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How does green finance affect cleaner industrial production and end-of-pipe treatment performance? Evidence from China

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Abstract

Effectively identifying the role and mechanism of green finance in environmental governance provides an important guarantee that green finance serves the ecological environment. Based on the panel data of 30 provinces in China from 2001 to 2015, this paper explores the impact of green finance on cleaner industrial production and end-of-pipe treatment and further reveals the mediating effect of industrial structure optimization and the moderating effect of environmental regulation. The results show that (1) China’s cleaner industrial production performance, end-of-pipe treatment performance and systematic governance performance show a clear upwards trend, and the end-of-pipe treatment performance was generally better than the cleaner production performance. (2) Green finance promotes cleaner production performance but inhibits end-of-pipe treatment performance. The optimization of industrial structure plays a partial intermediary role in the impact of green finance on cleaner production and end-of-pipe treatment. (3) Both “market-incentive” and “command-and-control” environmental regulations weaken the positive impact of green finance on cleaner production; “market-incentive” environmental regulation alleviates the negative impact of green finance on end-of-pipe treatment, while the moderating effect of “command-and-control” environmental regulation on end-of-pipe treatment is not significant.

Keywords: green finance, cleaner production performance, end-of-pipe treatment performance, industrial structure optimization, environmental regulation
1 Introduction

Environmental pollution is not only related to the happiness index of human beings but also directly represents the high-quality development of a country’s economy. Over the past 40 years of reform and opening, China’s economy has created a miracle of rapid growth over a long period of time in which industrialization has played a key role (Huang et al., 2020). However, with the continuous advancement of industrialization, resource extraction and environmental problems caused by a growth pattern of high inputs and high energy consumption have become the “shackles” of social and economic development (Shao et al., 2019). Especially over the past 10 years, the negative impact of environmental degradation has been prominent, ranging from ecological destruction and health loss to agricultural productivity decline and global warming. Meanwhile, the Chinese government has gradually realized the importance of environmental governance and has promulgated a series of environmental policies that have improved environmental quality to a certain extent (Zhang et al., 2022). Even so, China’s economic system remains fragile, and its environmental carrying capacity is still facing enormous challenges (Ronald et al., 2017). In the face of this severe environmental situation, in October 2017, the Central Committee of the Communist Party of China strategically deployed the promotion of green development and acceleration of the reform of ecological civilization in the report of the 19th National Congress of the Communist Party of China. The party further clarified the importance of improving environmental quality at the fifth plenary session of the 19th Central Committee of the Communist Party of China, and systematically elaborated on the key tasks and main measures to reach this goal. At present, China’s environmental governance is in a critical stage of “pressure multiplication”, and there is an urgent need to develop appropriate environmental governance tools that can not only promote economic growth but also contribute to environmental protection (Zha et al., 2020). As an important starting point to promote the sustainable development of the regional economy and environment, green finance can improve the operational efficiency of the market through resource integration and promote the green transformation of industry with the help of financial integration functions, effectively ensuring the advancement of regional environmental governance (Yu et al., 2021). However, at present, there is a lack of literature that empirically tests the environmental governance performance in tandem with China’s green finance and a lack of literature that conducts an in-depth discussion of how green finance works. These deficits make it difficult to provide a scientific decision-making basis for promoting regional environmental governance with the help of green finance.

To better solve the increasingly urgent issue of promoting environmental governance through green finance, this paper summarizes and analyses the research of domestic and foreign scholars on the relationship between green finance and environmental governance and specifically carries out the following work: (1) it constructs an indicator system for green finance from the
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four dimensions of green credit, green securities, green insurance and government support and uses the entropy method to calculate the green finance development index of each province in China from 2001 to 2015; (2) industrial environmental governance is divided into two stages: cleaner production and end-of-pipe treatment, and the data envelopment model of the two-stage network DEA is used to measure the systematic environmental governance performance, cleaner production performance and end-of-pipe treatment performance for industrial systems in each province in China from 2001 to 2015; (3) the dynamic relationship between green finance and environmental governance performance is empirically analysed by using a fixed-effects model, and the mediating role played by industrial structure optimization is further explored; (4) in view of the fact that it is difficult for a single environmental policy to effectively guarantee the implementation of industrial environmental governance, different types of environmental regulations are introduced to examine the moderating effect between green finance and environmental governance.

The contribution of this paper is mainly reflected in the following: (1) compared with the existing single-dimensional green finance evaluation indicators, we rely on green credit, securities, insurance and government funds to build a multidimensional indicator system for green finance, which ensures that the long-term trends of indicators are presented and makes the evaluation results more systematic and complete; (2) different from the existing research, which mainly measures the performance of environmental governance from a single stage, we decompose China’s environmental governance into two stages of cleaner production and end-of-pipe treatment, and based on the two-stage network DEA method, the performance of the decomposition process of China’s environmental governance from 2001 to 2015 is measured. This analysis makes it easy for us to characterize the dynamic changes in the effectiveness of environmental governance and reveal the possibility of the win-win outcome of economic growth and environmental protection at different stages of development; (3) it is the first time that green finance and the decomposition performance of industrial environmental governance have been incorporated into the same research framework. Based on exploring the connection between green finance and the decomposition performance of environmental governance, we further test the intermediary role of industrial structure optimization and the moderating effect of environmental regulation, thus providing important theoretical value and practical significance for opening the “black box” of the connections between regional environmental governance and green finance.

The structure of the rest of this paper is as follows. Section 2 reviews previous research. Section 3 introduces the empirical model and methodology. Section 4 describes the data for this study. Section 5 discusses the empirical findings. Section 6 summarizes the findings and puts forward corresponding policy recommendations.
2 Literature review

(a) Scholars mainly use qualitative or quantitative analytical methods to evaluate the operation of green finance. In qualitative analysis, some international organizations, such as the International Finance Corporation (Kyte, 2008), the World Wildlife Fund (China Banking Regulatory Commission et al., 2014) and the Organization for Economic Co-operation and Development (OECD, 2007), aim to guide financial institutions to provide better green financial services by judging the effectiveness of financial institutions in implementing green responsibilities. In quantitative analysis, some scholars use the perspective of financial institutions. Penny and Monaghan (2001) evaluated the energy conservation and environmental protection performance of financial institutions in operations and management. Marcel (2001) selected several financial institutions around the world as research samples and examined the stage of green finance development of different financial institutions. Chinese scholars mainly choose a single indicator or build a comprehensive indicator system to evaluate the development level of green finance. Wen et al (2022) regarded the ratio of financial resources in the environmental protection industry to all industrial financial resources as an alternative indicator of green finance. Xie (2021) took the coupling and coordination degree of regional financial development and green development as a proxy for green finance. Wang and Wang (2021a) believe that green credit occupies the largest weight in the green financial system, so the proportion of green credit to GDP is used to characterize the development level of green finance. However, some scholars believe that the use of a single indicator for multiple regions will obscure the relevant evaluation of green finance development; it is difficult to reflect the essence of green finance development, and the construction of a comprehensive green finance indicator system can better reflect the true level of green finance (Lee and Lee, 2022).

Guo (2022) selected green credit, green investment, green venture capital and government support to conduct a comprehensive assessment of China’s green finance development level from 2001 to 2018. Lee and Lee (2022) believed that green credit, green securities, green insurance, green investment, and carbon finance more comprehensively cover the connotations of green finance, and on this basis, they calculated China’s green finance development index for 2006-2018.

(b) Currently, scholars mainly use data envelopment analysis (DEA) and stochastic frontier analysis (SFA) to assess environmental governance performance (Song et al., 2019). Since DEA has advantages over SFA in terms of function form setting and evaluation of homogeneous decision units, DEA or its extended model is usually used for efficiency analysis (Shao et al., 2021). The existing environmental governance performance measurement mainly adopts single-stage and multistage DEA models. The single-stage DEA model mainly includes the traditional DEA model considering undesirable output (Sueyoshi and Yuan, 2015; Zhao et al., 2014), the slack-based SBM-DEA model (Xie et al., 2017), the DEA-based Malmquist productivity index model that considers cross-period environmental governance performance (Oh and Heshmati,
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2010; Miao et al, 2019), and various extended DEA models (Chen and Delmas, 2011; Dimaria, 2014; Wang et al, 2018). In the single-stage DEA model, the entire process from production to pollution treatment is still a “black box”, which makes it difficult to reflect the real situation of environmental governance performance. The proposal and development of the network DEA model provides a possibility to open the “black box” of environmental governance from a multistage perspective. Färe and Grosskopf (2006) proposed from a theoretical perspective that the network DEA model can provide a unified framework for evaluating environmental governance performance. Hampf (2014) uses the network DEA model to decompose environmental governance efficiency into production efficiency and emission reduction efficiency from the application level, realizing a leap from theory to practice. Song et al (2018) took the lead in putting a two-stage look at environmental governance performance into the actual production process in China and chose the expanded network SBM model as a new tool to analyse the internal environmental governance performance of the system. Wang and Feng (2020), Shao et al (2021) further calculated overall efficiency and separate efficiencies of three substages of wastewater, waste gas and solid waste treatment based on measuring the total factor productivity and environmental governance efficiency of the industrial system in the two connected stages.

(c) Green finance and environmental governance have formed a symbiotic relationship of mutual influence and interdependence. Lee (2020) believes that the development of green finance is an inevitable requirement for realizing the coordinated progress of the economy, society and the environment and achieving sustainable development. Ng (2018) pointed out that green finance is an economic activity that can support the improvement of the ecological environment and improve the efficiency of resource use to effectively combat climate change. Mohd and Kaushal (2018) believe that green finance focuses on environmental protection and pollution control and balances the contradictory relationship between economic development and environmental governance through the rational allocation of financial resources. Zhou et al (2020) examine the impact of green finance on economic growth and environmental quality by constructing empirical models, and the research results show that the development of green finance promotes economic growth and environmental governance to achieve a “win-win situation”.

In the process of green finance promoting environmental governance, industrial structure optimization plays a key role as an intermediary (Wang and Wang, 2021b). First, the environmental information disclosure and capital supervision system upheld by green finance has aggravated the debt financing costs of traditional industrial enterprises, and while promoting the transformation of traditional industrial enterprises to green enterprises where possible, green financing conditions have forced traditional industrial enterprises that cannot go green to stop production and withdraw from the market (Shi et al, 2022; Yu et al, 2021). Second, green finance guides the flow of funds to industrial enterprises that focus on green development, creates the scale of green
How does green finance affect cleaner industrial production and ... funds by lowering the investment threshold and increasing financial support, and encourages industrial enterprises to increase investment in clean technologies, thereby promoting the development of green industries (Jiang et al., 2022).

In addition, multidimensional environmental policy coordination is a “booster” to improve regional environmental governance capabilities. At present, the “command-and-control” environmental regulation represented by laws and regulations and the “market-incentive” environmental regulation represented by environmental taxes and sewage charges play a key role in the practice of environmental governance, and it is uncertain whether they can promote environmental governance in synergy with green finance. On the one hand, there are complementary effects between environmental regulation and green finance (Zhu et al., 2021a). Environmental regulation directly restricts traditional industrial enterprises by setting access thresholds and governance standards, and green finance focuses on cultivating green industries, with a view to improving the cleaner production efficiency of industrial enterprises through controlling capital and promoting a virtuous cycle of capital (Wang et al., 2016). On the other hand, green finance and environmental regulation have similar mechanisms of action (Zhu et al., 2021b). Among them, “command-and-control” environmental regulation controls traditional industrial enterprises by setting regulatory thresholds, and green finance limits the threshold for industrial enterprises to obtain green funds by setting environmental protection standards. “Market-incentive” environmental regulations encourage industrial enterprises to reduce pollutant emissions through cleaner production technologies, while compliant industrial enterprises can shift the cost of paying sewage charges to the research and development of cleaner production technologies and promote the all-round governance of industrial production. Green finance opens up “green channels” for industrial enterprises that focus on the use of clean technologies, alleviating their financing pressure by increasing loan amounts, reducing loan interest rates and enhancing their willingness to carry out clean technology innovation (Wang and Xu, 2015).

In summary, for the research of green finance, we can find the following two basic facts from the research of domestic and foreign scholars: (1) domestic and foreign scholars mostly use a single indicator such as green credit, green investment, green securities, and green insurance to indicate the level of green finance development in different regions, and few studies have conducted a comprehensive evaluation by building a systematic indicator system. (2) In the literature evaluating the development level of green finance by constructing systematic indicators, if more specific green finance indicators are adopted, it is necessary to shorten the research interval of the paper. Therefore, based on the mainstream research views of scholars at home and abroad and considering the availability of data, this paper constructs an indicator system of green finance based on the four dimensions of green credit, green securities, green insurance and government support, which reflect long-term changes to green finance while maintaining relative comprehensiveness.
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For research on environmental governance performance, we can summarize the following two viewpoints from the research of domestic and foreign scholars: (1) the DEA model considering undesirable output is the mainstream method for evaluating environmental governance performance. (2) The evaluation of environmental governance performance must be multistage, and treatment of the entire process from production to pollution treatment as a “black box” will produce estimation bias. Therefore, based on the existing research of scholars at home and abroad, this paper divides environmental governance into two stages of cleaner production and end-of-pipe treatment and uses the two-stage network DEA model to establish an indicator system for environmental governance performance.

At present, domestic and foreign scholars have conducted in-depth research on the measurement of green finance and environmental governance performance. We have reached a consensus on the symbiotic relationship between green finance and environmental governance. However, what impact will green finance have on environmental governance performance? Can green finance work with existing environmental regulations to promote environmental governance? Scholars at home and abroad lack relevant research on such issues. Therefore, based on examining the relationship between green finance and environmental governance performance, we further examine the intermediary role of industrial structure optimization and the moderating effect of environmental regulation.

3 Empirical model and methodology

3.1 Two-stage network DEA model

As shown in Fig. 1, this paper decomposes industrial environmental governance performance into cleaner production performance and end-of-pipe treatment performance. By constructing a two-stage network DEA model, we evaluate the state of interprovincial environmental governance in China from 2001 to 2015. The inputs of the cleaner production stage are the industrial capital stock, the number of industrial employees and industrial energy consumption. The outputs of the cleaner production stage are the gross industrial output value and the volume of three kinds of industrial wastes, which is also used as the input of the end-of-pipe treatment stage. Other inputs in the end-of-pipe treatment stage are the number of full-time environmental protection personnel and the capital stock of the three industrial waste treatments. The output of the end-of-pipe treatment stage is the volume of three industrial waste treatments. It should be noted that the volume of industrial waste water is equal to the volume of treated waste water and the amount of discharged waste water, and the volume of industrial waste gas is equal to the volume of gas emissions and gas removal. Since industrial NOx emissions were not counted before 2011, the industrial exhaust gases included in this article only include industrial sulfur dioxide, soot, and dust. In addition, the industrial capital stock is expressed as the annual average of the net industrial fixed
How does green finance affect cleaner industrial production and ... asset value. The capital stock of the three industrial waste treatments refers to the study of Caselli (2005), which sets the depreciation rate to 6.0% and is measured by the perpetual inventory method.

Fig. 1 Two-stage network DEA process of environmental governance

In this paper, the performance of environmental governance is calculated based on the two-stage network DEA model proposed by Wu et al (2016). Suppose there are $n$ decision-making units, each of which is labelled $DMU_j (j = 1, 2, \ldots, n)$. The cleaner production stage has $m_1$ inputs $X_1 = (x_{1j}^1, x_{2j}^1, \ldots, x_{mj}^1)^T$, $t_1$ outputs $Y_1 = (y_{1j}^1, y_{2j}^1, \ldots, y_{tj}^1)^T$, and $d$ intermediate outputs $Z = (z_{1j}, z_{2j}, \ldots, z_{dj})^T$. The end-of-pipe treatment stage has $m_2$ inputs $X_2 = (x_{1j}^2, x_{2j}^2, \ldots, x_{mj}^2)^T$, $d$ intermediate inputs $Z = (z_{1j}, z_{2j}, \ldots, z_{dj})^T$, and $t_2$ outputs $Y_2 = (y_{1j}^2, y_{2j}^2, \ldots, y_{tj}^2)^T$.

The two-stage system performance ($SP$) calculation for decision-making unit $d$ is as follows:

$$SP = \max \sum_{r=1}^{t_1} \varphi^1_{rd} y^1_{rj} + \sum_{r=1}^{t_2} \varphi^2_{rd} y^2_{rj}$$

subject to:

$$\sum_{r=1}^{t_1} \varphi^1_{rd} y^1_{rj} + \sum_{r=1}^{t_2} \varphi^2_{rd} y^2_{rj} - \sum_{i=1}^{m_1} \phi^1_{id} x^1_{ij} - \sum_{i=1}^{m_2} \phi^2_{id} x^2_{ij} \leq 0$$

$$\sum_{r=1}^{t_1} \varphi^1_{rd} y^1_{rj} + \sum_{q=1}^{o_1} \psi_{qd} z_{jq} - \sum_{i=1}^{m_2} \phi^1_{id} x^1_{ij} \leq 0$$

$$\sum_{r=1}^{t_2} \varphi^2_{rd} y^2_{rj} - \sum_{i=1}^{m_2} \phi^2_{id} x^2_{ij} - \sum_{q=1}^{o_1} \psi_{qd} z_{jq} \leq 0$$

$$\sum_{i=1}^{m_1} \phi^1_{id} x^1_{id} + \sum_{i=1}^{m_2} \phi^2_{id} x^2_{id} = 1$$

$$\phi^1_{id}, \phi^2_{id}, \varphi^1_{rd}, \varphi^2_{rd}, \psi_{qd} \geq 0, j = 1, 2, \ldots, n$$

(1)

Based on Equation (1), the first stage of performance measures is as follows:

$$CPP = \max \sum_{r=1}^{t_1} \varphi^1_{rd} y^1_{rj} + \sum_{q=1}^{o_1} \psi_{qd} z_{jq}$$

subject to:

$$\sum_{r=1}^{t_1} \varphi^1_{rd} y^1_{rj} + \sum_{q=1}^{o_1} \psi_{qd} z_{jq} - \sum_{i=1}^{m_1} \phi^1_{id} x^1_{ij} \leq 0$$

$$\sum_{i=1}^{m_1} \phi^1_{id} x^1_{id} = \alpha \left(1 + \sum_{q=1}^{o_1} \psi_{qd} z_{jq}\right)$$

$$\phi^1_{id}, \varphi^1_{rd}, \psi_{qd} \geq 0, j = 1, 2, \ldots, n$$

(2)
Based on Equation (1), the second stage of performance measures is as follows:

\[
    EPP = \max \sum_{r=1}^{t_2} \varphi_r^2 y_{r}^2 \\
    \text{s.t.} \\
    \sum_{r=1}^{t_2} \varphi_r^2 y_{r}^2 \geq \sum_{i=1}^{m_2} \varphi_{id}^2 x_{id}^2 - \sum_{q=1}^{o_1} \psi_q z_{qj} \\
    \sum_{i=1}^{m_2} \varphi_{id}^2 x_{id}^2 = 1 - \alpha \left( 1 + \sum_{q=1}^{o_1} \psi_q z_{qj} \right)
\]  

(3)

3.2 Econometric models

3.2.1 Benchmark model

The benchmark regression model is as follows:

\[
    CPP_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_2 ISR_{it} + \alpha X_{it} + \sigma_i + \lambda_t + \varepsilon_{it}
\]  

(4)

\[
    EPP_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_2 ISR_{it} + \alpha X_{it} + \sigma_i + \lambda_t + \varepsilon_{it}
\]  

(5)

where the subscripts \( i \) and \( t \) represent the province and year, \( GF \) represents the level of green finance development, \( CPP \) represents cleaner production performance, \( EPP \) represents the end-of-pipe treatment performance, \( X \) represents the control variable of each province, \( \sigma_i \) represents the fixed effect of the province, \( \lambda_t \) represents the fixed effect of time, \( \varepsilon_{it} \) represents the random error term, and \( \alpha_1, \alpha_2 \) and \( \alpha \) are the coefficients of \( GF, ISR \) and \( X \), respectively. Note that although \( ISR \) is a mediating variable in Equations (4) and (5), it is still treated as a control variable, and it is marked separately to facilitate the interpretation of its coefficients in the mediating effect model section.

3.2.2 Mediating effect model

Effectively identifying the mechanism of green finance on environmental governance performance is of great significance for accelerating green transformation. This study uses stepwise regression to verify the mediating variable of industrial structure optimization.

Equations (4), (6), (7) and Equations (5), (6) and (8) list the test steps of industrial structure optimization in green finance for cleaner production performance and end-of-pipe treatment performance, respectively.

\[
    ISR_{it} = \alpha_0 + \beta_1 GF_{it} + \beta X_{it} + \sigma_i + \lambda_t + \varepsilon_{it}
\]  

(6)

\[
    CPP_{it} = \alpha_0 + \gamma_1 GF_{it} + \gamma X_{it} + \sigma_i + \lambda_t + \varepsilon_{it}
\]  

(7)

\[
    EPP_{it} = \alpha_0 + \gamma_1 GF_{it} + \gamma X_{it} + \sigma_i + \lambda_t + \varepsilon_{it}
\]  

(8)

where \( ISR \) represents industrial structure optimization, \( \beta_1 \) and \( \gamma_1 \) represent the coefficients of \( GF \), and \( \beta \) and \( \gamma \) represent the coefficients of \( X \). It should be noted that Equations (7) and (8) are different from Equations (4) and (5); the difference is that the control variables of Equations (4) and (5) contain \( ISR \), while the control variables of Equations (7) and (8) do not contain \( ISR \), and the rest of the variables remain consistent. The specific mediating effect judgement method refers to the research of Wen and Ye (2014).
3.2.3 Moderating effect model

Unlike the mediating effect, the moderating effect is a test of whether green finance is affected by other relevant variables when it has an impact on environmental governance performance. This paper examines the moderating effect of different types of environmental regulations in the mechanism of green finance influencing environmental governance performance and then provides an important value reference for the coordinated formulation of regional environmental regulation policies and green finance policies. We refer to the practice of Balli and Sørensen (2013) and decentralize the interaction terms. The specific moderating effect model is set as follows:

\[ CPP_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_2 MER_{it} + \alpha_3 CER_{it} + \alpha_4 \left( GF_{i,t} - \bar{GF}_{i,t} \right) \times \left( MER_{i,t} - \bar{MER}_{i,t} \right) + \alpha X_{it} + \sigma_i + \lambda_t + \epsilon_{it} \]  \hspace{1cm} (9)

\[ EPP_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_2 MER_{it} + \alpha_3 CER_{it} + \alpha_4 \left( GF_{i,t} - \bar{GF}_{i,t} \right) \times \left( CER_{i,t} - \bar{CER}_{i,t} \right) + \alpha X_{it} + \sigma_i + \lambda_t + \epsilon_{it} \]  \hspace{1cm} (10)

where \( GF_{i,t}, MER_{i,t} \) and \( CER_{i,t} \) represent the average of green finance development levels, “market-incentive” environmental regulations, and “command-and-control” environmental regulations, respectively, and \( \alpha_4 \) represents the regression coefficient of the interaction term between green finance and environmental regulation after subtracting the sample mean.

4 Data description

4.1 Sample selection and data sources

For the following reasons, we selected panel data from 30 provinces in China from 2001 to 2015 for empirical investigation. The first criterion for the selection of research samples was the exclusion of Tibet, Macao, Hong Kong, and Taiwan because of the unavailability of relevant data. The second criterion is the selection of the research interval. 2001 is the first year of China’s policy on green finance, and the data in 2001 are also the earliest green finance data that we can obtain, so we chose 2001 as the starting period of this study. Considering that since 2016, the statistical style of the “China Environment Yearbook” has changed, resulting in the inability to obtain the required environmental governance data, 2015 is selected as the termination period of this study.

The green finance data are mainly from the China Statistical Yearbook, China Environment Yearbook, Yearbook of China’s Insurance, and the statistical yearbooks for related provincial-level regions. The raw data of the two-stage DEA model for measuring environmental governance performance are mainly from the China Statistical Yearbook, China Environment Yearbook, China Industry Statistical Yearbook, and China Energy Statistical Yearbook. The data of the control variables and subsequent robustness tests are mainly from the China Statistical Yearbook, China Environmental Yearbook, and the
statistical yearbooks for related provincial-level regions. All data at current
prices are deflated to be constant at 2000 prices. Table 1 shows the descriptive
statistical results for the variables.

Table 1  Descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observation</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF(−)</td>
<td>450</td>
<td>0.14</td>
<td>0.01</td>
<td>0.05</td>
<td>0.63</td>
</tr>
<tr>
<td>SP(−)</td>
<td>450</td>
<td>0.76</td>
<td>0.13</td>
<td>0.47</td>
<td>1.00</td>
</tr>
<tr>
<td>CPP(−)</td>
<td>450</td>
<td>0.75</td>
<td>0.23</td>
<td>0.22</td>
<td>1.00</td>
</tr>
<tr>
<td>EPP(−)</td>
<td>450</td>
<td>0.80</td>
<td>0.15</td>
<td>0.37</td>
<td>1.00</td>
</tr>
<tr>
<td>CER(−)</td>
<td>450</td>
<td>0.53</td>
<td>0.53</td>
<td>0.00</td>
<td>2.14</td>
</tr>
<tr>
<td>MER(−)</td>
<td>450</td>
<td>10.36</td>
<td>1.06</td>
<td>6.76</td>
<td>12.53</td>
</tr>
<tr>
<td>ISR(−)</td>
<td>450</td>
<td>10.98</td>
<td>9.29</td>
<td>3.13</td>
<td>52.37</td>
</tr>
<tr>
<td>PGDP(RMB</td>
<td>450</td>
<td>9790.60</td>
<td>5340.97</td>
<td>2601.88</td>
<td>30039.14</td>
</tr>
<tr>
<td>yuan/person)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UR(%)</td>
<td>450</td>
<td>1.87</td>
<td>0.97</td>
<td>0.65</td>
<td>5.43</td>
</tr>
<tr>
<td>TRAD(%)</td>
<td>450</td>
<td>0.33</td>
<td>0.42</td>
<td>0.04</td>
<td>1.84</td>
</tr>
<tr>
<td>EGG(%)</td>
<td>450</td>
<td>8.50</td>
<td>7.58</td>
<td>0.19</td>
<td>57.89</td>
</tr>
<tr>
<td>INT(%)</td>
<td>450</td>
<td>10.80</td>
<td>12.53</td>
<td>1.02</td>
<td>50.46</td>
</tr>
</tbody>
</table>

4.2 Variable selection

4.2.1 Explained variable

Cleaner production performance (CPP) and end-of-pipe treatment performance (EPP) are the measurement results of the cleaner production stage and
the end-of-pipe treatment stage of the above two-stage DEA model, respectively. In the benchmark regression results, CPP and EPP are obtained based
on Equations (2) and (3), and the detailed calculation results are shown in Section 5.

4.2.2 Core explanatory variable

To present the long-term dynamic trend of green finance development, this
ter paper sets green credit, green investment, green insurance, and government
support as first-level indicators and constructs the green finance development
index of each provincial-level region. Among them, green credit is represented
by the ratio to GDP of the interest expenses of the six high-energy-consuming
industries, green investment is represented by the ratio to GDP of investment
in pollution control, green insurance is represented by the ratio of agricultural
insurance revenue to total agricultural output value, and government support
is represented by the ratio of fiscal environmental protection expenditure to
fiscal general budget expenditure.

Based on determining each indicator layer, this paper uses the entropy
method to measure the development level of green finance in each provincial-
level region, and the specific index calculation is carried out in three steps.
First, each indicator is standardized through mathematical transformations to eliminate the problem of incommensurability between indicators. To this end, indicators are divided into positive and negative groups, which are processed using the formula of the range value between groups. Therefore, the standardized treatment is as follows:

Positive indicator: \[ x'_{\theta ij} = \frac{x_{\theta ij} - x_{\min}}{x_{\max} - x_{\min}} \]  

Negative indicator: \[ x'_{\theta ij} = \frac{x_{\max} - x_{\theta ij}}{x_{\max} - x_{\min}} \]

where \( x_{\theta ij} \) is the original value of the \( j \)th indicator of the \( i \)th province in the \( \theta \)th year and \( x_{\max} \) and \( x_{\min} \) are the maximum and minimum values of the \( j \)th indicator of each provincial-level region in China, respectively. Second, after the standardization of each indicator, a weight matrix \( (w_j) \) is established, and the indicators are weighted according to the relative importance of each indicator in the evaluation process. Third, using the standardized values and the weight of each indicator, the comprehensive index of green finance in each province is obtained:

\[ GF_{\theta i} = \sum_j w_j x'_{\theta ij} \]

where \( GF_{\theta i} \) is the development level of green finance of the \( i \)th province in the \( \theta \)th year.

### 4.2.3 Mediation variable

Industrial structure optimization (ISO). Industrial structure optimization is an important indicator to measure the transformation and upgrading of regional industrial structure, and previous studies have only used a structural deviation index that compares industrial structure and employment structure to measure the degree of industrial structure optimization. However, this structural deviation index gives different industries the same weight, ignoring the heterogeneity of the economy overall. As suggested by Cheng et al (2018), we use the reciprocal of the Thiel index to indicate industrial structure optimization. The calculation is as follows: \( ISR = \sum_{i=1}^{n} \left( \frac{Y_i}{Y} \right) \ln \left( \frac{Y_i}{Y_i / Y} \right) \), where \( Y \) represents the output value, \( L \) represents the number of workers, and \( n \) represents the number of industries.

### 4.2.4 Moderating Variable

“Command-and-control” environmental regulation (CER) and “market-incentive” environmental regulation (MER) are used as moderating variables. We use the number of environmental impact assessment programs and “Three simultaneous” programs as the proxy for the “command-and-control” environmental regulations and use the ratio of the sewage charges to GDP as the proxy for the “market-incentive” environmental regulation.
4.2.5 Control Variable

Income level (PGDP). We use real GDP per capita to characterize regional income level, and the specific indicator is calculated based on the use of a GDP deflator to convert nominal GDP into real GDP and then divide by the average local population at the end of the year. The environmental Kuznets curve (EKC) hypothesis suggests an inverted U-shaped curve between income level and environmental quality. To further validate the existence of the EKC hypothesis, we add GDP per capita and its square term to the model. If the EKC hypothesis holds, the coefficient for PGDP should be positive, and the coefficient for its square term should be negative, indicating a decoupling relationship between China’s income level and environmental quality (Wang et al., 2020).

Urbanization level (UR). The rapid aggregation of labour and resources has led to a surge in energy consumption demand, which has hindered regional environmental governance (Chatti and Majeed, 2022). In this paper, we use the ratio of the urban population to the total population to characterize the urbanization level, and its impact on environmental governance performance is negative.

Foreign Trade level (TRAD). The hypothesis of “the Environmental Gains from Trade” holds that foreign trade brings advanced clean technology and management experience to host countries and improves the efficiency of capital and resource utilization, thus having a positive impact on environmental governance performance (Caldwell and Vogel, 1996). The hypothesis of “race to the bottom” posits that attracting foreign investment by lowering environmental standards will increase the pressure on regional environmental governance, thereby having a negative impact on environmental governance performance (Frankel and Rose, 2005). Therefore, we measure the foreign trade level by the ratio of total import and export trade to GDP, and the direction of its impact on environmental governance performance is uncertain.

Economic Growth Target (EGG). Regional economic growth targets are set with the direct involvement and responsibility of the officials, which is both a central-to-local assessment criterion and a local commitment to the central government’s performance. When the actual economic growth rate deviates from the set growth target, local officials may reduce their control over environmental governance to meet the set economic growth targets (Yu and Pan, 2019). Therefore, we believe that the impact of regional economic growth targets on environmental governance performance is negative.

Informatization level (INT). The popularization of internet technology has created a transparent and efficient network platform for the public, broadened the channels for the public to participate in politics and deliberations, and enabled the public to freely express their needs for environmental quality, thus having a positive impact on the formulation of central or local environmental policies (Xie et al., 2022). Therefore, we use internet penetration to measure the degree of regional informatization, and its impact on environmental governance performance is positive.
5 Results and discussion

5.1 Quantitative characteristics of environmental governance performance

5.1.1 Trends in environmental governance performance

Fig. 2 depicts a trend map of China’s environmental governance performance. The results show that from 2001 to 2015, China’s cleaner production performance (CPP), end-of-pipe treatment performance (EPP) and system governance performance (SP) showed an upwards trend, especially from 2001 to 2011. It is worth noting that the change direction of system governance performance is similar to that of cleaner production performance, and cleaner production performance is much lower than end-of-pipe treatment performance, which indicates that the lag of cleaner production performance has become a bottleneck restricting the improvement of China’s environmental governance performance.

Due to the different trends in environmental governance performance at each stage, we divided the sample period into three phases: 2001-2006, 2007-2011 and 2012-2015 based on the key nodes of green finance and environmental governance policies.

Phase I: 2001-2006. In 2001, the China Securities Regulatory Commission issued the “Guidelines for the Content and Format of Information Disclosure of Companies Publicly Offering Securities No. 9 - Application Documents for Initial Public Offering of Shares”, which directly linked corporate financing to environmental responsibilities, marking the beginning of green finance in China. In 2002, the promulgation of the “Cleaner Production Promotion Law of the People’s Republic of China” prompted the transformation of China’s pollution control model from end-of-pipe treatment to cleaner production. Although cleaner production performance began to decline in 2005 under the impact of the oil crisis, cleaner production performance generally increased to a certain extent at this stage, while end-of-pipe treatment performance declined during this period, and systematic environmental governance performance also showed an upwards trend driven by cleaner production performance.

Phase II: 2007-2011. In 2007, the State Environmental Protection Administration of China, the People’s Bank of China and the China Banking Regulatory Commission jointly issued the “Opinions on Implementing Environmental Protection Policies and Regulations to Prevent Credit Risks”, marking the official construction of China’s green credit policy system and the transformation of green finance from the embryonic stage to the development stage. At this stage, China’s systematic environmental governance performance, cleaner production performance and end-of-pipe treatment performance showed a clear upwards trend. However, the occurrence of the US subprime mortgage crisis in 2008 forced China to shift its focus to restoring its...
domestic economy, temporarily reducing the intensity of environmental governance and resulting in a certain degree of decline in environmental governance performance.

Phase III: 2012-2015. In 2012, the China Banking and Insurance Regulatory Commission issued the “Green Credit Guidelines”, marking a period of large-scale development of green finance. At the same time, the regional environment entered a stage of comprehensive governance, and environmental regulations such as the Environmental Protection Law of the People’s Republic of China were promulgated in succession to form a synergy with green finance policies. However, China’s environmental governance performance had not risen and had even shown a slight downwards trend. We believe that the reason for this phenomenon is that there was a clear alternative relationship between green finance policies and environmental governance policies influencing environmental governance performance, an idea that we have confirmed in Section 5.2.4.

![Fig. 2 Trends of cleaner production performance, end-of-pipe treatment performance and systematic environmental governance performance during 2001-2015](image)

**5.1.2 Interprovincial comparison of environmental governance performance**

The environmental governance performance of each province and its decomposition performance from 2001 to 2015 are shown in Fig. 3. Overall, the average industrial systematic environmental governance performance at the national level is 0.792, indicating that most provinces have low environmental governance efficiency. The average cleaner industrial production performance at the national level is 0.696, which is a large distance from the efficiency frontier of cleaner production performance. The areas with higher cleaner production performance are mainly concentrated in the east, such as Zhejiang ($CPP = 0.895$), Fujian ($CPP = 0.943$) and Guangdong ($CPP = 0.906$), while...
How does green finance affect cleaner industrial production and ... 

the areas with low cleaner production performance are mainly concentrated in the central and western regions, such as Shanxi ($CPP = 0.504$), Liaoning ($CPP = 0.528$), Heilongjiang ($CPP = 0.549$), Gansu ($CPP = 0.402$) and Xinjiang ($CPP = 0.409$). The average of the national level industrial end-of-pipe treatment performance ($EPP$) is 0.910, indicating that most provinces are close to the efficiency frontier of end-of-pipe treatment performance. The areas with low end-of-pipe treatment performance are mainly concentrated in the west, such as Sichuan ($EPP = 0.785$), Shaanxi ($EPP = 0.750$), Gansu ($EPP = 0.772$) and Xinjiang ($EPP = 0.702$). Compared with end-of-pipe treatment performance, cleaner production performance is generally lower. Because end-of-pipe treatment has developed relatively well in China and the concept of cleaner production was not formally proposed until 2002, its development stage is shorter than that of end-of-pipe treatment, and a systematic and complete governance system for cleaner production has not been formed. In addition, $CPP$ and $EPP$ show a positive correlation, indicating that most provinces that focus on industrial end governance are gradually beginning to pay attention to cleaner production.

![Fig. 3 Averages of provincial cleaner production performance, end-of-pipe treatment performance, and systematic environmental governance performance during 2001-2015.](image)
5.2 Effect of green finance on environmental governance performance

5.2.1 Regression analysis of green finance on cleaner production performance and end-of-pipe treatment performance

Table 2 shows the regression results of the effect of green finance on cleaner production performance and end-of-pipe treatment performance. The estimation results in Model (1) of Table 2 show that the coefficient of green finance for cleaner industrial production is 0.649 at the 1% level, revealing that the development of green finance has positively contributed to cleaner industrial production. This is because cleaner production starts from the perspective of the whole life cycle, emphasizes source reduction, realizes emission reduction through green product design, production process optimization and comprehensive utilization of byproducts, and ultimately encourages enterprises to achieve economically sustainable and environmentally friendly development. This coincides with the development concept of green finance, which mainly supports green industries, guides the flow of financial funds to green projects, and optimizes the economic structure by promoting the green transformation and upgrading of the industry. Therefore, green finance can provide sufficient financial support for industrial enterprises that focus on cleaner production, alleviate the financing pressure of such enterprises, and then improve the performance of cleaner production.

The estimation results in Model (2) of Table 2 show that the coefficient of green finance for cleaner industrial production is \(-0.398\) at the 1% level, indicating that the development of green finance has an inhibitory effect on end-of-pipe treatment performance. Compared with cleaner production, the traditional end-of-pipe treatment model focuses on the treatment of the pollutants that have been generated, and as such, industrial enterprises are more concerned about how to meet current pollution emission standards; that is, they tend to develop short-term environmental performance improvement plans. Moreover, we believe that the negative impact of green finance on industrial end-of-pipe treatment performance is staged. Existing research has also confirmed that there is a U-shaped relationship between financial development and environmental governance performance, and when the development of green finance crosses the threshold, it will achieve a transition from negative to positive (Khan et al., 2022).

Regarding the control variables, the coefficients of \(\ln(PGDP)\) and \([\ln(PGDP)]^2\) in Model (1) of Table 2 are significantly positive and negative, respectively, thus verifying the existence of an EKC curve (Zhao et al., 2016). The coefficient of \(UR\) is significantly negative in both Model (1) and Model (2) of Table 2, indicating that the rapid advancement of urbanization has caused a surge in energy consumption demand, thus hindering industrial environmental governance. The coefficient of \(EGG\) is significantly positive in Model (1) of Table 2, indicating that regional economic growth targets promote cleaner
Table 2 Baseline regression results of the effect of green finance on cleaner production performance and end-of-pipe treatment performance

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>(1) CPP</th>
<th>(2) EPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF</td>
<td>0.649***</td>
<td>−0.398***</td>
</tr>
<tr>
<td></td>
<td>(0.243)</td>
<td>(0.149)</td>
</tr>
<tr>
<td>ISR</td>
<td>0.008***</td>
<td>−0.002*</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>MER</td>
<td>0.049***</td>
<td>0.022***</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>CER</td>
<td>0.029***</td>
<td>0.013***</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>ln(P GDP)</td>
<td>2.770***</td>
<td>−0.245</td>
</tr>
<tr>
<td></td>
<td>(0.863)</td>
<td>(0.531)</td>
</tr>
<tr>
<td>[ln(P GDP)]^2</td>
<td>−0.116***</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>(0.048)</td>
<td>(0.030)</td>
</tr>
<tr>
<td>TRAD</td>
<td>−0.084</td>
<td>−0.035</td>
</tr>
<tr>
<td></td>
<td>(0.056)</td>
<td>(0.034)</td>
</tr>
<tr>
<td>UR</td>
<td>−0.020***</td>
<td>−0.003*</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>EGG</td>
<td>0.011**</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>INT</td>
<td>0.010***</td>
<td>0.002**</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Cons</td>
<td>−15.114***</td>
<td>1.044</td>
</tr>
<tr>
<td></td>
<td>(3.890)</td>
<td>(2.394)</td>
</tr>
</tbody>
</table>

Note: Standard errors of coefficients are reported in parentheses; *, **, and *** indicate that the coefficients are statistically significant at the 10%, 5%, and 1% levels, respectively.

industrial production performance, and the pattern of economic growth at the expense of the environment gradually disappears. The coefficient of INT is significantly positive in both Model (1) and Model (2) of Table 2, indicating that the improvement of the informatization level has broadened the channels for the public to participate in politics and deliberations. Currently, the public can make suggestions to government departments through formal network platforms, and government departments have also given positive feedback to the public.

5.2.2 Mediation effect test

Green finance has a significant positive impact on cleaner industrial production performance and a significant negative impact on industrial end-of-pipe treatment performance. However, the mechanism of impact of green finance on cleaner industrial production and end-of-pipe treatment is still unclear. As the core tool for coordinating the economy and the environment, industrial structure optimization is directly related to how the economic system uses
resources and discharges waste, so we analyse the transmission path from the perspective of industrial structure optimization.

Model (3) of Table 3 shows the effects of green finance on industrial structure optimization, indicating that green finance can effectively promote industrial structure optimization. Model (1) of Table 2 shows that industrial structure optimization has promoted cleaner production performance. Combined with the comprehensive comparison of Model (1) in Table 3, it can be found that green finance can improve cleaner industrial production by guiding industrial structure optimization, thus verifying the transmission path of “green finance-industrial structure optimization-improved cleaner production performance”. For industrial end-of-pipe treatment performance, Model (2) of Table 2 shows that industrial structure optimization has a significant inhibitory effect on end-of-pipe treatment performance. Combined with the comprehensive comparison of Model (2) in Table 3, industrial structure optimization has a suppressive effect on industrial end-of-pipe treatment performance, even though green finance encourages optimization of the industry, thus verifying the existence of the transmission path of “green finance-industrial structure optimization-decline in industrial terminal governance performance”.

5.2.3 Robustness test

(1) In our first test, we attempt to alleviate the omission bias. Although we added control variables such as ln(PGDP), [ln(PGDP)]^2, TRAD, UR, EGG, and INT to Table 2 and controlled the fixed effects of both the year and the region, it is impossible to eliminate the influence of other factors on the benchmark results, and there may still be missing variables. Therefore, we further set government intervention (GI), regional population density (PD), and years of schooling (EDU) as control variables to alleviate endogenous problems caused by missing variables. As shown in Model (1) and Model (2) of Table 4, the coefficient of green finance on cleaner production performance is significantly positive, and the coefficient of influence on end-of-pipe treatment performance is significantly negative, indicating that the research results of this paper are reliable.

(2) Considering the mutual causal relationship between green finance and heterogeneous environmental governance performance, we used the current green finance development level and the environmental governance performance of the lagged period to conduct an empirical analysis. As shown in Model (3) and Model (4) of Table 4, there is a positive correlation between the green finance development level and the cleaner production performance of the lagged phase, and there is a negative correlation relationship with the end-of-pipe treatment performance of the lagged phase; both are significant at the level of at least 10%, which also shows that the implementation effect of green finance policies has a certain degree of sustainability.

(3) We then attempted to alleviate self-selection bias. Due to the advantages of the eastern region in terms of development strategy, economic development level and institutional environment, financial institutions are
Table 3 The results of mediation effect test

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF</td>
<td>0.727***</td>
<td>-0.422***</td>
<td>10.048*</td>
</tr>
<tr>
<td></td>
<td>(0.245)</td>
<td>(0.149)</td>
<td>(5.200)</td>
</tr>
<tr>
<td>MER</td>
<td>0.041***</td>
<td>0.024**</td>
<td>-0.947***</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.010)</td>
<td>(0.339)</td>
</tr>
<tr>
<td>CER</td>
<td>0.030**</td>
<td>0.013*</td>
<td>0.083</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.007)</td>
<td>(0.261)</td>
</tr>
<tr>
<td>ln(P GDP)</td>
<td>2.628***</td>
<td>-0.200</td>
<td>-18.489</td>
</tr>
<tr>
<td></td>
<td>(0.872)</td>
<td>(0.531)</td>
<td>(18.532)</td>
</tr>
<tr>
<td>[ln(P GDP)]^2</td>
<td>-0.110**</td>
<td>0.021</td>
<td>0.775</td>
</tr>
<tr>
<td></td>
<td>(0.049)</td>
<td>(0.030)</td>
<td>(1.040)</td>
</tr>
<tr>
<td>TRAD</td>
<td>-0.119**</td>
<td>-0.024</td>
<td>-4.543***</td>
</tr>
<tr>
<td></td>
<td>(0.055)</td>
<td>(0.034)</td>
<td>(1.177)</td>
</tr>
<tr>
<td>UR</td>
<td>-0.020***</td>
<td>-0.003*</td>
<td>-0.003</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.061)</td>
</tr>
<tr>
<td>EGG</td>
<td>0.011**</td>
<td>0.003</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.001)</td>
<td>(0.114)</td>
</tr>
<tr>
<td>INT</td>
<td>0.009***</td>
<td>0.002**</td>
<td>-0.049</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.033)</td>
</tr>
<tr>
<td>Cons</td>
<td>-14.149***</td>
<td>0.745</td>
<td>125.031</td>
</tr>
<tr>
<td></td>
<td>(3.928)</td>
<td>(2.392)</td>
<td>(83.445)</td>
</tr>
<tr>
<td>Province FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>450</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>Adjusted − R²</td>
<td>0.749</td>
<td>0.685</td>
<td>0.952</td>
</tr>
</tbody>
</table>

Note: Model (1) and Model (2) correspond to Equation (7) and Equation (8); Model (3) corresponds to Equation (6). Standard errors of coefficients are reported in parentheses; *, **, and *** indicate that the coefficients are statistically significant at the 10%, 5%, and 1% levels, respectively.

more inclined to carry out green financial activities in the eastern region. As of 2019, more than 40% of the branches of urban commercial banks have gathered in the eastern coastal areas, indicating that there is an obvious geographical “self-selection” problem in the expansion of financial institutions. To alleviate the distortion caused by self-selection bias, this paper refers to the research of Zhang and Chen (2021) and excludes samples from Jiangsu, Zhejiang, and Shanghai in a re-estimation of the model. As shown in Model (5) and Model (6) of Table 4, we found that even after excluding the sample data of eastern economic centers, the impact of green finance on cleaner production performance and end-of-pipe treatment performance is consistent with the results of the baseline regression.

5.2.4 Moderating effects test

The regression results of Model (1) in Table 2 show that the influence coefficients of “market-incentive” environmental regulation and “command-and-control” environmental regulation on cleaner production are significantly positive at the 1% level, indicating that both “market-incentive” and
“command-and-control” environmental regulation have a significant role in promoting cleaner production when implemented separately. According to the regression results of Model (1) and Model (2) in Table 5, it can be found that the interaction term coefficients between green finance and “market-incentive” regulation and between green finance and “command-control” regulation are significantly negative, indicating that the implementation of heterogeneous environmental regulation weakens the positive impact of green finance on cleaner production and that there is a clear substitution between China’s green finance and heterogeneous environmental regulation in the process of influencing cleaner production. On the one hand, there is an overlapping effect between green finance and “command-and-control” environmental regulation in the establishment of environmental standards. “Command-and-control” policies regulate high-pollution industrial enterprises by setting relevant regulatory requirements, and green finance regulates high-pollution industrial enterprises by setting relevant environmental protection standards; only industrial enterprises that meet these standards can be supported by green funds. On the other hand, green finance and “market-incentive” regulations intersect in terms of economic benefits. “Market-incentive” regulations create economic incentives for industrial enterprises to reduce pollutant emissions through cleaner production technology. Industrial enterprises that meet regulatory standards can shift the amount of their sewage charges to invest in the research and development of cleaner production technologies, thereby promoting the source
governance and all-round governance of industrial production. Green finance opens a green channel for industrial enterprises that focus on adopting clean technology, alleviates the financing pressure of such industrial enterprises by increasing loan amounts and reducing loan interest rates, and enhances industrial willingness to carry out clean technology innovation, thereby promoting the green and sustainable development.

Table 5 The results of the moderating effect test

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>(1) CPP</th>
<th>(2) CPP</th>
<th>(3) EPP</th>
<th>(4) EPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF</td>
<td>0.598***</td>
<td>1.397***</td>
<td>−0.386***</td>
<td>−0.382**</td>
</tr>
<tr>
<td></td>
<td>(0.236)</td>
<td>(0.275)</td>
<td>(0.149)</td>
<td>(0.175)</td>
</tr>
<tr>
<td>MER</td>
<td>0.073***</td>
<td>0.017</td>
<td>0.016</td>
<td>0.021**</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.017)</td>
<td>(0.010)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>CER</td>
<td>0.010</td>
<td>0.019</td>
<td>0.018</td>
<td>0.013*</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.008)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>GF × MER</td>
<td>−0.411***</td>
<td>0.094***</td>
<td>(0.054)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.085)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GF × CER</td>
<td>−0.712***</td>
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<td>−0.015</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.136)</td>
<td></td>
<td>(0.087)</td>
<td></td>
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<tr>
<td>Other Control Variables</td>
<td>Control</td>
<td>Control</td>
<td>Control</td>
<td>Control</td>
</tr>
<tr>
<td>Cons</td>
<td>−13.008***</td>
<td>−10.997***</td>
<td>0.561</td>
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<tr>
<td></td>
<td>(3.809)</td>
<td>(3.848)</td>
<td>(2.403)</td>
<td>(2.448)</td>
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<td>Province FE</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>N</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>Adjusted – R²</td>
<td>0.769</td>
<td>0.770</td>
<td>0.688</td>
<td>0.686</td>
</tr>
</tbody>
</table>

Note: Standard errors of coefficients are reported in parentheses; *, **, and *** indicate that the coefficients are statistically significant at the 10%, 5%, and 1% levels, respectively.

From the regression results of Model (2) in Table 2, it can be obtained that the “market-incentive” environmental regulation and the “command-and-control” environmental regulation have a significant role in promoting the end-of-pipe treatment performance of Chinese industries. According to the regression results of Model (3) and Model (4) in Table 5, the interaction term coefficients between green finance and “market-incentive” environmental regulation are significantly positive, indicating that “market-incentive” environmental regulation mitigates the negative impact of green finance on industrial end-of-pipe treatment performance. This is because financial institutions are more willing to invest green funds in industrial enterprises that tend to implement cleaner production technology, thus crowding out the funds that might go to industrial enterprises that focus on end-of-pipe treatment. Industrial enterprises that meet environmental protection standards through end-of-pipe treatment, however, can also internalize the costs originally used to pay sewage charges so that some funds go to the improvement of end-of-pipe treatment technology. The interaction term coefficient between green finance
and “command-and-control” environmental regulation is not significant, indicating that “command-and-control” environmental regulation has not played a good moderating effect in the impact of green finance on the performance of industrial end-of-pipe treatment.

6 Research conclusions and policy implications

6.1 Conclusions

The promotion and implementation of China’s regional environmental governance requires the help of green finance capital; indeed, serving environmental governance through green finance has become the proper means of promoting regional green transformation and sustainable development. Based on panel data from 30 provincial-level regions in China from 2001 to 2015, this paper constructs an empirical model to discuss the relationship and impact mechanism between green finance and environmental governance performance. The main conclusions are as follows: (1) China’s cleaner industrial production performance, end-of-pipe treatment performance and systematic environmental governance performance showed an upwards trend, and the end-of-pipe treatment performance was better than the cleaner production performance. (2) Green finance promotes cleaner industrial production performance while inhibiting end-of-pipe treatment performance. (3) Industrial structure optimization plays a partial intermediary role in the impact of green finance on cleaner production and end-of-pipe treatment. (4) For cleaner industrial production, the implementation of “market-incentive” environmental regulation and “command-and-control” environmental regulation weakens the positive impact of green finance on cleaner industrial production performance. For industrial end-of-pipe treatment, “market-incentive” environmental regulation mitigates the negative impact of green finance on industrial end-of-pipe treatment, while the moderating effect of “command-and-control” environmental regulation is not significant.

6.2 Policy Implications

The policy recommendations in this paper are as follows:

(1) Enrich green finance products and enhance the scale of green finance. The results show that green finance mainly contributes to cleaner industrial production, crowding out funds for industrial end-of-pipe treatment, so increasing the scale of green finance will help realize the transformation from a negative impact to a positive impact. Therefore, for industrial enterprises that focus on end-of-pipe treatment, the government and financial institutions need to formulate corresponding green financial support policies. Within the scope of green financial funds, industrial enterprises should focus on end-of-pipe treatment to raise funds and encourage them to introduce new equipment and new processes so that green finance can not only help cleaner industrial production but also help industrial end-of-pipe treatment.
(2) Relying on green finance promotes industrial structure optimization. Green finance can help enterprises introduce and develop production technologies by paying the sunk costs of technological innovation, thereby promoting the optimization and upgrading of the industrial structure. In the process of industrial restructuring, enterprises adhere to the concept of synergy between development and governance, alleviate the contradiction between development and pollution by promoting technological change, and achieve the greatest economic and environmental benefit ratio. Therefore, on the premise of increasing the scale of green finance, it is necessary to achieve the standards of cleaner industrial production and end-of-pipe treatment through the path of industrial structure optimization.

(3) Existing environmental regulation policies should be aligned and the establishment of a sound green financial system should be accelerated. This study shows that it is difficult for green finance to coordinate with the current environmental regulation policies to promote industrial production and end-of-pipe treatment. To this end, each province should implement the development concept of “green and coordinated” and actively develop green finance to make it compatible with the current environmental regulation policies. On the one hand, by reducing the interest rate of green credit and increasing the scale of green investment, the profitability of green finance will be further enhanced. On the other hand, the common goal of green finance and environmental regulation should be set in synergy, and the behaviour of enterprises that do not meet the requirements of environmental regulation should be restricted and punished financially, thereby weakening the overlapping effect of environmental regulation and green finance.

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Data availability Data and materials are available from the authors upon request.

Declarations

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References


Guo XY (2022) Green finance boosts the transformation of a low-carbon economy interaction effects and spatial spillover effects. South China Finance (01):52–67

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