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Comprehensive Evaluation and Comparative Analysis of the Green Development Level of Provinces in Eastern and Western China

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Abstract: Considering the green development initiatives vigorously promoted by China, this paper constructs an evaluation index system that covers six areas, including resource utilization, pollution control, living environment, ecological protection, circular economy, and quality of economic growth. This paper also establishes an improved comprehensive evaluation model by using the method of Vertical Projection Distance-Set Pair Analysis in order to optimize the traditional method of Technique for Order of Preference by Similarity to Ideal Solution. Based on the official data released by China, this paper quantitatively analyzes the green development level of 21 provinces in eastern and western China in the aforementioned six areas from 2005 to 2020, and makes a regional comparison between eastern and western China. The results show that the level of green development in eastern China is significantly higher than that in western China. In 2020, when the research period ends, the comprehensive evaluation values of green development in all the eastern provinces, except Hebei, are higher than 4.0; meanwhile, no province in the western region has a comprehensive evaluation value exceeding 4.0 in 2020, and there is a large gap between the eastern region and the western region in areas such as economic growth quality and pollution control. On this basis, this paper puts forward relevant suggestions in terms of the coordinated green development of the eastern and western regions of China in the future.

Keywords: green development; evaluation index system; comprehensive evaluation model; V-SPA; TOPSIS

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1. Introduction

Since the reform and opening up, China has made great achievements in economic development. However, due to the inefficient use of resources, the relationship between economic development and ecological protection has not been well balanced, which has led to a series of ecological and environmental problems [1–3]. In order to fundamentally solve the ecological and environmental problems it faces and realize sustainable development, China urgently needs to achieve green transformation and implement green development policies that suit its own economic and social development needs, as well as local conditions, and explore a green development path with its own characteristics [4].

The Chinese leaders have attached great importance to green development. The report of the 20th National Congress of the Communist Party of China has clearly pointed out that it is necessary to promote green development and the harmonious coexistence between man and nature. [5]. In recent years, China has deepened reform in various fields, has vigorously promoted the construction of ecological civilization, and has emphasized the green development of various areas such as resource utilization, pollution control, the living environment, ecological protection, the circular economy, and economic growth quality; this is with the goal of achieving a harmonious coexistence between man and nature, as well as comprehensive and coordinated sustainable development [6].

However, green development is a complex systematic project that involves various fields, including the economy [7,8], society and environment [9,10], and there are close links between each field [11]. In addition, China has a vast territory, and there are large differences in the level of development between the regions [12,13]. Compared with the eastern region, the overall development level of the central and western regions is relatively low [14,15]. Therefore, it is necessary to construct a green development index system with scientifically selected indicators, and to comprehensively and accurately evaluate the green development level of various regions in China in order to realize sustainable development. This topic has also attracted the attention of the academic community [16,17].

Therefore, the motivation of this paper is to construct a comprehensive evaluation index system that fully reflects China's green development level, covering six areas: resource utilization, pollution control, living environment, ecological protection, circular economy, and the quality of economic growth. In addition, this paper has improved the traditional model of Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) by using the Vertical Projection Distance-Set Pair Analysis (V-SPA) method. By substituting the vertical distance for the connection vector distance in the set pair analysis, this paper has constructed an optimized evaluation model in order to comprehensively evaluate and compare the green development levels of 21 provinces in eastern and western China from 2005 to 2020.

According to the official classification of the National Bureau of Statistics of China [18], this paper has selected 10 provinces in eastern China (Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan), and 11 provinces in western China (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang). The above-mentioned analysis scope has covered more than 80% of China's territory, so it has good representativeness.

This paper attempts to contribute to existing research in the following areas:

(1) By constructing an index system covering six major fields, this paper attempts to enrich the existing literature on the green development index system, and further explore improvements to the sustainable development evaluation index system.

(2) To make a contribution to the development of a research methodology, we have constructed an improved comprehensive evaluation model and adopted the set pair analysis method to improve the TOPSIS method, and further improved the model for the green development level evaluation by substituting the vertical distance for the connection vector distance in the set pair analysis.

(3) Through the comprehensive evaluation of the green development level of different regions of China and the comparative analysis of the east region and the west region, this paper attempts to provide quantitative analysis tools and research ideas for the study of green development levels of other regions and other countries, thus making contributions to academic research in the field of sustainable development.

The deficiencies in this paper are mainly as follows:

(1) Due to the availability of data, there are many gaps in China's official data released after 2020. This paper does not use simple interpolation or moving average methods to make up for missing values, but chooses to limit the research period to ensure the integrity of the data and the scientific nature of this research. Thus, there is the drawback that the data is not up to date to some extent.

(2) In order to illustrate the differences in the level of green development in China, this paper selects 21 provinces in eastern and western China, but does not include 9 provinces in central and northeastern China. Although this is more convincing from a comparative perspective, the above-mentioned 9 provinces still remain to be included in a comprehensive study in the future.

The structure of this paper is as follows: Part 2 introduces the comprehensive evaluation index system of green development, including detailed indicators in six fields, and constructs a comprehensive evaluation model for the green development level; by using the aforementioned index system and evaluation model, Part 3 calculates the evaluation results of the eastern and western provinces of China based on the official statistical data; Part 4 discusses the evaluation results in depth, based on the development and implementation of green policies in eastern and western China during the research period; and Part 5 summarizes the paper, and provides relevant policy suggestions for China's future green development.

2. Literature Review

The academic community has conducted much research on China's green development [19–21]. The key themes that have been involved in these papers include the following:

(1) Challenges and successes. Studies have evaluated the challenges and successes of China's green development efforts. For example, a number of papers have noted the progress made in reducing carbon emissions [22,23] and promoting renewable energy [24], while others have pointed out the ongoing challenges in areas such as air quality [25,26] and balancing economic development with environmental protection [27,28].

(2) Public and private sector involvement. Many papers have focused on the role of the public and private sectors in China's green development [29,30], including the awareness and implementation of green practices by companies [31], as well as the influence of public opinion on the government's efforts [32–34].

(3) Government initiatives and measures. Many academic papers have analyzed the various policies and initiatives introduced by the Chinese government to promote environmentally friendly development. This includes the "Ecological Civilization" plan [35,36], restrictions on industrial production and coal use [37], and the promotion of renewable energy and electric vehicles [38].

(4) Evaluation of green development level. Researches on the evaluation of green development level have used comprehensive and multi-dimensional approaches to assess the progress and challenges of sustainable development, especially the Multi-criteria decision-making (MCDM) methods [39–42]. These studies emphasize the importance of considering various factors such as economic, social, and environmental impacts, as well as the availability and quality of data, in order to arrive at a more accurate evaluation of the green development level [43]. Moreover, the existing research highlights the role of government policies [44], investment [45], and public participation [46] in promoting and sustaining green development.

(5) International cooperation. A number of academic papers have explored China's role in international cooperation and its impact on green development [47], including its collaborations with other countries and organizations [48], as well as its participation in global climate agreements [49].

Overall, academic papers on China's green development have provided an understanding of the country's efforts to achieve sustainable growth, as well as the challenges and opportunities facing these efforts. The research has demonstrated the importance of continued efforts to address environmental issues and promote environmentally friendly development in China and beyond.

However, most of the studies focus on the green development level of certain cities or provinces in China. There are very few studies that comprehensively analyze the green development level of various regions in China with regional comparative analysis. Moreover, the index systems constructed are often concentrated in a specific field and fail to cover the multiple fields involved in green development such as economy, society and environment. Hence, we hope to further enrich the existing literature of green development via the research in this paper.

3. Materials and Methods

3.1. The Green Development Evaluation Index System

The evaluation of the regional green development level is a multi-dimensional and multi-faceted complex task [50]. Therefore, building an indicator system in order to evaluate the green development level is also a complex systematic project [51,52]. Different indicators reflect different aspects of regional green development, but they are not completely independent of each other. The indicator system, formed by indicators with certain correlations, can meet the requirements of a comprehensive evaluation and analysis of the regional green development level. By referring to relevant research [53,54], and in consideration of scientificity and operability, this section has constructed an evaluation index system covering 6 Level-1 indicators (resource utilization, pollution control, living environment, ecological protection, circular economy, and quality of economic growth) and 28 Level-2 indicators (see Table 1).

Table 1. The Green Development Evaluation Index System.

Level 1 Indicator	Level 2 Indicator	Unit of Measurement	Positive/Negative
Resource Utilization	Energy Consumption per 100 Million RMB of GDP	10 Thousand Tons of Standard Coal/100 Million RMB	Negative
	Natural Gas as a Percentage of Energy Consumption	%	Positive
	Water Consumption per 100 Million RMB of Agricultural Output	10 Thousand Cubic Meters/100 Million RMB	Negative
	Water Consumption per 100 Million RMB of Industrial Output	10 Thousand Cubic Meters/100 Million RMB	Negative
	Land Occupied per 100 Million RMB of Agricultural Output	Hectare/100 Million RMB	Negative
	Land Occupied per 100 Million RMB of Industrial Output	Hectare/100 Million RMB	Negative
Pollution Control	Chemical Oxygen Demand (COD) Emissions	10 Thousand Tons	Negative
	Ammonia Nitrogen Emissions	10 Thousand Tons	Negative
	Carbon Dioxide Emissions	10 Thousand Tons	Negative
	Sulfur Dioxide Emissions	10 Thousand Tons	Negative
	Smoke (Dust) Emissions	10 Thousand Tons	Negative
Living Environment	Green Coverage Rate of Urban Areas	%	Positive
	The Rate of Garden Green Space in Urban Areas	%	Positive
	Implementation Rate of Sanitary Toilet in Rural Areas	%	Positive
	The Ratio of Number of Days Per Year in which the Air Quality of the Provincial Capital City Reaches Grade 2 or Above	%	Positive
Ecological Protection	The Proportion of Protected Areas	%	Positive
	The Proportion of Wetland	%	Positive
	Total Afforestation Area	Hectare	Positive
	Forest Coverage Rate	%	Positive
	Forest Stock	10 Thousand Cubic Meters	Positive
Circular Economy	Urban Water Recycle Rate	%	Positive
	Comprehensive Utilization Rate of Industrial Solid Waste	%	Positive
	Comprehensive Utilization Rate of Hazardous Waste	%	Positive
	Harmless Treatment Capacity of Domestic Waste	Tons per day	Positive
	Harmless Treatment Rate of Domestic Waste	%	Positive
Quality of Economic Growth	GDP per capita	RMB	Positive
	Per capita Disposable Income of Urban Residents	RMB	Positive
	Per capita Disposable Income of Rural Residents	RMB	Positive
	The Proportion of Added Values of the Tertiary Industry in GDP	%	Positive
	Main Operation Incomes of the High-Tech Industry	100 Million RMB	Positive

3.2. Index Calculation Method and Data Source

1. Resource Utilization. The resource utilization indicators reflect the use of energy, water resources and land, and focus on the utilization efficiency of these resources in economic development, with the purpose of promoting a resource-saving economy [55–57]. The level-2 indicators of resource utilization cannot be obtained directly, and need to be calculated from existing data.

2. Pollution Control. The pollution control indicators reflect the main pollutants in wastewater, the main pollutants in exhaust gas and greenhouse gas emissions, with the purpose of stimulating different regions to control the discharge of pollutants by various methods.

3. Living Environment. The living environment indicators include the green coverage rate and the rate of garden green space in urban areas, the air quality of provincial capital cities, and the implementation rate of sanitary toilets in rural areas. These indicators reflect the quality of the living environment of urban and rural residents.

4. Ecological Protection. The ecological protection indicators include the basic conditions of protected areas, wetlands, afforestation and forests in each region, with the purpose of encouraging different regions to actively protect the local ecology and make full use of the local ecological advantages.

5. Circular Economy. The circular economy indicators include the recycle rate of water resources and industrial solid waste, reflecting the ability to reuse and convert waste into renewable resources. The harmless treatment capacity and rate of domestic waste are also included in order to measure the level of recycling waste [58].

6. Quality of Economic Growth. The indicators of economic growth quality include the GDP per capita, per capita Disposable Income, the Proportion of Added Values of the Tertiary Industry in GDP, and the Main Operation Incomes of the High-Tech Industry. These indicators not only reflect the economic development level of each region, but also reflect the economic structure and high-tech industries of each region, with the purpose of encouraging different regions to improve their economic structure and focus on the development of high-tech industries.

The data of the above indicators come from various yearbooks officially released by China and statistical data recognized by academic circles [59–63], thus ensuring the reliability of the calculation results

3.3. Comprehensive Evaluation Model

Based on the above-mentioned green development index system, this section has improved the traditional TOPSIS method with the V-SPA method. This paper has established a comprehensive evaluation model in order to analyze the green development level of different regions from 2005 to 2020 by substituting the vertical distance for the connection vector distance in the set pair analysis and combing it with the approaching ideal point sorting method. TOPSIS is a multi-feature-based sample evaluation method. The basic idea is to select an optimal value and a worst value in the sample for each index, and construct a positive ideal solution and a negative ideal solution that do not actually exist. Taking these two solutions as the reference system, for each sample, the TOPSIS method respectively calculates its distances to the positive ideal solution and the negative ideal solution, and obtains the evaluation score based on the degree of proximity [64,65]. However, the traditional TOPSIS method uses the Euclidean distance when calculating the degree of proximity of the sample to the positive and negative ideal solutions. In some cases, it might happen that the sample is close to both the positive ideal solution and the negative ideal solution, thereby leading to the problem of rank reversal [66]. In order to solve this problem, this section has adopted the set pair analysis method to improve the TOPSIS method, and further improved the model for green development level evaluation by substituting the vertical distance for the connection vector distance in the set pair analysis.

The set pair analysis method is a systematic analysis method raised by Keqin Zhao [67]. This method can analyze uncertain problems based on the degree of connection. It can analyze certainty, uncertainty, and the interaction between the two using a system of similarities and differences. In order to apply the set pair analysis method to comprehensive evaluation, first, two samples should be selected as pairs for analysis; this is the basic unit of a set-pair analysis. Next, the identity, opposition and difference between the two samples should be analyzed, in which identity and opposition are mainly used to analyze the deterministic connection between the samples, while difference is used to study the uncertainty connection between the samples. Through an analysis of the identity, opposition and difference in the samples, the degree of connection in the set pair can be obtained [68]. For example, we can analyze the set pair $H = (A, B)$, which is made up of sample A and sample B, and obtain the degree of connection between sample A and sample B, as shown in below Equation (1):

$$\mu_{AB} = a + bk + cl \tag{1}$$

In the above equation, a represents the coefficient of identity between sample A and sample B; b represents the coefficient of difference between sample A and sample B; and c is the coefficient of opposition between sample A and sample B. The vector composed of these three coefficients (a, b, c) is the connection vector between sample A and sample B. In particular, when we analyze the set pair $H = (A, A)$, which is made up of sample A and itself, the connection vector obtained will be $(1, 0, 0)$, that is, sample A is identical to itself, and there is no difference or opposition. The approaching ideal point sorting method analyzes the set pair made up of each sample and its positive and negative ideal solutions respectively, obtains the connection vector between each sample and its positive and negative ideal solutions, and then obtains the degree of connection of each sample with its positive ideal solution by calculating the connection vector distance between each sample and its positive and negative ideal solutions.

The traditional set pair analysis method calculates the distance between samples based on the connection vector distance. This method basically considers two connection vectors as two points in space, and then calculates the Euclidean distance between them. In this way, in the case that the sample is both far away from the positive ideal solution and the negative ideal solution, this method cannot correctly reflect the strength and weakness of the sample [69]. Therefore, this section has optimized the set pair analysis method by substituting the vertical distance for the connection vector distance, which has been proven effective by existing research [70,71].

By combining the vertical distance-set pair analysis method with the approaching ideal point sorting method, this paper has established a comprehensive evaluation model for the green development level of different regions. The specific steps are as follows:

Step 1: determine the positive ideal solution $S^+ = \{s_1^+, s_2^+, \ldots, s_n^+\}$ and the negative ideal solution $S^- = \{s_1^-, s_2^-, \ldots, s_n^-\}$ based on the data x_{ij}, as shown in Equations (2) and (3):

$$s_j^+ = \begin{cases} \max\limits_i x_{ij} \; j \in J_1 \\ \min\limits_i x_{ij} \; j \in J_2 \end{cases} \tag{2}$$

$$s_j^- = \begin{cases} \min\limits_i x_{ij} \; j \in J_1 \\ \max\limits_i x_{ij} \; j \in J_2 \end{cases} \tag{3}$$

Here, J_1 represents the set of positive indicators, and J_2 represents the set of negative indicators. The positive ideal solution is constructed based on the maximum value of the positive indicator and the minimum value of the negative indicator. The negative ideal solution is constructed based on the minimum value of the positive indicator and the maximum value of the negative indicator. According to the idea of set pair analysis, it can be considered that the positive ideal solution S^+ and the negative ideal solution S^- are in opposition to each other in the system.

Step 2: calculate the degree of connection μ_i^+ between sample A_i and its positive ideal solution S^+. Based on the set pair $H^+ = (A_i, S^+)$ made up of sample A_i and its positive ideal solution S^+, calculate μ_i^+ and μ_{ij}^+ according to the following Equations (4) and (5):

$$\mu_i^+ = a_i^+ + b_i^+ k + c_i^+ l = w_1\mu_{i1}^+ + w_2\mu_{i2}^+ + \ldots + w_n\mu_{in}^+ = \sum_{j=1}^{n} w_j\mu_{ij}^+, i = 1, 2, \ldots, m \quad (4)$$

$$\mu_{ij}^+ = a_{ij}^+ + b_{ij}^+ k + c_{ij}^+ l, i = 1, 2, \ldots, m, j = 1, 2, \ldots, n \quad (5)$$

in which a_i^+ represents the degree of identity between sample A_i and its positive ideal solution S^+; b_i^+ represents the degree of difference between sample A_i and its positive ideal solution S^+; and c_i^+ represents the degree of opposition between sample A_i and its positive ideal solution S^+. The vector composed of these three coefficients $\left(a_i^+, b_i^+, c_i^+\right)$ is the connection vector between sample A_i and its positive ideal solution S^+, written as $\mu_i^+ = \left(a_i^+, b_i^+, c_i^+\right)$; w_j is the weight of indicator j. When $j \in J_1$, if $x_{ij} = s_j^-$, then $a_{ij}^+ = b_{ij}^+ = 0$, and $c_{ij}^+ = 1$; otherwise, if $x_{ij} \in \left(s_j^-, s_j^+\right]$, then $a_{ij}^+ = \frac{x_{ij}}{s_j^+}$, $b_{ij}^+ = 1 - a_{ij}^+$, $c_{ij}^+ = 0$. When $j \in J_2$, if $x_{ij} = s_j^-$, then $a_{ij}^+ = b_{ij}^+ = 0$, $c_{ij}^+ = 1$; otherwise, if $x_{ij} \in \left[s_j^+, s_j^-\right)$, then $a_{ij}^+ = \frac{s_j^+}{x_{ij}}$, $b_{ij}^+ = 1 - a_{ij}^+$, $c_{ij}^+ = 0$.

Step 3: calculate the degree of connection μ_i^- between sample A_i and its negative ideal solution S^-. Based on the set pair $H^- = (A_i, S^-)$ made up of sample A_i and its negative ideal solution S^-, calculate μ_i^- and μ_{ij}^- according to the following Equations (6) and (7):

$$\mu_i^- = a_i^- + b_i^- k + c_i^- l = w_1\mu_{i1}^- + w_2\mu_{i2}^- + \ldots + w_n\mu_{in}^- = \sum_{j=1}^{n} w_j\mu_{ij}^-, i = 1, 2, \ldots, m \quad (6)$$

$$\mu_{ij}^- = a_{ij}^- + b_{ij}^- k + c_{ij}^- l, i = 1, 2, \ldots, m, j = 1, 2, \ldots, n \quad (7)$$

in which a_i^- represents the degree of identity between sample A_i and its negative ideal solution S^-; b_i^- represents the degree of difference between sample A_i and its negative ideal solution S^-; and c_i^- represents the degree of opposition between sample A_i and its negative ideal solution S^-. The vector composed of these three coefficients $\left(a_i^-, b_i^-, c_i^-\right)$ is the connection vector between sample A_i and its negative ideal solution S^-, written as $\mu_i^- = \left(a_i^-, b_i^-, c_i^-\right)$; w_j is the weight of indicator j. When $j \in J_1$, if $x_{ij} = s_j^+$, then $a_{ij}^+ = b_{ij}^+ = 0$, and $c_{ij}^+ = 1$; otherwise, if $x_{ij} \in \left(s_j^-, s_j^+\right]$, then $a_{ij}^+ = \frac{s_j^-}{x_{ij}}$, $b_{ij}^+ = 1 - a_{ij}^+$, $c_{ij}^+ = 0$. When $j \in J_2$, if $x_{ij} = s_j^+$, then $a_{ij}^+ = b_{ij}^+ = 0$, $c_{ij}^+ = 1$; otherwise, if $x_{ij} \in \left[s_j^+, s_j^-\right)$, then $a_{ij}^+ = \frac{x_{ij}}{s_j^-}$, $b_{ij}^+ = 1 - a_{ij}^+$, $c_{ij}^+ = 0$.

Step 4: calculate the connection vector distance between sample A_i and its positive ideal solution S^+. The connection vector of the positive ideal solution S^+ is $\mu^+ = (1, 0, 0)$, and the connection vector of sample A_i is $\mu_i^+ = \left(a_i^+, b_i^+, c_i^+\right)$. The connection vector distance between sample A_i and its positive ideal solution S^+ can be calculated according to Equation (8) below:

$$D_i^+ = \sqrt{\left(1 - a_i^+\right)^2 + \left(b_i^+\right)^2 + \left(c_i^+\right)^2} \quad (8)$$

Step 5: calculate the connection vector distance between sample A_i and its negative ideal solution S^-. The connection vector of the negative ideal solution S^- is $\mu^- = (1, 0, 0)$, and the connection vector of sample A_i is $\mu_i^- = \left(a_i^-, b_i^-, c_i^-\right)$. The connection vector distance between sample A_i and its negative ideal solution S^- can be calculated according to Equation (9) below:

$$D_i^- = \sqrt{\left(1 - a_i^-\right)^2 + \left(b_i^-\right)^2 + \left(c_i^-\right)^2} \quad (9)$$

Step 6: calculate the connection vector distance D between the positive ideal solution S^+ and the negative ideal solution S^-, as shown in Equation (10) below:

$$D = \sqrt{1 + \left(\sum_{j=1}^{n} w_j\right)^2} \tag{10}$$

Step 7: calculate the vertical distance VD_i^+ between sample A_i and its positive ideal solution S^+, as shown in Equation (11) below:

$$VD_i^+ = \frac{D^2 + \left(D_i^+\right)^2 - \left(D_i^-\right)^2}{2D} \tag{11}$$

Step 8: calculate the vertical distance VD_i^- between sample A_i and its negative ideal solution S^-, as shown in Equation (12) below:

$$VD_i^- = \frac{D^2 + \left(D_i^-\right)^2 - \left(D_i^+\right)^2}{2D} \tag{12}$$

Step 9: calculate the degree of relative connection C_i^+ between sample A_i and its positive ideal solution S^+, as shown in Equation (13) below:

$$C_i^+ = \frac{VD_i^-}{\left(VD_i^+ + VD_i^-\right)}, i = 1, 2, \ldots, n \tag{13}$$

where C_i^+ is the evaluation score of the sample, and $0 \leq C_i^+ \leq 1$. The closer C_i^+ is to 1, the closer sample A_i is to the ideal solution, and the higher the evaluation score of sample A_i is. In reality, the case of $C_i^+ = 1$ is very rare.

4. Results and Discussion

Based on the methods and data sources described in Section 2, this paper has obtained the calculation results of the level-1 indicators for green development, as shown in Figures 1–6 below (for specific calculated values, please refer to Tables S1–S26 in the complementary PDF file as Supplementary Materials).

4.1. Resource Utilization

In terms of resource utilization (refer to Figure 1), the evaluation values of the eastern region are significantly higher than that of the western region. As far as the situation of 2005 is concerned, the evaluation values of most provinces in the eastern region are above 0.45, while in the western region, only Chongqing, Sichuan and Shaanxi have evaluation values higher than 0.4. At the end of the research period in 2020, the evaluation values of the eastern region are still generally higher than that of the western region; the average value of the eastern region reached 0.8095, which is much higher than the 0.6201 of the western region.

However, it is worth noting that during this period, the rate of increase in the evaluation value of resource utilization in the western region exceeded that in the eastern region. Among them, the evaluation values of Qinghai, Guizhou, Gansu and Guangxi all increased by more than 100%. This is of course directly related to the low starting point of the resource utilization evaluation values in the western region; however, more importantly, the western region attaches great importance to improving resource utilization efficiency, so that the evaluation value of resource utilization has been significantly improved.

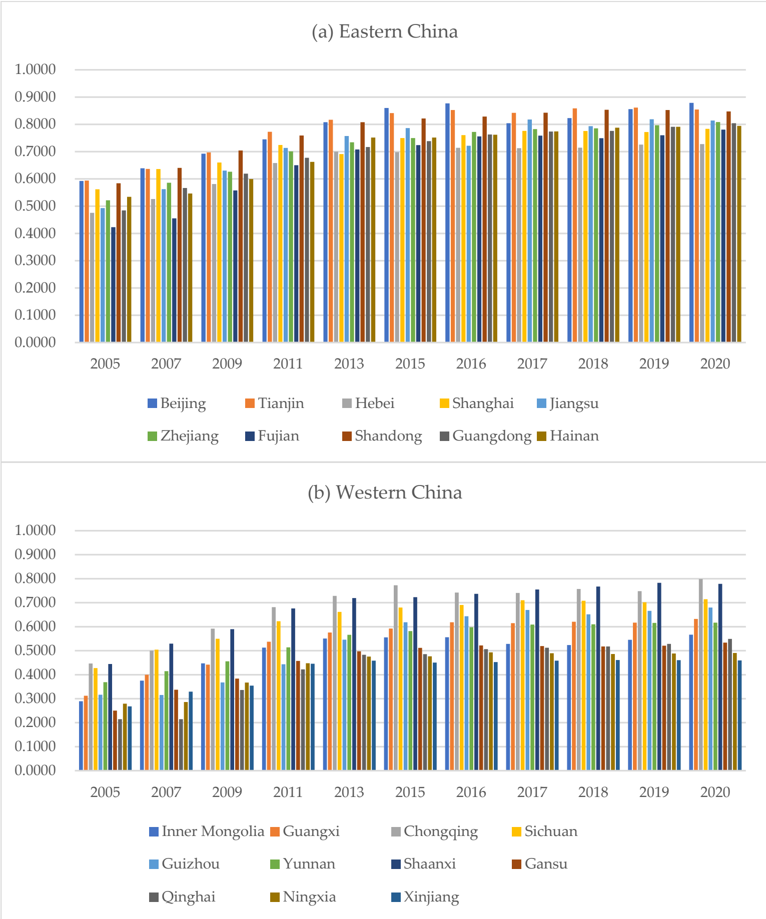

Figure 1. Calculation Results of Resource Utilization Indicators of Provinces in China, 2005–2020: (**a**) Eastern China; (**b**) Western China.

During the research period, the western provinces of China have strived to improve resource utilization efficiency, of which the major policies are as follows:

(1) Development of Clean Energy Sources: The western provinces have encouraged the development of clean energy sources such as wind, solar, hydro, and geothermal energy to reduce their dependence on fossil fuels and improve resource utilization efficiency [72].

(2) Implementation of Energy Efficiency Programs: The western provinces have implemented energy efficiency programs that are aimed at reducing energy consumption in various sectors, including the industrial, residential, and commercial sectors. These programs have helped to improve resource utilization efficiency [73].

(3) Encouragement of Water Conservation: The western provinces have taken measures to conserve water resources, such as promoting water-saving technologies, improving water management systems, and building water-saving infrastructure [74].

(4) Protection of Natural Resources: The western provinces have adopted policies to protect their natural resources, such as forests, grasslands, and wetlands [75].

These policy measures have helped to improve resource utilization performance in western China and have contributed to the increase in the evaluation value of resource utilization during the research period.

4.2. Pollution Control

In terms of pollution control (refer to Figure 2), the eastern provinces also showed a higher overall level than the western provinces. During 2005–2020, the urban agglomerations represented by the Beijing–Tianjin–Hebei region in the eastern region experienced relatively serious air pollution, resulting in fluctuations in the environmental pollution evaluation value. However, due to the Chinese government's vigorous governance since 2013, the Beijing–Tianjin–Hebei region and other regions' environmental pollution has been well controlled.

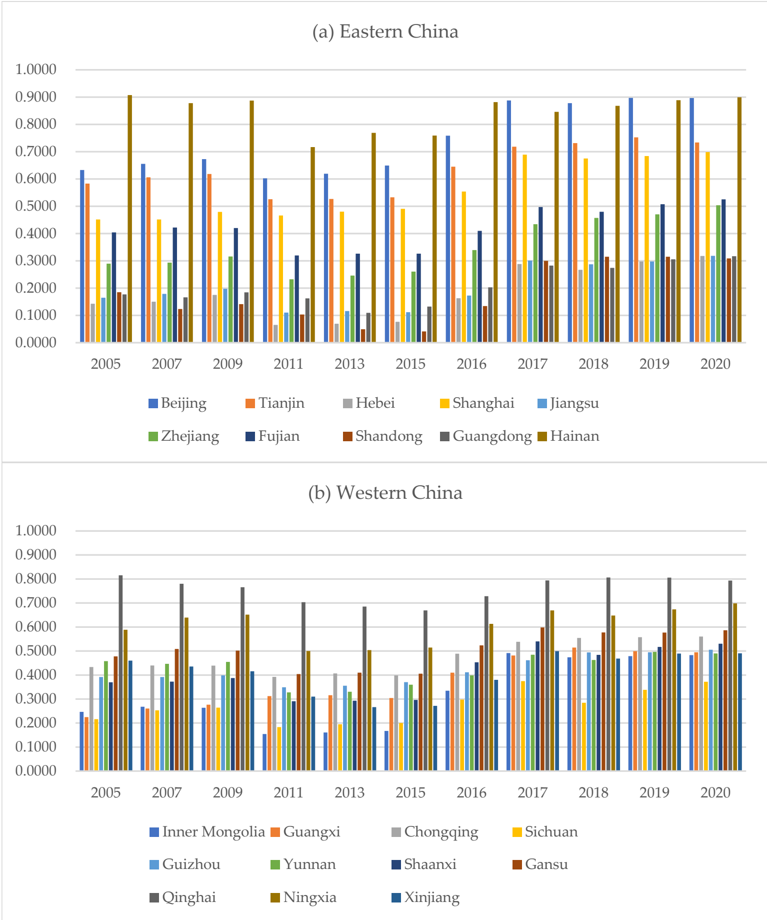

Figure 2. Calculation Results of Pollution Control Indicators of Provinces in China, 2005–2020: (**a**) Eastern China; (**b**) Western China.

In the eastern region, the pollution control policies adopted by the Chinese government mainly include the following:

(1) The Air Pollution Prevention and Control Action Plan. This was launched in 2013 and aims to reduce the concentration of fine particles in the Beijing–Tianjin–Hebei region, the Yangtze River Delta, and the Pearl River Delta by about 25%, 20%, and 15% respectively, by 2017. It also required that the annual average concentration of fine particles in Beijing be controlled at about 60 micrograms per cubic meter by 2017 [76].

(2) The Action Plan for Water Pollution Prevention and Control. It was launched in 2015 and aims to improve water quality in rivers and lakes in eastern China by 2020. It includes measures to regulate the discharge of pollutants, reduce water usage in agriculture and industry, and improve wastewater treatment facilities [77].

(3) The Action Plan for the Prevention and Control of Soil Pollution. It was launched in 2016 and aims to address soil contamination caused by industrial activities, agriculture, and waste disposal. It includes measures to assess soil pollution, clean up contaminated sites, and improve the management of hazardous waste [78].

As far as western region is concerned, overall speaking, the evaluation scores of Guangxi Province and Inner Mongolia showed the largest increase in western China from 2005 to 2020, which increased by 0.2702 and 0.2367, respectively. For Guangxi Province, its overall evaluation score in the field of pollution control showed a steady upward trend during the research period. Although the evaluation score showed a slight decline in certain years, its growth rate is quite significant during the "Twelfth Five-Year Plan" period. This paper thinks that the underlying reasons for these findings are as follows: among the provinces and cities in the western region, Guangxi has rich non-ferrous metal mineral resources, and is one of the main producing areas of non-ferrous metals in China [79]. In its early development stage, Guangxi faced the problem of the over-exploitation of non-ferrous metal resources and old-fashioned production technologies. Compared to other types of pollution, heavy metal pollution is more prominent in certain parts of the province. In order to facilitate soil pollution control in the region, since 2011, Guangxi Province has issued the Decision on Promoting Industrial Transformation and Upgrading through Environmental Protection Initiatives. By shutting down heavy metal companies, eliminating outdated production capacity, and setting strict emission targets for heavy metal pollutant emissions in key prevention and control areas, Guangxi Province has promoted the transformation and upgrading of local traditional industries. In addition, according to the data on the portal website of the government of Guangxi Zhuang Autonomous Region, from 2011 to 2015, the compliance rate in terms of heavy metal pollutant discharge by key enterprises increased from 75.4% to 97% [80], and the heavy metal pollution has been improved to a certain extent, which is consistent with our calculation results.

For Inner Mongolia, the acceleration in industrial development is represented by the energy and heavy chemical industry during the "Eleventh Five-Year Plan" period (2006–2010). In just five years, the industrial economy of this region has achieved rapid growth. However, in some areas, the focus of development has gradually shifted to GDP growth, while the importance of pollution control has been ignored; GDP achieved rapid growth at the expense of regional ecology. At the same time, the local governments did not make sufficient investments in environmental protection. In cities such as Baotou and Chifeng, the pace of pollutant treatment cannot catch up with the speed of pollutant growth, which increased the difficulty of regional pollution control as a whole. In addition, in the early stage of the "Twelfth Five-Year Plan" period (2011–2015), the rapid increase in the number of motor vehicles and the growth in local industrial production activities led to increasingly prominent air pollution issues in Inner Mongolia, which have attracted the attention of the local government [81,82]. In the early stage of the "Thirteenth Five-Year Plan" period (2016–2020), the State Council made "strengthening environmental governance" one of the key components of ecological civilization construction, and carried out environmental protection inspections in Inner Mongolia, Guangxi and other regions. In order to actively respond to the national policies and initiatives, Inner Mongolia has strengthened the pollution prevention and control measures in key industries, such as electric power, steel, nonferrous metals, petrochemicals, metal smelting, and chemicals; they have also implemented pollutant discharge permits for industries with high energy consumption and heavy pollution, and comprehensively taken measures such as installing central heating, reducing the burning of raw coal, and using natural gas and other clean energy, which has effectively alleviated the problem of local environmental pollution [83].

4.3. Living Environment

In terms of the living environment (refer to Figure 3), the eastern region not only has a superior development foundation compared with the western region, but also continuously optimizes key elements of the living environment, such as urban greening, garden construction, and public health facilities during the research period. For example, Shanghai initiated the 13th Five-Year Plan (2016–2020) for the Greening and City Appearance of Shanghai, which aimed to increase the city's green coverage to 40% by 2020 [84]. The plan included the planting of more trees and the creation of green belts along major roads and waterways. Moreover, in Hangzhou, the capital of Zhejiang Province, Xixi Wetland has become the first and only national wetland park in China that integrates urban wetland, farming wetland and cultural wetland [85]. The park features a variety of landscapes, including reed marshes, lakes, and forests, and is home to a diverse range of flora and fauna, which provides residents with a place to enjoy nature and take part in outdoor activities.

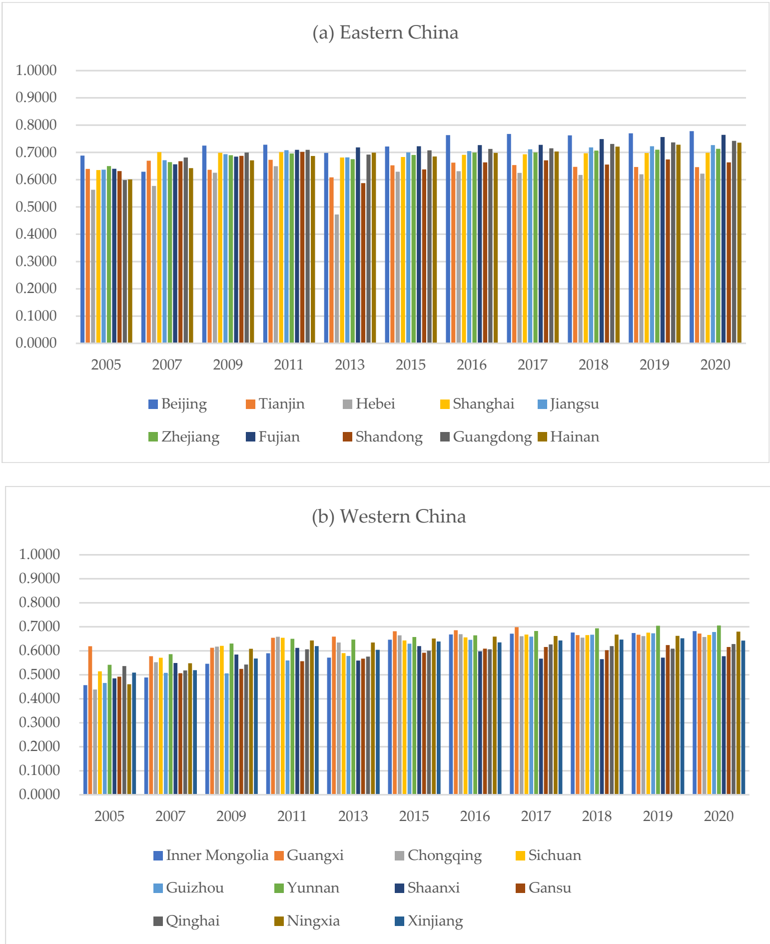

Figure 3. Calculation Results of Living Environment Indicators of Provinces in China, 2005–2020: (**a**) Eastern China; (**b**) Western China.

As far as the western region is concerned, the growth in the evaluation scores in this field is relatively low compared to the other fields. The absolute growth values of the evaluation score of Inner Mongolia, Chongqing, Guizhou, and Ningxia are around 0.2, while the evaluation scores of the other provinces and cities did not show obvious improvements. In general, it is true that the Western Development Strategy has helped various provinces and cities in the western region to achieve remarkable progress in terms of economic and social development. The urbanization process has been accelerated. As the cities continue to expand, their interior space structure and functions have been improved and updated. However, in the process of rapid economic growth, especially for cities with extremely fragile environmental conditions, more emphasis is placed on the development of commercial centers; meanwhile, the development of urban greening is ignored to some extent, resulting in a relatively low level of greening in some cities. In addition, infrastructure and the supporting infrastructure close to residential areas are still relatively simple [86]. Therefore, although the living environment of the western region has been improved slightly in the past 20 years, it is still unsatisfactory on the whole, which is also the key aspect that the western region should strive to improve during the current "14th Five-Year Plan" period.

4.4. Ecological Protection

In terms of ecological protection (refer to Figure 4), there is not much difference between the evaluation values of the eastern region and the western region, and in terms of the evaluation values in 2020, a number of provinces in the western region have surpassed the eastern region. The main reason is that the indicator of ecological protection focuses on the proportion of protected areas, wetlands and afforestation areas in the total area of the jurisdiction, while the eastern region has a relatively small proportion of protected areas, wetlands and forests due to the high degree of urbanization. Hence, the evaluation values of a few provinces in the eastern region are lower. However, during the research period, the provinces in the eastern region have also adopted a series of measures to improve its own level of ecological protection. For example, the "Green Great Wall" program is introduced in eastern China, aiming to combat desertification and improve soil and water conservation. The Hebei province planned to afforest 4.2 million mu in 2015 as part of the program [87]. Shanghai also implemented the "Ecological Red Line" policy in 2017, designating certain areas as protected zones in which development is limited [88].

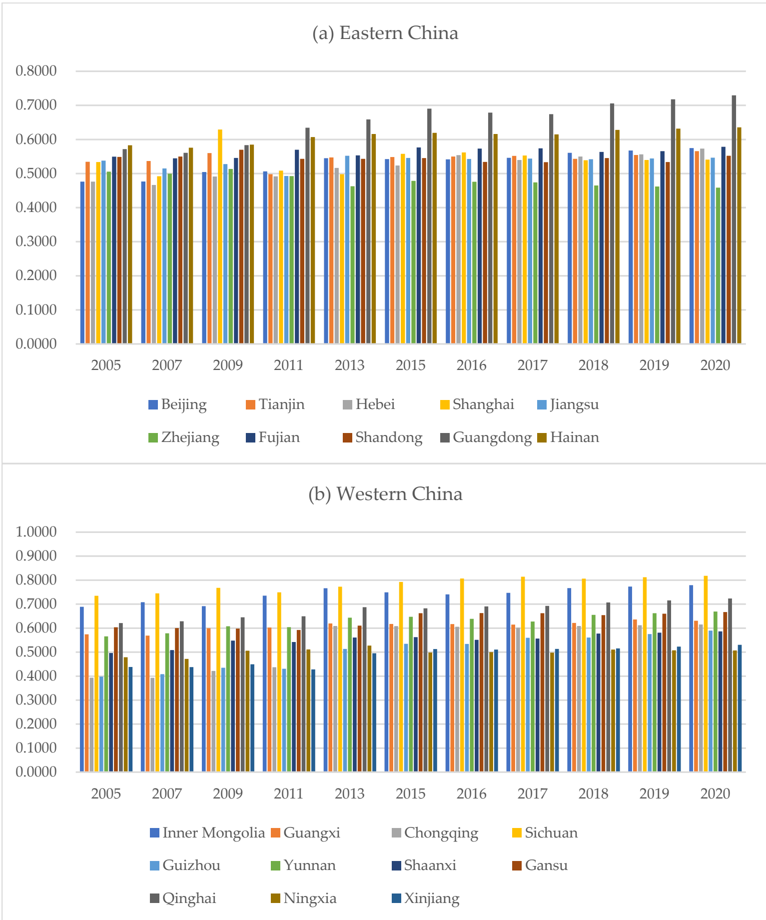

Figure 4. Calculation Results of Ecological Protection Indicators of Provinces in China, 2005–2020: (**a**) Eastern China; (**b**) Western China.

In the western region, Chongqing and Guizhou Province have shown remarkable improvements in these two fields, and their evaluation scores have ranked quite high among the provinces and cities in the western region. As an important driver of the high-quality economic development in western China, Chongqing plays a critical role in promoting the Western Development Strategy of China. In its early stage of development, Chongqing vigorously stimulated the growth of the local economy with its rich natural resources and superior natural conditions. With the growing development intensity, the conflict between economic growth and environmental protection has become increasingly prominent [89]. In recent years, in order to improve the ecological environment and achieve sustainable development, Chongqing has issued multiple policies including the Opinions on Further Promoting the Development of the Yangtze River Economic Belt and Accelerating the Construction of a Land with Beautiful Mountains and Clear Waters, Chongqing City's

Action Plan for Implementing a Green Development Strategy that Prioritizes Ecology Protection (2018–2020), and Chongqing City Pollution Prevention and Control Implementation Plan (2018–2020). With the support of a large number of local policies, the ecological environment of Chongqing has been improved to a certain extent. According to the data released by the Chongqing Municipal Bureau of Ecology and Environment, as of August 2021, Chongqing is committed to rectifying outstanding problems such as environmental pollution and ecological environment protection. In terms of environmental pollution, taking air pollution as an example, the number of days with good air quality has increased to 333 days, and the atmospheric concentrations of air pollutants such as $PM_{2.5}$, NO_2, and SO_2 have all reached the national standard for level-2 air quality. In terms of ecological environment protection, Chongqing has maintained the stability of the regional ecosystem by launching various initiatives, including ecological punch cards and experience sharing in natural ecological environment management cases. According to the data of Chongqing [90], in 2020, the forest coverage rate in Chongqing reached 52.5%, and the number of natural reserves reached 58, accounting for about 9.76% of the city's land area. However, for Guizhou, compared with other provinces and cities, although the province has a great competitive advantage in the reserves of natural resources, with high vegetation coverage and a wide variety of biological species, the local ecological environment is still highly fragile [91]. Therefore, Guizhou became the only ecological civilization pilot site in western China in 2016. Through continuous investment in ecological environment protection in recent years, Guizhou Province has made considerable achievements in this field. Since 2016, Guizhou Province has been committed to the implementation of key ecological projects, such as returning farmland to forests and the comprehensive treatment of stony desertification. A total of 4.77 million mu of farmland has been converted to forests, and 1000 square kilometers of land with stony desertification have been treated [92]. In addition, Guizhou Province has launched the compilation work of a list of provincial important wetlands while conducting the fourth general investigation into forest resources in the province, thus attaching great importance to the local ecological protection. At the same time, in the utilization of natural resources, Guizhou Province has made full use of its own forest resources. With the development of its characteristic forestry industry being the core, Guizhou Province has invested a lot of money in the construction of pilot forest health care centers, which not only improves the ecological environment, but also drives the rapid growth of the local economy.

In addition, it is worth noticing that most of the provinces and cities in western China did not perform well in ecological environment protection. This shows that, currently, the ecological environment protection work in western China is not effective enough. Problems such as soil erosion and desertification are still effectively controlled with difficulty, and it is not uncommon to see that the ecological environment is being damaged while being treated at the same time [93].

4.5. Circular Economy

In terms of the circular economy (refer to Figure 5), the development level of the eastern region is generally higher than that of the western region. Taking 2020 as an example, five provinces in the eastern region, Shanghai, Jiangsu, Zhejiang, Shandong, and Guangdong, have evaluation values exceeding 0.9, while those of the western provinces are generally lower. In addition to the relatively weak foundation and technical level of the circular economy in the western region, the provinces in the eastern region made full use of their own developed urbanization level and technological advantages in order to recycle urban water, comprehensively utilize industrial wastewater and solid waste. They also made relatively large progress in the harmless treatment capacity of domestic waste. For example, Shanghai has established a comprehensive water circulation system and built several large-scale water recycling plants, which effectively recycle and reuse treated wastewater [94]. Jiangsu has implemented a series of measures to comprehensively utilize industrial wastewater, including improving the treatment capacity of wastewater and promoting the reuse of treated wastewater in the industrial sector [95]. Zhejiang province has actively promoted the utilization of solid waste, including the construction of several large-scale waste-to-energy plants, which effectively utilize and reduce the amount of solid waste [96]. Guangdong province has made efforts to improve the treatment capacity of domestic waste, including building several large-scale domestic waste incineration plants and promoting waste separation and recycling [97].

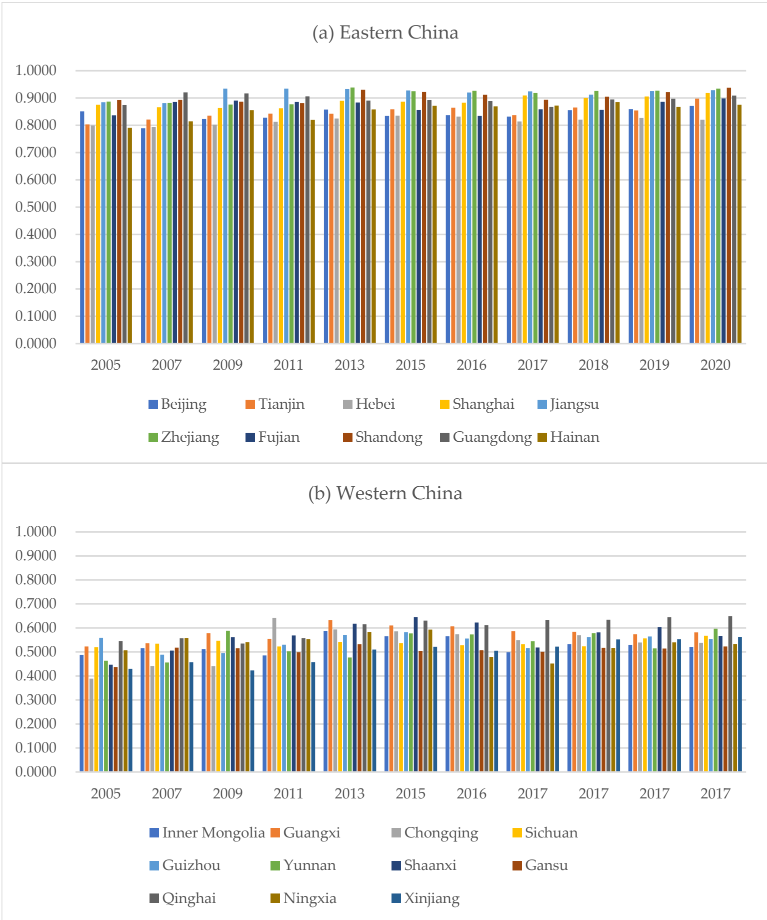

Figure 5. Calculation Results of Circular Economy Indicators of Provinces in China, 2005–2020: (**a**) Eastern China; (**b**) Western China.

In addition, it can be seen from the calculation results that although Guangxi and Inner Mongolia perform relatively well in the field of pollution control, their evaluations scores in terms of the circular economy are at an average level. In comparison, although the evaluation score of Qinghai Province in terms of pollution control has dropped instead of increased, its evaluation score in the field of the circular economy has increased significantly. The reason is that, at this stage, Qinghai Province listed 15 cities and counties, including Xining City and Haixi Prefecture, as pilot areas for Qinghai's circular economy program. Among these cities and counties, the Qaidam Circular Economy Pilot Zone was approved by the National Development and Reform Commission (NDRC) in 2005 as one of the first 13 circular economy pilot zones in China. Therefore, Qinghai Province has accumulated rich practical experience in the field of circular economy, and its evaluation score has performed well in the past fifteen years [98].

4.6. Economic Growth Quality

In terms of the quality of economic growth (refer to Figure 6), overall speaking, the evaluation scores of various provinces and cities in the western region are relatively low compared to their counterparts in the eastern region, especially in the early stage of development. The evaluation scores of most of the provinces and cities are in the range of 0.2 to 0.3.

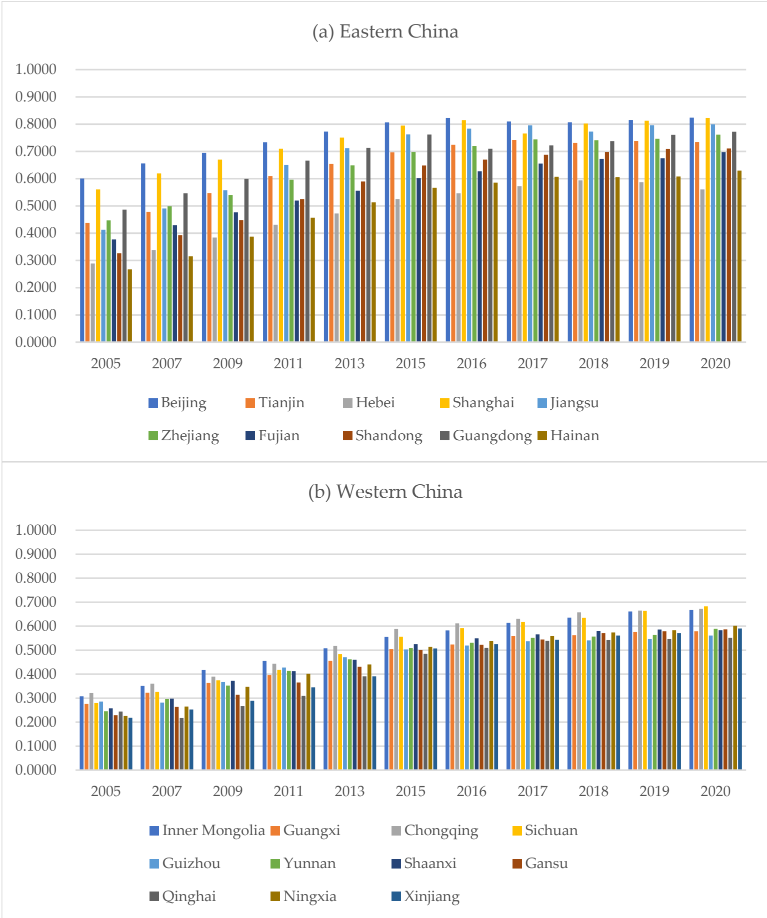

Figure 6. Calculation Results of Economic Growth Quality Indicators of Provinces in China, 2005–2020: (**a**) Eastern China; (**b**) Western China.

However, although the starting point is not high, in terms of the growth rate, the quality of economic growth in the provinces and cities of western China has seen dramatic improvements. Among these provinces and cities, the evaluation score growth of Sichuan and Inner Mongolia in the field of economic growth quality has ranked top; they have reached 0.4032 and 0.3592, respectively.

The main reason that the western region has a larger growth in the evaluation score of this field than the eastern region is that in the early stage of development, although the western region is rich in natural resources and energy reserves, the economic development of most provinces and cities is quite old-fashioned and the western region faces the risk of further widening the gap with other parts of the country [99]. In order to promote the improvement in the economic development quality of various provinces and cities in the western region while balancing it with the development of the local ecological environment, China implemented the Western Development Strategy in 2000, which greatly accelerated the overall economic development of the western region [100].

In addition, it is worth noticing that the absolute growth value of Sichuan Province's evaluation score in the field of economic growth quality is No. 1 among all the provinces and cities in the western and eastern region. This is mainly because, on the one hand, in the past 20 years, Sichuan Province has made the electronic information, equipment manufacturing, advanced materials, energy and chemical industries the pillar industries of the province. Through continuous trial and exploration, Sichuan Province has gradually upgraded its industrial structure towards the direction of high efficiency and high end products, which has effectively promoted the rapid growth of the local economy. On the other hand, with the continuous growth in the regional economy, the economic ties between different cities have become more and more close. During the "Twelfth Five-Year Plan" period, Sichuan Province proposed to focus on the development of four major urban agglomerations in Chengdu Plain, South Sichuan, Northeast Sichuan and Panxi; they the province also defined their scope and city level, building a multi-point and multi-level support system for the development of Sichuan Province, and made full use of their unique location advantages in order to drive the development of the overall economy.

4.7. Overall Evaluation and Comparison with Other Studies

Based on the above calculation results, this paper finds that there are large differences in the level of green development among provinces and cities in the western region, and compared with the eastern region, the overall development level of the western region is relatively low. It is undeniable that in the early stage of development, the western region has lower comprehensive evaluation scores due to its location, reflected by the slow progress of economic and social development and by serious environmental pollution in the region. With the acceleration of urbanization and the attention paid by local governments to the ecological environment, most provinces and cities in the region have made great progress in terms of green development. Despite this, there are still a few provinces and cities with a small increase in the comprehensive evaluation score. The growth of their comprehensive evaluation score is not as significant as other provinces and cities in the western region, and as of 2020, their comprehensive evaluation scores are much lower than provinces and cities in the eastern region. In comparison, the comprehensive evaluation scores of provinces and cities in the eastern region were already quite high in 2005. Benefiting from their geographical advantages and the strong support of local governments' policies, the comprehensive evaluation scores of most regions in eastern China exceeded 4.0 in 2020. At the same time, compared with the western region, the eastern region has a better foundation for economic development. Therefore, although the growth of the comprehensive evaluation score of the eastern region has been slightly slower than that of the western region in the past 20 years, the comprehensive evaluation score of the eastern region is still ahead of that of the western region in general.

Through the discussions of the above research results, this paper provides detailed evaluation results for the comparison of the level of green development in the eastern and western regions of China. It can help the eastern region better apply its own advanced green development advantages in order to assist the western region to effectively improve the level of green development. On the basis of these research results and discussions, the western region can learn and gain advanced experience from its eastern counterpart in terms of developing a green economy, effectively improving its own level of green development, and making contributions to China's overall sustainable development.

The above research results are consistent with the regional differences in China's green development level in the existing research. For example, Tan et al. [101] constructed an evaluation index system for green innovation in Chinese cities, and conducted research on the level of green innovation in major cities in China during 2006–2017. The results show that the average green innovation level of China's major cities has increased significantly during the research period, but the regional imbalance is obvious: the eastern region is much higher than the average level, while the western region is lower than the average level. Yang et al. [102] used a three-stage DEA model to study the efficiency of urban green development in the Yangtze River Delta region of China. The results of the study show that the green development efficiency of the third stage in the Yangtze River Delta region is better than that of the first stage, but there are significant differences among cities in different geographical locations. Feng et al. [103] used the Super-SBM model to study the green innovation efficiency of 19 urban agglomerations in China from 2006 to 2018. The results show that the green innovation efficiency of these urban agglomerations in China mostly had an upward trend during the research period, and that the efficiency values of the Eastern region are significantly higher than those of the Central and Western regions.

By constructing the improved evaluation index system and evaluation method, we have further confirmed the differences in green development between the eastern and western regions of China, and enriched the existing literature on green development. Since green development is an important and growing area of research that focuses on the interplay between environmental and social sustainability, our study topic in the future will further consider the impact of economic and social development on the environment, such as the impact of green development on the local economy and job creation, the relationship between green development and poverty reduction in China, and the impact of green development on the health and well-being of communities, etc.

5. Conclusions

This paper has constructed a comprehensive evaluation index system for green development, and improved the traditional TOPSIS method with the use of the V-SPA method. By substituting the vertical distance for the connection vector distance in the set pair analysis, and combining it with the approaching ideal point sorting method, this paper has conducted a comprehensive evaluation and comparative analysis of the green development levels of 21 provinces in eastern and western China from 2005 to 2020.

We find that the level of green development in eastern China is significantly higher than that in the western region, and there are large differences in the level of green development among the provinces and cities of western China; the following conclusions can be especially made:

(1) In 2020, when the research period ends, the comprehensive evaluation values of green development in all eastern provinces, except Hebei, are higher than 4.0. Among them, the evaluation values of Beijing and Hainan exceed 4.5, and the evaluation value of Shanghai is also close to 4.5. However, no province in the western region has a comprehensive evaluation value exceeding 4.0 in 2020, and there is a big gap between the eastern region and the western region in areas such as economic growth quality and pollution control.

(2) Thanks to the Western Development Strategy, the provinces and cities in the western region have greatly improved their evaluation scores in the field of economic growth quality, but the improvements in the fields of pollution control and circular economy are still lower, reflected by a low urban green coverage and insufficient infrastructure.

(3) Overall, the evaluation scores of most provinces and cities in the western region have shown an improvement trend over the years, and some provinces and cities have seen large increases in their evaluation scores. As of the end of the research period, some provinces and cities even reached the same level of evaluation scores as the eastern region. However, in terms of the overall development level, there is still a large gap between the western region and the eastern region in various fields.

In view of this, we have listed the following policy recommendations to help the eastern and western regions of China learn from each other's strengths and jointly improve their level of green development, leading to a more sustainable and environmentally friendly future for China as a whole:

(1) Establishing green development partnerships. The two regions can establish cross-regional partnerships to jointly plan, implement, and monitor green development projects. This will allow both regions to learn from each other's experiences and work together to achieve shared goals.

(2) Promoting green innovation. Both regions can encourage green innovation by providing incentives and support for entrepreneurs and businesses that are developing green technologies and products. This can include funding, mentorship, and technical assistance.

(3) Transferring green technology. The eastern region can share its advanced green technology and best practices with the western region, while the western region can provide valuable insights into the practical implementation of these technologies in local

conditions. This can be achieved through joint research and development programs, technical exchanges, and the sharing of resources.

(4) Jointly investing in green infrastructure. Both regions can invest in shared green infrastructure, such as renewable energy projects, environmental protection programs, and green transportation systems, to improve their overall green development levels. The eastern region can bring its advanced technology and experience in project management, while the western region can offer its abundant natural resources and untapped potential for green development.

(5) Promoting green consumption patterns. Both regions can work together to promote sustainable consumption patterns by encouraging the use of green products and services, and promoting environmentally friendly lifestyles. This can be achieved through education and awareness campaigns, spiritual and material rewards, and incentives for businesses and individuals to adopt green practices.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15053965/s1.

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