among them, the financial indicators of green bonds accounted for the largest increase of 34% and innovation indicators of the number of green patents in industrial enterprises above the scale increased by up to 14 times. Moreover, infrastructure indicators of green fiscal spending proportion is relatively stable.

5.2. Calculation of Indicator Weights

After standardizing the indicators of green finance and regional economy in Gansu Province, the contrastive σ_j, contradictory f_j, information-carrying capacity C_j and weight w_j of each indicator are calculated by equations (3)-(6) respectively, and the calculation results are shown in Table 2.

Table 2 Index weights of green finance and regional economy system in Gansu Province

Subsystem	Indicators	Comparability σ_j	Ambivalence f_j	Information-carrying capacity C_j	Weight w_j
Green Finance	Green credit (X_1)	0.260	1.263	0.329	0.117
	Green bonds (X_2)	0.293	0.757	0.222	0.079
	Green investment (X_3)	0.270	0.935	0.253	0.090
	Green development funds (X_4)	0.306	1.032	0.316	0.113
	Green insurance (X_5)	0.335	0.734	0.246	0.088
	Carbon finance (X_6)	0.267	1.062	0.284	0.101
	Number of Green Patents of Industrial Enterprises above Designated Size (X_7)	0.360	0.881	0.317	0.113
	Green fiscal expenditure (X_8)	0.302	2.782	0.839	0.299
Regional Economy	First industrial output (Y_1)	0.270	3.565	0.963	0.041
	Second industrial output (Y_2)	0.263	4.355	1.145	0.048
	Tertiary industrial output (Y_3)	0.328	3.255	1.066	0.045
	Ratio of import and export (Y_4)	0.325	15.896	5.162	0.218
	GDP(Y_5)	0.291	3.162	0.919	0.039
	Gross industrial product (Y_6)	0.305	3.751	1.143	0.048
	Retail sales of consumer goods (Y_7)	0.289	3.145	0.910	0.038
	Resident population (Y_8)	0.297	17.424	5.176	0.218
	Investment in fixed assets (Y_9)	0.281	6.291	1.770	0.075
	GDP per capita (Y_{10})	0.282	3.216	0.907	0.038
	Local fiscal revenue (Y_{11})	0.313	3.245	1.016	0.043
	Wastewater emission/GDP (Y_{12})	0.298	3.251	0.969	0.041
	SO_2 emission/GDP(Y_{13})	0.362	3.534	1.278	0.054
	Number of valid invention patents of up-scale industrial enterprises (Y_{14})	0.343	3.775	1.293	0.055

From Table 2, firstly, the large ambivalence of the green fiscal expenditure indicator in the green financial system makes its weight increase. On one hand, it is because the fiscal expenditures are not directly used in a large amount on enterprise green financing and have little correlation with financial level indicators. On the other hand, the government needs to have more public facilities infrastructure input because the financial input will have a significant effect in the early stage of green finance construction, so the large weight is reasonable. However, when the fixed input part of infrastructure construction, such as the public information platform, is completed, the proportion of government-led green financial expenditure should be appropriately reduced, and the indicator can be removed so that the invisible hand of the market can lead the green finance system to enhance efficiency.

When it comes to the regional economic system, the ambivalence of the import/export ratio is as high as 15.89. Though decreasing since 2009, the import/export ratio of Gansu Province has always been much greater than 1 and has increased significantly since 2017, indicating that imports are much greater than exports in Gansu Province. In other words, the province lacks competitive or high-value-added industries and is increasingly dependent on imports only exporting low-value products. This economic indicator is very important for the long-term development of Gansu Province, implying that Gansu Province has to undergo industrial transformation to build up the core economic competitiveness of the province, and is therefore given great weight. In addition, the regional economic system has the largest ambivalence in the number of resident population at 17.424, which is much higher than the other indicators. Although the number of resident population steadily increases from 2010-2018, it decreases significantly from 2019 onwards, which shows that Gansu

Province is not attractive enough for the population. However, talent is an important element of economic development and needs more attention from the market and the government.

5.3. Analysis of Synergy Degree

The degree of order of the regional green finance and regional economy subsystems in Gansu Province are calculated according to equation (6), and then the degree of synergy of the regional green finance and regional economy composite system is derived according to equation (7). The trends in the degree of orderliness of the green finance and regional economic subsystems and the degree of synergy of the composite system in Gansu Province are shown in Figure 3.

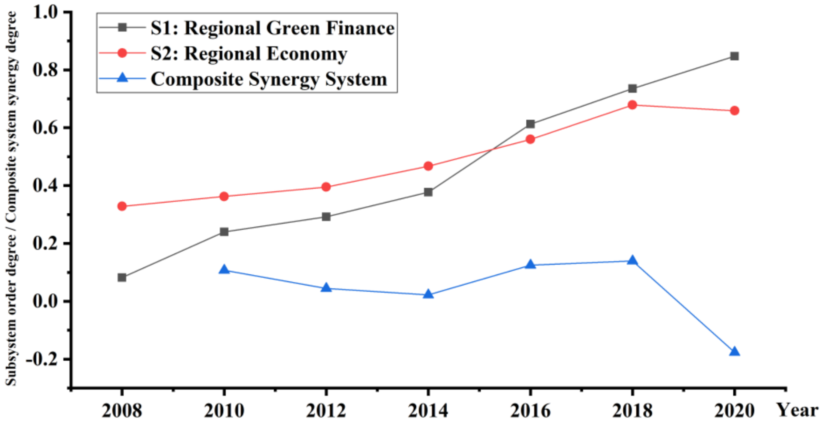

Fig. 3 Subsystem order / composite system synergy in Gansu Province.

5.3.1 Subsystem Order Degree Analysis

Figure 3 shows that, in general, there are rising trends for the orderliness of the regional green finance and regional economy subsystems in Gansu Province, and the orderliness of the regional green finance subsystem is growing faster than that of the regional economy subsystem**.**

Regarding the regional green finance subsystem, its orderliness rose from 0.08172 in 2008 to 0.8471 in 2020, and in 2015 the orderliness of the regional green finance subsystem exceeded that of the regional economic subsystem for the first time. Moreover, in 2019, Lanzhou New Area in Gansu Province became the second batch of Green Finance Reform and Innovation Experimental Zones, and then Gansu released the Implementation Plan on Accelerating the Establishment of a Sound Economic System for Green, Low-Carbon and Circular Development, with increasing policy promotion. From the construction of standards, assessment and evaluation of the green financial system and monetary incentives to the formation of a multi-level green financial product market, regional green finance has been effectively developed.

In addition, from 2008 to 2015, the regional economy was ahead of green finance, indicating that the economy guided and promoted the development of green finance. However, from 2015 to 2020, the growth of the regional economy order slowed down, and the gap with the regional green finance order gradually increased. The regional economy declined slightly in 2020 after being hit by the COVID-19 pandemic and international trade constraints.

5.3.2 Composite System Synergy Analysis

Figure 3 shows that there exists a down-up-down development trend for the synergy degree of the composite system which is generally at a low level of synergy. Moreover, the change of composite synergy can be divided into the following three stages:

Phase I: 2008-2014, the orderliness of regional green finance and regional economic systems gradually increased, but the synergy of the composite system gradually decreased, but the synergy was always greater than 0, indicating a slight synergy between the two subsystems. The Chinese national strategy focusing on environmental and economic sustainability was put forward during this period, and rapid economic growth led to the rapid development of green finance, with the emergence of multi-level green financial products such as green credit and green insurance.

Phase II: Years 2014-2018 saw rapid growth in regional green finance and a slowdown in regional economic growth, with the synergy of the composite system increasing year on year and reaching a peak in 2018, showing that the two systems have been in a good state of synergy. This indicates that regional green finance can contribute to regional economic growth. During this period, the rapid growth in the issuance of green financial products such as green bonds in Gansu Province has reduced the dependence of economic growth on high-emission heavy industries and traditional energy sources, and increased the share of clean energy in the energy mix. And the growth of the regional economy has provided more financial support for regional finance because the injection of government capital has incentivised more market capital to involve in the green finance market. In 2018, Gansu ranked 11th in the country in the level of green financial development with the largest increase in China.

Phase III: 2018-2021, although regional green finance is still growing at a high rate, the regional economy is declining, and the synergy of the composite system is negative, indicating that the two subsystems are in a slightly dysfunctional state with no synergistic effect. In particular, despite the establishment of the Lanzhou New Area Green Finance Reform and Innovation Pilot Zone in Gansu Province in 2019 to lead the province's green economy, the degree of synergy is insufficient resulting from the decline in economic dynamism, possibly due to the impact of the COVID-19 pandemic.

6. Conclusion

(1) From the system dimension, this paper selects 8 sequential parameters representing regional green finance subsystem that can reflect the scale of regional green finance, green innovation capacity and green infrastructure construction and 14 sequential parameters representing regional economic subsystem that can reflect the regional economic structure, economic aggregate, economic efficiency, economic sustainability and economic innovation to construct a composite system. A synergy effect analysis of the composite system was carried out to evaluate the synergistic development of regional green finance and regional economy in Gansu Province.

(2) Taking Gansu Province as the research object, the synergy model was applied to analyze the synergy benefits between regional green finance and regional economy in underdeveloped regions. The results show that the synergy of the compound system in Gansu Province shows a decreasing-rising-decreasing trend, and the overall degree of synergy is at a low level.

(3) The CRITIC algorithm is innovatively used to assign weights to indicators by calculating and the degree of dispersion of indicators and the degree of correlation between indicator. The contrast and contradiction between indicators are comprehensively considered, which fully reduces the subjective tendency and repeatability of weights.

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