

# Research on the Coupled and Coordinated Development of Green Finance and Low-Carbon Economy: Evidence from Central and Eastern Provinces in China

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## Abstract

Against the backdrop of intensifying global climate change and the continued advancement of China's *Carbon Peaking and Carbon Neutrality Goals*, green finance and the low-carbon economy have become two core systems driving green economic transformation and high-quality development. Taking 16 provinces in eastern and central China as the research objects, this paper focuses on the interactive relationship between green finance and the low-carbon economy, constructs a comprehensive evaluation framework, and employs the entropy method and the coupling coordination degree model to analyze the development levels and synergistic status of the two systems in the sample regions from 2010 to 2022. The results show that: (1) the coupling coordination degree between green finance and the low-carbon economy generally exhibits an evolutionary pattern characterized by continuous improvement with slight local fluctuations, and the overall level in 2022 is significantly higher than that in 2010; (2) from a temporal perspective, the coupled and coordinated development of green finance and the low-carbon economy has roughly undergone three stages, namely the initial cultivation stage, the steady growth stage, and the rapid advancement stage, among which the improvement after 2020 is the most significant; (3) from a spatial perspective, Zhejiang, Tianjin, and Beijing are at relatively high levels, whereas Henan exhibits characteristics of relative stagnation in the low-carbon economy, rapid growth in green finance, but a mismatch between the two systems. Based on the findings, this paper proposes promoting green finance innovation by category, optimizing the layout of low-carbon industries, and strengthening regional policy coordination, so as to provide support for achieving the *Dual Carbon Goals*.

## Keywords

green finance, low-carbon economy, coupling coordination degree, regional comparison, dual carbon goals

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## 1. Introduction

Global warming is profoundly reshaping the modes of production and daily life in human society. The resulting extreme weather events, such as floods, droughts, heatwaves, and wildfires, have not only caused substantial economic losses but also posed long-term threats to ecological security and human well-being [1]. As a key factor contributing to global warming, carbon emissions have become a central governance target in

the process of green transformation worldwide [2, 3]. As a responsible major country, China officially proposed in 2020 the *Carbon Peaking and Carbon Neutrality Goals* of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060. Under this strategic background, green finance and the low-carbon economy have gradually become important instruments for promoting China's green transformation, high-quality development, and Chinese modernization. From a practical perspective, significant differences exist across regions in China in terms of resource endowments, levels of economic development, industrial structures, infrastructure conditions, and carbon emission characteristics. Benefiting from locational advantages, a strong foundation for industrial upgrading, and technological innovation capacity, the eastern region has long maintained a leading position in the development of green finance and the low-carbon economy. In contrast, the central region, relying on its energy resources and industrial transfer advantages, has accelerated green transformation under the impetus of the *Dual Carbon Goals* and has become an important hub connecting eastern and western China [4]. For this reason, examining the coupled and coordinated development of green finance and the low-carbon economy from a comparative perspective between eastern and central China is not only of strong practical significance but also of important policy value.

Therefore, taking 16 provinces in eastern and central China as the research objects, this paper systematically analyzes the overall trends, stage-specific characteristics, and regional echelon patterns of the coupled and coordinated development of green finance and the low-carbon economy based on a review of existing studies, and puts forward corresponding policy recommendations, with a view to providing references for optimizing green transformation pathways in different regions.

## 2. Literature Review

### 2.1 Research on the Measurement of Green Finance

Existing domestic studies generally adopt comprehensive evaluation systems to construct measurement indicators for green finance from dimensions such as scale, structure, and efficiency, with a focus on core financial instruments including green credit and green bonds, while gradually introducing a spatial analysis perspective to reveal regional differences [6, 7]. Existing studies show that the development level of green finance in China has generally exhibited an upward trend. The eastern region has improved rapidly, while the central region has also achieved steady development in the context of industrial transformation. The central and western regions as a whole demonstrate fluctuating growth, with regional disparities gradually narrowing. Foreign studies, by contrast, tend to place greater emphasis on cross-country comparative analyses under international standard frameworks, using ESG ratings and the issuance scale of green financial instruments as key measures [8, 9], which provides a reference for the continuous optimization of China's green finance measurement system.

### 2.2 Research on the Measurement of Low-Carbon Economy

Regarding the measurement of the low-carbon economy, existing studies have developed an analytical approach combining "single indicators and composite indices" [10]. Single-indicator studies usually focus on carbon emission intensity and carbon productivity, whereas comprehensive evaluation studies integrate multidimensional factors such as economic growth, industrial structure, technological innovation, and the ecological environment, and widely employ methods such as the entropy method and TOPSIS for estimation. From a practical perspective, the eastern region has achieved relatively outstanding progress in low-carbon economic development. The central region, relying on its industrial foundation and resource conditions, has accelerated low-carbon development under the guidance of the *Dual Carbon Goals*. However, due to the incomplete adjustment of industrial structure, a certain gap remains between its low-carbon economic efficiency and that of the eastern region.

### 2.3 Research on the Relationship Between Green Finance and Low-Carbon Economy

Existing studies generally suggest [11, 12] that green finance has a significant promoting effect on the low-carbon economy and can facilitate emission reduction and efficiency improvement through mechanisms such as capital allocation, incentives for technological innovation, and industrial structure optimization. The eastern region has accumulated substantial experience in cross-border coordination in green finance, targeted

allocation of green credit, and financing support for low-carbon projects. Although the green finance system in the central region has been gradually improving, its driving effect has not yet been fully released due to constraints such as the concentration of financial resources, policy coordination, and industrial transfer capacity. Some studies also point out that in regions with underdeveloped financial systems and greater pressure for industrial transformation, the positive effect of green finance on the low-carbon economy may exhibit a certain time lag.

## 2.4 Literature Review and Commentary

Overall, existing studies have gradually expanded from the single measurement of green finance or the low-carbon economy to analyses of their relationship and interaction effects. Research methods have become increasingly mature, providing a solid foundation for this study. Meanwhile, several shortcomings remain in the existing literature. First, the measurement of green finance does not comprehensively cover instruments such as green insurance and green funds. Second, detailed studies on differences between eastern and central China remain relatively weak, particularly lacking comparative analyses that integrate resource endowments, industrial structure, and financial development capacity. Based on these gaps, this paper attempts to further investigate the coupled and coordinated development of green finance and the low-carbon economy from the comparative perspective of 16 provinces in eastern and central China.

## 3. Research Design

### 3.1 Research Objects and Sample Scope

This study selects 16 provinces, namely Zhejiang, Tianjin, Beijing, Jiangsu, Shandong, Hubei, Hunan, Hainan, Guangdong, Shaanxi, Fujian, Anhui, Shanghai, Hebei, Jiangxi, and Henan, as research samples, with the study period spanning from 2010 to 2022.

### 3.2 Construction of the Indicator System

This study defines green finance and the low-carbon economy as two relatively independent yet interrelated subsystems. A comprehensive indicator system for the green finance subsystem can be constructed from dimensions such as financial scale, financial structure, and financial efficiency. The low-carbon economy subsystem can be measured from dimensions including the quality of economic development, industrial structure optimization, technological innovation capability, energy utilization efficiency, and ecological-environmental constraints.

### 3.3 Entropy Weight Method

The entropy weight method is an objective weighting approach that assigns weights to indicators according to the magnitude of their information entropy. Based on the concept of information entropy, it measures the amount of information contained in each indicator by calculating its entropy value and then derives the corresponding indicator weights. This study adopts the entropy weight method, an objective weighting method, to determine indicator weights and further measure the levels of green finance and the low-carbon economy.

To eliminate the influence of different indicator dimensions, the range normalization method is used to process the raw data:

$$X'_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \quad (1)$$

where  $X'_{ij}$  denotes the standardized value of indicator  $j$  for province  $i$ ,  $X_{ij}$  denotes the original value, and  $\max(X_j)$  and  $\min(X_j)$  represent the maximum and minimum values of indicator  $j$ , respectively.

First, the proportion of province  $i$  under indicator  $j$  is calculated as:

$$P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^n X'_{ij}} \quad (2)$$

Then, the information entropy of indicator  $j$  is calculated as:

$$e_j = \frac{1}{\ln n} \sum_{i=0}^n P_{ij} \ln P_{ij} \quad (3)$$

Further, the weight of indicator  $j$  is calculated as:

$$w_j = \frac{1-e_j}{\sum_{j=1}^m (1-e_j)} \quad (4)$$

where  $n$  is the total number of provinces,  $m$  is the total number of indicators, and  $w_j$  denotes the entropy weight of indicator  $j$ , satisfying  $\sum_{j=1}^m w_j = 1$ .

Finally, the composite index is calculated as:

$$Y = \sum_{i=1}^n w_j \times X'_{ij} \quad (5)$$

where  $Y$  is the composite index,  $w_j$  is the entropy weight of indicator  $j$ , and  $n$  is the total number of indicators. Its value ranges from  $[0,1]$ , with a larger value indicating a higher development level.

### 3.4 Coupling Coordination Degree Model

The measurement of coupling coordination degree includes three levels: coupling degree, coordination degree, and coupling coordination degree. The coupling degree reflects the interaction intensity between the two systems:

$$C = 2 \times \sqrt{\frac{DE \times GLC}{(DE + GLC)^2}} \quad (6)$$

where  $C$  denotes the coupling degree, ranging from  $[0,1]$ . A larger value of  $C$  indicates a stronger interaction between the two systems.

The coordination degree reflects the synchronicity of development between the two systems:

$$T = \alpha \times DE + \beta \times GLC \quad (7)$$

where  $T$  is the coordinated development index, and  $\alpha$  and  $\beta$  are weights to be determined. Considering the equal importance of the two systems, this study sets  $\alpha=\beta=0.5$ .

The coupling coordination degree comprehensively reflects the synergistic development level of the two systems:

$$D = \sqrt{C \times T} \quad (8)$$

where  $D$  denotes the coupling coordination degree, ranging from  $[0,1]$ . A larger value of  $D$  indicates a higher level of coupled and coordinated development between the two systems.

## 4. Analysis of Empirical Results

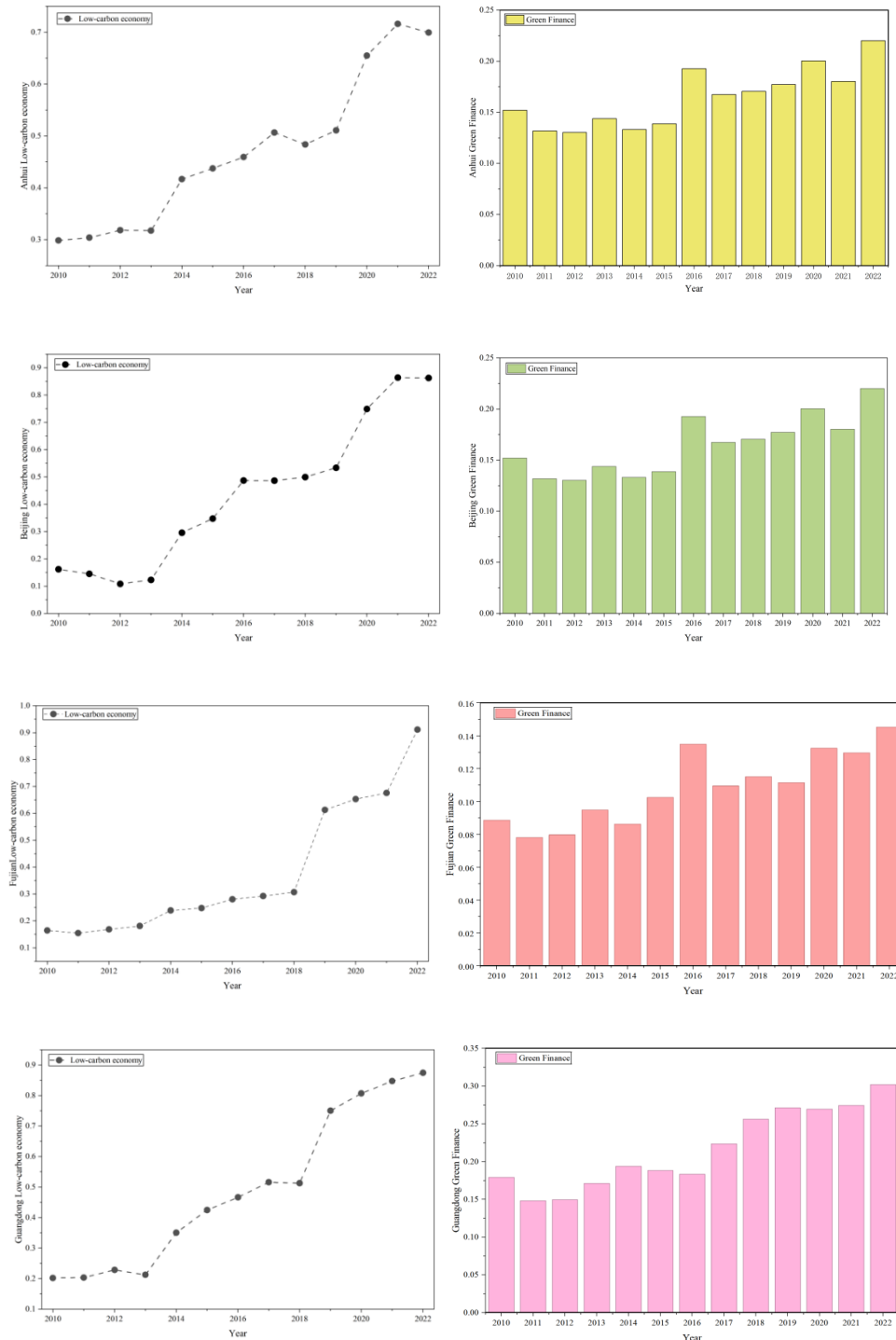
### 4.1 Evolutionary Characteristics of the Green Finance and Low-Carbon Economy Systems

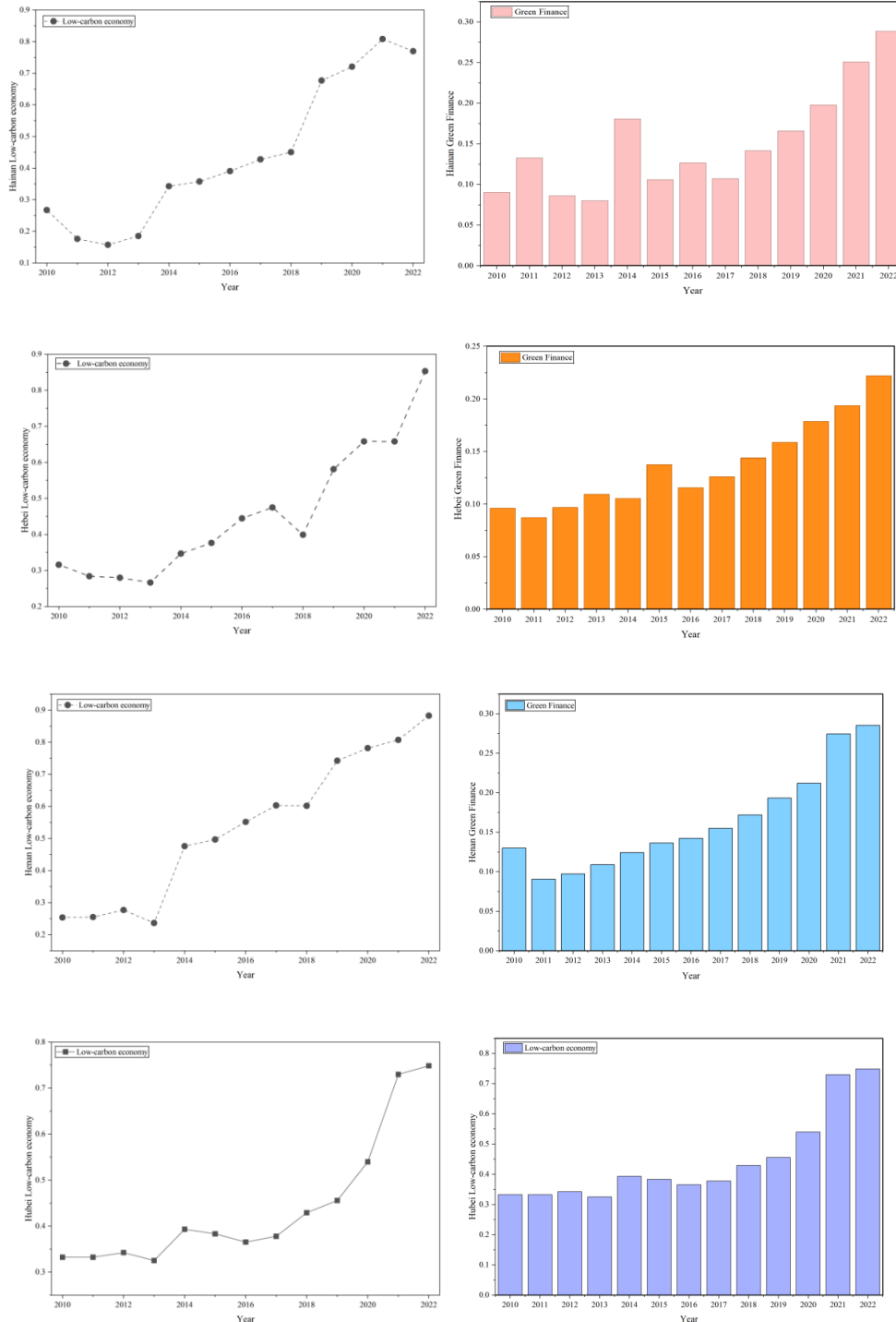
From the overall trend, during the study period, the coupling coordination degree between green finance and the low-carbon economy in all provinces exhibited the core characteristic of “continuous and steady improvement with slight local fluctuations,” and the overall level in 2022 was generally significantly higher than that in 2010. This indicates that with the continuous deepening of the green development concept, the connection between the two systems of green finance and the low-carbon economy has become increasingly close, gradually moving from a relatively disconnected initial state toward a development trajectory characterized by mutual support and coordinated advancement. Due to space limitations, the main text presents the system evolution trends for eight provinces.

The development of the low-carbon economy and green finance across provinces exhibits differentiated characteristics while sharing overall commonalities. In most provinces, including Anhui, Beijing, Fujian, Guangdong, Hainan, Hebei, Hubei, Jiangsu, Jiangxi, Shandong, Shanghai, Shaanxi, Zhejiang, and Tianjin, the low-carbon economy generally shows a sustained upward trend, with only slight declines in a few individual years. Green finance also demonstrates overall steady growth with minor local fluctuations. Both systems have

risen from relatively low levels at the beginning of the study period to higher levels at the end, with a significant improvement in coordination, generally reflecting a development pattern of “overall improvement plus local fluctuations.” Only Hunan and Tianjin exhibit the characteristic of “overall improvement plus differentiated local fluctuations.” Specifically, green finance in Hunan was slightly lower at the end of the period than at the beginning, while green finance in Tianjin experienced slight growth followed by stabilization. Henan is the only province showing a distinct pattern. Its low-carbon economy remained basically stable with minor fluctuations during 2010–2022, without obvious increases or declines, whereas green finance continued to rise significantly. The development pace of the two systems was clearly differentiated, and the overall coordination level exhibited a characteristic of “fluctuating divergence,” failing to achieve synchronized improvement.

Figure 1: Development Indices of the Low-Carbon Economy and Green Finance Across Provinces





## 4.2 Analysis of the Stage-Specific Characteristics of Coupling Coordination Degree

From a temporal perspective, the evolution of the coupling coordination degree can be broadly divided into three stages. The main text presents the changing trends in coupling coordination degree for nine provinces.

The first stage is the initial cultivation stage (2010–2014). During this period, both green finance and the low-carbon economy were in their nascent stage of development. The policy system had not yet been fully established, and market participants had limited awareness. The coupling coordination degree in most provinces remained within the low-level coordination range, indicating a weak development foundation for the two systems, limited inter-system linkage, and the insufficient manifestation of synergistic effects.

The second stage is the steady growth stage (2015–2019). With the gradual implementation of green finance pilot policies and the increasing diffusion of low-carbon transition concepts, provinces began to simultaneously promote industrial low-carbon transformation and the development of green finance systems. The overall coupling coordination degree rose to the moderate coordination range. The financial support role of green finance for the low-carbon economy gradually strengthened, and the synergy between the two systems improved significantly.

The third stage is the rapid advancement stage (2020–2022). Following the formal proposal of the *Dual Carbon Goals*, governments at all levels intensively introduced policies related to green development and low-carbon transition, while resources such as capital, technology, and human talent accelerated their concentration in green and low-carbon sectors. In most provinces, the coupling coordination degree exceeded 0.8, entering a stage of relatively high coordination or even high coordination. Zhejiang and Tianjin, in particular, approached the level of high-quality coordination, reflecting the significant outcomes generated by the combined efforts of policy support and market forces.

Figure 2: Coupling Coordination Degree Across Provinces



## 5. Conclusions and Policy Recommendations

### 5.1 Research Conclusions

Based on the estimation results for 16 provinces in eastern and central China from 2010 to 2022, this paper systematically analyzes the coupled and coordinated development of green finance and the low-carbon economy. The results show that the coupling coordination degree between green finance and the low-carbon economy in the sample regions has continuously improved overall. Although local fluctuations exist, the long-term upward trend is clear, and the two systems are gradually moving from relative disconnection toward coordinated advancement.

From a temporal perspective, the evolution of coupling coordination in the sample regions has undergone three stages: the initial cultivation stage, the steady growth stage, and the rapid advancement stage. Among these, the improvement after 2020 is the most significant, indicating that the *Dual Carbon Goals* and the

improvement of the green development policy system have played a decisive role in promoting synergy between the two systems.

From a spatial perspective, there is a clear echelon differentiation among the sample provinces. Zhejiang and Tianjin are in leading positions, followed closely by Beijing and Jiangsu. Shandong, Hubei, and Guangdong fall within the medium-to-high coordination range, whereas Henan remains at a relatively low level due to industrial structure inertia and system mismatch. This suggests that the coupling coordination between green finance and the low-carbon economy is not achieved automatically, but is jointly influenced by differences in regional policies, industrial structures, energy endowments, and financial innovation capabilities.

## 5.2 Policy Recommendations

First, for regions with high and relatively high levels of coordination, efforts should continue to consolidate first-mover advantages by further deepening breakthroughs in green financial product innovation, carbon finance market development, cross-regional capital allocation, and research and development of core low-carbon technologies, thereby continuously enhancing high-level synergistic capacity and playing a national demonstration and leading role.

Second, for regions with medium-to-high levels of coordination, efforts should accelerate the low-carbon and clean transformation of traditional high-energy-consuming industries, strictly control the expansion of high-energy-consumption and high-emission projects, and vigorously foster green and low-carbon industries such as new energy, new materials, and high-end manufacturing. In the financial sector, innovative products such as transition finance and carbon account loans should be enriched to promote the deeper integration of green finance into the industrial transformation process.

Third, for regions with medium levels of coordination, development should be based on local resource endowments and industrial foundations, with accelerated industrial structure optimization, strengthened cultivation of low-carbon industries and project reserves, and active efforts to obtain national policy support for green development. Meanwhile, foundational systems such as green credit and green bonds should be improved to guide more financial resources toward low-carbon sectors and promote progress toward a higher stage of coordination.

Fourth, for regions with low levels of coordination, priority should be given to overcoming industrial structure inertia and insufficient project absorption capacity. Through formulating specialized low-carbon transformation plans, strengthening investment promotion, fostering low-carbon industrial clusters, and improving green finance incentive mechanisms, the chain of “financial support–industrial implementation–economic transformation” should be opened up, thereby gradually enhancing the systemic synergy between green finance and the low-carbon economy.

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