

Research Article

The Measurement of Green Finance Development Index and Its Poverty Reduction Effect: Dynamic Panel Analysis Based on Improved Entropy Method

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Finance contributes to poverty alleviation through economic growth, and the development of green finance is related to the sustainable development of the world economy and environment. Green finance not only helps promote sustainable economic development but also helps reduce poverty. Based on the analysis of related theories about green finance and poverty alleviation, this paper selects 18 indicators from three dimensions of economic development, financial development, and social environmental development and uses the improved entropy method to measure the green finance development index of China's 25 provinces and municipalities from 2004 to 2017. The results show that the development level of green finance in China's 25 provinces and municipalities is quite different. On the basis of the above analysis, make an empirical analysis of the impact of the green finance development index on poverty alleviation using multiple regression analysis and static panel and dynamic panel estimation methods. The research results show that there is a significant positive correlation between green finance and poverty alleviation; the higher the level of green finance development, the more conducive the poverty alleviation. So, this paper suggests that poverty can be better alleviated by improving the level of green finance development, financial asset level, and economic development level.

1. Introduction

Throughout human history, peace and prosperity have always been the goals that people have pursued, but poverty has always been a chronic disease that human society cannot get rid of. In the “Transforming Our World: 2030 Agenda for Sustainable Development” adopted by the United Nations in September 2015, “eliminating all forms of poverty in the world” became the first goal among the 17 sustainable development goals. Around the world, we are still facing enormous development challenges brought about by poverty. The 2019 Global Multidimensional Poverty Index Report released by the United Nations Development Program shows that 1.3 billion people worldwide are in a

“multidimensional poverty state,” and there are huge differences in poverty levels between countries and regions within countries. The report covers 101 countries, including 31 low-income countries, 68 middle-income countries, and 2 high-income countries.

Since 2015, China has paid more attention to poverty alleviation and has adopted diversified poverty reduction measures. 2020 is the year when China's grand goal of building a moderately prosperous society in an all-round way is realized, and it is also the final year of China's fight against poverty. China's poverty alleviation work has achieved world-renowned achievements, not only benefiting the Chinese people but also benefiting the whole world. It has made important contributions to the realization of the

goals set by the United Nations “2030 Agenda for Sustainable Development.” The Chinese style “road to poverty” has become the focus of world attention.

To study poverty, we should define it at first. Because poverty is a complex concept that constantly evolves along with the development of economies and societies, it is “an elusive concept.” Human understanding of poverty as a concept has evolved, and scholars have used varying definitions of poverty. The study of poverty by Rowntree and Booth is considered to represent the beginning of the study of poverty in the social sciences. In their study, poverty is the lack of materiality in an economic sense. Booth defines the “poor” as middle-aged people who earns £1 or less per week, and Rowntree describes poverty as applying to a household whose total income cannot cover its most basic survival activities. Rowntree and Booth emphasize family income because of its necessity to survival. From the perspective of income, another definition of “survival poverty” is termed as “absolute poverty.” In 1948, a World Bank report introduced the concept of “income poverty” and linked the world’s rich and poor to gross national product for the first time, with less than US\$100 annual income on average representing poor or underdeveloped status.

The Grameen Bank successfully used microloans to help people out of poverty. This case has attracted great attention from the academic community. Many scholars show their concerns about the relationship between finance development and poverty [1–5], such as Jalilian (2002), Philip and Asena (2004), Jordan (2005), Sehrawat and Giri (2016), and Yilmaz (2017). Financial constraints are proved to be the greatest difficulty in poverty elimination according to the antipoverty experiences from many developing countries. In the process of poverty alleviation through finance, we must also pay attention to the sustainable development of the economy. In particular, the green finance development to alleviate poverty is more conducive to achieving the 2030 sustainable development goals adopted by the United Nations.

We should consider alleviating poverty effectively not only by finance development but also by green economy development. Although many developing countries have not clearly formulated a green indicator system so far, some of these countries have adopted “green growth” as a core strategy of national development. China’s 12th Five-Year Plan (2011–2015) proposed “green development and resource conservation.” India highlighted sustainable development in its national 12th Five-Year Plan, emphasizing the goals of a “friendly, environment-friendly society” and “fast, sustainable, and more inclusive growth,” which demonstrate the shift of national strategic priorities. Many scholars did many research studies in green development and green finance [6–9], such as Csete and Horváth (2012), Edward (2013), Wang and Zhi (2016), and Xiong and Qi (2018). Therefore, promoting the development of green finance has become a priority. In addition, financial institutions worldwide have been actively developing green finance. The development history of green finance can be traced back to

the 1970s in the last century. As early as 1974, the Federal Republic of Germany established the world’s first policy-based environmental protection bank, named “Eco Bank,” which was responsible for providing preferential loans for environmental projects that general banks were unwilling to accept. Since 2002, many financial institutions around the world have adopted the “Equator Principles” to pay more attention to the development of green finance.

Green finance is a subject worthy of further study. How to measure the development of green finance is the first step in this area. At present, there are few articles measuring the green finance index (GFI). Existing literatures mainly use alternative indicators to be the proxy of the green finance development index, such as Sarah et al. (2020) [10] replaced green finance with carbon finance. Some scholars make special calculations on the energy security index. Song, Zhang, and Sun (2019) [11] introduced a new aggregated indicator, the China energy security index (CESI), for evaluating how China’s energy security has changed over years. The CESI includes the energy supply dimension, economic-technical dimension, and environmental dimension of energy security. A small amount of the literature uses complex network methods to study energy financial market issues currently. Li et al. (2016) [12] used complex network methods to study the global energy investment structure and found that most foreign investment and foreign investment relations are still controlled by a few Countries. Xi & An (2018) [13] used the financial indicators of energy stocks to construct a complex network. The study found that the threshold of 0.7 is a mutation point of the network, and as the threshold increases, the independence of the community increases. Some scholars have made related research on green finance. For example, Li, Yuan, and Wang (2019) [14] constructed a green finance-ecological environment composite system coupling and coordinated development evaluation system and measured the development level of green finance and the comprehensive level of ecological environment in the three major economic circles. Lei and Wang (2020) [15] used panel regression methods to analyze the relationship between environmental pollution, green finance, and high-quality economic development and used spatial measurement methods to conduct robustness tests. The results show that environmental pollution has a significant inhibitory effect on high-quality economic development, but green finance has the effect of promoting high-quality economic development through environmental improvement effects. There are regional differences in this effect, which is stronger in the central region and weaker in the eastern region. Zhu (2020) [16] selected 8 indicators from the aspects of scale and profit and business operation to represent green finance and selected 14 indicators from marine resources, marine environment, and marine activities to represent the marine eco-environment evaluating the coupling coordination degree of green finance and marine eco-environment based on AHP and grey system theory. Liu (2019) [17] used the analytic hierarchy process to comprehensively evaluate the development status and shortcomings

of green finance in 17 cities in Shandong Province, but she did not calculate the Shandong Province green finance development index.

Although those approximate indicators can reflect the development of green finance to a certain extent, their accuracy is questionable. This paper tries to measure the GFI by the entropy weight method. The entropy method has been widely used in financial research [18–25], for example, Wang et al. (2008), Wang et al. (2015), Jin and Liu (2017), Gong et al. (2019), Dai and Niu (2019), Long et al. (2019), Zhang and Wang (2019), and Jiang et al. (2019).

Compared with existing research, we find that there is very little literature analyzing the relationship between green finance development and poverty alleviation, but more research studies examine that financial development does matter on poverty alleviation. Most scholars align themselves with one or more of the following representative views. The first representative view is that finance development and poverty alleviation are positively correlated [26–28], such as Beck et al. (2007), Park (2016), and Rashid et al. (2017). The second view is that there is a nonpositive correlation between finance development and poverty alleviation [29–31], such as Kappel (2010), Perez-Moreno (2011), and Sehrawat and Giri (2016). The third representative view is a nonlinear relationship between finance development and poverty alleviation [32–34], such as Greenwood and Jovanovic (1990), Townsend and Ueda (2006), and Zahonogo (2017). The fourth representative view is that finance development may be detrimental to poverty alleviation [35], such as Claessens and Perotti (2007). Different types of samples and statistical methods used in finance development and poverty alleviation research lead to varied conclusions. The paper analyzes the effect of green finance on poverty alleviation from an empirical perspective and verifies the value of sustainable development for green finance, indicating that green development and economic growth are not incompatible. Developing green finance is conducive to eliminating poverty and generating wealth. The result reveals positive correlations between the GFI and the poverty alleviation. The higher GFI is more conducive to poverty alleviation.

This paper has the following contributions. Firstly, this paper uses the improved entropy weight method to construct the GFI of Chinese provinces and cities. It can intuitively demonstrate the level of green finance development in various parts of China. Secondly, this paper selects multiple basic indicators from the three dimensions of economy, finance, and environment to build the GFI. The indicator system of the GFI is relatively comprehensive. Thirdly, this paper systematically studies the relationship between the green finance development and poverty alleviation. Empirical results show that the development of green finance can effectively reduce poverty.

The arrangement of this paper is as follows: the first part is the introduction; the second part is the theoretical introduction of green finance and poverty alleviation; the third part is the empirical analysis; and the fourth part is the conclusion and policy recommendations.

2. Theoretical Analysis of the Impact of Green Finance Development on Poverty Alleviation

The research is divided into two parts: (1) using the entropy weight method to calculate the GFI and (2) studying the impact of the green finance development index on poverty alleviation. We will conduct theoretical analysis from those selected basic indicators through the entropy weight method and regression analysis.

2.1. Indicators for Measuring GFI. This paper will use the entropy method to measure the degree of green finance development in 25 provinces and municipalities in China. When using the entropy method to measure the green finance development index, some basic indicators are needed. The goal set by the United Nations “2030 Agenda for Sustainable Development” is to thoroughly solve the development problems of the three dimensions of society, economy, and environment through an integrated approach and to promote human beings to the path of sustainable development. Green finance achieves the sustainable development goal of the quality of economic growth by promoting environmental governance. In theory, “green finance” means that the financial sector regards environmental protection as a basic policy. Potential environmental impacts must be considered in investment and financing decisions, and the potential returns, risks, and costs related to environmental conditions must be integrated. In daily business, we pay attention to the protection of the ecological environment and the treatment of environmental pollution in financial business activities and promote the sustainable development of society through the guidance of social economic resources. Potential environmental impacts should be considered in investment and financing decisions, and potential returns, risks, and costs related to environmental conditions should be integrated into daily business. Pay more attention to the protection of the ecological environment in financial business activities, and promote the sustainable development of society through the guidance of social economic resources. This paper believes that green finance means that financial institutions incorporate environmental assessment into the process and pay attention to the protection of the ecological environment and the development of green industries in their investment and financing activities. Compared with traditional finance, the most prominent feature of green finance is that it emphasizes the environmental benefits of human society. Many scholars suggest to protect the ecological environment and promote the development of green finance [36–38], such as Pulviranti; Costa; Pavone (2015), Ferrauto; Costa; Pavone; Cantarella (2013), and Cuspilici; Monforte; Ragusa (2017). It takes environmental protection and effective use of resources as one of the criteria for measuring the effectiveness of its activities and guides all economic entities pay attention to natural ecological balance. It emphasizes the coordinated development of financial activities, environmental protection, and ecological balance and ultimately achieves

sustainable economic and social development. Therefore, this paper selects indicators from the three dimensions of economy, finance, and environment when constructing the green finance development index. When selecting specific indicators, it combines the availability of data and the research of previous scholars. All the indicators are shown in Table 1.

2.1.1. The Dimension of Economics. This paper argues that economic development promotes green finance. When the economy develops to a certain extent, people focus more on sustainable economic development. For the dimension of economic development, this paper considers three indicators: GDP per capita, income per capita, and unemployment rate. The higher GDP per capita is, the greater local economic development is, and the more strongly green finance is promoted. Therefore, GDP per capita is a positive indicator of the green finance development index. The higher income per capita is, the higher overall income is, and the more environmental protection is emphasized. Therefore, income per capita is a positive indicator of green finance. The higher the unemployment rate, the lower the development of green finance. Therefore, the unemployment rate is a negative indicator of green finance.

2.1.2. The Dimension of Finance. We believe that there is a positive correlation between the level of financial development and the degree of green finance. For the dimension of finance, this paper considers eight indicators: number of banks per areas, number of bank staff per areas, and so on. There is a positive relationship between all indicators and green finance.

2.1.3. The Dimension of Environment. In this dimension, six indicators are selected to measure three aspects of environmental development: waste discharge, energy consumption, and environmental protection. The rate of sulfur dioxide, the rate of solid waste, and the rate of energy consumption are negative indicators of green finance development. The rate of nature reserve and the rate of forest are positive indicators of green finance development.

2.2. The Entropy Weight Method. The entropy weight method is used to calculate the GFI of various provinces and cities in China. The advantages and improved models of the entropy weight method will be introduced below.

2.2.1. Advantages of Entropy Weight Evaluation Model. Research demonstrates that the entropy weight evaluation model has the benefits of high calculation accuracy, a wide application range, and limited susceptibility to subjective factors. The primary reasons for using the entropy weight evaluation model to measure green finance development are as follows.

First, according to the relationship between basic indicators and green finance, the basic indicators are divided

into positive indicators and negative indicators. It shows the basic ideas of positive-negative image duality, thus ensuring the consistency of the research perspective between the theoretical and empirical research. Second, the weight value obtained by the algorithm of the entropy weight evaluation model and the corresponding final evaluation value not only provide objective results but also reflect the information contained in various indicators for evaluating green finance development. Third, calculation of the green finance development index includes various evaluation indicators such as GDP, waste discharge, and environmental protection. This model integrates these indicators comprehensively. Besides that, the entropy weight evaluation model algorithm and standardized data are more likely to ensure consistent and rational scientific evaluation results. Finally, the GFI based on the entropy weight method ensures the comparability of green finance development indices between provinces.

2.2.2. Improved Entropy Weight Method. The general entropy weight method has at least two shortcomings for the study of green finance development. Firstly, the general entropy weight method will cause a large change in the entropy weight of indicators, which will lead to a large error in the entropy weight coefficient. The resulting GFI lacks rationality. Secondly, the GFI calculated by the traditional entropy weight method can only provide horizontal comparison among different provinces, and it is no help when it comes to time series data of green finance development. Therefore, this paper uses an improved entropy weight method to calculate the GFI. The improved entropy weight method is defined as follows:

- (1) If m provinces are selected for measuring their GFIs, in order to calculate the GFI, we choose n indicators. Suppose x_{ij} stands for the j^{th} indicator of the i^{th} province. The following matrix serves as a basic indicator of green finance development levels:

$$Z = (z_{ij})_{m \times n} = \begin{pmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{m1} & \cdots & z_{mn} \end{pmatrix}_{m \times n}. \quad (1)$$

- (2) Because the units of each indicator are inconsistent, we need to standardize equation (1) by (2):

$$r_{i,j} = \begin{cases} \frac{z_{ij} - \min z_{ij}}{\max z_{ij} - \min z_{ij}}, & \text{if } z_{ij} \text{ is a positive indicator,} \\ \frac{\max z_{ij} - z_{ij}}{\max z_{ij} - \min z_{ij}}, & \text{if } z_{ij} \text{ is a negative indicator.} \end{cases} \quad (2)$$

- (3) Normalize the matrix as follows:

TABLE 1: Relevant indicators of green finance development.

Dimension	Basic indicator	Calculation method	Code	Attributes
Economics	GDP per capita	GDP/population	Z1	+
	Income per capita	Disposable income/population	Z2	+
	Unemployment rate	—	Z3	—
Finance	Number of banks per areas	Amount of banks/areas	Z4	+
	Number of bank staff per areas	Amount of bank staff/areas	Z5	+
	Number of banks per capita	Amount of banks/population	Z6	+
	Number of banks per capita	Amount of bank staff/population	Z7	+
	Deposits	Deposits/GDP	Z8	+
	Loans	Loan/GDP	Z9	+
	The density of insurance	Premium/population	Z10	+
	The depth of insurance	Premium/GDP	Z11	+
Environment	The rate of wastewater	Wastewater/(deposit + loan)	Z12	—
	The rate of sulfur dioxide	Amount of sulfur dioxide/(deposit + loan)	Z13	—
	The rate of solid waste	Amount of solid waste/(deposit + loan)	Z14	—
	The rate of energy consumption	Amount of energy consumption/(deposit + loan)	Z15	—
	The rate of nature reserve	Amount of nature reserve/(deposit + loan)	Z16	+
	The rate of forest	Amount of forest/(deposit + loan)	Z17	+

$$\gamma_{ij} = \begin{cases} \frac{z_{ij}}{\sqrt{\sum_{i=1}^m z_{ij}^2}}, & \text{if } z_{ij} \text{ is a positive indicator,} \\ \frac{1/z_{ij}}{\sqrt{\sum_{i=1}^m (1/z_{ij})^2}}, & \text{if } z_{ij} \text{ is a negative indicator.} \end{cases} \quad (3)$$

(4) Modify the normalization matrix as follows:

$$b_{ij} = r_{ij} + 0.0001, \quad (4)$$

$$p_{ij} = \frac{b_{ij}}{\sum_{i=1}^m b_{ij}}. \quad (5)$$

(5) The entropy H_j and difference coefficient G_j of the j^{th} indicator are obtained as shown in equations (6) and (7):

$$H_j = -\frac{1}{\ln(m)} \cdot \sum_{i=1}^m p_{ij} \ln p_{ij}, \quad j = 1, 2, \dots, n, \quad (6)$$

$$G_j = 1 - H_j, \quad j = 1, 2, \dots, n. \quad (7)$$

(6) The improved entropy weight coefficient is calculated as follows:

$$\begin{aligned} \omega_j &= \frac{G_j + 0.1 \cdot \sum_{j=1}^n G_j}{\sum_{j=1}^n (G_j + 0.1 \cdot \sum_{j=1}^n G_j)} \\ &= \frac{1 - H_j + 0.1 \cdot \sum_{j=1}^n (1 - H_j)}{\sum_{j=1}^n (1 - H_j + 0.1 \cdot \sum_{j=1}^n (1 - H_j))}. \end{aligned} \quad (8)$$

(7) A standardized decision matrix is obtained:

$$V = (v_{ij})_{m \times n} = \begin{pmatrix} \omega_1 \gamma_{11} & \cdots & \omega_n \gamma_{1n} \\ \vdots & \ddots & \vdots \\ \omega_1 \gamma_{m1} & \cdots & \omega_n \gamma_{mn} \end{pmatrix}. \quad (9)$$

The positive ideal solution v_j^+ and negative ideal solution v_j^- of the j^{th} index can be expressed as follows:

$$v_j^+ = \max\{v_{ij} | i = 1, 2, \dots, m\}, \quad (10)$$

$$v_j^- = \min\{v_{ij} | i = 1, 2, \dots, m\}. \quad (11)$$

- (8) The Euclidean distance of the positive and negative ideal solutions is calculated as s_i^+ and s_i^- , respectively, as follows:

$$s_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2}, \quad i = 1, 2, \dots, m, \quad (12)$$

$$s_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}, \quad i = 1, 2, \dots, m. \quad (13)$$

- (9) GFI_i is calculated according to the Euclidean distance of a province's and city's positive and negative ideal solutions:

$$GFI_i = \frac{s_i^-}{s_i^+ + s_i^-}, \quad i = 1, 2, \dots, m. \quad (14)$$

A higher (lower) GFI value indicates a higher (lower) level of green finance development.

2.3. Effect of the GFI on Poverty Alleviation

2.3.1. Influence of GFI on Poverty Alleviation according to Linear Regression. We first use a simple multivariate linear regression method to study the effect of the China's GFI on poverty alleviation. The model is built as follows:

$$Y_i = \alpha + \beta_1 GFI_i + \beta_2 CPI_i + \beta_3 LROAD_i + \beta_4 LGV_i + \beta_5 LOPEN_i + \beta_6 LEDU_i + \beta_7 LASSET_i + \beta_8 LPGDP_i + \varepsilon_i. \quad (15)$$

Here, Y_i is the explained variable, poverty alleviation, GFI_i is the green finance development index, CPI_i is the inflation level, $LROAD_i$ is the infrastructure construction, LGV_i is the level of government economic intervention, $LOPEN_i$ is the economic openness, $LEDU_i$ is the education level, $LASSET_i$ is the financial assets, and $LPGDP_i$ is the economic development level.

2.3.2. Influence of GFI on Poverty Alleviation according to Panel Regression. Static and dynamic panel regression models are employed.

$$Y_{it} = \alpha Y_{it-1} + \beta Z_{it} + u_t + \delta_{it}, \quad (16)$$

where Y_{it-1} is the first-order lag of the explained variable and Z_{it} is the explanatory variable. Poverty alleviation is a dynamic process because of the continuity and inertia of poverty. Therefore, dynamic panel models must be used to study the dynamic relationship between the GFI and poverty alleviation. This paper introduces a first-order lag term of the green finance development index into the model. The dynamic panel model is built as follows:

$$LPK_{it} = \alpha_0 LPK_{it-1} + \alpha_0 GFI_{it} + \beta Z_{it} + u_t + \lambda_{it}, \quad (17)$$

where LPK represents the poverty level and its explained variable. In the aforementioned formula, the explanatory variable contains the first-order lag item of the explained variable; therefore, the dynamic panel estimation method can be used for analysis. For estimating dynamic panel models, predominantly the differential GMM and system GMM are used. Compared with the differential GMM, the system GMM can effectively deal with unobserved heterogeneity problem. It is widely used in parameter estimation of dynamic panel models. Therefore, in this paper, we use the system GMM to do the estimation.

In China, medical and educational expenditures comprise a higher proportion of overall household expenditure. So, the Engel coefficient is not suitable for China's case. Limited by the statistical data availability for all regions, this paper adopts per capita consumption expenditure to represent poverty levels and analyze the ability of green finance development to explain poverty. Inflation level, infrastructure construction, government intervention economic level, economic openness, education level, financial asset development level, and economic development level are selected as control variables. Details are shown in Table 2.

3. Empirical Analysis

3.1. Data. In data selecting and processing for establishing the China's GFI, relevant indicator data from 2004 through 2017 are used. The data processing is conducted as follows: (1) after removing the missing values, we select sample data from 25 provinces and cities in China for empirical analysis; (2) using per capita consumption expenditure as a proxy variable for poverty alleviation in China; and (3) the data are from the statistical yearbooks of various provinces, as well as their annual financial report.

3.2. The Result of GFI. Before we use the entropy weight method to calculate the GFI, we need to describe the statistical properties of the sample data. Table 3 shows the statistical characteristics of the 17 indicators in this paper.

Table 2 and Model (3) are used to obtain the normalized matrix seen in Table 4.

The GFI for each region is shown in Table 5 and Figures 1–7.

From Table 5 and Figures 1–7, the green finance development is unbalanced not only in different regions but also in different provinces within a specific region. The characteristics of the green finance development in different regions and provinces of China can be summarized as follows.

Figure 1 indicates the unbalanced green finance development in north China. From 2004 to 2008, the green finance development index of Beijing showed an upward trend and then gradually decreased with a small decrement, but it is still the highest in north China and even the whole country. Tianjin's GFI is relatively high as well. Hebei's GFI

TABLE 2: Measures of major variables.

Variable name	Variable meaning	Construction method
LPK	Poverty level	Logarithm of per capita consumption expenditure
GFI	Green financial development level	Green financial development index
CPI	Inflation level	Consumer price level
LROAD	Infrastructure construction	Logarithm of the number of road mileage
LGV	Government intervention in economic level	Logarithm of government expenditures
LOPRN	Economic openness	Logarithm of the total import and export volume
LEDU	Education level	The logarithm of the average number of students enrolled in higher education institutions per 100,000 people
LASSET	Financial asset development level	Logarithm of the total assets of financial institutions
LPGDP	The level of economic development	Logarithm of GDP per capita

Notes: because of space limitations, the statistical characteristics of only some indicators from 2017 are provided.

TABLE 3: Statistical data characteristics.

	Mean	Median	Maximum	Minimum	Std. dev	Skewness
X1	59746.68	49558.00	128994.00	18756.00	27933.63	1.06
X2	27005.92	22219.94	58988.00	16011.00	11372.21	1.73
X3	3.27	3.34	4.21	1.43	0.62	-0.83
...
X15	0.25	0.26	0.59	0.03	0.14	0.58
X16	1.39	0.18	24.26	0.01	4.83	4.51
X17	0.06	0.05	0.14	0.01	0.04	0.62

Notes: because of space limitations, the statistical characteristics of only some indicators from 2017 are provided.

TABLE 4: Normalized matrix for the green finance development index in 2004.

	γ_1	γ_2	γ_3	...	γ_{15}	γ_{16}	γ_{17}
Beijing	0.53	0.44	0.52	...	0.53	0.00	0.03
Tianjin	0.39	0.24	0.18	...	0.18	0.00	0.04
Hebei	0.16	0.16	0.17	...	0.05	0.00	0.06
...
Shanxi	0.11	0.13	0.18	...	0.10	0.01	0.22
Gansu	0.08	0.13	0.20	...	0.08	0.07	0.07
Qinghai	0.11	0.13	0.17	...	0.04	1.00	0.27

TABLE 5: Green finance development levels of each province and city from 2004–2017.

Region	Province	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
North China	Beijing	0.88	0.87	0.91	0.92	0.92	0.90	0.89	0.88	0.89	0.84	0.87	0.89	0.88	0.73	
	Tianjin	0.88	0.81	0.79	0.73	0.76	0.74	0.75	0.79	0.79	0.63	0.58	0.65	0.60	0.58	
	Hebei	0.10	0.10	0.09	0.09	0.08	0.07	0.09	0.06	0.08	0.04	0.03	0.04	0.04	0.05	
	Shanxi	0.18	0.22	0.34	0.14	0.23	0.22	0.19	0.35	0.35	0.30	0.18	0.26	0.29	0.27	
Northeast China	Liaoning	0.70	0.52	0.42	0.49	0.68	0.42	0.56	0.63	0.60	0.56	0.56	0.64	0.62	0.57	
	Jilin	0.38	0.60	0.54	0.38	0.38	0.30	0.44	0.46	0.47	0.29	0.31	0.40	0.48	0.58	
	Heilongjiang	0.25	0.22	0.21	0.09	0.30	0.25	0.24	0.32	0.36	0.26	0.25	0.29	0.27	0.24	
East China	Shanghai	0.86	0.91	0.92	0.94	0.91	0.79	0.85	0.89	0.90	0.93	0.93	0.86	0.83	0.82	
	Jiangsu	0.08	0.13	0.09	0.08	0.15	0.09	0.10	0.15	0.20	0.17	0.14	0.23	0.19	0.24	
	Zhejiang	0.44	0.53	0.53	0.48	0.54	0.64	0.68	0.68	0.72	0.61	0.69	0.71	0.66	0.63	
	Anhui	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.00
	Fujian	0.18	0.22	0.20	0.16	0.24	0.22	0.19	0.24	0.30	0.20	0.19	0.24	0.23	0.20	
	Jiangxi	0.03	0.02	0.03	0.02	0.03	0.02	0.02	0.02	0.03	0.04	0.02	0.02	0.03	0.04	0.03
	Shandong	0.07	0.13	0.12	0.05	0.05	0.04	0.04	0.07	0.09	0.05	0.06	0.03	0.07	0.06	
South China	Henan	0.02	0.03	0.02	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.04	
	Hubei	0.01	0.07	0.05	0.04	0.04	0.03	0.02	0.03	0.05	0.02	0.02	0.03	0.02	0.02	
	Hunan	0.01	0.04	0.03	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	
	Guangdong	0.40	0.26	0.27	0.23	0.30	0.25	0.23	0.24	0.38	0.19	0.25	0.30	0.23	0.22	

TABLE 5: Continued.

Region	Province	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Southwest China	Chongqing	0.06	0.05	0.04	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.04	0.05
	Sichuan	0.11	0.12	0.11	0.12	0.12	0.11	0.12	0.15	0.19	0.12	0.11	0.13	0.12	0.11
	Guizhou	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
	Yunnan	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northwest China	Shaanxi	0.08	0.10	0.09	0.06	0.09	0.05	0.06	0.11	0.11	0.08	0.07	0.09	0.09	0.09
	Gansu	0.04	0.04	0.03	0.02	0.04	0.03	0.05	0.06	0.09	0.05	0.04	0.07	0.06	0.08
	Qinghai	0.36	0.31	0.28	0.21	0.27	0.23	0.22	0.29	0.40	0.26	0.25	0.35	0.40	0.35

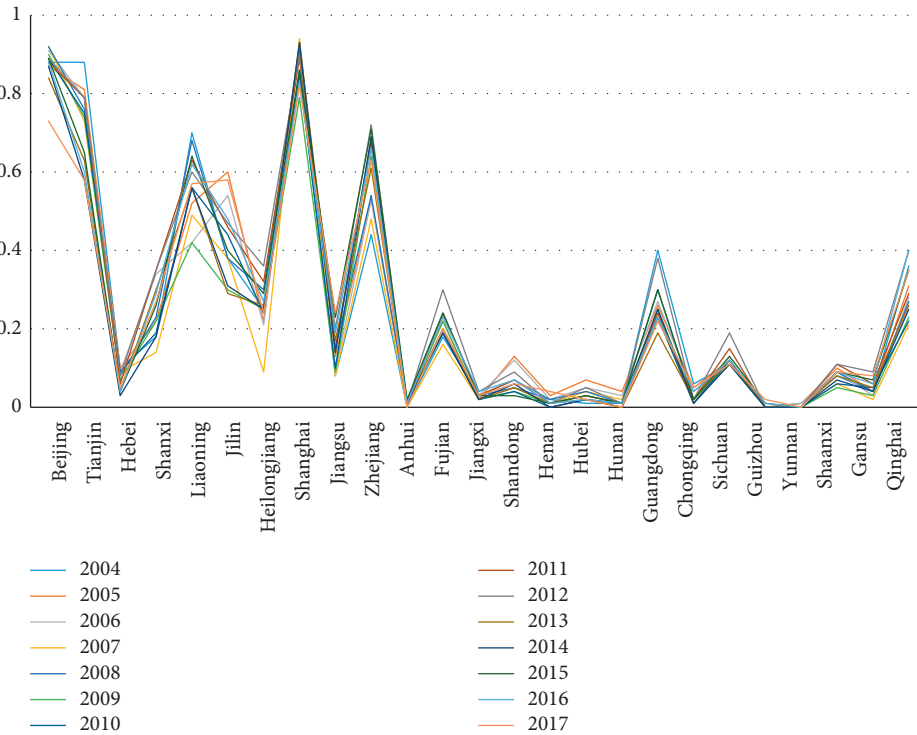


FIGURE 1: GFI of provinces and cities from 2004 through 2017.

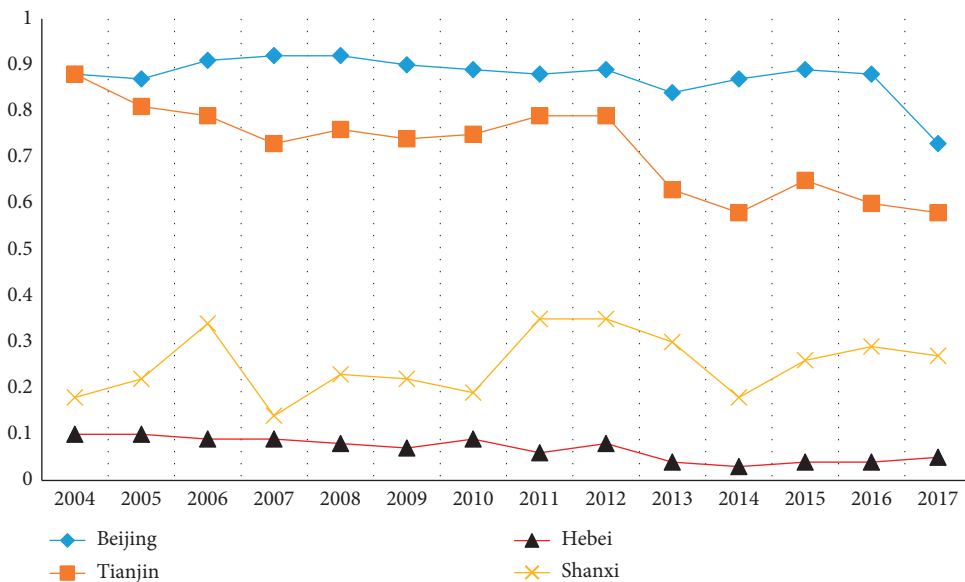


FIGURE 2: GFI in north China from 2004–2017.



FIGURE 3: GFI in northeast China from 2004–2017.

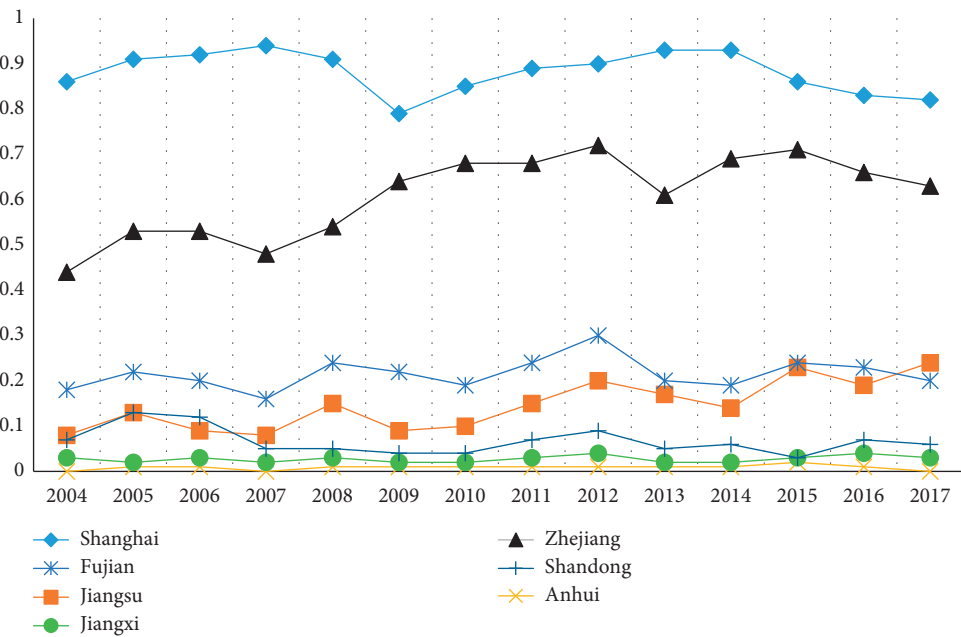


FIGURE 4: GFI in east China from 2004–2017.

is relatively low. The Shanxi’s green finance development index is not high in north China.

Due to the high forest coverage rate of the three northeast provinces, the overall GFI of northeast China is higher. In the eastern and southern regions in China, the GFIs of Shanghai, Zhejiang, and Guangdong with better economic development are higher, while other provinces’ GFIs are lower. Apart from Qinghai and Sichuan Province, the GFIs in Northwest and Southwest China are relatively low.

From the above analysis, we can find that there is a positive relationship between the degree of green finance and regional economic development. The GFIs of Beijing, Shanghai, Tianjin, Zhejiang, and Jiangsu are relatively high, while the GFIs of Anhui, Yunnan, and other regions with the low economic development level are relatively low. The GFIs of Beijing, Shanghai, Shanxi, Qinghai, and other regions show a stable trend, while Jiangsu, Sichuan, Zhejiang, and other regions show an upward trend.

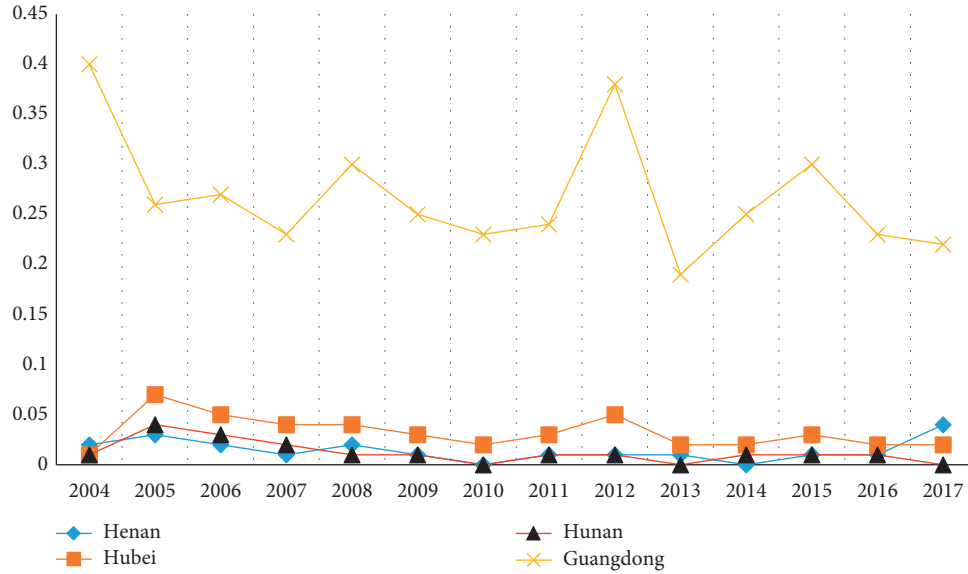


FIGURE 5: GFI in south China from 2004–2017.

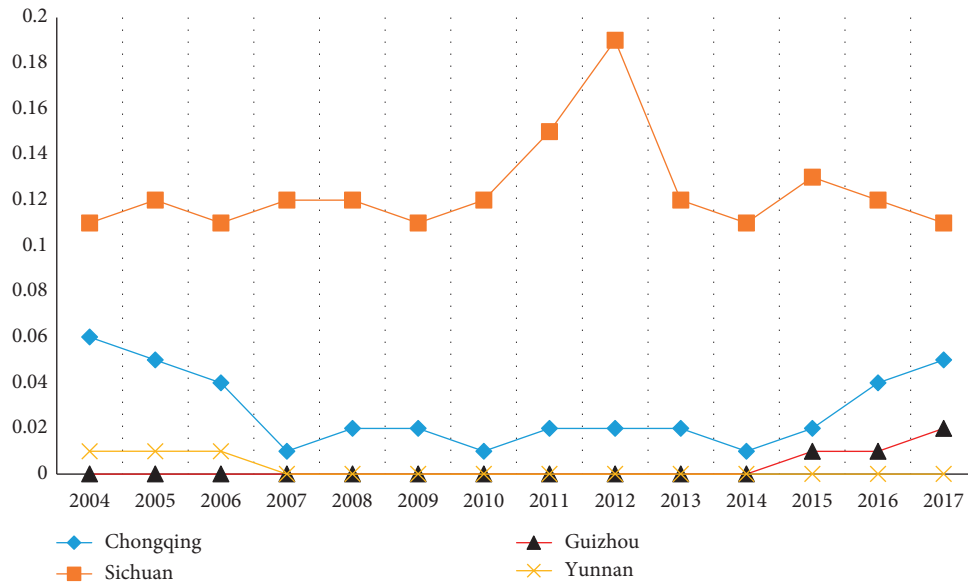


FIGURE 6: GFI in southwest China from 2004–2017.

3.3. *Effects of GFI on Poverty Alleviation.* The multiple regression method and static and dynamic panel regression method are all used to analyze the relationship between the GFI and poverty alleviation. For the panel regression, a panel regression with random effects is established. The Hausman test statistic is 123.9259, and the corresponding P value is 0. We reject the null hypothesis that no systematic difference exists between the fixed-effect model and the random-effect model. The fixed-effect model is constructed. The parameter estimation results appear in Table 6.

Table 7 shows the estimation results of the multiple regression model and static (fixed-effect) and dynamic (system GMM) panel model.

The results of multiple regression analysis demonstrate that the GFI, inflation, financial asset level, and economic development level all significantly positively affect poverty alleviation. Infrastructure construction and openness have significant negative effects on poverty alleviation.

The results of the fixed-effect analysis demonstrate that the GFI, size of financial assets, and level of economic development all have a significant positive effect on poverty alleviation. Government spending and openness have a significant negative effect on poverty alleviation.

System GMM analysis reveals that GFI, infrastructure construction, and financial asset levels have significant

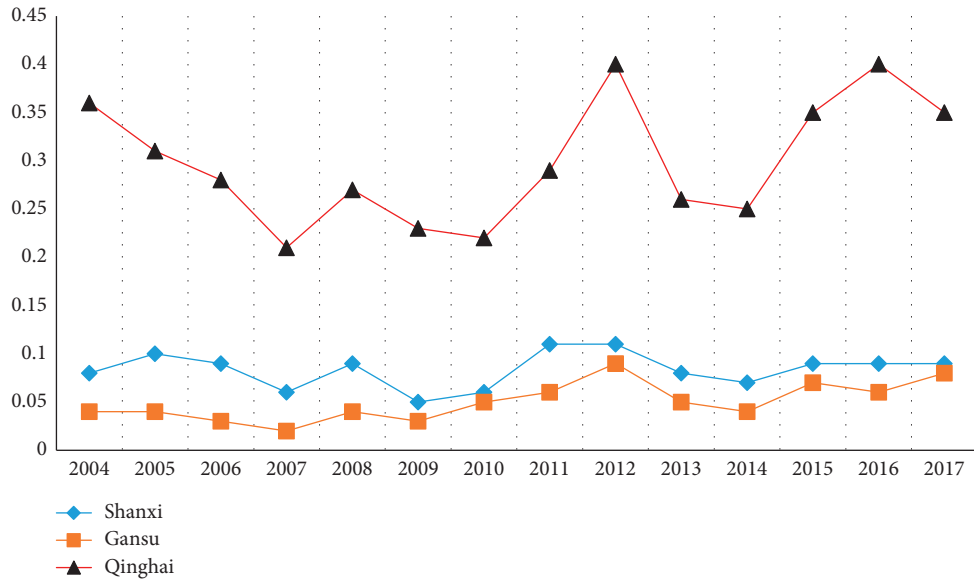


FIGURE 7: GFI in northwest China from 2004–2017.

TABLE 6: Hausman test results.

Test summary	Chi-sq. Statistic	Chi-sq. d.f.	Prob.
Cross section random	123.9259	8	0.0000

TABLE 7: Regression analysis of the impact of green financial development on poverty alleviation.

Variable	Multiple regression analysis	Fixed effect	System GMM
LPK (-1)			-0.4143*** (-4.7012)
GFI	0.1274** (3.0157)	0.2127* (2.4668)	0.6370* (1.6604)
CPI	0.0135*** (8.4430)	0.0023 (0.9541)	0.0081 (1.3223)
LROAD	-0.2127*** (-6.6589)	0.0027 (0.0450)	0.2304* (1.8444)
LGV	0.0230 (0.6828)	-0.1373*** (-4.5649)	-0.1381 (-1.0336)
LOPEN	-0.1682*** (-9.0565)	-0.1603*** (-3.6618)	-0.4001*** (-2.9249)
LEDU	-0.0459 (-0.9926)	-0.1130 (-1.3100)	0.2371 (0.7523)
LASSET	0.6461*** (13.6912)	0.4365*** (5.4059)	0.9961** (2.4700)
LPGDP	0.3081*** (10.6054)	0.7648*** (5.2025)	0.4174 (0.7346)
CONSTANT TERM		-0.3215 (-0.8474)	-1.9514* (-1.8837)
N	350	350	325
R ²	0.8815	0.9429	
F		163.7293	
AR (1)			0.4741
AR (2)			0.1292
Hansen test			0.1333

t: statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

positive effects on poverty alleviation, and openness has a significant negative effect on poverty alleviation.

4. Conclusions and Policy Recommendations

This paper selects 17 basic indicators and uses the improved entropy weight method to measure the GFI of different provinces and cities in China. The relationship between the GFI and poverty alleviation is studied by using the dynamic panel regression method. The results show that there are obvious

differences in the GFI among provinces and cities in China. The GFIs of Beijing and Shanghai are relatively high. Multiple regression and static panel and dynamic panel estimation methods all reveal a significant positive relationship between the GFI and poverty alleviation, indicating that developing green finance can effectively reduce poverty. The sustainable development of green finance can enable to support environmental conservation, demonstrate the optimization of economic and environmental benefits, and realize the development of the green economy, all of which ultimately help to alleviate poverty.

Financial assets and economic development both show positive correlations with poverty alleviation. Thus, greater financial assets and superior economic development are more conducive to poverty alleviation. Openness negatively affects poverty alleviation. This may result from that China has increased its level of openness and promoted economic growth on an ongoing basis, but it has also accelerated capital outflows, which are not beneficial for alleviating poverty. The coefficient of government spending is -0.1373 , indicating that increasing government spending causes poverty. The reason for this relationship may be that increasing government spending exerts a crowding-out effect that inhibits private sector investment activities to a certain extent, causing a decline in private consumption and investment. In addition, such a decline is not conducive to poverty alleviation. Based on the research conclusions, this paper advances the following policy recommendations:

- (1) The empirical analysis shows that there is a significant positive correlation between the development level of green finance and poverty alleviation. Therefore, we should improve the green finance development index of each region and improve the level of green finance development. Each province should pay attention to the innovation of green financial development. Financial institutions should further develop green credit, green financial bonds, and other financial innovation businesses. All provinces and cities should develop green energy, green environmental protection industry, and energy conservation and environmental protection industry. Green financial industry has the characteristics of long industrial chain, high degree of relevance, and strong absorption capacity, which has a comprehensive pulling effect on economic development and can effectively alleviate poverty.
- (2) Financial assets should be increased. Empirical analysis indicates there is a positive correlation between financial assets and poverty alleviation. The greater financial assets are, the greater poverty alleviation is. Therefore, various measures should be adopted to increase the financial assets of financial institutions, continually deepen financial system reform, improve the industrial financing situation, and increase the income of residents. In addition to improving and strengthening their supervision, financial institutions should eliminate rural financial repression, further loose access requirements, focus on improving the professionalism of financial institutions, expand the scale of credit funds, and improve bond issuance and loan financing for the real economy industry. In conclusion, the quality of financial enterprises' service to the real economy should be improved, and the problems such as financial difficulties should be eliminated. Poverty alleviation requires active adjustment to the credit structure of financial institutions, suitable financial products and services, rational reduction of corporate financing costs, enhancement of regional business environments, support of real economic

development, and efficient integration of finance and industry.

- (3) The level of economic development should be improved in all regions. Empirical analysis demonstrates a positive correlation between economic development and poverty alleviation. Therefore, the economic development of various regions should be promoted in a variety of ways. To reduce poverty, all regions should combine their own characters, identify their most advantageous resources, fully exploit their comparative advantages, vigorously develop their advantageous industries, and improve their economic development. This helps to facilitate poverty elimination more effectively.
- (4) Increasing investment in infrastructure. From the above empirical analysis, we can see that infrastructure construction has a positive role in promoting poverty alleviation. The development of infrastructure plays an indispensable role in a country's economic development. Infrastructure construction is the driving force of economic development, which plays a huge role in promoting national economic growth. Increasing infrastructure investment can effectively improve the working environment in economic activities and reduce transaction costs, so it can improve people's living standards and alleviate poverty.

Data Availability

All data used to support the findings of the study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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