The coupling coordination development between green finance and environmental governance in China: Measurement and spatial-temporal analysis

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Abstract

To direct financial resources for achieving the goal of environmental governance, the Chinese government has devoted increasing efforts to developing green finance. However, few studies explored the relationship between green finance and environmental governance. Thus, this paper first theoretically discusses the interactive connection between green finance and environmental governance. Then we construct two comprehensive indicator systems and use entropy method to calculate green finance index (GFI) and environmental governance index (EGI) for 30 provinces of China from 2004 to 2020. Using the data of GFI and EGI, the coupling coordination degree of green finance and environmental governance (CCDGE) is measured by coupling coordination model. The findings of spatial-temporal analysis show that GFI has grown more rapidly than EGI, but the development of green finance still lags behind environmental governance because of its short history. Although CCDGE is increasing steadily, it has been hovering in the moderate coupling coordination stage for a long time, and still has a great distance to the high coupling coordination level. The relationship between green finance and environmental governance are still in a state of disorderly development that restricts each other. Additionally, there are obvious regional differences in GFI and EGI and the interactive effect between green finance and environmental governance. Specifically, GFI and EGI in eastern China are highest, while CCDGE presents a ladder decline status of ‘eastern region > central region > northeast region > west region’.

1. Introduction

According to 2021 Statistical Bulletin on National Economic and Social Development of China, total energy consumption in 2021 is 5.24 billion tons of standard coal, an increase of 5.2% over 2020. Although energy consumption per unit of GDP decreased by 2.7% compared with 2020, the reduction target of 3% set in the 2021 government work report has not been achieved. With the rapid growth of Chinese economy in the post epidemic era, the development of industries with high pollution, high energy consumption and overcapacity has brought a heavy pressure to sustainable development. Therefore, it is vital for China to maintain green development and strengthen environmental governance in future. As early as the 19th National Congress of CPC, Chinese government formally initiates the idea of green development, which has become a vital path for sustainable development (Sohag et al., 2019; Taşkin et al., 2020). As we know, it is very important to develop green technology for the practice of green development (Zhao et al., 2020). However, green development cannot effectively attract funds for green technical innovation because of its high risks and low rate of return. Therefore, it is of great significance to integrate various sources of capital from government, enterprise and society into the field of green development in order to protect environment and control pollution.

In order to achieve the sustainable goal of green development, it is necessary to increase the financing for environmental protection through new financial instruments and policies, such as green bonds, green credit and carbon trading instruments, which is known as ‘green finance’. As an institutional arrangement and a market mechanism, green finance not only contributes to the realization of green development goal and the industrial structure adjustment (Yin and Xu, 2021), but also contributes to sustainable development of economy (Soundarrajan and Vivek, 2016). Especially, green finance can guide the funds flowing into the fields of cleaner production and pollution prevention, so as to improve the efficiency of environmental governance. Due to be the largest emitter of greenhouse gases, China has committed to reach carbon peak in 2030 and carbon neutralization in 2060, which poses great challenges and opportunities for green finance. Up to now, Chinese government has paid more and more attention to the role of green finance in sustainable development, and has raised a lot of funds for environmental protection by green finance policies. However, environmental protection has positive externalities, i.e., it not only needs a lot of funds, but also has a low profitability and a long return cycle. Therefore, investors including enterprises, financial institutions and social capitals are unwilling to invest in the green field, and the government has been the main body of investment. As of 2020, the investment for environmental protection and pollution control has reached 1063.89 billion Yuan in China, of which the investment from enterprises is less than 10%. Moreover, green credit only provided incentives for the short-term financing behavior of high energy consumption and high pollution enterprises (Zhang et al., 2021). In this context, it is very urgent for China to introduce social resources into green finance field through green policies guidance and support and market-oriented approaches to reduce carbon emissions, curb environmental degradation, and ultimately improve the efficiency of environmental governance.

This study integrates green finance and environmental governance into a unified framework to theoretically and empirically analyze the coupling coordination relationship between them in China. Under the separate and interactive conditions of green finance and environmental governance, it is important to understand their relationship and clarify how their coupling coordination effect varies over time and distributes spatially at region level. The findings of the study can provide theoretical and practicable foundations for the government to formulate differentiated green development policies at region level.

There are at least three contributions of this paper. First, this study theoretically discusses the coupling coordination mechanism between green finance and environmental governance, laying a solid theoretical foundation for the empirical study. Second, this study constructs two indicator systems for comprehensively calculating the green finance index (GFI) and environmental governance index (EGI). Using these calculated data, the connection of green finance and environmental governance is analyzed for the first time. Third, the spatial-temporal features of GFI, EGI and the coupling coordination degree between green finance and environmental governance (CCDGE) at nation level and at region level are unveiled. The findings of this paper have an important meaning for China to implement green development policies and achieve the goals of ‘Double Carbons’ [1].

The rest of this paper is organized as follows. The literature is reviewed in Section 2. Section 3 is a theoretical analysis and Section 4 provides a detailed description of methodology and data sources. The results of empirical analysis are presented in Section 5, and Section 6 concludes and provides some policy implications.

[1] ‘Double Carbons’ is the abbreviation of carbon peak and carbon neutralization. In September 2020, China clearly puts forward the goals of carbon peak in 2030 and carbon neutralization in 2060.

2. Literature Review
2.1. Financial development and environmental quality

The impacts of financial development on environmental quality, including the carbon emissions reduction, energy efficiency and energy intensity, have been explored by an extensive literature. Some studies hold the view that financial development can alleviate financing constraints of enterprises, and then increase energy consumption and carbon emissions by stimulating the growth of investment. For instance, Sadorsky (2010) discover that financial development makes it easier to obtain loan for purchasing energy-intensive products, thereby deteriorates environmental quality. For India, financial development has a long-term positive impact on carbon emissions, which means that financial development promotes environmental degradation (Boutabba, 2014). Similarly, the study of Nasir et al. (2019) shows that there is a long-run co-integration relationship between financial development and environmental degradation in the five ASEAN countries, i.e., financial development increases environmental degradation. The recent study of Chen et al. (2022) reveals that financial development impedes sustainable development in China. However, Shahbaz et al. (2013) believe that financial development and trade opening play a vital role in improving environmental quality and can effectively reduce carbon emissions. With the development of finance, the sufficient sources of R&D funds can support the research of clean technologies and transform the energy consumption structure, and then reduce carbon emissions (Tamazian et al., 2009; Jailil and Feirudin, 2011; Shahbaz et al., 2013). In additions, using the panel data of 83 countries, Acheampong et al. (2020) find that there are differences in the nonlinear impact and regulatory effect of financial market development on the intensity of carbon emissions among countries. Specifically, financial market development can reduce the intensity of carbon emissions in developed and emerging financial economies, increase in frontier financial economies, but has no direct impact in standalone financial economies.

2.2. Green finance and environmental quality

Financial resources should be invested in industry and infrastructure not only considering the economic interest, but also considering the potential environmental impact. As a special pattern of financial development, green finance aims to integrate environmental protection (green) with economic profits (finance), and can realize the effective management of environmental risks and the optimal allocation of financial resources (Wang and Zhi, 2016). Green finance is a market-based investing and lending program aiming to connect financial industry, environmental improvement and economic growth, and has been the core of low carbon economy (Soundarajan and Vivek, 2016). Therefore, unlike the uncertain effects of traditional financial development, it has been proved that green finance can improve environmental quality by many studies. For example, Liu et al. (2017) unveil that green credit policies can effectively curb investment in energy-intensive industries. While Li et al. (2018) theoretically prove that green credit and government subsidy can improve environmental quality by reducing energy consumption and enhancing the intention to technique innovation of enterprises. Green investment is also helpful to improve environmental quality, and green financing in renewable energy sectors is beneficial for achieving the goal of zero net emissions (Wang et al., 2020). Similarly, green finance can mitigate carbon intensity (Ren et al., 2020) and carbon emissions through promoting green technology innovation in China (Huang et al., 2021; Chen and Chen, 2021). Furthermore, the development of green finance can relax the financing constraints of environmental protection infrastructure, new energy exploitation, R&D of new materials, and then provides more low-carbon products or services to support the development of environment-friendly economy (Taghizadeh-Hesary et al., 2021). Green finance also can scale down the production of polluting product by reducing the credit supply to high-pollution and high-emission investment (Huang and Zhang, 2021).

2.3. Environmental governance

Most studies on environmental governance discuss the regional differences of environmental governance efficiency of China. For example, Wang et al. (2018) discover that among the five major urban agglomerations in China, the environmental governance efficiency of the Pearl River Delta is the most efficient, while Chengdu-Chongqing urban agglomeration has the lowest environmental governance efficiency. For the environmental governance efficiency of Chinese iron and steel enterprises, it has remained at a low level, and the impact of different types of environmental regulation on the efficiency is heterogeneous (Li et al., 2019; Zhu et al., 2021). The environmental governance efficiency at provincial levels in China shows a spatial cluster over time, which is caused by the spatial dependence of the government's environmental governance behaviors (Peng et al., 2021).

The existing literature on environmental governance mainly analyzes carbon emissions reduction, environmental regulation and environmental pollution control from the perspective of enterprises and government. As an emerging field, the study on the impact of green finance on environmental governance still needs to be deeply explored. Especially, the studies on the relationship between finance development (green finance) and environmental problems only focus on the one-way impact of finance development. Therefore, this paper initiates to discuss the interactive relationship between green finance and environmental governance from the perspective of coupling coordination development. Based on the theoretical analysis of coupling coordination mechanism, we construct two indicator systems for the evaluation of green finance index and environmental governance index respectively. Then using the entropy method, the coupling coordination model and ArcGis software, green finance index, environmental governance index, and their coupling coordination degree are calculated, and the spatial variation of the 30 provinces of China are analyzed from 2004 to 2020. The theoretical and empirical findings not only are helpful to understanding the interactive relationship between green finance and environmental governance, but also can provide some supports for how to take the advantage of green finance to enhance the environmental governance efficiency.

3. The Coupling Coordination Mechanism Between Green Finance And Environmental Governance

This paper uses Fig. 1 to analyze the coupling coordination mechanism between green finance and environmental governance. In the three stages of environmental governance, including initial stage, growth stage and mature stage, environmental governance needs different supports of green finance. We thus argue that the coupling coordination development between green finance and environmental governance also can be divided into three levels, i.e., low, moderate and high coupling coordination, just as shown in Fig. 1.

At the initial stage of environmental governance, due to serious environmental pollution, imperfect environmental protection technology, high governance cost, great governance difficulty and the lack of environmental protection awareness of enterprises, social organizations and the public, the government is forced to
be mainly responsible for the governance subject. The government must undertake the functions of regulation, overall planning, guidance and demonstration of environmental governance. For example, it imposes environmental constraints on enterprises by issuing a series of environmental protection laws and regulations. At this stage, it is very difficult to get the support of commercial financial market. Therefore, the government has to increase the support of policy finance for guiding the capitals flowing into the industries related environmental protection. As the most closely related to environmental protection, the green industry would be developed to a certain extent, which in turn can bring more investment opportunities and attract more funds. Finally, a green financial market dominated by policy finance and supplemented by commercial finance is formed, and the investment enthusiasm of commercial financial institutions in green industries is preliminary activated at this stage.

At the growth stage, environmental governance does not only depend on government. Enterprises perform the partial functions of environmental governance by pollution control, carbon emissions reduction and ecological environment protection according to the environmental law and regulation. At this stage, the industries related to environmental governance have greater development space, and also need more financial supports from both policy finance and commercial finance. Specially, policy finance pays more attention to invest with commercial finance to promote technological innovation of green industry. In this context, the scale of green finance is further expanded because of the driven of policy and profit. With the strong supports of policies and the development of green finance, the efficiency of environmental governance is improved.

At the mature stage, environmental governance presents some new characteristics, including the breakthrough innovation of environmental protection technology, the diversification of environmental governance means, and the enhancement of environmental awareness of the whole society. A pluralistic co-governance concerning enterprises, social organizations, government and the extensive public has gradually formed. At this stage, the innovation ability of green enterprises has been enhanced, the green market has developed stably, and the sustainable growth of green industry also expands the profit space. Therefore, commercial financing constraints are decreasing and commercial financial institutions gradually become the best sources of credit. With the extensive financial support, the innovation abilities of green industry have been further improved. Conversely, green industry appeals higher requirements for green financial instruments, which further promotes the optimization of green financial structure. The development of green finance and the level of environmental governance are promoted together at this stage.

It is worth to mention that the coupling coordination effect between green finance and environmental governance emerges through green industry. On the one hand, green finance guides the capital flow through financial means such as green credit and green insurance, which leads funds to get into green industry by enabling green enterprises to obtain more credit granting. With the financial support of green finance for technological innovation, the development of green industry would upgrade the industrial and energy structure, and make the economic development mode be low-carbon and advanced, which should bring about the improvement of environmental governance. On the other hand, the improvement of environmental governance can create a better external condition for the vigorous development of green industry. Furthermore, the development of green industry can bring the higher profitability and broader prospect for green investment, which is related to the scale and quality of green financial market. Only when green industry is able to bring high profit for investors and establish the confidence for green investment, green finance and environmental governance would enter the stage of high-quality development.

Therefore, the improvement of environmental governance relies on green finance, and also can encourage more social capitals to invest in green industry, and then promote the development of green finance. The complementary and mutual reinforcing relationship of the interaction between green finance and environmental governance is shown in Fig. 1.

4. Methodology And Data Sources

4.1 The entropy method

Before measuring the CCDGE, the comprehensive evaluation of GFI and EGI needs to be done by the entropy method with Eq. (1).

\[ U_i = \sum_{j=1}^{m} w_j u_{ij} \]

where \( U_i \) represents GFI or EGI of \( i \)-th (\( i = 1, 2, ..., n \)) sample, and \( w_j \) is the weight of the \( j \)-th (\( j = 1, 2, ..., m \)) indicator and meets \( \sum_{j=1}^{m} w_j = 1 \). Since artificially assigned weights might induce subjective bias (Zhang and Li, 2020), all indicators are first standardized with the extreme difference method (Liu et al., 2018). In Eq. (1), \( u_{ij} \) is the value of the \( j \)-th indicator of the \( i \)-th sample standardized with Eqs. (2) and (3).

For positive indicator: \( u_{ij} = \frac{x_{ij} - \min (x_j)}{\max (x_j) - \min (x_j)} \) \hspace{1cm} (2)

For negative indicator: \( u_{ij} = \frac{\max (x_j) - x_{ij}}{\max (x_j) - \min (x_j)} \) \hspace{1cm} (3)

where \( x_{ij} \) is the original data, and \( \max (x_j) \) and \( \min (x_j) \) represent the maximum and minimum values of the \( j \)-th indicator respectively.

Then the information entropy of \( j \)-th indicator is calculated with Eq. (4).

\[ e_j = -\ln(n) \sum_{i=1}^{n} p_{ij} \ln p_{ij} \]
where \( p_{ij} = u_{ij}/ \sum_{i=1}^{n} u_{ij} \). Then we can obtain the weight of \( j \)th indicator with Eq. (5).

\[
    w_j = \left(1 - e_j\right) / \left[m - \sum_{j=1}^{m} e_j\right]
\]

4.2. The coupling coordination model

As a physical concept, coupling means that two or more systems affect each other, which emphasize the dynamic connection among interdependence, coordination and promotion (Wang et al., 2019). It can present the dynamically evolutionary process of this connection from a low level to a high level or from disorder to order (Zhou et al., 2017). To detect the interactive relationship between green finance and environmental governance, we use the coupling coordination model to calculate CCDGE at province level in China.

First, we use Eq. (6) to calculate the coupling degree between green finance and environmental governance.

\[
    C = 2 \sqrt{GFI \times EGI} / (GFI + EGI)
\]

where the coupling degree \( C \) ranges from \([0, 1]\). \( C \) can be used to present the coupling relationship between green finance and environmental governance, and the bigger \( C \) means higher coupling degree between them.

However, the connection between green finance and environmental governance are interactive, dynamic and unbalanced, just as illustrated in Fig. 1. If both of them are at a low level, the value of \( C \) will still be great. Therefore, only using the coupling degree \( C \) to measure the dynamic relationship would be biased, which cannot reflect the synergistic effect between green finance and environmental governance. Coordination are further used to present the features of cooperative and harmonious relationship, with which each subsystem can form a unified whole in the process of system evolution (Li et al., 2012). The coordination relationship between green finance and environmental governance can be measured by Eq. (7).

\[
    T = a \times GFI + b \times EGI
\]

where parameter \( a \) and \( b \) equal 0.5 because green finance and environmental governance are given same importance in this paper. \( T \) represents coordination degree of green finance and environmental governance and reflects the system’s synergistic effect as a whole. Then we can obtain CCDGE with Eq. (8).

\[
CCDGE = \sqrt{C \times T}
\]

If green finance and environmental governance are coupling coordination, CCDGE will be at a high level, which means that green finance and environmental governance achieve simultaneously rapid development. In order to clearly reflect the coupling coordination process between green finance and environmental governance, we divide the process into three stages according to the measurement results of CCDGE and the theoretical analysis above, just as shown in Table 1.

<table>
<thead>
<tr>
<th>The stages of coupling coordination</th>
<th>The range of CCDGE</th>
<th>The characteristics of coupling coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low coupling coordination</td>
<td>( 0 &lt; CCDGE \leq 0.4 )</td>
<td>The coordinated and orderly development of green finance and environmental governance is very low.</td>
</tr>
<tr>
<td>Moderate coupling coordination</td>
<td>( 0.4 &lt; CCDGE \leq 0.6 )</td>
<td>Green finance can better improve environmental governance, and they can develop in harmony.</td>
</tr>
<tr>
<td>High coupling coordination</td>
<td>( 0.6 &lt; CCDGE \leq 1 )</td>
<td>Green finance has played a great role in environmental governance, and environmental governance has been greatly improved.</td>
</tr>
</tbody>
</table>

4.3. Indicators and data sources

This paper evaluates the development of green finance from four dimensions, including green credit, green investment, green insurance and government support with four indicators (Ren, 2020; Lee and Lee, 2022). While the evaluation for EGI involves two dimensions, including environmental governance intensity and environmental governance effect with ten indicators (Peng et al., 2021). The details of the specific indicators for evaluating GFI and EGI are illustrated in Table 2.
5. Results

5.1. A trend analysis

As shown in Figure 2, China's EGI has not changed much from 2004 to 2020, and has been always hovering in a low range from 0.3 to 0.4. In addition, EGI has risen slightly before 2013, but shows a weak downward trend in recent years. However, GFI and CCDGE have always been an upward trend. Specifically, GFI has risen from 0.09 to 0.239 and CCDGE has increased from 0.408 to 0.502. In the past 17 years, although the green finance of China has been significantly developed and environmental governance has not been greatly improved, GFI still far lower than EGI implies that the development of green finance still lags behind environmental governance. Furthermore, CCDGE has been staying in the stage of moderate coupling coordination for a long time, and there is still a great distance to high coupling coordination. Since the development of green finance in China has a short history[2], the imperfect legal policies and market mechanisms make GFI be not high. In recent years, with the national emphasis on environmental protection, the development of green economy has become a national strategic direction. As an important means of serving green economy, green finance has begun to develop rapidly. As for environmental governance, the long-term existence of the economic development mode at the cost of sacrificing the environment has brought a heavy burden to China's environmental governance, which results that environmental governance lags behind environmental pollution. In addition, environmental pollution has trans-regional and long-term features, also resulting in the low efficiency of environmental governance. The uncoordinated development between green finance and environmental governance cause a moderate CCDGE.

5.2. The spatial-temporal analysis of GFI

In 2004, the average of GFI is 0.09, which means that the development of green finance is very low. Specifically, only the GFI of Beijing (0.24) is above 0.2, while the GFI of all other provincial districts are less than 0.2 in 2004. Henceforth, green finance shows a development trend with low speed, and the average of GFI in 2020 reaches 0.239. The GFI of Beijing has always been the highest and has the fastest growth rate from 2004 to 2020. By 2020, the highest GFI (Beijing) rises to 0.839, while the lowest GFI (Xinjiang) is only 0.101. These results indicate that green finance in China is still at a low development level and has a giant provincial gap, and conversely unveil that green finance in China has a huge development space. Furthermore, we analyze the variation of GFI from the perspective of spatial distribution in 2004, 2010, 2015 and 2020. In order to take into account the geographical difference, this paper further divides 30 provincial districts into eastern region, northeast region, central region and western region[3]. As shown in Figure 3, the GFI varies substantially across provincial districts and tends to cluster in space. Specifically, the provincial districts characterized by high GFI are shown to cluster in the central and eastern region of the country over time, and the GFI of coastal provincial districts in eastern region are far more than other districts. One possible explanation is that the coastal provincial districts actively innovate and vigorously support the green industry relying on their geographical advantages and economic foundation. Especially, the issuance of green bonds in recent years provides financial support for the development of green industry, which greatly promotes the development of green finance of coastal provincial districts in eastern region. For example, the main issuers of green bonds in 2021 are Beijing and the

<table>
<thead>
<tr>
<th>Evaluation objective</th>
<th>Evaluation dimension</th>
<th>Indicators (Measurement methods)</th>
<th>The type of indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFI</td>
<td>Green credit</td>
<td>Proportion of interest expenditure of high energy consuming industries (Interest expenditure of six high energy consuming industries / Total industrial interest expenditure)</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Green investment</td>
<td>Investment in environmental pollution control (Investment in environmental pollution control/GDP)</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Green insurance</td>
<td>Depth of agricultural insurance (Agricultural insurance income/Gross agricultural output)</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Government support</td>
<td>Proportion of fiscal environmental protection expenditure (Financial environmental protection expenditure/Financial general budget expenditure)</td>
<td>Positive</td>
</tr>
<tr>
<td>EGI</td>
<td>Environmental governance intensity</td>
<td>Total investment in industrial pollution control</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total investment of waste water treatment project</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total investment in urban environmental infrastructure</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The number of special vehicles for city appearance and environmental sanitation</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation cost of industrial waste gas treatment facilities</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>Environmental governance effect</td>
<td>Utilization rate of general industrial solid waste</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greening coverage rate of built-up area</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forest coverage rate</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban sewage treatment rate</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Harmless treatment rate of domestic waste</td>
<td>Positive</td>
</tr>
</tbody>
</table>

All data in this paper are from China Industrial Statistics Yearbook, China Insurance Statistics Yearbook, Chinese Environmental Statistical Yearbook, Chinese Statistical Yearbook and Statistical Bulletins of provincial districts. Because of the lack of data, Macau, Hong Kong, Taiwan and Tibet are excluded from the sample, which consists of 30 provincial districts ultimately.
eastern coastal areas. Specifically, the issuance amounts of Beijing, Guangdong, Jiangsu, Shanghai, Tianjin, Zhejiang, Shandong and Fujian account for 80.19% of the total issuance amount of the whole country.

5.3. The spatial-temporal analysis of EGI

From 2004 to 2020, the mean of EGI ranges from 0.3 to 0.387, which shows that the ability of Chinese environmental governance has been at a low-level stage for a long time. Especially, it shows a decreasing trend in recent years from 2013 to 2020. We believe that there are three explanations for these findings. First, the economic development with huge environmental cost has brought a heavy burden to Chinese environmental governance, which results that the efficiency of environmental governance lags behind the speed of environmental pollution. Second, the imperfect laws related to environmental governance, and the conflict between the government's responsibility for environmental governance and economic development are very vital for the low EGI in China. Third, environmental pollution with cross-regional and long-term characteristics also leads to the low efficiency of environmental governance (Peng et al., 2021). As shown in Figure 4 for the regional differences, EGI in eastern region is relatively high, and all four provinces with EGI means above 0.5 locate in this region, including Jiangsu, Guangdong, Zhejiang and Shandong. While EGI in western regions are lowest, and all four provinces with EGI means below 0.2 locate in this region, including Gansu, Guizhou, Qinghai and Xinjiang. These findings imply that eastern region pays more attention to the investment and the quality of urban environmental governance. Jiangsu, Guangdong, Zhejiang and Shandong provinces are located in coastal economic zones, and thus have more resources to improve the environmental quality. Although western region has advantageous natural environment, the limitation of input in environmental governance because of the undeveloped economy and the lack of environmental governance ability of government are the important reasons for the low EGI.

5.4. The spatial-temporal analysis of CCDGE

Table 3. The CCDGE of 30 provinces from 2004 to 2020
to effectively attract social capital. In addition, the green financial instruments and products are not created to fully introduce social capital into green increasing capital demand for environmental governance. Especially, there is no perfect supporting and incentive policies for the development of green finance. The number of provinces in China from 2004 to 2020, and green finance has not yet made great contributions to the improvement of environmental governance in Table 3, the average of CCDGE at country level indicates that the coupling coordination development between green finance and environmental governance of the stage of high coupling coordination, but Qinghai, Xinjiang and Ningxia in western region are still in the stage of low coupling coordination[4]. As shown in region > Northeast region > West region' as shown in Figure 5. In 2004, only 13 provinces, including Beijing, Tianjin, Shanghai, Shandong, Jiangsu, Guangdong, Fujian, Zhejiang, Hainan, Henan, Hubei, Sichuan and Liaoning, have a coupling coordination degree of above 0.4, which indicates that CCDGE in these provinces were in the stage of moderate coupling coordination. Until 2020, only Beijing, Shandong, Jiangsu, Zhejiang and Guangdong in eastern region reach the stage of high coupling coordination, but Qinghai, Xinjiang and Ningxia in western region are still in the stage of low coupling coordination[4]. As shown in Table 3, the average of CCDGE at country level indicates that the coupling coordination development between green finance and environmental governance of China is always moderate. These findings imply that there is a disorderly interaction between green finance and environmental governance in a considerable number of provinces in China from 2004 to 2020, and green finance has not yet made great contributions to the improvement of environmental governance in most provinces. A possible explanation is that China has not yet formed a sound green financial development system, which is not enough to meet the increasing capital demand for environmental governance. Especially, there is no perfect supporting and incentive policies for the development of green finance to effectively attract social capital. In addition, the green financial instruments and products are not created to fully introduce social capital into green industry.
In 2016, at the G20 Hangzhou Summit, China introduced green finance into the G20 agenda for the first time, established a G20 green finance research group, and released the ‘G20 Green Finance Comprehensive Report’. The eastern region consists of Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; The northeast region consists of Liaoning, Jilin and Heilongjiang; The central region consists of Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan; The western region consists of Chongqing, Sichuan, Guizhou, Yunnan, Inner Mongolia, Shaanxi, Gansu, Qinghai, Ningxia, Guangxi and Xinjiang.

6. Conclusions And Implications

6.1. Conclusions

First, although green finance has a greater growth rate than environmental governance, the development of green finance still lags behind the improvement of environmental governance. A possible explanation is that the history of green finance in China is short, which lead to a low scale of green finance market. Just because of the uncoordinated development between green finance and environmental governance, CCDGE is still in the stage of moderate coupling coordination.

Second, the development of green finance and environmental governance in eastern region is faster than those in other regions. In eastern region of China, geographical advantage and superior economic foundation can promote innovations in green industry and increase investment in environmental governance, so that green finance and environmental governance in eastern region are developed more rapidly.

Third, CCDGE in China shows a steady upward trend, but it has not yet reached a stage with high coupling coordination. Especially, a considerable number of provinces are in a disorder development state of mutual restriction between green finance and environmental governance. In addition, there is an obvious regional characteristics of coupling coordination with a ladder decline status of 'Eastern region > Central region > Northeast region > West region'.

6.2. Implications

6.2.1. Deepen the development of green industry

It is very meaningful to strive to develop green industry through carrying out green reform on traditional industries. For China, economic development has entered a new normal[5], which requires the government to upgrade and transform 'Two high and one surplus'[6] industries to the direction of green development. Specifically, the government should attach more importance to the role of scientific and technological innovation by increasing investment in technology research and development to support green projects and green industry. For example, preferential tax should be given to high-tech green enterprises in order to encourage them to innovate, exploit more environmental protection projects and then improve the production capacity of green products. Furthermore, guide more social capital to invest in environmental governance through the green development policies, so that green finance and environmental governance can form an orderly, coordinated and synchronous development trend. For example, regional special green finance fund, or financial discount subsidy fund and government risk mitigation fund for green finance can be set up to motivate various market entities to actively participate in the development of green industry.

6.2.2. Further improve green financial market

The innovation of green financial products and services should be promoted for building a multi-level and diversified green financial market. In terms of green credit, the government should increase its scale of green credit market and introduce more funds into green industries. In order to ensure that the funds really flow into the fields of green development, environmental risk analysis on green industries and environmental governance effect tracking should be conducted. In terms of green bonds, funds should be precisely invested in the field of sustainable development, including clean and efficient utilization of energy, technical transformation of energy conservation and carbon emission reduction, recycling transformation and ecological agriculture and forestry. Since the development of green bond market in China lags behind international market, the government should establish cross-border green bond market to connect domestic with international market as soon as possible. In terms of green investment, the threshold for green industry investment should be lowered to attract private capital or overseas capital to increase green investment (Zhang et al., 2022). In terms of green funds and insurance, it is important to train relevant professionals in education system, and solve the problems of the lack of green funds establishment and green insurance talents.

6.2.3. Implement differentiated green finance and environmental governance policies

It is vital to implement differentiated green finance and environmental governance policies at region level to promote the balanced development among regions. For green finance, policies should be made according to regional endowments, including population size, resources ownership and the number of polluting enterprises, and give priority to the development of local green financial reform and innovation pilot areas. The financial instruments, such credit, tax, bonds, funds and insurance should be fully exploited to raise funds for the development of green industry. As for environmental governance, the policies should be made to support the environmental governance ability of governments in western and northeast region. For example, Cross regional exchanges of local officials can promote policy diffusion and balance regional development, and then bring advanced environmental governance practices in developed regions to underdeveloped regions. In addition, enterprises, social organizations and public in western and northeast region should be further motivated to participate in environmental governance, and then form the idea of sustainable development in the whole society by changing people's lifestyle, and establish an all-round and multi-level environmental governance system. Especially, inter-regional coordination policies must play an important role in the coupling coordination development between green finance and environmental governance. The cooperation between the eastern region and the central region should be strengthened to drive the development of the western and northeastern region. In addition, the provinces with high CCDGE should be incentive to drive the
enhancement of adjacent provinces, and then improve the coupling coordination development between green finance and environmental governance among the whole system.

[5] New normal of economy is a concept of economics, which refers to the sustainable development and stable growth of economy based on the symmetrical state of economic structure.

[6] Two High refer to resource industries with high pollution and high energy consumption, and one surplus refers to the industries with overcapacity.

**Declarations**

**Author Contributions** Geng Peng and Tiantian Wang contributed to the study conception and design. Material preparation, data collection and analysis were performed by Tiantian Wang, Lijuan Ruan and Kaiyou Tian. The first draft of the manuscript was written by Geng Peng and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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**Availability of data and materials** The datasets used and/or analyzed in the study are available from the corresponding author upon reasonable request.

**References**


Figures
Figure 1
The interactive mechanism between green finance and environmental governance

Figure 2
The variation of GFI, EGI and CCDGE over time
Figure 3

The spatial distribution of GFI in 2004, 2010, 2015 and 2020
Figure 4

The spatial distribution of EGI in 2004, 2010, 2015 and 2020
Figure 5

The spatial distribution of CCDGE in 2004, 2010, 2015 and 2020