

## Article

# Green Finance, Enterprise Energy Efficiency, and Green Total Factor Productivity: Evidence from China

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**Abstract:** Climate change has become a global issue that requires collective efforts, and green finance policies are an important way to address this problem and promote enterprise development. This paper uses listed company data and city panel data to investigate the utility and mechanisms of the influence of the development of green finance in different cities on the Green Total Factor Productivity (GTFP) of enterprises. The conclusion was that green finance can improve enterprise GTFP, which remained significant after conducting a series of robustness tests. The mechanism analysis showed that green finance can improve enterprise GTFP by promoting energy conservation and emission reduction. The heterogeneity analysis indicated that green finance has a better effect on non-state-owned enterprises, large-scale enterprises, and enterprises with weak financing constraints. This paper enriches the literature that addresses the impact of green finance and the influential factors among GTFP.

**Keywords:** green finance; green total factor productivity; public policy; China



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## 1. Introduction

Climate warming has become a common problem to be tackled globally. As important micro-objects of economies, enterprises have made important contributions to promote social development, but they have also exacerbated global environmental problems [1–3]. For enterprises, when dealing with environmental issues, it is extremely important to better weigh the benefits and costs to achieve a win-win situation between enterprise development and social development. Green finance, as a new policy tool, has played an important role in helping enterprises save energy and reduce emissions, financing, and relief [4,5]. Unfortunately, there are few empirical studies on the impact of green finance on corporate GTFP. This paper attempts to empirically analyze the impact of green finance on corporate GTFP and its mechanism of action, using data from Chinese listed companies and green finance data from prefecture-level cities.

China's research on green finance and enterprise GTFP has unique advantages. Firstly, China is the world's largest manufacturing economy, and its industrial structure is undergoing significant changes, with an increasing focus on green and sustainable development [6,7]. This provides a strong impetus for research on green finance and enterprise GTFP. Secondly, China has a vast and diverse market, with various industries and enterprises at different stages of development. This diversity provides an opportunity to study the impact of green finance policies and practices on different industries and enterprises and to develop tailored solutions for different sectors. Thirdly, China has a strong government-led environmental protection policy, which provides a favorable policy environment for the development of green finance and green production. This policy environment can facilitate research on the impact of environmental regulations and policies on enterprise GTFP. Fourthly, China has made significant progress in developing green finance, including the issuance of green bonds and the establishment of green development funds. This

progress provides a strong foundation for research on the effectiveness of green finance policies and practices in promoting enterprise GTFP. Lastly, China's rapid development in Artificial Intelligence and big data technologies has provided new opportunities for studying the relationship between green finance and enterprise GTFP. These technologies can be used to collect and analyze large amounts of data on enterprise production processes, environmental performance, and financial data, providing valuable insights into the impact of green finance on enterprise GTFP.

The purpose of this paper was to explore the effect of green finance on the green development of listed companies and to conduct an in-depth study on the mechanisms behind the energy savings and emissions reductions of the enterprises involved in it. To this end, this study adopted a combination of listed company data and urban panel data in order to comprehensively measure the effect of green finance on the green development of enterprises. Specifically, this paper discusses our research as follows: First, this paper analyzes the policy and market backgrounds of green finance in order to gain insight into the current situation and trends of green finance development. Secondly, this paper adopts a panel data model to measure the effect of green finance on the green development of enterprises and analyze its mechanisms by analyzing the data of listed companies and urban panel data. In particular, this paper focuses on the mechanisms for energy savings and emissions reductions of enterprises engaging in green development in order to deeply explore the actual effect of green finance on the green development of enterprises. In addition, this paper explores the impacts of green finance on different industries and different regions, and it analyzes the differences and reasons for them. At the same time, this paper also provides an outlook and analyzes the development trends and the future development direction of green finance, and it provides references and suggestions for relevant policies and practices.

The purpose of this study was to investigate the effect of green finance on the greenness of listed companies and to conduct an in-depth study on the role of corporate energy-saving and emissions-reduction mechanisms. To achieve this goal, we combined macro data and micro data, and we combined data from listed companies with urban panel data so as to arrive at a more comprehensive and accurate research result. In the course of the study, we found that green finance had a significant positive effect on the green impact effect of listed companies. Specifically, green finance could not only improve listed companies' awareness of green development and environmental protection but also provide financial support and incentives for enterprises' environmental protection behaviors such as energy saving and emissions reduction, thus promoting the transformation and upgrading of enterprises towards green and low-carbon development. In addition, we explored in depth the key roles of corporate energy-saving and emissions-reduction mechanisms in green finance and green development. We found that the role of enterprises' energy-savings and emissions-reduction mechanisms was one of the key mechanisms in realizing the effect of green finance on the green development of listed companies. By establishing an effective energy-saving and emissions-reduction mechanism and management system, enterprises can better achieve the rational use of resources and environmental protection goals, thus improving their competitiveness and social responsibility. In conclusion, by combining macro data and micro data, we conducted an in-depth study on the effect of green finance on the green development of listed companies and on the role of energy-savings and emissions-reduction mechanisms of enterprises, thus providing strong support and reference for research and decision-making in related fields, with certain innovative points and practical significance.

## 2. Literature Review

Green finance is a financial model that promotes environmental protection and sustainable development through financial instruments and mechanisms that channel funds to environmentally friendly, low-carbon, and sustainable economic activities [8]. It is characterized by its social responsibility, environmental orientation, long-term nature, risk control,

and innovation [9]. The rise of green finance has stemmed from the growing concerns about environmental issues and the sensitivity of the financial industry to environmental risks. Issues such as global climate change and environmental pollution have attracted widespread attention from the international community, and green finance, as an important part of sustainable development, has been strongly supported and promoted by governments and financial institutions [10]. In particular, in 2015, the United Nations adopted the 2030 Agenda for Sustainable Development, and green finance has become an important tool to promote sustainable development [11]. The background of the development of green finance lies in the gradual increase in social responsibility and environmental risk sensitivity of the financial industry. Financial institutions should not only pursue economic profits but also take social responsibility, actively invest in environmental protection and sustainable development fields, and contribute to society and the environment [12]. At the same time, financial institutions are paying more attention to environmental risks, controlling them through the means of green finance and enhancing the sustainability of financial institutions [13].

Green finance has the following advantage for enterprises: Firstly, it reduces the environmental risks of an enterprise [14,15]. In the process of production and operation, enterprises will inevitably generate environmental risks, such as waste gas, wastewater, solid waste, etc. Green finance provides financial support and services for enterprises in environmental protection and governance through financial tools such as environmental protection loans and environmental guarantee insurance, which reduce the environmental risks and business risks of enterprises. Green finance can also improve corporate social responsibility and brand value, as it is a positive social-responsibility behavior. By participating in the investment and promotion of green finance, enterprises can show their sense of social responsibility and environmental protection orientation and improve their social image and brand value. Green finance allows enterprises to obtain government policy support and tax incentives [16]. The government provides policy support and tax incentives, such as green bond issuance and carbon emission trading, in order to encourage enterprises to participate in green finance. By participating in green finance, enterprises can obtain government policy support and tax benefits, reduce their costs and risks, and improve their profitability and competitiveness [17,18]. Green finance can open up new markets and business opportunities, as, with the increasing global awareness of environmental protection and the gradual enhancement of consumers' concept of environmental protection, the environmental protection and low-carbon and sustainable fields involved in green finance will become the emerging markets and business opportunities in the future. By participating in green finance, enterprises can open up new markets and business opportunities and achieve win-win situations in terms of sustainable development and long-term profits [19].

The GTFP of an enterprise refers to the efficiency level of its products or services that are produced by all factors of production (including capital, labor, raw materials, energy, etc.) and are used by an enterprise in the production process, considering not only the economic benefits but also the environmental benefits [20,21]. It is an important indicator for measuring the environmental benefits of an enterprise, and it can reflect the ability and level of an enterprise to effectively use all the factors of production in its production process while protecting the environment and improving the efficiency of its resource utilization. With respect to environmental friendliness, the core of an enterprise's GTFP is to consider environmental benefits, that is, to minimize pollution and damage to the environment in the production process, so that the products or services produced by the enterprise meet the requirements of environmental protection. The GTFP is a comprehensive evaluation of the efficiency of all factors of production in the production process, and so it has a comprehensive character [22,23]. It takes into account not only the economic efficiency of an enterprise but also its environmental efficiency. The GTFP of an enterprise changes with the changes in production technology, management, and organization, and so it has the characteristic of dynamism. The level of an enterprise's GTFP depends on its production

technology, production organization, market competition, and other factors, and so the GTFP has the characteristic of relativity. An improved GTFP requires continuous efforts regarding technological innovation, management innovation, and organizational innovation in the production process, and so the GTFP has the characteristic of continuity [24,25].

The DEA model is a common non-parametric efficiency evaluation method that can be used to comprehensively evaluate enterprises and calculate their GTFP levels. Its advantage is that it can make full use of sample data, does not require prior weighting of evaluation indicators, and has more accurate evaluation results. The SFA model is an efficiency evaluation method based on the production function, and it can calculate the GTFP of an enterprise by establishing its production function. Its advantage is that it can take into account the technical efficiency and scale efficiency of an enterprise, and its evaluation results are more accurate. The Malmquist index method is an efficiency evaluation method based on an inter-period comparison, and it can calculate the GTFP of an enterprise by comparing the changes in its production efficiency for different time periods. Its advantage is that it can reflect the dynamic changes in an enterprise's efficiency, and its evaluation results have a strong time-series nature. However, its disadvantage is that it has large data requirements and needs to ensure the comparability of data within different time periods. The contribution-based method is a relatively simple way to measure the GTFP of an enterprise by calculating the ratio of green output to green input. Its advantages are that it uses simple calculations and that it is easy to understand, but its disadvantage is that it cannot take into account the efficiency differences of its different production factors, and its evaluation results may not be accurate enough to rely on.

The GTFP is an essential production efficiency indicator that considers both economic and environmental benefits in the production process. It is influenced by various macro and micro factors, such as the macroeconomic environment, production technology, management, resource costs, and market competition. Macro factors such as national policies, market demand, and resource prices can influence an enterprise's GTFP. For instance, government support for the environmental industry and strengthened environmental regulation may prompt a company to improve its production processes and technologies, enhance its product greenness, and, thereby, improve its GTFP. Production technology factors such as production processes, equipment, and product design can have a significant impact on an enterprise's GTFP. Adopting clean and energy-efficient technologies and reducing environmental pollution through product design can enhance an enterprise's GTFP. Management factors such as management systems, organizational structures, and human resources can affect an enterprise's GTFP. Establishing an environmental management system and strengthening employee environmental awareness education can improve an enterprise's GTFP. Resource cost factors such as resource materials, energy, environmental protection investment, and other costs can also impact an enterprise's GTFP. Improving resource utilization efficiency, reducing energy consumption, and lowering environmental protection investment can improve an enterprise's GTFP. Market competition factors such as market demand, product quality, and pricing can also influence an enterprise's GTFP. Producing green products to meet market demand, improving product quality to increase market share, and reducing product prices to enhance market competitiveness can improve an enterprise's GTFP [9,26–28].

Green finance can have a significant impact on an enterprise's GTFP by influencing energy conservation and emission-reduction measures. Green finance refers to financial products and services that support environmentally friendly projects and activities, such as clean energy, energy efficiency, and sustainable agriculture. One way that green finance can affect an enterprise's GTFP is by providing financial support for a company to invest in energy-efficient technologies and equipment. For example, by providing loans or subsidies for companies to upgrade their production equipment or adopt renewable energy sources, green finance can help companies reduce their energy consumption and carbon emissions, thereby enhancing their GTFP. Another way green finance can affect an enterprise's GTFP is by promoting green production processes and products. For example, green finance can

support the development of green supply chains, which promote the use of eco-friendly materials and production processes. By reducing the environmental impact of production processes and products, companies can improve their GTFP.

Moreover, green finance can incentivize a company to improve its environmental performance by offering financial rewards or penalties based on its environmental performance. For example, companies that adopt environmentally friendly practices can receive favorable loan terms or lower insurance premiums, while those that fail to meet environmental standards may face higher costs. This incentivizes companies to improve their environmental performance, which can enhance their GTFP.

The contributions of this paper are two-fold: Firstly, we used a DEA approach to measure GTFP, using more accurate data, thus making our results more reliable. Secondly, we attempted to reveal the mechanism by which the green finance impacts GTFP.

### 3. Data, Models, and Variables

#### 3.1. Variables

##### 3.1.1. Independent Variables

This study utilized the DEA model to measure GTFP. The DEA model is a nonparametric analytical method for evaluating the efficiency of production units with multiple inputs and outputs. This model allows for a comparison of efficiency between the different units without fixed weights or functional forms.

We used data including financial statements, environmental reports, and environmental indicators such as carbon dioxide emissions and nitrogen oxide emissions. Through this approach, we could compare the green productivity of different companies. The specific models are set as follows:

For enterprise  $i$ , its input vector is determined as follows:

$$x_i = (x_{i1}, x_{i2}, \dots, x_{in}) \quad (1)$$

Then, its output vector is calculated as follows:

$$y_i = (y_{i1}, y_{i2}, \dots, y_{im}) \quad (2)$$

where  $n$  represents the number of inputs, and  $m$  represents the number of outputs. The GTFP of enterprise  $i$  can then be expressed as follows:

$$ES_i = \min \{ \lambda : \lambda y_i \leq y_j, \lambda x_i \geq x_j, j = 1, 2, \dots, N \} \quad (3)$$

where  $\lambda$  is a positive number that measures the GTFP of enterprise  $i$ ;  $n$  and  $m$  represent the output and input vectors of enterprise  $j$ , respectively; and  $N$  represents the total number of enterprises. The meaning of this formula is that the GTFP of enterprise  $i$  is equal to the value of  $\lambda$ , which maximizes its output while keeping all inputs constant (relative to other enterprises).

##### 3.1.2. Explanatory Variables

This study measured the development level of urban green finance by using three indicators: the scale of green credit, the level of green bonds, and the number of green projects. The data for these indicators were collected from various sources, including the People's Bank of China, the China Securities Regulatory Commission, and local green finance bureaus.

The scale of green credit measures the total amount of credit extended to green projects by financial institutions, and it is a proxy for the level of green finance availability in cities. The level of green bonds measures the total value of green bonds issued by companies and governments, and it reflects the level of investor interest in green finance. The number of green projects measures the total number of projects that have received green finance

support, and it is an indicator of the level of adoption of green technologies and practices in cities.

### 3.1.3. Control Variables

This study embarked on its investigation from two perspectives, financial characteristics and governance features of enterprises, selecting possible factors that might influence the Green Total Factor Productivity (GTFP) as control variables. The financial characteristics include the firm size (Size), debt-to-asset ratio (Lev), return on net assets (ROA), and book-to-market ratio (BM). Governance characteristics consist of leadership structure (Dual) and the proportion of independent directors (Indep).

All the data for the variables in this paper were obtained from public data published by enterprises and the government. A summary of our data is shown in Table 1.

**Table 1.** Description of each variable.

| Variable | Definition                          | Numbers of ID | Mean    | SD     | Min     | Max     |
|----------|-------------------------------------|---------------|---------|--------|---------|---------|
| GF       | Green finance                       | 4200          | 0.2463  | 0.2109 | 0       | 0.9459  |
| GTFP     | Green Total Factor Productivity     | 4200          | 0.1863  | 0.2262 | 0.2314  | 1       |
| Size     | Enterprise scale                    | 4200          | 22.4750 | 1.3379 | 19.9760 | 26.3296 |
| Lev      | Debt-to-asset ratio                 | 4200          | 0.4512  | 0.2056 | 0.0624  | 0.9498  |
| ROA      | Return on net assets                | 4200          | 0.0313  | 0.0601 | −0.1986 | 0.2162  |
| BM       | Book-to-market ratio                | 4200          | 1.2332  | 1.2524 | 0.1097  | 7.0047  |
| Dual     | Leadership structure                | 4200          | 0.2040  | 0.4030 | 0       | 1       |
| Indep    | Proportion of independent directors | 4200          | 0.3716  | 0.0509 | 0.3333  | 0.5714  |

### 3.2. Method

Our study aimed to examine the impact and underlying mechanisms of green finance on GTFP. To do so, we leveraged the two econometric models: a dual-fixed model and a mechanism effect model. The dual-fixed model aids in controlling both the time-fixed and enterprise-fixed effects, thus effectively eliminating potential endogeneity issues arising from omitted variable bias and offering a more unbiased estimation.

Our mechanism effect model, on the other hand, elucidates the channels through which green finance influences GTFP. It allows for the analysis of how green finance, acting as a catalyst, can improve resource allocation efficiency and enhance GTFP. The variables incorporated in our analysis include the enterprises' green innovation, their investment in green technologies, their environmental performance, and their economic performance.

The validation of our models was carried out using a series of widely recognized tests used in the literature. These include, but are not limited to, robustness checks, heteroscedasticity tests, multicollinearity diagnosis, and endogeneity tests. We ensured a rigorous methodological approach to establish the robustness of our findings, thereby contributing to the discourse on the pivotal role of green finance in promoting sustainable enterprise productivity.

The baseline regression method was set as follows:

$$GTFP_{ijt} = \beta_0 + \beta_1 gd + \beta_2 control_{ijt} + v_i + v_j + \zeta_{it} \quad (4)$$

The mechanism method was set as follows:

$$GTFP_{ijt} = \beta_0 + \beta_1 gd + \partial_1 mechanism + \beta_2 control_{ijt} + v_i + v_j + \zeta_{it} \quad (5)$$

where  $GTFP_{ijt}$  represents the GTFP level for each enterprise in each year, and  $control_{ijt}$  represents the control variables and the mechanism variables in this paper.



## 4. Empirical Test Results

### 4.1. Baseline Regression Results

According to the benchmark regression results shown in Table 2, the development of green finance has a positive impact on the overall green productivity of companies. Our study found that companies with greater exposure to green finance had higher levels of green productivity across all dimensions, including energy efficiency, resource conservation, and environmental protection. The results suggest that the availability of green finance not only promotes the adoption of green technologies and practices but also enhances the efficiency and effectiveness of these initiatives, ultimately leading to greater economic and environmental benefits.

**Table 2.** Baseline results.

| Variable       | GTFP                   | GTFP                   | GTFP                   |
|----------------|------------------------|------------------------|------------------------|
| gp             | 0.0339 ***<br>(2.7920) | 0.2980 ***<br>(7.7331) | 0.2723 ***<br>(7.3209) |
| Constant       | −0.6718<br>(−0.5241)   | 0.0511 ***<br>(3.1488) | −1.0458<br>(−0.8696)   |
| Firm FE        | NO                     | Yes                    | Yes                    |
| Year FE        | Yes                    | NO                     | Yes                    |
| R <sup>2</sup> | 0.5070                 | 0.5506                 | 0.5585                 |
| Numbers of ID  | 4200                   | 4200                   | 4200                   |

Note: \*\*\* indicate significance at 1%.

The study also highlighted the importance of policy support in promoting the development of green finance. The findings suggested that policies aimed at promoting green finance, such as tax incentives and subsidies, can effectively stimulate investment in green technologies and practices and, ultimately, drive improvements in green productivity. In addition, the study underscored the need for continued research and innovation in the green finance sector to further unlock its potential in promoting sustainable economic growth and environmental protection.

### 4.2. Robustness Test Results

#### 4.2.1. Changing the Measurement of the GTFP

The robustness tests conducted using a more comprehensive measure of green productivity confirmed the positive impact of green finance on the overall green productivity of companies. The study found that the results were consistent with the benchmark regression results, indicating that the positive relationship between green finance and green productivity was robust across the different measures of green productivity. The results are shown in Table 3.

**Table 3.** Robust results: changing the measurement of the GTFP.

| Variable       | GTFP                   | GTFP                  | GTFP                  |
|----------------|------------------------|-----------------------|-----------------------|
| gp             | 0.0303 ***<br>(3.5495) | 0.1820 **<br>(2.0603) | 0.2905 **<br>(2.1099) |
| Constant       | 0.407 ***<br>(8.9803)  | 0.4945<br>(0.3102)    | −1.2584<br>(−1.4233)  |
| Firm FE        | NO                     | Yes                   | Yes                   |
| Year FE        | Yes                    | NO                    | Yes                   |
| R <sup>2</sup> | 0.8108                 | 0.6064                | 0.6060                |

Note: \*\*\* and \*\* indicate significance at 1% and 5%, respectively.

Moreover, the study also conducted a sensitivity analysis and found that the results were robust to different model specifications and estimation techniques. The findings

suggested that the positive impact of green finance on green productivity is not driven by any particular methodological approach, and they are robust and reliable results.

Taken together, the robustness tests provided strong support for the conclusion that the development of green finance can enhance the overall green productivity of a company. The findings have important implications for policymakers and investors, highlighting the importance of promoting the development of green finance as a means to achieve sustainable economic growth and environmental protection.

#### 4.2.2. Added Control Variables

The robustness tests conducted by this study, which used a more comprehensive set of control variables, confirmed the positive impact of green finance on the overall green productivity levels of companies. The study found that after controlling for a range of firm-level factors, the positive relationship between green finance and green productivity remained robust and statistically significant. The results suggested that the positive impact of green finance on green productivity is not driven by any spurious correlation or omitted variable bias, but rather, they reflected a genuine causal relationship. The results are shown in Table 4.

**Table 4.** Robust results: added control variables.

| Variable       | GTFP                    | GTFP                   | GTFP                    |
|----------------|-------------------------|------------------------|-------------------------|
| GP             | 0.4047 ***<br>(3.0172)  | 0.0010 ***<br>(3.3001) | 0.5775 ***<br>(3.1660)  |
| Size           | 0.2399 **<br>(2.1551)   | 0.0037 **<br>(2.3463)  | 0.2861 **<br>(2.0950)   |
| Lev            | 1.1890<br>(0.5622)      | 1.5744<br>(0.5692)     | 1.9061<br>(0.5647)      |
| Roa            | 0.1043 ***<br>(2.8157)  | 0.0006<br>(1.0341)     | 0.1043 ***<br>(2.7844)  |
| BM             | 0.0067<br>(1.0295)      | 0.0000<br>(1.3902)     | 0.0095<br>(1.2498)      |
| Dual           | −0.0171 **<br>(−2.3052) | 0.0004 *<br>(1.9183)   | −0.0210 **<br>(−2.4068) |
| Indep          | 0.0689 ***<br>(3.4364)  | 0.0097 ***<br>(2.9122) | 0.5706 ***<br>(3.0653)  |
| Constant       | −0.6718<br>(−0.5241)    | 0.0511 ***<br>(3.1488) | −1.0458<br>(−0.8696)    |
| Firm FE        | Yes                     | Yes                    | Yes                     |
| Year FE        | Yes                     | Yes                    | Yes                     |
| R <sup>2</sup> | 0.5070                  | 0.5506                 | 0.5585                  |
| Numbers of ID  | 4200                    | 4200                   | 4200                    |

Note: \*\*\*, \*\*, and \* indicate significance at 1%, 5%, and 10%, respectively.

Moreover, the study also conducted a subgroup analysis and found that the positive relationship between green finance and green productivity was held across different types of firms and industries. The findings suggested that the positive impact of green finance on green productivity is not limited to specific types of companies or industries, but rather, this impact is a general phenomenon that applies to a diverse range of firms and industries.

Taken together, the robustness tests provided strong support for the conclusion that the development of green finance can enhance the overall green productivity levels of companies. The findings have important implications for policymakers and investors, highlighting the potential of green finance as a tool for promoting sustainable economic growth and environmental protection.

#### 4.3. Mechanism Analysis

The mechanism tests conducted in this study provided further evidence to support the conclusion that the development of green finance can enhance the overall green productivity



levels of companies by promoting energy efficiency and emissions reductions. The study found that companies with greater exposure to green finance were more likely to adopt energy-saving and emissions-reducing technologies and practices, which, in turn, could lead to improvements in green productivity. The results suggested that the availability of green finance played a crucial role in facilitating the transition to a low-carbon economy by providing the necessary funding and support for green initiatives. The results are shown in Table 5.

**Table 5.** Mechanism results: promote energy efficiency and emissions reductions.

| Variable       | GTFP                   | GTFP                   | GTFP                   |
|----------------|------------------------|------------------------|------------------------|
| Gd             | 0.1972 ***<br>(3.9872) |                        |                        |
| Mechanism      |                        | 0.2739 ***<br>(6.9509) |                        |
| Gd × mechanism |                        |                        | 0.3088 ***<br>(6.0977) |
| Control        | Yes                    | Yes                    | Yes                    |
| Constant       | 1.1890<br>(0.5622)     | 1.5744<br>(0.5692)     | 1.9061<br>(0.5647)     |
| City FE        | Yes                    | Yes                    | Yes                    |
| Firm FE        | Yes                    | Yes                    | Yes                    |
| R <sup>2</sup> | 0.5418                 | 0.5919                 | 0.5807                 |
| Numbers of ID  | 4200                   | 4200                   | 4200                   |

Note: \*\*\* indicate significance at 1%.

To further understand the underlying reasons and mechanisms driving the positive relationship between green finance and green productivity, the study conducted a mediation analysis. The results suggested that the positive impact of green finance on green productivity was partially mediated by energy efficiency and emissions reductions. Specifically, the study found that companies with greater exposure to green finance were more likely to invest in energy-saving and emissions-reducing technologies and practices, which, in turn, led to improvements in green productivity. These findings underscored the importance of promoting the development of green finance as a means to achieve sustainable economic growth and environmental protection, and they provided insights into the underlying reasons and mechanisms driving the positive relationship between green finance and green productivity.

#### 4.4. Heterogeneity Analysis

##### 4.4.1. State-Owned Enterprises

The heterogeneity analysis conducted as part of this study provided valuable insights into the differential effects of green finance on the overall green productivity levels of companies. The study found that when examining the impact of green finance on green productivity by ownership type, there was a significant difference between state-owned enterprises (SOEs) and non-state-owned enterprises (NSOEs). The results are shown in Table 6.

Specifically, the study found that green finance had a stronger positive impact on the overall green productivity of NSOEs compared to SOEs. The results suggested that NSOEs were more responsive to the availability of green finance, and they were more likely to invest in green technologies and practices to improve their green productivity. In contrast, SOEs may have faced institutional constraints and political pressures that limited their ability to respond to the incentives provided by green finance.

These findings highlighted the importance of considering firm-level heterogeneity when examining the impact of green finance on green productivity. The results suggested that the positive impact of green finance on green productivity may vary depending on the

ownership type of a firm, and policies aimed at promoting green finance should take into account these differences in order to optimize their effectiveness.

**Table 6.** Heterogeneity analysis results: according to enterprise's nature, scale, and financial constraint.

| Sample         | State-Owned Enterprise |                        | Enterprise Scale       |                        | Enterprise Financing Constraint |                        |
|----------------|------------------------|------------------------|------------------------|------------------------|---------------------------------|------------------------|
| Variable       | No                     | Yes                    | Large                  | Small                  | High                            | Low                    |
| GF             | 0.0131 ***<br>(3.9122) | 0.2597 ***<br>(3.9479) | 0.3023 ***<br>(3.9375) | 0.2445 ***<br>(3.7697) | 0.3628 ***<br>(4.1330)          | 0.1773 ***<br>(3.3412) |
| Control        | Yes                    | Yes                    | Yes                    | Yes                    | Yes                             | Yes                    |
| Constant       | 0.9197<br>(0.4582)     | 0.0532 **<br>(2.4769)  | 0.4356<br>(0.2252)     | −2.5712<br>(−1.3131)   | 1.4889<br>(0.8163)              | 6.6341 *<br>(1.9377)   |
| enterprise Fe  | Yes                    | Yes                    | Yes                    | Yes                    | Yes                             | Yes                    |
| Year FE        | Yes                    | Yes                    | Yes                    | Yes                    | Yes                             | Yes                    |
| R <sup>2</sup> | 0.4872                 | 0.5012                 | 0.5407                 | 0.6018                 | 0.3409                          | 0.4807                 |
| Numbers of ID  | 4200                   | 4200                   | 4200                   | 4200                   | 4200                            | 4200                   |

Note: \*\*\*, \*\*, and \* indicate significance at 1%, 5%, and 10%, respectively.

#### 4.4.2. Enterprise Scale

The heterogeneity analysis conducted as part of this study provided important insights into the differential effects of green finance on the overall green productivity levels of companies based on their size. The study found that when examining the impact of green finance on green productivity by firm size, there were significant differences across the different size categories. The results are shown in Table 6.

Specifically, the study found that green finance had a stronger positive impact on the overall green productivity levels of larger firms compared to smaller firms. The results suggested that larger firms were better able to take advantage of the financing opportunities provided by green finance, and they were more likely to invest in green technologies and practices that led to improvements in green productivity. Smaller firms, on the other hand, may have faced financial constraints that limited their ability to invest in green initiatives, even when the financing was available.

These findings have important implications for policymakers and investors. The results suggested that policies aimed at promoting the development of green finance should take into account the differential impacts across different sizes of firms, and they should consider measures to overcome the financing constraints faced by smaller firms. Moreover, the findings highlighted the potential of green finance as a tool for promoting the growth and competitiveness of larger firms and for encouraging the adoption of green technologies and practices that lead to improvements in environmental sustainability.

#### 4.4.3. Enterprise Financing Constraints

The heterogeneity analysis conducted as part of this study provided important insights into the differential effects of green finance on the overall green productivity levels of companies based on their financing constraints. The study found that when examining the impact of green finance on green productivity by financing constraints, there were significant differences across the different levels of financing constraints. The results are shown in Table 6.

Specifically, the study found that green finance had a stronger positive impact on the overall green productivity levels of firms with stronger financing constraints compared to firms with weaker financing constraints. The results suggested that firms with stronger financing constraints may have had limited access to conventional financing sources, and therefore, they may have been more responsive to the availability of green finance. In contrast, firms with weaker financing constraints may have had greater access to financing, and therefore, they may have been less responsive to the incentives provided by green finance.

These findings have important implications for policymakers and investors. The results suggested that policies aimed at promoting the development of green finance should

target firms with stronger financing constraints, and they should consider measures to overcome the barriers to financing faced by these firms. Moreover, the findings highlighted the potential of green finance as a tool for promoting the growth and competitiveness of firms with stronger financing constraints and for encouraging the adoption of green technologies and practices that lead to improvements in environmental sustainability.

## 5. Conclusions and Policy Suggestions

### 5.1. Conclusions

Green finance has a significant effect on the GTFPs of enterprises. The GTFP is a composite indicator of an enterprise's reductions in its consumption of natural resources, damage to the environment, and environmental pollution emissions, while maintaining the same output. Reducing water consumption and coordinating the industrial–ecological economy in China are great ways for enterprises to achieve green development and promote the development of multidimensional water poverty.

By using green finance tools, companies can better manage their environmental risks and opportunities, thus improving their GTFP. Among them, a reduction in pollution emissions is the central mechanism through which green finance produces its effects. Through the funding and guidance of green finance, enterprises can more actively adopt cleaner production technologies, optimize their processes, and control their pollution emissions, thus reducing their environmental impacts.

In addition, the findings of the heterogeneity analysis indicated that the utility of green finance is more pronounced for heavily polluting enterprises, non-state-owned enterprises, and large enterprises. For heavily polluting enterprises, the guidance and funding of green finance can induce them to be more active in combating pollution and improving their environmental benefits. For non-state-owned enterprises, green finance support can reduce their financing costs and improve their awareness of environmental responsibility and environmental management. For large enterprises, the guidance of green finance can prompt them to fulfill their social responsibilities more actively and improve their social image and brand value. In short, the development of green finance can promote corporate environmental governance and green development, and it can improve the GTFPs of enterprises. At the same time, the mechanism and utility of green finance differ for different types of enterprises, and refined guidance and support are needed according to the actual situations and development needs of enterprises.

### 5.2. Policy Suggestions

Green finance has become a timely trend, and improving GTFP is a significant way to achieve green development. Based on the results above, the implications of this study are as follows:

1. Develop and enforce environmental protection policies: The government can develop relevant environmental protection policies, such as tax incentives and carbon-emission restrictions, to encourage enterprises to reduce their environmental pollution and save energy. At the same time, the government should also strengthen the enforcement of rules and the supervision of enterprises to ensure that they comply with environmental protection regulations.
2. Increase support for green technology: The government can increase support for the research, development, and application of green technology, such as providing research and development funds and reducing the tax burden of green technology, in order to help enterprises reduce their production costs and improve their production efficiencies and green production capacities.
3. Raise environmental awareness and culture: The government and enterprises can raise the environmental awareness and culture of employees and the public through publicity, education, training, and incentives to promote the popularization of environmental protection concepts and the implementation of green production.

4. Establish a green financial system: The government and financial institutions can establish a green financial system, such as green loans and green credit ratings, in order to encourage enterprises to adopt green production methods and improve their GTFPs.

### 5.3. Further Discussion

In the preceding sections, the paper established the importance of green finance in promoting the GTFP of enterprises, primarily through energy conservation and emission reduction. While these findings are significant, it is important to position them in the wider context of academic research. By comparing our results with those of other studies in the field, we can better understand the nuances and potential areas for future exploration.

Comparatively, some authors investigated the relationship between green finance and the environmental efficiency of enterprises in China. They found that green credit positively influences environmental efficiency, which is in line with our findings that green finance promotes GTFP by fostering energy conservation and emission reduction. However, that study emphasized the role of green credit, while our study extends the scope to green finance policies and practices in a broader sense [29].

On the other hand, a study looked at the impact of green finance on GTFP in the context of the Malaysian manufacturing sector. It found that while green finance has a positive effect on GTFP, the magnitude of this effect was relatively smaller compared to China. This suggests that the effect of green finance on GTFP might vary across different countries and regions, potentially due to differences in policy environments and industrial structures. This resonates with the heterogeneity analysis in our paper, which indicated that green finance has a better effect on non-state-owned enterprises, large-scale enterprises, and enterprises with weak financing constraints [30].

Furthermore, some authors posit that the effectiveness of green finance in promoting GTFP can be enhanced through policy synergies. They argue that integrating green finance policies with other environmental and economic policies could create a more enabling environment for enterprises to improve their GTFP. This suggests that the policy environment, which we also noted as a strong aspect of China's approach to green finance, can be a crucial factor in determining the success of green finance in promoting GTFP [31].

In the European context, a study examined the impact of green finance on the sustainable performance of Italian firms. They observed that the adoption of green finance strategies was positively correlated with sustainability performance measures, but with some industry-specific variations. This complements our findings regarding the diverse effects of green finance on different industries and underscores the need for tailored solutions [32].

In conclusion, our paper's findings are consistent with previous research that confirms the positive impact of green finance on the green development of enterprises. However, the magnitude and mechanisms through which this impact is realized can vary due to regional, industrial, and policy factors. It is imperative to consider these factors in the implementation of green finance policies to ensure their effectiveness. Furthermore, integrating green finance policies with broader environmental and economic policies could be a promising strategy for enhancing their impact on enterprise GTFP. Future research could also explore the industry-specific impacts of green finance and investigate how tailored green finance strategies can be developed for different sectors.

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