УДК 336.648 DOI 10.63874/2218-0281-2026-1-92-100

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AN EMPIRICAL STUDY ON THE EVALUATION AND DRIVING FACTORS OF CHINA'S GREEN FINANCE DEVELOPMENT

This study constructs a comprehensive evaluation system for provincial-level green finance development, encompassing four dimensions: supply scale, market activity, investment efficiency, and policy environment. The Green Finance Development Index (GFDI) for 30 provinces in China from 2015 to 2023 was calculated. The study finds that while the overall level of green finance development in China shows an upward trend, significant spatial clustering and regional differentiation exist. This is manifested in the coexistence of «high-high» clustering in the east and «low-low» clustering in the west, exhibiting clear spatial positive autocorrelation and polarization trends. This provides important quantitative evidence for subsequent empirical research on driving factors and policy optimization.

Key words: *Green Finance Development Index, comprehensive evaluation, spatial clustering, regional differences, provincial panel data.*

Эмпирическое исследование оценки и факторов, определяющих развитие «зеленого» финансирования в Китае

Разработана комплексная система оценки развития «зеленого» финансирования на провинциальном уровне, охватывающая четыре измерения: масштаб предложения, рыночная активность, эффективность инвестиций и политическая среда. Был рассчитан Индекс развития «зеленого» финансирования (ИПЗ) для 30 провинций Китая за период с 2015 по 2023 г. Исследование показало, что, хотя общий уровень развития «зеленого» финансирования в Китае демонстрирует тенденцию к росту, существуют значительные пространственные кластеры и региональные различия. Это проявляется в сосуществовании кластеров «высокий – высокий» на востоке и кластеров «низкий – низкий» на западе, демонстрируя четкую пространственную положительную автокорреляцию и тенденции поляризации. Это предоставляет важные количественные данные для последующих эмпирических исследований движущих факторов и оптимизации государственной политики.

Ключевые слова: *Индекс развития «зеленого» финансирования, комплексная оценка, пространственные кластеры, региональные различия, панельные данные по провинциям.*

Introduction

The emergence of green finance is an inevitable response to global environmental challenges and the pursuit of sustainable development. Its theoretical foundation integrates environmental economics, finance, and public policy, aiming to internalize environmental externalities through financial instruments and market mechanisms, thereby redirecting capital from high-pollution and energy-intensive sectors toward green and low-carbon activities [1, p. 8222]. At its core, green finance focuses on supporting environmental improvement, addressing climate change, and promoting resource efficiency as economic objectives. It establishes a multi-stakeholder system involving governments, financial institutions, enterprises, and third-party organizations, and employs a series of innovative tools – such as green credit, green bonds, green insurance, and carbon finance – to systematically advance the green transformation of the economy and society [2, p. 19].

Existing research has developed a multi-level framework for measuring development levels. At the macro level, methods often combine qualitative assessments of policy systems with quantitative statistics on the scale

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of green credit and bonds [3, p. 2688–2701]. At the meso- and micro-levels, attention is directed toward the proportion of green business in financial institutions, corporate environmental information disclosure, and the market activity of green finance [4, p. 175]. However, current measurements generally suffer from weak data foundations, inconsistent statistical standards, an overemphasis on «scale» at the expense of «efficiency», and insufficient consideration of regional heterogeneity. These gaps highlight the need for and direction of this study to develop a more refined and comparable provincial-level evaluation system for China.

Regarding the impact of green finance, research has delineated a three-dimensional spectrum encompassing environmental, economic, and financial effects. Studies on environmental effects confirm its positive role in reducing pollution emissions and facilitating energy structure transformation [5, p. 19]. These findings collectively indicate that the efficacy of green finance is systemic, ultimately contributing to the coordinated development of the environment, economy, and finance.

Constructing a Comprehensive Evaluation System for China's Green Finance Development Level

In terms of its philosophy, the system aims to deeply reflect the strategic essence of «finance serving the green transformation of the real economy». It not only statically describes the «quantity» of green finance activities but also dynamically measures their «quality» and «effectiveness», adhering to a dual orientation: first, a «status assessment» orientation, which objectively captures the market scale, product structure, and the degree of policy framework perfection in each province at a specific point in time; second, a «trend and potential» orientation, which reflects the growth momentum and future potential of various regions in promoting the in-depth development of green finance through forward-looking indicators, such as green finance innovation activity and support for low-carbon technologies [6, p. 101312]. This approach ensures that the evaluation results can serve both horizontal comparisons – identifying regional disparities – and vertical tracking – revealing development trajectories, thereby providing policymakers with decision support that is both diagnostic and predictive.

In terms of construction principles, the system follows four core criteria: systematicity, representativeness, operability, and dynamism. Systematicity requires comprehensive coverage of key aspects of the green finance ecosystem, including the funding supply side (bank credit, bond markets), market operation and demand side (corporate green investment, project reserves), and the institutional and policy environment side (local government support, regulatory standards) [7, p. 12194]. All indicators in the system are derived from official statistical yearbooks (China Financial Yearbook, China Environmental Statistical Yearbook), publicly available data from national ministries and financial regulatory agencies (the People's Bank of China, the National Financial Regulatory Administration, the Ministry of Ecology and Environment), and authoritative commercial databases such as Wind and CNRDS, the Five-Year Plans for National Economic and Social Development. For the few data points without direct statistics, internationally accepted proxy variables or scientifically sound estimation methods are employed and explicitly explained, ensuring that the entire evaluation process is quantifiable, verifiable, and comparable across provinces [8, p. 637–668]. By focusing on trends in indicators over time, the system can effectively capture the phased characteristics and evolutionary path of China's green finance development.

Construction of the Comprehensive Evaluation Indicator System

To comprehensively, objectively, and scientifically assess the development level of green finance at the provincial level in China, this study constructs a comprehensive evaluation indicator system based on the aforementioned design philosophy and principles. The system consists of four core dimensions, focusing not only on the «quantity» of funding supply but also on the «vitality» of market operations, the «efficiency» of resource allocation, and the «stability» of institutional safeguards as a specific composition of the indicator system (Table 1). It aims to form a multi-angle, multi-layered, and three-dimensional measurement framework.

Table 1 – Comprehensive Evaluation Indicator System for China's Provincial Green Finance Development Level

Criterion Layer (Dimension)	Indicator Layer	Indicator Attribute	Data Source / Calculation Notes
1. Scale of Green Fund Supply	1.1 Ratio of Green Credit Balance to Total Loan Balance (Core)	Positive	Local branches of the People's Bank of China, reports from the China Banking and Insurance Regulatory Commission
	1.2 Ratio of Annual Green Bond Issuance to Total Credit Bond Issuance (Core)	Positive	Wind database, ChinaBond website
	1.3 Depth of Green Insurance (Supplementary)	Positive	China Insurance Yearbook, local statistical bureaus
2. Market Activity of Green Finance	2.1 Proportion of Green Enterprises Among Listed Companies (Core)	Positive	CSRC industry classification of listed companies, environmental protection directories
	2.2 Proportion of Investment in Environmental Protection PPP Projects (Core)	Positive	PPP project management database of the Ministry of Finance
	2.3 Carbon Market Trading Activity (Supplementary)	Positive	Public data from carbon emissions trading exchanges
3. Efficiency of Green Investment and Resource Allocation	3.1 Energy Conservation and Emission Reduction Supported per Unit of Green Credit (Core)	Positive	Estimated based on green credit data and environmental statistical bulletins
	3.2 Financing Cost Advantage of Green Bonds (Core)	Positive (when the interest rate spread is negative)	Wind bond issuance interest rate data
4. Policy Support and Institutional Environment	4.1 Green Finance Policy Intensity Index of Local Governments (Core)	Positive	Textual analysis of publicly available documents from provincial governments
	4.2 Dummy Variable for Green Finance Reform and Innovation Pilot Zones (Core)	Positive	Approval documents from the State Council and relevant ministries
	4.3 ESG Report Disclosure Rate of Listed Companies (Supplementary)	Positive	Official websites of Shanghai and Shenzhen Stock Exchanges, company annual reports

Note – All quantitative indicators have been subjected to dimensionless processing. An indicator attribute labeled as «Positive» indicates that a larger indicator value represents a higher level of development in that dimension.

A linear weighted comprehensive model, as shown in Equation 1, was used to calculate the annual Green Finance Development Index (GFDI) and its sub-dimension indices for each province.

Equation 1: Green Finance Development Index Calculation Model

$$GFDI_{it} = \sum_{j=1}^{4} W_j^{sub} \times \left(\sum_{k=1}^{mj} W_{jk}^{com} \times X_{ijkt}'\right).$$

$GFDI_{it}$ represents the comprehensive development index for province i in year t. W_j^{sub} denotes the subjective weight for criterion layer (dimension) j, determined via the Analytic Hierarchy Process (AHP) m_j is the number of indicators within dimension j. W_{jk}^{com} represents the final combined weight for the k-th indicator within dimension j. X_{ijkt}' is the standardized value of the corresponding indicator.

The measurement results for the provincial levels are presented in the form of the comprehensive index and its four sub-dimension indices: Scale of Fund Supply Index, Market Activity Index, Investment Efficiency Index, and Policy Environment Index. To visually display the evaluation results for provinces, Table 2 lists the provinces in terms of their comprehensive index ranking, along with their performance across the main dimensions.

Table 2 – Green Finance Development Index (GFDI) and Sub-Dimension Scores for Selected Chinese Provinces in 2023

Rank	Province	Comprehensive Index (GFDI)	Supply Scale Index	Market Activity Index	Investment Efficiency Index	Policy Environment Index
High-Performance Group						
1	Beijing	0,856	0,912	0,845	0,801	0,898
2	Zhejiang	0,812	0,843	0,821	0,784	0,795
3	Guangdong	0,803	0,831	0,809	0,765	0,802
4	Shanghai	0,791	0,855	0,788	0,721	0,813
5	Jiangsu	0,779	0,802	0,791	0,752	0,773
6	Fujian	0,701	0,723	0,712	0,685	0,692
7	Jiangxi	0,689	0,698	0,674	0,702	0,688
8	Sichuan	0,675	0,682	0,665	0,691	0,673
9	Hubei	0,663	0,671	0,648	0,680	0,662
10	Chongqing	0,652	0,665	0,639	0,667	0,650
11	Tianjin	0,645	0,678	0,632	0,640	0,638
12	Shandong	0,638	0,665	0,625	0,628	0,645
13	Anhui	0,631	0,652	0,618	0,635	0,622
14	Hunan	0,625	0,638	0,612	0,628	0,631
15	Henan	0,618	0,632	0,605	0,622	0,625

Rank	Province	Comprehensive Index (GFDI)	Supply Scale Index	Market Activity Index	Investment Efficiency Index	Policy Environment Index
16	Shanxi	0,601	0,615	0,588	0,605	0,612
17	Liaoning	0,592	0,608	0,581	0,595	0,601
18	Hainan	0,585	0,602	0,571	0,588	0,595
19	Shanxi	0,578	0,595	0,565	0,581	0,588
20	Hebei	0,572	0,588	0,558	0,575	0,582
Low-Performance Group						
21	Heilongjiang	0,423	0,435	0,401	0,445	0,418
22	Jilin	0,412	0,428	0,395	0,432	0.,05
23	Neimenggu	0,401	0,445	0,378	0,410	0,388
24	Ningxia	0,398	0,420	0,385	0,405	0,392
25	Gansu	0,385	0,398	0,372	0,398	0,378
26	Qinghhai	0,379	0,405	0,361	0,390	0,365
27	Xinjiang	0,365	0,388	0,348	0,381	0,352
28	Yunnan	0,358	0,375	0,342	0,372	0,348
29	Guangxi	0,345	0.362	0,331	0,358	0,336
30	Guizhou	0,332	0.355	0,318	0,345	0,325

Data source – Calculated by this study. Note: The sub-dimension indices have been normalized to the range of 0-1 based on their respective weights to facilitate cross-dimensional comparison.

Preliminary observations indicate a significant tiered distribution in development levels. High-ranking provinces (such as Beijing, Zhejiang, and Guangdong) exhibit relatively balanced and leading performance across all four dimensions, with particularly pronounced advantages in policy environment and supply scale. This suggests that their development is underpinned by solid institutional support and financial foundations. In contrast, low-ranking provinces generally show weaknesses across all dimensions, with the Market Activity Index being the lowest, reflecting insufficient cultivation of their green finance market ecosystems.

Analysis of Temporal Evolution

To analyze the dynamic development, Figure 1 illustrates the evolving trends of the average comprehensive Green Finance Development Index at the national level and across the eastern, central, and western regions from 2015 to 2023. The national average GFDI increased continuously from 0,412 in 2015 to 0,587 in 2023, with an average annual growth rate of approximately 4,5 %, confirming the rapid expansion of China’s green finance system.

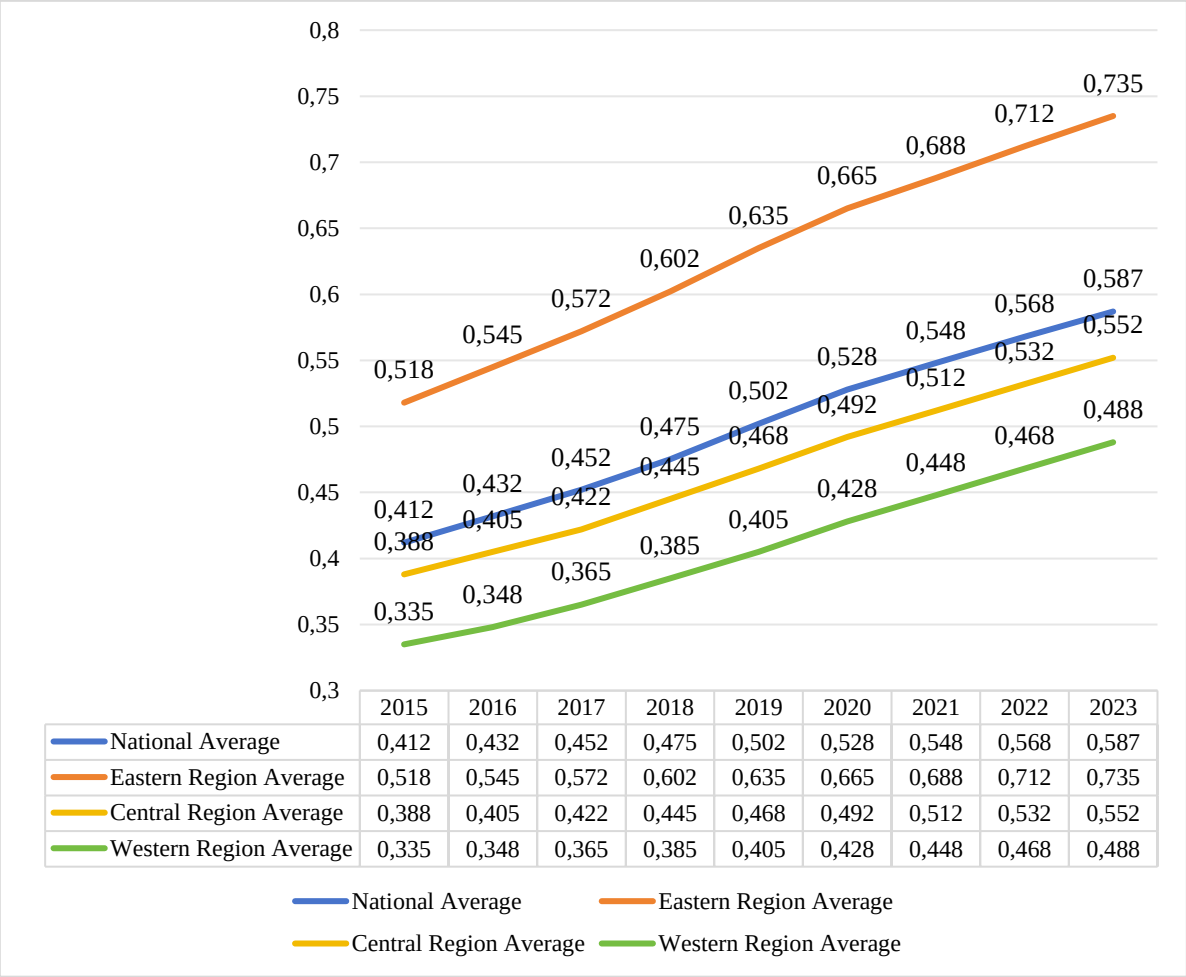

Figure – Trends in the Green Finance Development Index at National and Regional Levels, 2015–2023

Data source – Calculated by this study. Note: The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western region includes Sichuan, Chongqing, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Guangxi, and Inner Mongolia.

Trend analysis reveals the following characteristics.

The period 2015–2017 was an initial phase with moderate growth rates. Following the full implementation of the Guidance on Building a Green Financial System in 2018, growth accelerated noticeably.

After 2020, driven by the «Dual Carbon» goals, the index exhibited a trend of accelerated increase. It was detected persistent but differentially evolving regional disparities.

Eastern Region: Consistently leading with a steep growth curve. Its early growth was driven by a dual engine of supply scale (pioneering green credit and bonds) and policy environment (taking the lead in issuing local implementation rules).

In later stages, the contributions of market activity and investment efficiency increased significantly, indicating an evolution of its development model from «policy-driven» to «market and innovation-driven».

Central Region: Its growth rate was largely in sync with the national average, but its absolute level remained below that of the eastern region.

Its improvement primarily benefited from actively undertaking the transfer of green industries from the east, which boosted green credit growth and environmental PPP project investment. However, shortcomings remain in green financial product innovation and the utilization of capital markets.

Western Region: Starting from a low base, it experienced slow growth in the early

period, but growth picked up after 2020. Its growth exhibited a typical «policy and project-driven» characteristic.

The Policy Environment Index (benefiting from national strategic support) and the Investment Efficiency Index in specific sectors (relatively high credit environmental benefits supporting large-scale clean energy base construction) performed relatively well.

However, market activity remained persistently low, indicating insufficient endogenous market momentum.

Spatial Pattern Analysis

To explore the spatial correlation of green finance development, ArcGIS software and Geoda spatial analysis tools were used to calculate the Global Moran's I for the period 2015–2023.

The results of the Global Moran's I calculation (Table 3) show that the index values for all years are positive and statistically significant ($p < 0,01$).

This indicates a significant positive spatial autocorrelation in China's provincial green finance development levels, meaning that provinces with similar development levels tend to cluster spatially.

Table 3 – Global Moran's I for the Green Finance Development Index, 2015–2023

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023
Moran's I	0,352	0,368	0,371	0,385	0,402	0,415	0,428	0,436	0,441
Z	4,125	4,287	4,301	4,456	4,632	4,785	4,901	4,987	5,012

Note – Indicates significance at the 1 % level.

Based on Local Spatial Autocorrelation Analysis (LISA), four typical types of spatial agglomeration can be identified, among which the «High-High» (HH) and «Low-Low» (LL) clusters hold significant policy implications.

Table 4 summarizes the significant agglomeration regions identified by LISA analysis for 2023.

Table 4 – Significant Agglomeration Areas from Local Spatial Autocorrelation (LISA) Analysis of Green Finance Development Level in 2023

Agglomeration Type	Province(s)	Implication
High-High (HH)	Shanghai, Jiangsu, Zhejiang, Guangdong	High local development level, surrounded by other high-level provinces, forming a core area of positive spillover effects.
Low-Low (LL)	Yunnan, Guizhou, Guangxi	Low local development level, surrounded by other low-level provinces, trapped in a low-level equilibrium.
Low-High (LH)	Anhui, Jiangxi, Fujian (in certain years)	Relatively low local development level but surrounded by high-level provinces, indicating potential to receive spillovers and catch up.
High-Low (HL)	Beijing, Tianjin (in specific years)	High local development level but surrounded by low-level provinces, serving as a regional "highland" or "enclave."

The main findings of the spatial pattern analysis are as follows:

Formation and Reinforcement of «High-High» (HH) Clusters. The Yangtze River Delta region (Shanghai, Jiangsu, Zhejiang) and the Guangdong-Hong Kong-Macao Greater Bay Area (Guangdong) have consistently remained stable and core HH clusters.

These regions, characterized by developed economies, mature financial markets, and strong policy innovation capabilities, generate significant positive spatial spillover effects in green finance, driving development in neighboring provinces (Anhui, Fujian).

Persistence and Contiguity of «Low-Low» (LL) Clusters. The southwestern region (Yunnan, Guizhou, Guangxi) and parts of the northwestern region exhibit contiguous LL clustering characteristics.

These areas face multiple constraints, including a weaker economic foundation, industrial structure, and degree of financial deepening, leading to insufficient momentum for green finance development.

They are at risk of falling into a low-level equilibrium trap due to «siphon effects» or «transmission blockages».

Emergence of a Spatial Polarization Trend. The slight year-on-year increase in the Moran's I index, coupled with the persistent stability of HH and LL clusters, suggests a certain degree of spatial polarization in China's green finance development.

Regional disparities may become entrenched due to agglomeration effects.

Conclusion

The calculated GFDI and its sub-dimension indices clearly and reasonably reflect the relative levels, strengths, and weaknesses of green finance development across provinces, validating the scientific rigor and practical utility of the evaluation system.

This index series constitutes an ideal dependent variable for panel data models.

While the national level shows continuous improvement, the eastern, central, and western regions exhibit different growth trajectories and driving force structures.

This suggests potential regional heterogeneity in driving factors, which needs to be tested in the empirical model (by introducing interaction terms with regional dummy variables).

Spatial Dimension Exhibits Significant Agglomeration and Spillover Effects. The strong spatial autocorrelation and clear HH/LL clusters indicate that a province's green finance development is not an isolated event but is significantly influenced by the development of neighboring regions.

This strongly suggests that when constructing the econometric model for driving factors, spatial effects must be considered. Spatial econometric models should be employed instead of ordinary panel models to avoid estimation bias and accurately identify the intensity and scope of spatial spillovers.

High-ranking provinces show relatively balanced development across all four dimensions, while low-ranking provinces exhibit clear «shortcomings» in specific dimensions (typically Market Activity and Investment Efficiency).

This implies that different driving factors may have differentiated effects on various dimensions of development.

Subsequent analysis can further explore the specific pathways through which driving factors influence both the comprehensive index and the individual sub-dimension indices.

The ultimate conclusion of this study reveals that the success of green finance lies, in essence, in the systematic and creative integration of a country's ecological endowments, industrial strategy, and financial instruments.

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Рукапіс паступіў у рэдакцыю 26.02.2026