

*Original Research*

# The Development Level of Green Finance in Chengdu-Chongqing Twin-City Economic Circle of China Based on Grey Correlation Model

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## Abstract

An evaluation index system for the development level of green finance from the five dimensions of green credit, green securities, green insurance, green investment, and carbon finance was constructed. The grey correlation model was used to calculate the grey correlation degree between cities and regions such as Chongqing and Chengdu under each index dimension, and further evaluates the contribution of cities in the Twin Cities Economic Circle of Chengdu-Chongqing Region to the development of regional green finance from the perspective of regional interior. The empirical results show that Chengdu and Chongqing have the highest contribution to the development of regional green investment, Mianyang and Chongqing have the highest contribution to the development of regional green insurance, Chengdu and Mianyang have the highest contribution to the development of regional green credit, Chengdu has the highest contribution to the development of regional green securities, and Chengdu and Chongqing have the highest contribution to the development of regional carbon finance. Overall, Chengdu and Chongqing have played a “dual core” role in the development of green finance in the twin-city economic circle in the Chengdu-Chongqing region. In the future, the Chengdu-Chongqing region should actively promote green investment, continue to develop green insurance, further promote green credit, actively expand the coverage of green securities, improve the construction of carbon trading markets, and further promote the construction of a regional green financial system.

**Keywords:** green finance, economic circle, grey correlation analysis

## Introduction

Social development is inseparable from financial support, and green development is also inseparable from green finance, and the definition of green finance has different connotations at different times. Green finance is also called “environmental finance” or “sustainable finance”, and scholars at home and abroad have different connotations of green finance. With the passage of time, the connotation of green finance in China has been enriched, developed and improved. In the early studies, green finance was understood as environmental finance, that is, financial activities that can be used to protect the environment and green development. In August 2016, the seventh ministry of the People’s Bank of China jointly issued the Guidance on Building a Green Financial System, which defines green finance as economic activities that support environmental improvement, climate change and the economical and efficient use of resources, i.e. financial services provided for project investment and financing, project operation and risk management in the fields of environmental protection, energy conservation, clean energy, green transportation and green buildings, etc. In September 2016, the G20 Green Finance Study Group released the G20 Green Finance Synthesis Report, which defines “green finance” as investment and financing activities that can generate environmental benefits to support sustainable development. In this paper, the concept of green finance adopts the definition of green finance in the Guidance on Building Green Financial System and briefly introduces the green financial system to understand the service forms of green finance from the perspectives of green credit, green securities, green insurance, and other green financial services.

At the December 2009 Climate Conference in Copenhagen, China proposed that by 2020, China’s carbon dioxide emissions per unit of GDP should be reduced by 40%-45% compared with 2005. In March 2016, the 13<sup>th</sup> Five-Year Plan clearly proposed to “establish a green financial system, develop green credit and green bonds, and establish a green development fund”. In August 2016, seven ministries and commissions jointly issued the Guiding Opinions on Building a Green Financial System, which further elaborated on the construction of a green financial system, indicating that the development of green finance has risen to the height of national strategy. In 2021, carbon peaking and carbon neutrality goals were incorporated into the 14<sup>th</sup> Five-Year Plan and became an important issue for sustainable development in China. Since the release and implementation of the Outline plan for the construction of the Twin Cities Economic Circle in the Chengdu-Chongqing Region in 2021, the Chengdu-Chongqing Twin Cities Economic Circle has helped the economic development of the western region, and has become an important reserve support for the Yangtze River Economic Belt. Meanwhile, it has promoted the sustainable

development of the Yangtze River Economic Belt, and has laid a solid economic foundation for the green financial development of the Chengdu-Chongqing area. Therefore, it is of great significance to study the development of green finance in the twin-city economic circle in the Chengdu-Chongqing region.

China’s green finance is still in the early stage of development, but with the continued implementation of green finance policies, China’s green finance has grown significantly. China’s financial system is dominated by banks, and green credit has become the main force of China’s green financial system, of which the cumulative green credit balance growth rate in 2020 was as high as 23.73%, and green credit achieved linear growth. The growth rate of green credit balance in the eastern region steadily ranks first, accounting for more than 86% of the national ratio. While the scale of green credit in the eastern region is leading the development, the central and western regions are also accelerating to catch up. The scale of green bonds is second only to green credit, and is the second largest vehicle of green finance in China. 2020 issuance amounted to 550.8 billion yuan, and the cumulative issuance amount reached 115.89 billion yuan green credit scale achieved exponential growth. Similarly, the number of green bond scale in the eastern region far exceeds that in the western region. Green insurance, in recent years, product types continue to innovate, the initial establishment of the service system, in green finance to play an increasingly medium to high role, green insurance risk protection efficacy continues to enhance.

The Chengdu-Chongqing Economic Circle is a key experimental area and demonstration area for the development of new-type urbanization in recent years, which not only provides an important platform for the large-scale development of the western region, but also provides strategic support for the Yangtze River Economic Belt. Using per capita GDP to measure the economic development level of Chengdu-Chongqing region, in general, the per capita GDP of Chengdu and Chongqing region continued to increase, and the per capita GDP level of Chengdu was relatively high, and the growth curve was relatively flat between 2012 and 2015, and the per capita GDP growth rate of Chengdu City accelerated significantly after 2016.

During 2012-2020, the level of green finance development in the twin-city economic circle of Chengdu-Chongqing region showed a year-on-year rising trend, with a slight decline during 2014-2016, and in general the overall development of green finance in the twin-city economic circle of Chengdu-Chongqing region showed an upward trend. the decline of green insurance in 2016 played a certain inhibiting effect on the growth of green finance development in the twin-city economic circle of Chengdu-Chongqing region, and green securities also from a slow decline in 2012-2015 to a slow rise in 2015-2020, meanwhile the scale of green credit development in Chongqing reached 1.05% in 2020, ranking 11<sup>th</sup> among the provinces and

municipalities, and in terms of growth rate, the growth rate of green credit in Chongqing was as high as 46.19% in 2020, ranking ninth, while the growth rate of Sichuan Province was relatively slow at 18.61%. Overall, the development of green finance in the twin-city economic circle in the Chengdu-Chongqing region rose sharply after 2016.

China's green finance is still in the early stage of development, the future of the state financial funds and financial resources will gradually tilt to the field of green economy, and as the economic center of the west, Chengdu-Chongqing region twin-city economic circle will also receive considerable policy support. Since the re-lease and implementation of the Outline plan for the construction of the Twin Cities Economic Circle in the Chengdu-Chongqing Region, the green finance development of the Chengdu-Chongqing Twin Cities Economic Circle can effectively promote the transformation of the economic structure, help achieve the "double carbon" goal, and help the Chengdu-Chongqing Twin Cities Economic Circle become the "fourth pole" of China's economic growth. How to guide and manage tilted resources to promote the healthy development of the country's economy and social ecology is inseparable from the support of green finance.

Compared with traditional finance, green finance integrates the concept of sustainable development and is a relatively broad concept. Therefore, it is necessary to analyze green finance not only qualitatively, but also quantitatively. At the same time, China has less information disclosure on green finance and lacks a unified statistical caliber, which has affected the implementation effect of green finance policies in China to a certain extent. This paper evaluates the development level of green finance, uses the grey correlation method to explore the correlation between the whole and part of the region, and studies the dynamic development law of green finance in the twin-city economic circle in Chengdu and Chongqing from a quantitative point of view, which is a useful supplement to the regional green finance research method. In this paper, 16 cities in the Chengdu-Chongqing Twin Cities Economic Circle are selected as urban samples, and the annual data from 2012 to 2020 are used as data samples, by constructing the evaluation index system of green finance development level, the grey correlation model is used to evaluate the development level of green finance in Chengdu-Chongqing Twin Cities Economic Circle.

Cowan (1998) thinks that green finance should focus on developing the financing of developing green economy, and it is the combination of green economy and finance [1]. Wang et al. (2019) consider green finance as a new financial tool to solve environmental problems, and the embodiment of financial innovation in the field of environmental protection [2]. Song et al. (2014) introduced the concept of green finance in their study of the effects of economic, social and environmental protection, and found that the synergetic development of economic and social protection could

effectively promote green finance development level [3]. Ji and Zhang (2019) point out that green financial development is a key determinant for the source industry development in future [4]. Cui et al. (2020) argued that a unified financial system for green finance can have an impact on sustainable economic development and green production enterprises [5].

Green finance has a very important significance for the realization of Sustainable Development of China's economy and society, many scholars at home and abroad have more qualitative analysis of it. However, in order to form a unified standard for green finance research and explain the general development law of green finance from a practical perspective, it is necessary to supplement the qualitative research. At present, although the theoretical research on green finance has undergone years of development, there is still no unified green finance evaluation system internationally. This paper sorts out the relevant literature, summarizes the existing research on green finance using comprehensive evaluation methods, and analyzes the views, and indicators and methods in related fields from both macro and micro perspectives.

The evaluation objects of green finance at home and abroad on micro perspectives are mainly micro financial institutions, and the research subjects mainly include scholars, international economic organizations and environmental organizations, the purpose of which is to examine whether financial institutions implement the green concept, implement green responsibilities, and integrate them into business activities, so as to carry out green financial services more professionally. Taking listed banks at home and abroad that comply with the Equator Principles as a sample, Deng et al. (2022) conducted a study on the level of green finance within financial institutions, and believed that the evaluation of green finance level should be based on the four aspects of business status, green strategy, green business and green operation, and the evaluation method adopted was the subjective empowerment method, which determined the weight of each indicator and scored it [6]. The Green Credit Report of the Environmental and Economic Policy Research Center of the Ministry of Environmental Protection of the People's Republic of China analyzes and evaluates the effect of green credit implemented by more than 50 banks in China, and its evaluation system is mainly constructed from the following aspects: green credit strategy and management, green financial services, organizational capacity building, communication and cooperation. Researches on green finance evaluation by the world's financial organizations are increasing, and environmental protection agencies are also involved in the evaluation of green finance. The subjective evaluation method used in the current research of most scholars cannot exclude the interference of human factors. This paper summarizes the relevant literature and finds that the micro research on green finance evaluation mainly focuses on the internal management

and business development of financial institutions, specifically mainly in green business, information disclosure, green operation, institutional strategy and other aspects, which is also the main content of the construction of the evaluation system.

The research on green finance evaluation conducted by scholars from a macro perspective basically focuses on the regional level, and the main purpose of their research is to try to combine regional green finance with the actual environment and evaluate the region as a whole. As China gradually attaches importance to green finance, the evaluation and research of macro perspective can show the implementation effect of green finance policies and can reveal the spatio-temporal history of regional green finance development. The research of green finance from a macro perspective needs to have a panoramic grasp of regional green finance and development, which contains many factors, so the focus of related research is not the same. Some scholars constructed indicators from the perspective of the service scope of green finance. According to China's economic development, Zeng et al. (2014) constructed indicators from the product category of green finance, and selected five levels of green credit, green investment, green insurance, green securities and carbon finance to conduct evaluation research on China's green finance level, and the evaluation method is subjective empowerment method, in the way of scoring to determine the weight of each indicator, it was found that although China's green finance is in the process of continuous development, but it fails to give full play to the role of green finance in promoting the economy, and its support to the economy is limited, so it still needs to develop vigorously [7]. Li (2022) made a comprehensive analysis of the development of green finance in 31 provinces in China in terms of green credit, green bonds, green insurance, and green funds [8]. Lei (2021) et al. Green credit perspective to analyze the spatial impact of green credit on green finance, and provide empirical evidence for the important role of green finance in achieving the win-win goals of economic growth and environmental protection [9]. He (2019) started to build a green finance evaluation index system from three aspects: green finance, green investment and green society, measured and evaluated the comprehensive level of sustainable development of green finance in China from three aspects, and conducted systematic research on the sustainability of China's green finance development [10]. Wang et al. (2021) constructed an indicator system from five aspects: green insurance, green credit, green securities, carbon finance and green investment, studied green finance based on the perspective of green financial service products, and then analyzed the development level of green finance in the region [11].

Some scholars construct evaluation indicators from the perspective of green development of the economic environment. Cai et al. (2017) established an indicator system for green development and used the standard

deviation method to determine the weight of the indicators, thereby measuring the green development status of 12 provinces and cities in the western region [12]. Wang et al. (2018) finally established 45 secondary indicators through analysis and adjustment on the basis of the green development indicator system issued by the four ministries and commissions of the country, which further raised the green development indicator system to a higher level [13]. Zhang et al. (2018) measured the level of green finance in each province in China, and the results showed that although the level of green finance development in each province is different, the degree of promotion of regional economic growth is low, so effective measures need to be introduced to promote the development of green finance, narrow the gap between the green finance levels of provinces, deepen the influence of green finance development, and enable provinces to achieve coordinated development of green finance [14]. Jiang et al. (2020) selected 18 indicators from the three dimensions of economic development, financial development and social environment development, and used the improved entropy method to measure the green finance development level of 25 provinces and cities in China from 2004 to 2017, and the results showed that the development level of green finance in 25 provinces and cities in China was quite different [15].

Some scholars also innovate the evaluation of green finance from the perspective of measurement methods. Yang and Wang (2017) constructed a multi-dimensional model of the indicator system, which can assess the development level of green finance from multiple perspectives, and measure the level of green finance development in Shanghai from 2011 to 2015 [16]. Wang et al. (2021) sorted out the development process of green finance and related green finance and indicator concepts, based on fuzzy mathematical principles and using improved fuzzy comprehensive evaluation methods, they constructed a measurement model suitable for measuring the development level of green finance [17].

At present, in the green finance evaluation research conducted from a macro perspective, an index construction mainly takes into account the scope of green financial services, which can combine green finance with the actual regional environment, thereby improving the comprehensiveness of the green finance evaluation system. Therefore, when constructing the indicators, this paper chooses to construct the index system based on the five dimensions of green credit, green insurance, green securities, green investment, and carbon finance, and considers the objectivity of the evaluation, and the objective empowerment method of this paper is evaluated and studied.

By combing the above research, this paper finds that most of the green finance evaluations from the macro perspective used subjective evaluation methods, which cannot exclude the interference of human factors, and there are few in-depth studies to analyze the

correlation between the overall development of the region and the development of green finance in various parts. Therefore, this paper uses the entropy weight method to objectively empower the weights of indicators, and uses the grey correlation model to analyze the contribution of various cities to the region as a whole, aiming to carry out green finance evaluation more objectively, analyzing the dynamic law of green finance development in the twin-city economic circle in Chengdu and Chongqing, and exploring the relationship between the whole and part of the development of green finance in this region.

**Materials and Methods**

This paper is based on the Guiding Opinions on Building a Green Financial System issued by seven ministries and commissions on August 31, 2016, the Key Evaluation Indicators for the Implementation of Green Credit issued by the China Banking Regulatory Commission on June 27, 2014, and the relevant research of Ma (2015) and Zhang (2018), and through the understanding of the connotation of green finance in the above article and the actual situation of the twin-city economic circle in the Chengdu-Chongqing region, the green finance development level index system of the Chengdu-Chongqing economic circle is established [18, 14].

First of all, the relevant concepts of green finance are considered in the construction of indicators, mainly considering the content of economic, social and environmental sustainable development, and eliminating other irrelevant factors to ensure that the evaluation results are accurate. Secondly, when selecting indicators, the data sources are true and reliable, so that the evaluation results can fully reflect the development level of green finance. Finally, there is a certain correlation between the constructed indicators, which makes the evaluation results reasonable. Based on the above considerations, the index system constructed includes 5 primary indicators of green investment, green insurance, green credit, green securities and carbon finance and 11 secondary indicators. Its specific indicator system is shown in Table 1.

(1) Green investment indicators. Under the green investment indicators, there are two secondary indicators, namely the proportion of public expenditure of energy conservation and environmental protection enterprises and the proportion of environmental governance investment, which can not only reflect the financial integration capacity of the Chengdu-Chongqing Twin-City Economic Circle in green investment, but also reflect the attention and support of the government departments in Chengdu and Chongqing to invest in green industries.

(2) Green insurance indicators. Under the green insurance index, there are two secondary indicators:

Table 1. Evaluation system of green finance development level in Twin-City Economic Circle.

Level indicators	The secondary indicators	Variable meaning
A Green investment	A1: Proportion of government expenditure in energy conservation and environmental protection industries	Public expenditure of energy-saving and environmental protection enterprises in the region/ total financial expenditure in the region
	A2: Proportion of investment in environmental governance	Investment in environmental governance of the region/ GDP of the region
B Green insurance	B1: Proportion of agricultural insurance scale	Agricultural insurance premiums in the region/gross premiums in the region
	B2: Agricultural insurance loss rate	Regional agricultural insurance payout/ regional agricultural insurance premium income
C Green credit	C1: Proportion of green credit scale	Total green credit of 36 listed banks in the region/ balance of local and foreign currency loans in the region
	C2: Information transmission, computer services and software loan share	Loan amount of information transmission, computer service and software industry in the region/ balance of local and foreign currency loans in the region
	C3: Proportion of loans to enterprises with high energy consumption	Loan amount of six energy-intensive industries in the region/ balance of local and foreign currency loans in the region
D Green securities	D1: Ratio of environmental protection enterprises to market capitalization	A stock market value of environmental protection enterprises in this region/ Total market value of this region (CSRC algorithm)
	D2: Ratio of market capitalization of energy-consuming enterprises	A-stock market value of six energy-intensive industries in the region/ Total market value of the region (CSRC algorithm)
E Carbon finance	E1: Carbon emission loan depth	Balance of local and foreign currency loans in the region/ Carbon emissions in the region
	E2: Energy sector debt ratio	Balance of liabilities of energy enterprises in the region/ balance of total liabilities in the region

the proportion of agricultural insurance scale and the loss rate of agricultural insurance. Green insurance can help mitigate the greater environmental impact on agriculture. Therefore, the scale of agricultural insurance and the loss rate are used to reflect the development of green insurance.

(3) Green credit indicators. The Green Credit Indicator consists of three secondary indicators, among which, the proportion of green credit and the proportion of loans in the information transmission, computer services and software industries reflect the positive support of the banking industry and high-tech enterprises for environmental optimization, and also reflect the participation of the banking industry and high-tech enterprises in green finance. The negative indicator of green credit in this paper uses the proportion of loans of high-energy-consuming enterprises to reflect the control of green finance over industries with high consumption and high pollution.

(4) Green Securities Indicator. Under the green securities indicators, there are two secondary indicators, namely, the proportion of the market value of environmental protection enterprises and the market value of high-energy-consuming enterprises, which mainly reflect the capital financing status of environmental protection enterprises and high-energy-consuming enterprises in the capital market in China, among which, the proportion of market value of high-energy-consuming enterprises is a negative indicator, which reflects the change in the proportion of high-energy-consuming A stock market value.

(5) Carbon finance indicators. Carbon finance indicators mainly include two secondary indicators: the depth of carbon emission loans and the proportion of energy enterprises' liabilities. The depth of carbon emission loans can reflect the role and effect of carbon finance in the Chengdu-Chongqing twin-city economic circle to improve the environment. Among them, the proportion of debt of energy enterprises is a negative indicator, which reflects the regional carbon dioxide emission.

The 11 indicators selected in this paper vary greatly in the dimensions of units, so the data cannot be directly compared. This chapter standardizes the data using the initial value calculation method to obtain a new sequence. Regarding the regional relevant indicators, namely green investment, green insurance, green credit, green securities, and carbon finance, the five indicators are obtained after the original data is standardized to ensure the comparability between the indicator data. The grey correlation coefficient and grey correlation degree between the twin-city economic circle area and 16 cities in the Chengdu-Chongqing area were calculated by using the steps of the above formula, and then the contribution of the 16 cities in the Chengdu-Chongqing twin-city economic circle to the overall region under the green finance indicators was judged.

Due to the lack of data on Chongqing counties and the fact that the twin-city economic circle of Chengdu-

Chongqing region basically covers most of the cities in Sichuan Province and Chongqing, the overall data from 2012-2020 for 15 cities in Sichuan Province and 16 cities in Chongqing are finally used. The original data of the green financial development level evaluation index system are obtained from the Sichuan Statistical Yearbook, Chongqing Statistical Yearbook, China City Statistical Yearbook, China Insurance Yearbook, statistical yearbooks of each sample city, Wind database and social responsibility reports and financial annual reports disclosed by each bank. At the same time, based on the actual situation of the twin-city economic circle in the Chengdu-Chongqing region and considering the need for subsequent research, the indicators without caliber in some cities are discarded, and certain indicators with missing data are completed by means of comprehensive measurement and Excel forecast worksheets. In this paper, we refer to and improve the indirect measurement method in the study of Qiu (2017) to measure certain indicators [19].

According to the index evaluation system of entropy law, a matrix of evaluation indicators consisting of  $s$  objects to be evaluated is constructed, and  $m$  evaluation index matrix is expressed as a formula (1).

$$\gamma_{ij} = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \dots & \gamma_{1m} \\ \gamma_{21} & \gamma_{22} & \dots & \gamma_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ \gamma_{s1} & \gamma_{s2} & \dots & \gamma_{sm} \end{bmatrix} \quad (1)$$

In the first step, due to the different dimensions of each indicator, the original data needs to be standardized, and the standardization of the data uses the initial value calculation method, as shown in formula (2).

$$X_{ij} = \left\{ \frac{x_i(1)}{x_i(1)}, \frac{x_i(2)}{x_i(1)}, \dots, \frac{x_i(n)}{x_i(1)} \right\}, j = 1, 2, \dots, n \quad (2)$$

The standardized processing process of the data is based on the data of the proportion of financial expenditure of energy saving and environmental protection industry in ChengYu, Chongqing, Chengdu, Zigong, Luzhou and Deyang (A1) indicator data, and the original data is shown in Table 2.

The original data of the financial expenditure ratio (A1) of the energy conservation and environmental protection industry are standardized to obtain the proportion of financial expenditure of the energy conservation and environmental protection industry (A1) under the unified dimension, and the specific results are shown in Table 3.

In the second step, the sequence difference is calculated, and at the same time  $j = 1, 2, 3$ , the absolute difference between the series and the reference series is compared, thereby determining the maximum and minimum differences of the two stages, as shown

Table 2. Raw data of A1 index.

City	2012	2013	2014	2015	2016	2017	2018	2019	2020
ChengYu	0.0305	0.0344	0.0305	0.0266	0.0267	0.0266	0.0291	0.0294	0.0316
Chongqing	0.0392	0.0473	0.0374	0.0319	0.0369	0.0340	0.0357	0.0353	0.0343
Chengdu	0.0149	0.0158	0.0141	0.0186	0.0152	0.0179	0.0190	0.0201	0.0215
Zigong	0.0213	0.0212	0.0245	0.0248	0.0178	0.0100	0.0115	0.0268	0.0207
Luzhou	0.0314	0.0266	0.0249	0.0194	0.0216	0.0309	0.0324	0.0317	0.0375
Deyang	0.0118	0.0139	0.0192	0.0191	0.0350	0.0360	0.0338	0.0503	0.0395

Table 3. Standardized data of A1 indicator.

City	2013	2014	2015	2016	2017	2018	2019	2020
ChengYu	1.1304	0.9996	0.8726	0.8772	0.8726	0.9536	0.9648	1.0357
Chongqing	1.2072	0.9547	0.8141	0.9408	0.8677	0.9110	0.8994	0.8749
Chengdu	1.0563	0.9439	1.2430	1.0182	1.1968	1.2700	1.3431	1.4378
Zigong	0.9941	1.1509	1.1666	0.8363	0.4706	0.5396	1.2576	0.9713
Luzhou	0.8481	0.7927	0.6173	0.6894	0.9826	1.0326	1.0089	1.1944
Deyang	1.1774	1.6304	1.6234	2.9706	3.0545	2.8659	4.2730	3.3579

Table 4. Calculation results of A1 indicator sequence difference.

City	2013	2014	2015	2016	2017	2018	2019	2020
Chongqing	0.0767	0.0449	0.0585	0.0636	0.0048	0.0426	0.0654	0.1609
Chengdu	0.0741	0.0557	0.3705	0.1410	0.3242	0.3164	0.3784	0.4021
Zigong	0.1363	0.1513	0.2941	0.0408	0.4020	0.4140	0.2929	0.0644
Luzhou	0.2823	0.2069	0.2553	0.1878	0.1100	0.0790	0.0441	0.1586
Deyang	0.0469	0.6308	0.7509	2.0935	2.1820	1.9123	3.3082	2.3222

Table 5.  $\xi$  calculation results of A1 indicator.

City	ChengYu	Chongqing	Chengdu	Zigong	Luzhou	Deyang
$\xi$ value	0.6393	0.5489	0.6671	0.4844	0.4768	0.5221

in Equation (3). The result of calculating the series difference of the A1 indicator is shown in Table 4.

$$\Delta_i = |s_{0j} - s_{ij}|, \quad i = 1, 2, \dots, s \quad (3)$$

The third step,  $\xi$  is generally 0.5 in the grey correlation algorithm, is to assume that each indicator has the same impact on the development of green finance, but this is not the case. Therefore, the value of  $\xi$  should be combined with the weights of different levels of indicators to illustrate that different indicators have different impacts on the development of green finance, so that the grey correlation algorithm is more

scientific and the calculation results are more reliable. The calculation formula of  $\xi$  is shown in equation (4), and the  $\xi$  calculation result of A1 is shown in Table 5.

$$y_i = \sum_{j=1}^n X_{ij} \times w_j (i = 1, 2, \dots, s), \quad \zeta = \frac{1}{n} \sum_{i=1}^n y_i \quad (4)$$

The fourth step is to calculate the correlation coefficient. The maximum and minimum values are found from the results calculated in formulas (3) and used to calculate the correlation coefficients, as shown in formula (5). Because the A1 index only uses some city data of the Chengdu-Chongqing Twin Cities

Table 6. Correlation coefficient of A1 index.

City	2013	2014	2015	2016	2017	2018	2019	2020
Chongqing	0.9595	0.9759	0.9688	0.9662	0.9973	0.9771	0.9652	0.9186
Chengdu	0.9675	0.9754	0.8562	0.9399	0.8719	0.8746	0.8536	0.8459
Zigong	0.9216	0.9137	0.8450	0.9752	0.7995	0.7947	0.8455	0.9614
Luzhou	0.8482	0.8841	0.8607	0.8936	0.9348	0.9523	0.9728	0.9086
Deyang	0.9736	0.7325	0.6970	0.4521	0.4418	0.4746	0.3430	0.4265

Economic Circle, the maximum and minimum values are no longer displayed, and the correlation coefficient calculation results of the A1 indicator are shown in Table 6.

$$\beta_i(j) = \frac{\min_k |s_{0j} - s_{ij}| + \xi \max_k |s_{0j} - s_{ij}|}{|s_{0j} - s_{ij}| + \xi \max_k |s_{0j} - s_{ij}|} \quad (5)$$

The fifth step, calculate the correlation degree, the role of each index in the comprehensive evaluation is different, the correlation coefficient is weighted average, to reflect the correlation relationship between the Chengdu-Chongqing area of the twin-city economic circle and the cities, the formula is shown in the formula (6):

$$R_i = \frac{1}{n} \sum_{j=1}^n w_j \beta_i(j) \quad j = 1, 2, \dots, n \quad (6)$$

Among which,  $\sum_{j=1}^n \omega_j = 1$

## Results and Discussion

As shown in Fig. 1, Fig. 2, Fig. 3, Fig. 4 and Table 7, the column of green finance development indicates the contribution of various cities to the development of green finance in the Chengdu-Chongqing area twin-city economic circle. The grey correlation degree of Chongqing and Chengdu both exceeded 0.85, which is significantly higher than that of other cities, indicating that Chengdu and Chongqing have the highest contribution to the development of green finance in the Chengdu-Chongqing Twin Cities Economic Circle. The grey correlation degree of green finance development in the 16 cities in the Chengdu-Chongqing Economic Circle is higher than 0.5, indicating that all cities in the Chengdu-Chongqing region are more closely related to the development of regional green finance. As the economic center of the northwest region, Chengdu-Chongqing region has long established a complementary and coordinated development relationship, so the Chengdu-Chongqing region as a whole is more likely to receive the overall impact of economy and policy, which can be seen from the gray correlation of green finance development in 16 cities in the Chengdu-

Chongqing economic circle. At the same time, Chengdu and Chongqing also actively innovate green financial products and services to support the development of energy conservation and emission reduction industries, so the green finance of the two has developed rapidly, which has played a good leading role in the development of green finance in the entire Chengdu-Chongqing Twin Cities Economic Circle.

The overall green financial development level of the twin-city economic circle in the Chengdu-Chongqing region has steadily increased, and the overall green financial development level of the twin-city economic circle in the Chengdu-Chongqing region has steadily increased during 2012-2020, and the regional green financial development has significantly accelerated after 2016, and this paper analyzes and expands the convergence from the perspective of practical significance, and believes that the green financial development of the twin-city economic circle in the Chengdu-Chongqing region maintains good momentum for the following reasons. It may be due to the release and implementation of the Guidance on Building Green Financial System in 2016, and the successive release of policy opinions on green financial development in the twin-city economic circle of the Chengdu-Chongqing region, which, as an important economic center in the west, has increased the importance and development of green finance subsequently.

The column A in Fig. 1 shows the grey correlation between the Chengdu-Chongqing Twin Cities Economic Circle and the cities under the green investment indicators. In terms of green investment, Chongqing has the highest degree of contribution to the development of regional green finance, with a correlation degree of 0.9199, and Ziyang City has the lowest degree of contribution to the development of regional green finance, with a correlation degree of 0.6255. This shows that Chongqing has the highest degree of contribution to the development of regional green finance in terms of green investment, and the possible reason is that Chongqing's total financial volume is the highest in the region, so Chongqing's green investment activity is relatively high and the investment amount is large. In recent years, Chongqing has taken a series of measures to support green investment, such as supporting the listing of green enterprises through the securities market, increasing energy conservation and

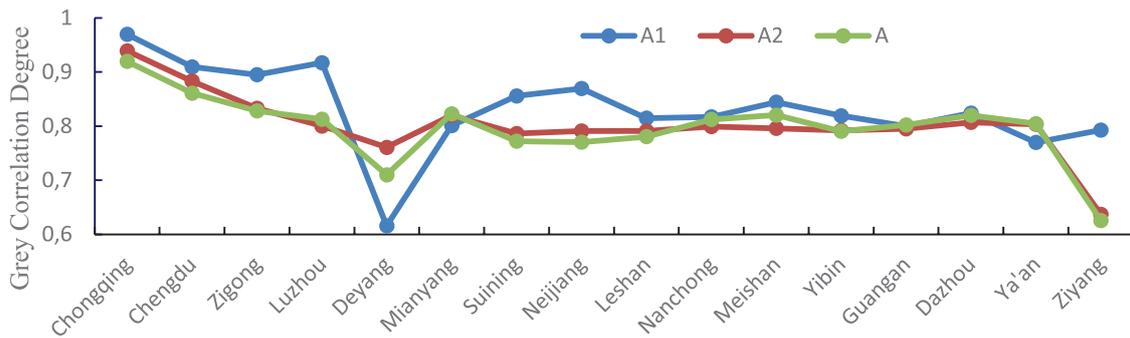


Fig. 1. Grey correlation degree of green investment.

environmental protection expenditure, and increasing the amount of investment in environmental governance, which has a significant role in promoting green investment.

This paper also further analyzes the contribution of various cities to the overall development of regional green finance under the secondary indicators. Specifically, as can be seen from Fig. 1, A1 reflects the proportion of financial expenditure of the energy-saving and environmental protection industry. On this indicator, the degree of green investment development between the Chengdu-Chongqing Twin Cities Economic Circle region and 16 cities is relatively consistent, and the overall green financial development degree of the cities and regions in the Chengdu-Chongqing Twin Cities Economic Circle is very high, and the correlation degree is generally above 0.6, of which Chongqing has the highest contribution to the region as a whole, with a correlation degree of 0.9698. A2 reflects the proportion of investment in environmental governance, and the grey correlation between the region and Chongqing municipality is the highest in this indicator, indicating that Chongqing has a higher degree of contribution under the current indicators and has done a better job in environmental governance. The Chengdu-Chongqing Twin Cities Economic Circle will strengthen inter-regional cooperation to jointly build ecological and environmental protection and increase its investment in environmental governance.

The B column in Fig. 2 shows the grey correlation of cities under the green insurance indicator. The grey correlation degree between the region and Mianyang city is the highest, with a correlation degree of 0.9254, indicating that Mianyang has the highest degree of contribution to the development of regional green finance in terms of green insurance. The grey correlation degree between the region and Ziyang city is the lowest, indicating that Ziyang city has the lowest contribution to the development of regional green finance in terms of green insurance. Mianyang City is the traditional industrial base in Sichuan, the primary and secondary industries account for a relatively high proportion, in recent years, the number of agricultural insurance enterprises in Mianyang area has reached about 300. The combination of compulsory agricultural insurance and commercial agricultural insurance has been actively constructed to promote the good operation and safe development of insurance market, thus supporting and promoting the development of green insurance in Chengdu-Chongqing Twin-City Economic Circle.

As can be seen from Fig. 2, green insurance is mainly measured from four levels, B1 reflects the scale of agricultural insurance, in this indicator, Leshan city has the highest contribution to the region as a whole, Ya'an city has the lowest contribution to the region as a whole, and the correlation between the two is 0.4041, reflecting the uneven development of the agricultural

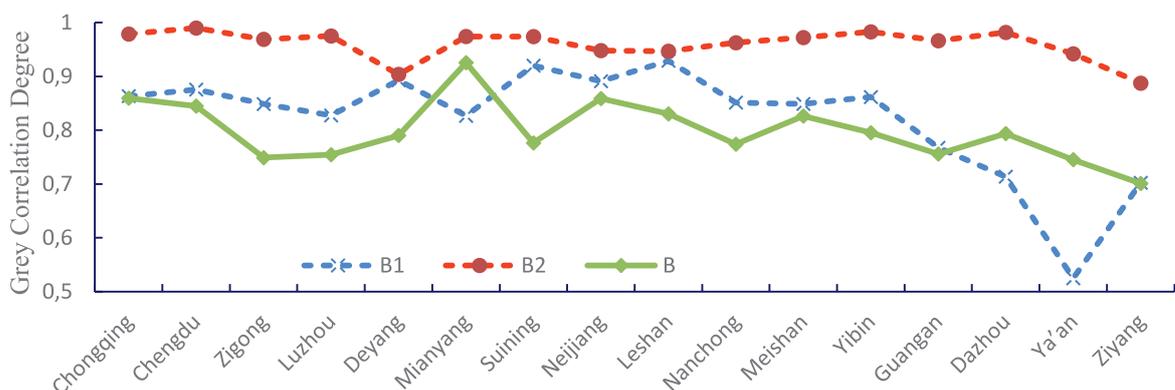


Fig. 2. Grey correlation degree of green insurance.

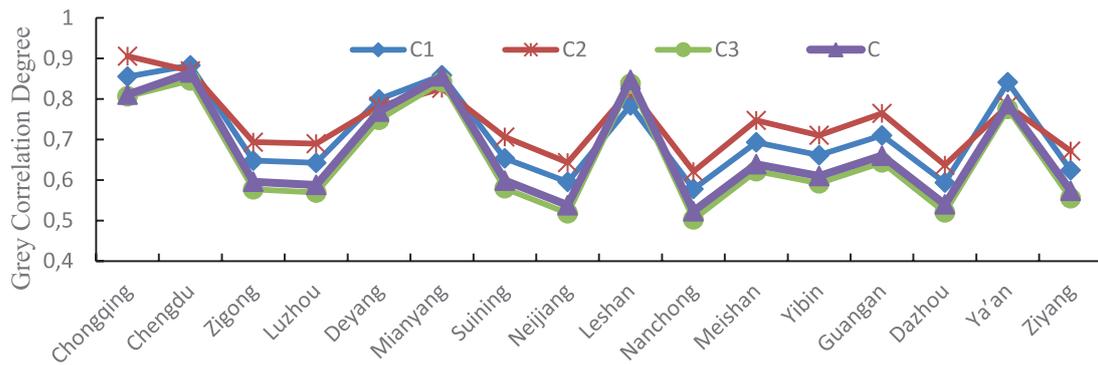


Fig. 3. Grey correlation degree of green credit.

insurance industry in the Chengdu-Chongqing Area Twin Cities Economic Circle, of which the development of the agricultural insurance industry in Ya'an city has played a certain inhibitory role in the development of the regional insurance industry in the Chengdu-Chongqing Twin Cities Economic Circle. B2 reflects the agricultural insurance payout ratio, in which Chengdu has the highest contribution to the region as a whole, and the correlation between cities among regions is not much different. In terms of green insurance, although the correlation between the Chengdu-Chongqing area and the city in the Chengdu-Chongqing Twin Cities Economic Circle is different, the correlation between other indicators is not much different, and in general, the green financial development level between the Chengdu-Chongqing region and the cities is basically balanced in the green insurance indicator.

As shown in Column C of Fig. 3, in terms of green credit, the grey correlation between the region and Chengdu is the highest, with a correlation degree of 0.8654, indicating that Chengdu has the highest contribution to the development of regional green finance in terms of green credit. The reason may be that the average annual growth rate of green credit (energy conservation and environmental protection and service project loans) in Chengdu is greater than the average growth rate of various loans, indicating that environmental protection and service project loans have an advantageous growth rate among various types of loans, which has a leading role in the development of green credit in the Chengdu-Chongqing twin-city economic circle.

As can be seen in Fig. 3, C1 represents the scale of green credit, and Chengdu has the highest contribution to the region as a whole, with a correlation of 0.8829.

C2 reflects the scale of loans to the information transmission, computer services and software industries, and Chongqing has the highest contribution to the region as a whole. In recent years, through the construction of Internet bases, communication links, and economic Internet strategies, Chongqing's information industry is developing at a high speed. C3 reflects the scale of loans to energy-intensive enterprises, and Chengdu has the highest contribution to the region as a whole. It shows that government agencies and financial institutions such as commercial banks in the Chengdu-Chongqing Twin Cities Economic Circle strictly control the credit scale of high-energy-consuming industries.

The grey correlation degree of each municipality under the green securities indicator is shown in column D of Table 7. Since there are no environmental protection listed enterprises or high-energy-consuming listed enterprises in some cities, the data is missing. From the existing data, in terms of green securities, the grey correlation between the region and Chengdu is 0.905, and the grey correlation between the region and Chongqing is 0.796, which can be clearly seen that the contribution of both in green securities is relatively high. The promotion and implementation of green securities in Chengdu and Chongqing have achieved remarkable results, which have significantly led to the development of green securities in the Twin Cities Economic Circle in Chengdu and Chongqing, and are two important engines for the development of green finance in the Twin Cities Economic Circle in Chengdu and Chongqing. Moreover, the Chengdu-Chongqing Twin Cities Economic Circle is accelerating the pace of integrated development, such as the establishment of the Chengdu-Chongqing Regional Stock Transfer Center "Twin Cities Pass", which has significantly improved

Table 7. Grey correlation degree of green securities.

City	Chongqing	Chengdu	Luzhou	Deyang	Mianyang	Leshan	Nanchong	Yibin	Ya'an
D1	0.881	0.9392					0.6275		
D2	0.7857	0.8653	0.6422	0.8121	0.7591	0.6855		0.7573	0.7121
D	0.796	0.905	0.6632	0.8754	0.8171	0.8289	0.6662	0.8072	0.7632

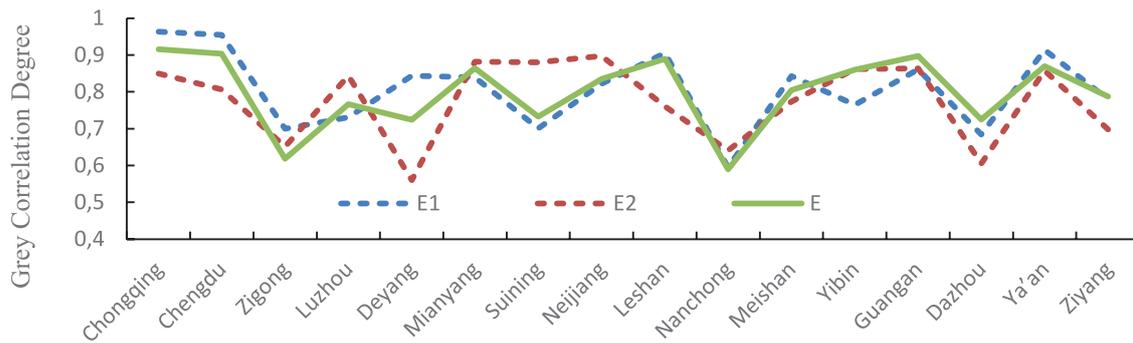


Fig. 4. Grey correlation of carbon finance.

the service capabilities of the Chengdu-Chongqing regional equity market.

As can be seen from Table 7, D1 reflects the proportion of the market value of environmental protection enterprises, and Chengdu has the highest contribution to the region as a whole on this indicator, because in the Chengdu-Chongqing area twin-city economic circle, there are only A-share listed environmental protection enterprises in Chongqing, Chengdu and Nanchong, so there is no correlation between the region and other cities. The average market value of listed environmental protection enterprises in Chengdu exceeds 10 billion yuan, reflecting that the development of listed environmental protection enterprises in Chengdu has a greater role in driving the regional financial development of the Chengdu-Chongqing Twin Cities Economic Circle, and plays a positive role in the development of the regional financial industry. D2 reflects the proportion of the market value of high-energy-consuming enterprises, because some cities do not have six high-energy-consuming listed companies, so the region has no correlation with these cities. Under this indicator, Chengdu has the highest contribution to the overall region, with a correlation degree of 0.8653, and the improvement of the green securities indicator mainly depends on the reduction of energy-consuming enterprises.

The E column in Fig.4 shows the grey correlation degree of cities in the Chengdu-Chongqing Twin Cities Economic Circle under the carbon finance indicator. Obviously, Chongqing has the highest degree of grey correlation in the region, with a correlation degree of 0.916, indicating that Chongqing has the highest contribution to the development of regional green finance in terms of carbon finance. The reason is speculated that as one of the first pilot cities in China, Chongqing established the carbon emission trading market in 2014, which provides solid market support for the development of carbon finance in Chongqing.

As can be seen from Fig. 4, E1 represents the depth of carbon emission loans, and Chongqing and Chengdu have the highest contribution to the region as a whole, and Nanchong has the lowest contribution to the region as a whole. E2 indicates the proportion of energy

enterprises' liabilities, in this indicator, Neijiang city has the highest contribution to the overall region, and Deyang city has the lowest contribution to the regional whole. The debt of traditional energy enterprises in Neijiang city accounts for a large proportion, and the existing development model can no longer drive the development of the local economy.

### Conclusions

This paper uses The Grey Correlation Model of Deng to analyze the contribution of each municipality to the development of regional green finance under each index of the Chengdu-Chongqing Twin Cities Economic Circle from different indicator levels. Judging from the analysis results of the index layer, Chengdu and Chongqing have the highest contribution to the development of regional green investment, Mianyang and Chongqing have the highest contribution to the development of regional green insurance, Chengdu and Mianyang have the highest contribution to the development of regional green credit, Chengdu has the highest contribution to the development of regional green securities, and Chengdu and Chongqing have the highest contribution to the development of regional carbon finance. In general, Chengdu and Chongqing have contributed the most to the development of green finance in the Chengdu-Chongqing Twin Cities Economic Circle, and the promotion effect is obvious, and it is more obvious that Chengdu and Chongqing have a greater contribution to most of the indicators, indicating that Chengdu and Chongqing have played a "double core" role in driving the development of green finance in the twin-city economic circle of Chengdu and Chongqing.

Some places still need to be further improved and perfected, so the following suggestions are made for the development of green finance in the Chengdu-Chongqing Twin Cities Economic Circle.

Actively promote green investment. Judging from the conclusion, green investment has little effect on promoting the overall development of green finance in the region, and Ziyang and Deyang have the lowest

contribution to the Chengdu-Chongqing Twin Cities Economic Circle, and Chengdu and Chongqing have the highest contribution to the Chengdu-Chongqing Twin Cities Economic Circle. Therefore, the twin-city economic circle of Chengdu-Chongqing region should pay more attention to and support green industry investment by government departments, and then actively guide all kinds of institutional investors to conduct business exchange and information exchange for the green investment projects they unfold, and actively guide new investors to enter the green investment field, thus improving the financing capacity of green investment in the twin-city economic circle of Chengdu-Chongqing region.

Continue to develop green insurance. Judging from the conclusion, green insurance has the greatest role in promoting the overall development of green finance in the region, and the contribution of Ziyang and Ya'an to the Chengdu-Chongqing Twin Cities Economic Circle is low, and Mianyang and Chongqing have the highest contribution to the Chengdu-Chongqing Twin Cities Economic Circle. Therefore, the twin-city economic circle in Chengdu-Chongqing region should take mandatory green insurance as the cornerstone, accelerate the reform and innovation of green insurance in the twin-city economic circle in Chengdu-Chongqing region, and actively promote green insurance such as environmental pollution liability insurance, agricultural insurance and green industry insurance. Increase the financial support to the green field, encourage insurance companies to vigorously develop new products, enhance the risk protection mechanism, and reduce the financing risks of different industries and enterprises.

Deeply promote green credit. Judging from the conclusion, green credit has a greater role in promoting the overall development of green finance in the region, and Nanchong and Neijiang have the lowest contribution to the Chengdu-Chongqing Twin Cities Economic Circle, and Chengdu and Mianyang have the highest contribution to the Chengdu-Chongqing Twin Cities Economic Circle. Therefore, the twin-city economic zone in the Chengdu-Chongqing region continues to increase the banking industry's green credit support for environmental protection enterprises by strengthening supervision and implementing different deposit reserves, as well as appropriately controlling the scale of credit for high energy-consuming industries.

Actively broaden the coverage of green securities. The empirical results show that green securities have the smallest role in promoting the development of green finance in the Chengdu-Chongqing Twin-City Economic Circle, and Luzhou and Nanchong have the lowest contribution to the Chengdu-Chongqing Twin-City Economic Circle, and Chengdu and Deyang have the highest contribution to the Chengdu-Chongqing Twin-City Economic Circle. Therefore, the twin-city economic circle in the Chengdu-Chongqing region should increase support for green securities, vigorously develop green securities, increase their coverage, and

actively promote the listing of environmental protection enterprises by appropriately relaxing the conditions for them. Promote the development of green finance business, raise funds for the development of green enterprises, and actively promote the securitization of green funds as well as improve the financing level of energy-saving and environmental protection enterprises.

Improve the construction of carbon trading markets. Judging from the analysis results, the role of carbon finance in promoting the development of green finance in the Chengdu-Chongqing Twin-City Economic Circle is more obvious, and the contribution of Zigong and Nanchong to the region is relatively low, and the contribution of Chengdu and Chongqing to the Chengdu-Chongqing Twin-City Economic Circle is the highest. Therefore, the twin-city economic circle in the Chengdu-Chongqing region should continue to improve the carbon trading market network on the basis of the currently established carbon trading market, and make reasonable layout planning for trading quotas and trading mechanisms. At the same time, with the advice of experts in the region on carbon peaking and carbon neutralization, the local governments will collaborate to promote the regional carbon peaking and carbon neutralization work to provide intellectual support and technical support.

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### Conflict of Interest

The authors declare no conflict of interest.

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