Research on the Energy-saving and Emission Reduction Effect of Green Finance Development--Based on the perspective of energy efficiency and energy consumption structure

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Abstract: Based on the panel data of 30 provinces from 2010 to 2020, this paper explores the energy-saving and emission reduction effects and action paths of green finance development from the perspective of energy efficiency and energy consumption structure . The results show that green finance has a significant effect on energy-saving and emission reduction. Green finance not only effectively promotes the improvement of energy efficiency, but also promotes the optimization and upgrading of energy consumption structure; Further analysis shows that there are regional differences in the energy efficiency and energy consumption structure of green finance in terms of energy-saving and emission reduction. The potential of green finance in energy-saving and emission reduction in the central and western regions is significantly greater than that in the eastern regions; In addition, green finance also has a heterogeneous impact on energy efficiency and energy consumption structure at different quantile levels. At the level of energy efficiency, the dividend period of green finance's energy-saving and emission reduction effect is relatively short, and the potential of green finance's energy-saving and emission reduction effect in adjusting the energy consumption structure is huge. The mechanism analysis found that green technology innovation and industrial structure optimization played a partial intermediary role in the impact of green finance on energy-saving and emission reduction,and green finance has a greater effect on energy conservation and emission reduction at the level of energy consumption structure through industrial structure optimization..

1.Introduction

Since the reform and opening up, China's economic development relies on the extensive growth model of high investment, high energy consumption and high pollution, and has achieved remarkable development results. However, the continuous deterioration of resources and environment indicates that China's current unsustainable economic growth model needs to be changed. In recent years, the government work report has repeatedly stressed the need to carry out "green" transformation and bid farewell to the traditional unsustainable and uncoordinated development mode.Energy conservation and emission reduction are the internal requirements for the realization of green and low-carbon development of China's economy. However, at present, China's energy consumption scale is very large, and the entire energy system is highly dependent on coal, so it is bound to face many challenges and constraints in the process of achieving energy-saving and emission reduction. So, as an important supporting force to deal with climate change, resource consumption and environmental pollution, does the development of green finance promote the realization of energy conservation and emission reduction? How to achieve it? This paper starts from the perspective of energy efficiency and energy consumption structure to explore the energy-saving and emission reduction effect of green finance and its implementation path, providing reference for promoting energy transformation and achieving the "30·60" carbon peaking and carbon neutrality goals.

2.Literature review

Energy conservation and emission reduction is not only an important policy content in the concept of sustainable development in China, but also an important way to achieve green development. Therefore, the research on the influencing factors of energy-saving and emission reduction has always been the focus of academic research. Liu et al.[1]using LMDI to decompose the carbon emission factors of China's manufacturing industry, the study points out that industrial activities are the primary factor hindering energy-saving and emission reduction, and improving R&D intensity and efficiency and increasing innovation investment are conducive to the realization of energy-saving and emission reduction.Li Xiaofan et al.[2]used the panel threshold model to explore that industrial agglomeration and urbanization level are also important factors affecting energy-saving and emission reduction. Zhang Xiufan et al.[3]found that the implementation of carbon emission trading market

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mechanism can improve carbon emission efficiency, in which industrial structure adjustment and technological innovation play an obvious intermediary role. Many other scholars have studied how economic growth[4-5], energy price[6-7], energy structure[8] and foreign direct investment[9] affect carbon emission reduction. It is worth noting that in the current research, scholars mostly choose some indicator that can represent the results of energy-saving and emission reduction to measure the effect of energy-saving and emission reduction, ignoring that the realization of energy-saving and emission reduction requires the dual optimization of structure (energy consumption structure) and efficiency (energy efficiency), which makes it difficult to study the role of energy-saving structure and energy efficiency in energy conservation and emission reduction. Therefore, it is particularly important to clarify the realization path of energy-saving and emission reduction. Only in this way can we promote the realization of energy-saving and emission reduction in a targeted way, and not fall into the dilemma of lack of economic development impetus and lack of energy-saving and emission reduction stamina.

With the increasing importance of financial development in economic development and environmental protection, more and more scholars have incorporated financial development into the impact factors of energy-saving and emission reduction. In recent years, research on the relationship between financial development and energy-saving and emission reduction has been endless, but no consensus has been reached. Some scholars have shown that financial development plays a positive role in energy-saving and emission reduction. Kuang Guojian[10]pointed out that China should learn from international advanced experience and establish a financial system serving energy-saving and environmental protection, which is conducive to the development of energy-saving and environmental protection in China. Tamazian et al.[11] found that financial deepening development can effectively reduce carbon emissions. Zhang Wenbin et al.[12]pointed out that financial development can not only directly promote energy-saving and emission reduction, but also indirectly promote energy-saving and emission reduction through scale effect, structure effect and technology effect. Guo Guixia et al.[13]found that digital inclusive finance can promote the industrialization of digital technology, thereby reducing overall carbon emissions, and realize regional carbon emission reduction by promoting the digital empowerment of industry. Some scholars also pointed out that financial development did not promote the realization of energy-saving and emission reduction. Chen Xiangyang[14]found that China's bank-based financial structure did not reduce carbon emissions, but increased the total carbon emissions. For this reason, some scholars put forward that the different results of financial development in energy-saving and emission reduction are mainly caused by the vast size of China and the different industrial base and factor endowment in different regions.

However, compared with traditional financial development, green finance takes into account economic development and environmental protection, and has advantages in promoting energy-saving and emission reduction. Du Li et al.[15]More scholars study the impact of green finance on energy-saving and emission reduction from a single or multiple financial instruments. Xiujing et al.[16]believe that green credit optimizes the allocation of credit resources and contributes to the realization of energy-saving and emission reduction in China's industry. Jiang Hongli et al.[17]studied the carbon emission reduction effect of green finance by taking green credit and green venture capital as examples, and found that the carbon emission reduction effect of green credit is better by comparison. You Zhiting et al. [18]selected green credit, green industry investment and green bonds to study the differences in energy-saving and emission reduction effects of different types of green finance business. At present, although scholars have studied the relationship between green finance and energy-saving and emission reduction from the perspective of energy consumption, relatively few and most of them only start from the perspective of energy consumption structure or energy efficiency. For example, Chen Qing[19]pointed out that the development of carbon finance can increase the proportion of clean energy consumption, thereby improving the energy consumption structure. Gao Xiaoyan et al.[20]taking new energy as a representative, combed the internal mechanism of green finance affecting the new energy industry and analyzes the bottleneck in the connection between the two.In addition, Liu Chuanzhe et al.[21]found that the development of green credit can effectively promote the low-carbon energy consumption structure. Shen Tao et al.[22]utilized the double difference model to empirically analyze and conclude that China's green finance pilot policy has an obvious negative effect on energy consumption intensity.

3.Research analysis

3.1 Direct effect of green finance on energy-saving and emission reduction

The energy-saving and emission reduction effects of green finance can be divided into two levels: efficiency and structure. From the perspective of energy efficiency, with the further development of domestic green finance, the gradual improvement of the green financial system and the continuous innovation of green financial instruments have made green finance play a better role in improving energy efficiency. On the one hand, financial institutions strictly review the potential environmental risks of the loan object in the credit approval and loan issuance process. As a result, for high-pollution and energy-consuming enterprises, the negative externalities of their environmental costs are internalized, financing costs and financing difficulties are increased, and the development of thehigh-pollution and energy-consuming industry is constrained, thus reducing the intensity of energy consumption and improving energy efficiency. On the other hand, green finance builds a green consumption system through policy guidance, product innovation and other ways to encourage green consumption and green investment of residents, which not only enriches the sources of funds for energy conservation and environmental protection industry, but also fosters green consumption behavior of the whole society, and promotes the improvement of energy efficiency of the whole society. From the perspective of energy consumption structure, green financial activities can optimize the allocation of funds in different industrial sectors. First of all, the green financial policy is introduced into the capital market, which affects the profit and income of enterprises through the financing cost of enterprises. As a result, enterprises will prefer production activities in the field of energy conservation and environmental protection and act on the production side, so that the use of polluting energy is relatively reduced, and the proportion of low-carbon and clean energy in energy consumption is increased, and the energy consumption structure is low-carbon from the perspective of the supply side. Secondly, as investors in the capital market, the public's awareness of environmental protection has been increasing, and the payment preference for green financial products has been enhanced. The scale of green financial consumption has been further expanded, and the use of high carbon energy such as coal and oil in the whole society has been reduced, which has promoted the low carbon of energy consumption, thus improving the energy consumption structure.

3.2 Indirect effects of green finance on energy-saving and emission reduction

In the short-term perspective, energy efficiency can be significantly improved quickly with the support of green technology innovation, while the adjustment of energy consumption structure is limited by the energy factor endowment, industrial structure and economic development stage, and its contribution to promoting energy-saving and emission reduction is weak. Technological innovation is the decisive factor for China's energy efficiency improvement[23], and green technological innovation cannot be separated from the support of funds. The development of green finance just meets the capital demand for green technological innovation. At the same time, green finance forms a virtuous circle of promoting green technology innovation through the functions of risk dispersion and capital optimization in the financial market, so that green finance can continue to promote the improvement of energy efficiency through green technology innovation. With the increase of green technology innovation, on the one hand, the cost of new energy exploitation has been reduced and the supply has increased, and the energy production structure has been further optimized. On the other hand, green technology innovation has reduced the energy consumption intensity, and the industrial upgrading brought by technology spillover has reduced the proportion of high energy consumption industries. Therefore, the overall energy consumption intensity of society has been gradually reduced, and the energy utilization efficiency has been continuously improved. However, the improvement of energy efficiency brought by green technology innovation has also improved the production efficiency of enterprises. In order to pursue the goal of profit maximization, enterprises will increase the input of production factors and expand the production scale, resulting in an increase in the intensity of energy consumption and hindering the realization of the goal of energy conservation and emission reduction of the whole society.

From a long-term perspective, it is increasingly difficult to improve energy efficiency through continuous efficient technological innovation, and the improvement of energy efficiency will also lead to rebound effects, especially in the industrial field, which will promote economic growth and increase energy consumption . Therefore, long-term and sustainable energy conservation and emission reduction should be realized by adjusting the energy consumption structure and optimizing the industrial structure. As a financial element, green finance can guide other production factors of the whole society to gather into advanced productive forces, support the development of green industries and the green transformation of traditional "two high and one surplus" industries. In the process of industrial structure optimization and upgrading, the energy consumption structure dominated by coal energy is gradually replaced by clean energy, and the energy consumption structure has been improved. Finally, under the interaction of green finance and industrial structure, promote the realization of energy transformation and energy conservation and emission reduction. It is worth noting that the industrial structure and energy consumption structure are subject to the industrial development stage and resource endowment. The effect of energy-saving and emission reduction needs to be coordinated with the improvement of the energy consumption structure and the optimization of the industrial structure. In this process, the energy consumption structure is adjusted with the evolution of the industrial structure optimization. The evolution of the industrial structure also needs to adapt to the existing energy industry development stage, so that energy conservation and emission reduction can be achieved through "dual structure optimization", Otherwise, it will fall into the dilemma of "incongruity" between the two, which will have a greater negative effect on the realization of energy-saving and emission reduction.

4. Model construction and empirical analysis

4.1Model design

In order to investigate the energy conservation and emission reduction effects of green finance at the level of energy efficiency and energy consumption structure, this paper sets the following measurement model:

$$efe_{i,j} = \alpha_0 + \alpha_1 gfi_{i,j} + \alpha_2 X_{i,j} + \varepsilon_{i,j} \quad (1)$$

$$esc_{i,j} = \alpha_0 + \alpha_1 gfi_{i,j} + \alpha_2 X_{i,j} + \varepsilon_{i,j} \quad (2)$$

Model (1) is to consider the energy-saving and emission reduction effect of green finance at the level of energy efficiency, and model (2) is to consider the energy-saving and emission reduction effect of green finance at the level of energy consumption structure; The subscripts i&j represent the region and time respectively. (efe) represents energy efficiency and (esc) represents energy consumption structure. (gfi) stands for green finance index; X represents control variable; Represents a random perturbation term.

In order to further test the effect path of green finance on energy conservation and emission reduction, the following intermediary effect regression model is constructed:

$$gtc_{i,j} = \beta_0 + \beta_1 gfi_{i,j} + \beta_2 X_{i,j} + \varepsilon_{i,j} \quad (3)$$

$$efe_{i,j} = \gamma_0 + \gamma_1 gfi_{i,j} + \gamma_2 gtc_{i,j} + \gamma_3 X_{i,j} + \varepsilon_{i,j} \quad (4)$$

$$gst_{i,j} = \beta_0 + \beta_1 gfi_{i,j} + \beta_2 X_{i,j} + \varepsilon_{i,j} \quad (5)$$

$$esc_{i,j} = \gamma_0 + \gamma_1 gfi_{i,j} + \gamma_2 gst_{i,j} + \gamma_3 X_{i,j} + \varepsilon_{i,j} \quad (6)$$

Models (3) and (4) are tests of the intermediary effect of green technology innovation (gtc) between green finance and energy efficiency; Models (5) and (6) are tests of the intermediary effect of industrial structure optimization (gst) between green finance and energy consumption structure.

4.2Variable selection and measurement

4.2.1 Explained variable

Energy-saving and emission reduction require energy conservation and pollution reduction. However, China's large economy and its energy and resource endowment are dominated by coal, resulting in the double irrationality of China's total energy consumption and structure. Therefore, if we want to achieve energy conservation and emission reduction and take the green and low-carbon development path, we must make efforts from both energy efficiency and energy consumption structure. Among them, energy efficiency is measured by the ratio of GDP to energy consumption; The energy consumption structure is measured by the proportion of coal in energy consumption. The smaller the index, the larger the proportion of clean energy, and the higher the low-carbon degree of the energy consumption structure.

4.2.2Core explanatory variable

In order to meet the needs of academic research, scholars have constructed green finance index from different angles. Based on the research of Li Xiaoxi and Xia Guang[24], this paper uses the entropy weight method to construct the green finance index as the core explanatory variable from the five dimensions of green credit, green securities, green insurance, green investment and carbon finance.The index system of green finance is shown in Table 1:

Table 1 Green finance index system

Level I index	Level II index	Level III index	Index interpretation	Index attribute
Green Finance Index	Green credit	Proportion of interest expenditure of energy-intensive industries	Interest expenditure of six energy-intensive industries/Total industrial interest expenditure	-
	Green investment	Proportion of investment in environmental pollution control	Investment in environmental pollution control/GDP	+
	Green insurance	Proportion of green insurance scale	Agricultural insurance expenditure/Total insurance expenditure	+
	Green securities	Market share of energy-intensive industries	Total market value of energy-intensive industries/Total market value of A shares	-
	Carbon finance	Carbon emissions per-unit of GDP	CO2 emissions/GDP	-

4.2.3Control variables

In order to reduce the bias of research estimates caused by missing variables, the main factors affecting energy conservation and emission reduction are controlled (Liu Dawei et al.[25], Lu Na et al.[26] , Lu Yongbin et al.[27]). The control variables are selected as follows: government expenditure, the government's fiscal expenditure is policy-oriented, which will guide the investment of social funds. On the one hand, in order to respond to the national environmental protection policy, local governments have to increase environmental protection expenditure; On the other hand, the appeal for political achievements urges the local government to invest limited funds in areas that can bring economic growth, so the government behavior also affects energy consumption to a large extent, which is measured by the proportion of local fiscal expenditure to local GDP. Foreign direct investment , foreign investment in China will inevitably have a certain degree of impact on the country's technological progress and industrial structure, thus affecting the country's energy utilization efficiency and energy consumption structure, measured by the logarithm of foreign direct investment. The level of human capital, which can affect the technological progress of the country, thus affecting the energy utilization and consumption of the country, is measured by the average years of education. Infrastructure level, infrastructure level provides a strong material basis for the development of green finance and energy utilization. Therefore, infrastructure construction can significantly affect the effect of green finance on energy efficiency and energy consumption structure, measured by the ratio of kilometers of each province to the regional planning area.

4.3Descriptive statistics

Since the relevant data and information of China's green finance were published in 2010, considering the availability of data, this paper selected 30 regions (excluding Tibet, Hong Kong, Macao and Taiwan) from 2010-2020 as the research samples. The data are compiled and calculated from the 2010-2020 China Statistical

Yearbook, Wind database, China Insurance database, EPS database, the official website of the People's Bank of China and the official website of various banks. Some data are missing, and the missing value of some years is replaced by the average value of the data of the next five years. The descriptive statistical results of the main variables are shown in Table 2:

Table 2 Descriptive statistics of main variables

Variable name	Meaning of variables	Number of samples	Mean	Std.dev	Min	Max
gfi	Green finance index	330	0.183	0.111	0.058	0.798
efe	Energy efficiency	330	1.617	0.776	0.457	5.339
esc	Energy consumption structure	330	0.393	0.149	0.007	0.687
gov	Government expenditure	330	0.262	0.114	0.113	0.758
fdi	Foreign direct investment	330	5.577	1.462	0.566	7.718
edu	Human capital level	330	9.165	0.955	6.764	12.782
jcd	Infrastructure construction	330	1.040	0.734	0.083	5.262
gtc	Green technology innovation	330	4.805	1.580	0.000	7.112
gst	Optimization of industrial structure	330	1.296	0.719	0.527	5.244

4.4Analysis of empirical results

4.4.1Benchmark regression analysis

In order to ensure the stability of the estimation results, this paper estimates the relationship between green finance, energy efficiency and energy consumption structure by using random effect model and fixed effect model. The detailed results are shown in Table 3:

It can be seen from the results in Table 3 that there is a correlation between green finance and energy efficiency and energy consumption structure, and the satisfaction is significant at the confidence level of 1%. There is a positive correlation between green finance and energy efficiency, while there is a negative correlation between green finance and energy consumption structure. This shows that the development of green finance can promote the realization of energy-saving and emission reduction from the aspects of energy efficiency improvement and energy consumption structure improvement, which is basically consistent with the previous research and analysis. In the economic sense, under the premise of controlling other variables, every one percentage point increase in the green financial index can make the energy efficiency index increase by 7.38%, and the proportion of coal in the energy consumption structure decrease by 0.67%. The reason for this may be that green funds have a preference for energy-saving and environmental protection, which forces traditional enterprises to break through the dilemma of "high energy-low output" through technological innovation and improve energy efficiency; At the same time, green finance supports the development of energy-saving and environmental protection industry by giving full play to its resource allocation and guidance functions through financial institutions, and forces the upgrading and transformation of traditional industries. The energy consumption structure is improved with the optimization of industrial structure.

From the perspective of other control variables, government expenditure has a significant negative impact on energy efficiency. The possible reason is that the local government, in order to achieve political achievements, instead of the actual use of financial funds, has flowed to industries that can bring rapid economic benefits, such as heavy industry. On the other hand, government expenditure will have a "crowding out effect" on market capital, which leads to the distortion of capital allocation and is not conducive to the improvement of energy efficiency; Foreign direct investment has a significant positive impact on energy conservation and emission reduction at the level of improving energy efficiency, while the effect on energy-saving and emission reduction at the level of energy consumption structure is not significant, reflecting that the technology spillovers brought by short-term foreign investment may promote the improvement of China's energy efficiency to a certain extent. But in the long run, foreign investment and international division of labor are inseparable. China is still at the middle and low levels of the international division of labor system. Most of the foreign direct investment received flows to industries such as high pollution and high energy consumption industries. This will not only aggravate the imbalance between China's industrial structure and energy structure, but also offset the policy dividend of reducing the differences in industrial structure and enriching the energy consumption structure implemented by China, Not conducive to the improvement of China's energy consumption structure; The level of human capital has no significant impact on the improvement of energy efficiency, but has a significant effect on the improvement of energy consumption structure. Finally, the energy-saving and emission reduction effect of infrastructure construction is very obvious both at the level of energy efficiency and the level of energy consumption structure, indicating that infrastructure provides conditions for the implementation of green finance to a certain extent, thus promoting the improvement of energy efficiency and energy consumption structure.

Table 3 Basic regression analysis

Variable	RE		FE	
	（1）	（2）	(3)	（4）
	efe	esc	efe	esc

gfi	6.861*** (19.45)	-0.675*** (-8.76)	7.376*** （20.54）	-0.673*** （-8.43）
gov	-0.437 (-1.18)	-0.005 (-0.06)	-1.225** （-2.44）	0.18 （1.63）
fdi	0.035** (2.01)	0.003 (0.88)	0.043** (2.42)	-0.001 (-0.11)
edu	0.042 （1.10）	-0.030*** （-3.55）	0.057 (1.45)	-0.035*** (-3.94)
jcd	0.293*** （4.97）	-0.040*** (-2.87)	0.366*** (5.08)	-0.036** (-2.23)
_cons	0.423 (-1.33)	0.815*** (11.65)	-0.567* (-1.81)	0.820*** （11.80）
N	330	330	330	330
R^2	0.7883	0.5028	0.7902	0.5078

t statistics in parentheses*p < 0.1, ***p < 0.05, *** p < 0.01

4.4.2 Further analysis

(1) Sub-sample regression

At the regional level, considering the differences in the industrial base and factor endowment in different regions in China, energy efficiency and energy consumption structure are bound to be different, and the development level of green finance in different regions is also very different. Therefore, the overall sample will be returned again according to the eastern and central regions[1] to explore the regional differences in the energy efficiency and energy consumption structure of green finance. The results are shown in Table 4:

By comparing the coefficients of green finance in Table 4, it can be found that the development of green finance in both the east and the central and western regions has promoted the improvement of energy efficiency and energy consumption structure, and both are significant at the level of 1%. However, it is obvious that green finance has a greater effect coefficient on the improvement of energy efficiency and energy consumption structure in the central and western regions. The reason for this may be that the level of science and technology and industrial structure in the eastern region are significantly better than those in the central and western regions. The eastern region is supported by services and high-tech industries. The industrial structure and energy consumption structure are more green, and the upgrading and transformation of the industrial structure has been basically completed, so the role of green finance in the improvement of energy efficiency and energy consumption structure in the eastern region is smaller. On the contrary, the development of green finance in the central and western regions is subject to such factors as economic basis, market conditions, industrial structure, factor endowment, etc. The adjustment of industrial structure and the development of green technology and energy projects are still in a rapid development stage. The development of green finance has increased the investment of green capital in the central and western regions, stimulated the enthusiasm of green technology innovation, and led the central and western regions to change from traditional high energy consumption The industrial structure and energy consumption structure with high emissions are transforming to green, and the central and western regions are rich in new energy resources such as wind energy, hydropower and solar energy due to natural factors such as terrain and terrain, which leads to the huge potential of green finance in energy-saving and emission reduction in the central and western regions, both in terms of energy efficiency and energy consumption structure. Therefore, the development of green finance can not only promote the central and western regions to break through their own limitations, but also alleviate the problems of unbalanced and inadequate development in China.

Table 4 Sub-sample regression analysis

Variable	Eastern (1) efe	 (2) esc	central and western (3) efe	 (4) esc
gfi	6.804*** （13.09）	-0.556*** （-7.31）	9.548*** （12.90）	-1.515*** (-7.49)
gov	-1.47 (-1.07）	-0.273 （-1.35）	-0.403 （-0.95）	0.080 (0.69)
fdi	0.086* （1.71）	-0.021*** （-2.87）	0.010 （0.70）	0.004 (1.02)
edu	0.046 （0.53）	-0.015 （-1.16）	-0.099** (-2.58)	0.006 (0.53)
jcd	0.166* (1.79)	0.003 (0.25)	1.218*** (7.98)	-0.178*** (-4.26)
_cons	-0.743 （-1.01）	0.493*** （4.57）	-0.549*** (9.00)	0.705*** (8.57)
N	121	121	209	209
R^2	0.6520	0.6524	0.8440	0.6518

t statistics in parentheses*p < 0.1, ***p < 0.05, *** p < 0.01

(2) Quantile regression

In order to further investigate the differences in the impact of green finance on energy efficiency and energy consumption structure at different quantiles, this paper selects five quantiles of 0.10, 0.25, 0.50, 0.75, 0.90 to carry out regression, and carries out in-depth research on

[1] Eastern provinces: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan
Midwest provinces: Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang

the regression coefficients of each quantile, and the results are shown in Table 5 :

Table 5 Quantile regression analysis

Interpreted variable1	(1) efe	(2) efe	(3) efe	(4) efe	(5) efe
Quantile	0.10	0.25	0.50	0.75	0.90
gfi	5.116*** (14.18)	5.379*** (14.55)	5.479*** (14.50)	5.130*** (10.40)	4.062*** (5.50)
_cons	0.624* (1.92)	1.219*** (3.19)	1.179*** (3.02)	1.379** (2.71)	0.344 (0.45)
N	330	330	330	330	330
control variable	YES	YES	YES	YES	YES
R^2	0.4846	0.5112	0.5216	0.5165	0.5342
Interpreted variable2	esc	esc	esc	esc	esc
Quantile	0.10	0.25	0.50	0.75	0.90
gfi	-1.235*** (-10.98)	-0.984*** (-6.70)	-0.992*** (-13.36)	-0.881*** (-7.96)	-0.614*** (-4.09)
_cons	0.249** (2.15)	0.518*** (3.42)	0.800*** (10.44)	1.055*** (9.24)	1.404*** (9.07)
N	330	330	330	330	330
Control variable	YES	YES	YES	YES	YES
R^2	0.4278	0.3718	0.3878	0.3407	0.3322

t statistics in parentheses*p < 0.1, ***p < 0.05, *** p < 0.01

According to the quantile regression results, comparing the absolute values of green finance estimation coefficients at different quantiles, it is found that with the improvement of energy efficiency, the overall effect of green finance on energy efficiency shows a trend of first rising and then falling, which may be that the effect of green finance on energy efficiency conforms to the law of diminishing marginal effect, that is, when the energy efficiency increases to a certain level, The marginal income brought by the development of green finance began to decline gradually; On the contrary, with the continuous improvement of energy consumption structure at the current stage, the role of green finance development in promoting the improvement of energy consumption structure is gradually strengthened. This also further shows that in the aspect of energy efficiency, the dividend period of the energy-saving and emission reduction effect of green finance is relatively short. In the long run, the energy-saving and emission reduction effect of green finance in adjusting the energy consumption structure still has great potential.

4.4.3Analysis of action mechanism

In order to further test the intermediary role of green technology innovation and industrial structure optimization in promoting energy-saving and emission reduction by green finance, this paper estimates the intermediary model. The green technology innovation index is obtained by taking the logarithm of the green patent authorization of each province, and the industrial structure optimization index is measured by the ratio of the added value of the tertiary industry to the added value of the secondary industry. The regression results are shown in Table 6:

Table 6 Regression analysis of intermediary effect

variable	（1） efe	（2） gtc	（3） efe	（4） esc	（5） gst	（6） esc
gfi	7.376*** (20.54)	10.182*** (7.47)	6.882*** (18.08)	-0.673*** (-8.43)	3.833*** (16.15)	-0.473*** (-4.36)
gtc			0.073*** (2.23)			
gst						-0.052*** (-2.70)
_cons	-0.567* (-1.81)	-7.037*** （-5.93）	-0.327 （-1.00）	0.820** (11.80)	-0.695*** (-3.36）	0.784*** (11.18)
N	330	330	330	330	330	330
control variable	YES	YES	YES	YES	YES	YES
R^2	0.7902	0.5753	0.7937	0.5078	0.7789	0.5197

t statistics in parentheses*p < 0.1, ***p < 0.05, *** p < 0.01

Regression (1) to regression (3) examined the intermediary role of green technology innovation in the impact of green finance on energy efficiency. Regression (1) shows that green finance can effectively promote energy efficiency and has the effect of energy conservation and emission reduction at the level of energy efficiency. According to the estimated coefficients of green finance and green technology innovation in regression (2) and regression (3) are significantly positive at the level of 1%, it is judged that green finance can improve energy efficiency through green technology innovation, and green technology innovation plays a part of intermediary role in green finance promoting energy efficiency, of which the intermediary effect should be about 0.746, accounting for about 10.84% of the total effect.

Return to (4) to (6) to examine whether green finance can affect the energy consumption structure by influencing the industrial structure adjustment. Among them, regression (4) examines the impact of green finance on the energy consumption structure, and the results show that green finance significantly improves the energy consumption structure, which is consistent with the previous research results; According to the regression (5), the coefficient of green finance is significantly positive and the regression (6), the coefficient of industrial structure optimization is significantly negative, and both are significant at the confidence level of 1%, it is further concluded that green finance can significantly promote the optimization of industrial structure, and then promote the improvement of energy consumption structure to achieve energy conservation and emission reduction, of which the medium effect should be about -0.199, accounting for about 29.6% of the total effect.

To sum up, green finance improves energy efficiency through green technology innovation, and improves energy consumption structure through industrial structure optimization, all of which promote the realization of energy-saving and emission reduction to a certain extent. However, it is obvious that green finance brings more energy-saving and emission reduction effects at the level of energy consumption structure through industrial structure optimization, which means that the realization of energy-saving and emission reduction in China is compared with the improvement of energy efficiency through green technology innovation, The path of promoting the optimization of industrial structure to drive the improvement of energy consumption structure should be more effective.

4.4.4Robust test

In the static panel regression, considering the possibility of endogenous explanatory variables and the cyclical characteristics of energy efficiency and energy consumption structure adjustment, this paper introduces the dependent variable to lag for a period, and uses the dynamic panel system GMM for robustness analysis. The specific regression results are shown in the (1) and (2) columns of Table 7: Sargan statistics and P of AR (2) meet the requirements of greater than 0.1, which indicates that the setting of instrumental variables is effective and there is no second-order autocorrelation in the disturbance term. In addition, through comparison, we can find that the positive and negative signs and significance of the core explanatory variables are consistent with the results of static panel regression, except for the change of coefficient value, so the empirical results are robust.

Table 7 System GMM estimation results

Variable	(1) eef	（2） ecs
L1.	0.809^{***}	0.814^{***}
	（50.24）	(20.54)
gfi	1.864^{***}	-0.354^{***}
	（13.76）	(-4.46)
gov	-0.503^{***}	0.110^{***}
	(-3.79)	(2.89)
fdi	0.0002	0.005^{***}
	(-0.10)	(2.44)
edu	-0.076^{***}	0.006
	(-8.06)	(1.54)
jcd	0.163^{***}	0.007
	(5.78)	(1.03)
_cons	0.717^{***}	0.012
	(7.92)	(0.29)
AR(1)	0.0005	0.0054
AR(2)	0.5782	0.5494
Sargan	0.1111	0.2892
N	300	300

5.Conclusions and suggestions

5.1 Main conclusions

Based on the perspective of energy efficiency and energy consumption structure, this paper selects the panel data of 30 provinces and cities in China from 2010 to 2020 to study the energy-saving and emission reduction effect of green finance development, and draws the following conclusions: (1) green finance has the energy-saving and emission reduction effect. Green finance not only effectively promotes the improvement of energy efficiency, but also promotes the optimization and upgrading of energy consumption structure, and helps the realization of energy-saving and emission reduction in China from the aspects of improving efficiency and optimizing structure; (2) There are regional differences in the energy-saving and emission reduction effects of green finance at the level of energy efficiency and energy consumption structure. Whether in terms of energy efficiency or energy consumption structure, the energy saving and emission reduction effect of green finance in the central and western regions is significantly better than that in the eastern regions, reflecting that the energy-saving and emission reduction effect of green finance is affected by regional economic base, industrial structure, factor endowment and other factors; (3) Under different levels of energy efficiency and energy consumption structure, the marginal effect of green finance in promoting energy-saving and emission reduction is different. With the continuous improvement of energy efficiency, the promotion role of green finance shows a trend of rising first and then declining, and the promotion role of green finance is also increasing with the continuous improvement of energy structure. Therefore, in terms of energy efficiency, the dividend period of green finance's energy-saving and emission reduction effect is relatively short. In the long run, green finance has great potential for energy-saving and emission reduction effect in adjusting the energy consumption structure; (4) The energy-saving and emission reduction of green finance at the efficiency level is realized by driving green technology innovation and improving energy efficiency; At the level of energy consumption structure, the development of green finance promotes the improvement of energy consumption structure by promoting the optimization and upgrading of industrial structure, so as to achieve energy-saving and emission reduction at the structural level.In addition, green finance has a greater effect on energy conservation and emission reduction at the level of energy consumption structure through industrial structure optimization.

5.2 Policy recommendations

Based on the above conclusions, this paper gives suggestions from the following four perspectives: First, we should improve the top-level design of the green financial system, so that green funds can really be used in the field of energy-saving and environmental protection. On this basis, we should enhance the sharing of green financial information. For enterprises and projects with excellent green ratings, we can consider reducing their financing costs and easing the financial constraints of green and low-carbon industries. The government should actively play the guiding role of the green finance policy, give policy support to the green industry, work closely with financial institutions to mobilize more social capital to invest in the energy conservation and environmental protection industry, and promote the improvement of the energy consumption structure and energy efficiency with the reasonable allocation of green funds. Second, adhere to the principle of adjusting measures to local conditions and optimize the regional layout of green finance. At present, the development level of green finance in the eastern part of China is significantly higher than that in the central and western regions, and the regional development imbalance is obvious, and the energy-saving and emission reduction potential of green finance in the eastern region is less than that in the central and western regions. Therefore, when formulating and implementing green financial policies to promote energy-saving and emission reduction, all regions should adhere to the principle of adjusting measures to local conditions and choose the green development path suitable for the local area. In the process of green development, the eastern region should focus on the quality of development and consolidate and strengthen the development achievements in the field of energy conservation and emission reduction. The western region should actively carry out the establishment of the green finance reform and innovation pilot zone, establish and improve the comprehensive pollution control and green development information disclosure mechanism, create a good external environment for green finance, guide capital into the field of energy conservation and emission reduction, accelerate the completion of industrial structure upgrading and energy transformation, and develop towards the direction of promoting energy-saving and emission reduction. Third, cultivate and strengthen the main body of green technology innovation, and strengthen the direction guidance of green technology innovation.We should vigorously develop green finance, leverage social capital and private capital to flow to green industry, meet the diversified capital needs of various stages of green technology innovation, and enhance the enthusiasm of enterprises and universities for green technology innovation. We should also continue to strengthen the support of the whole industry chain for green technology innovation in key areas. Focusing on green development fields such as clean energy, energy conservation and environmental protection, clean production, we will promote upstream and downstream enterprises to jointly carry out research and development, manufacturing and application of green technology and equipment, and promote the whole society to achieve energy conservation and emission reduction. Fourth, improve the docking mechanism between green finance and industrial policy, give full play to the driving role of industrial structure optimization, actively try the development model of "green finance+industry", cultivate environmental protection industry groups, and leverage financial funds to flow to energy conservation and environmental protection fields, especially green industries such as new energy industry; At the same time, the government can increase financial support for the new energy industry through green loans, guaranteed discount interest and the establishment of special support funds to ease its financing constraints. Financial institutions should innovate green financial products, pool social dispersed funds into capital to invest in energy-saving and environment-friendly enterprises or projects, and attract financial resources to gather in the field of energy-saving and emission reduction.

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