The Relationship Between Green Finance, Sustainable Technological Innovation and Energy Efficiency

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Abstract

Sustainable technological innovation can promote this progress in finance. This optimization and upgrading of energy efficiency can provide a good energy environment for green development. The collaborative innovation of financial enterprises has brought such development to the tertiary industry, driving the upgrading of consumer demand, and thus promoting the development of green finance. At this same time, sustainable technological innovation will increase investment in environmental protection, reduce energy consumption, promote the reduction of carbon emissions in the financial industry, and accelerate the development of green finance. This paper uses the data envelopment analysis method to calculate the Marquis production efficiency index, examines the dynamic generation efficiency of intertemporal energy input and output, and calculates the energy efficiency of green finance. This article measures and deconstructs energy efficiency at the provincial level, and pays attention to its changes. The study depicted the efficiency distribution of 28 provinces in two stages of the survey period. By using

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random kernel estimation for two periods during the survey period, dynamic distribution three-dimensional maps and density contour maps of total factor energy productivity, energy utilization efficiency, and energy allocation efficiency growth rates were drawn for the two periods. The results show that the transfer probability group of energy efficiency and its decomposition terms mainly falls near the diagonal, indicating that TFP and its decomposition term growth rate have certain transferability. From 2005 to 2015, the energy utilization efficiency of the seven economic regions has been significantly improved, and the energy efficiency differences in different regions have gradually converged. The energy efficiency of the Yangtze River Delta and the Pearl River Delta is the highest and has been continuously improved, followed by the Beijing Delta, the central region, the northeast region and the southwest region are again in terms of energy efficiency. Compared with provinces with relatively poor industrial structures, provinces with better industrial structures do not have significant advantages in energy efficiency, while provinces with higher levels of technological innovation typically have relatively higher energy efficiency.

Keywords: Green finance, sustainable technological innovation, energy efficiency, data envelope, Marquis.

1 Introduction

As the advancement of human civilization is inseparable from the support of energy. Energy policy will be having the relationship for the secure one and stability for our nation. Green finance provides financial support for renewable energy projects by providing financial products. By investing in renewable energy projects, green finance can promote the development of a low-carbon economy, create new job opportunities, and promote coordinated economic, social, and environmental development [1]. The rapid economic development has made energy and environmental problems increasingly prominent. With the increasing depletion of fossil energy such as oil and coal, the energy crisis and energy pollution problems are intensifying, and energy shortage has been the national economy. The improvement of energy efficiency can reduce energy consumption and greenhouse gas emissions, thereby reducing pressure on the environment. By adopting efficient energy equipment and optimizing energy usage, the efficiency of energy conversion and utilization can be improved, and energy waste and emissions can be reduced. In addition, improving energy efficiency can also promote the development of renewable energy, further reduce dependence on traditional fossil fuels, and reduce environmental pollution [2]. My country is the world's largest developing country with abundant resources, but it is also the world's largest energy consumer. In order to accurately estimate the mitigation effect of green finance on climate change, Nawaz et al. used the Difference in Differences (DID) method. DID is a quasi-experimental design that estimates policy effectiveness by comparing the differences between the control group and the experimental group before and after policy implementation. Here, we assume that there are systematic differences in climate change trends between China and the BRICS countries before and after implementing green finance policies, and this difference is causal with the implementation of green finance [3]. From the perspective of energy consumption structure, coal and oil are the mainstays of Chinese energy consumption. Public expenditure plays an important role in promoting the green economy. Government support for research and development and technology is an important driving force for transformation, which not only helps to alleviate market failures, but also maximizes the development of the green economy through composite and technological effects [4]. Public expenditure is an important force in promoting green economic growth. By directly investing and guiding social capital, it can promote the development of green industries such as renewable energy, and achieve sustainable economic, social, and environmental development [5]. The next 20 years will be an important period of opportunity for China's social and economic development. Technological innovation and public-private partnership investment can promote the development of green buildings, such as the use of environmentally friendly materials and energy-saving design. These measures can reduce energy consumption and carbon emissions of buildings, while improving their sustainability and ecological benefits [6]. To achieve the goal of low-carbon development, the direction of economic development will inevitably be constrained by energy consumption [7]. Only by enhancing technological innovation capabilities and establishing a sound carbon finance system can we achieve the dual goals of energy conservation, emission reduction, and sustained economic growth. And this process must break through the constraints of financial interests. It is particularly necessary to leverage a series of institutional control and regulatory functions of the financial market [8].

As the carrier of various production factors and transaction information, green finance has a huge impact on the optimal allocation of various resources and the smooth development of economic activities due to its unique operating laws and its effective support [9]. Green finance can utilize its advantages in capital, market, credit and other endowments to guide capital flow. By changing the way capital is used, a small amount of limited financial resources can guide technological innovation as much as possible. By analyzing data on consumer carbon emissions, we can see the impact of public-private partnerships on carbon emissions. In this context, public-private partnerships are seen as a policy tool that can guide and motivate consumers to change their consumption behavior, thereby reducing carbon emissions [10]. The total amount and aggregation capacity of financial resources can also meet the needs of financing diversity, adjustment and upgrading of the economic one, so reduce intensity for energy consumption [11]. High-level financial services can provide effective financial support. By analyzing data from 1998 to 2013, it was found that the impact of environmental regulations on energy efficiency varies by region and time. In the eastern and central regions, environmental regulations have a significant positive impact on energy efficiency, but this impact is not significant in the western region. In addition, the impact of technological innovation on energy efficiency also varies in different regions [12].

Green innovation and sustainable resource management require a large amount of data to support, including environmental data, energy data, economic data, etc. Collecting and processing this data is a huge challenge that requires advanced data collection, storage, and processing technologies [13]. In order to support the transition to a low-carbon economy, the government can adopt a series of policies to provide financial support and promote green innovation. The government can establish specialized funds to support early green technology innovation and related enterprises. This fund can provide support in capital investment, technical guidance, and market promotion, helping innovative enterprises overcome early financing difficulties [14]. The central bank can require financial institutions to disclose their environmental information and risks, promote the identification and management of environmental risks by financial institutions, and promote the development of green finance [15]. Financial markets and institutions may provide financing and support for high carbon emission industries, which will promote an increase in carbon emissions. Therefore, the direction and policy choices of financial development may have a positive or negative impact on carbon emissions [16]. The green bond market in developing countries faces some challenges, including a lack of corresponding policy frameworks, regulatory systems, and market infrastructure. However, with the increasing awareness of global climate change and the gradual realization of sustainable development goals, the green bond market in developing countries is expected to further develop [17]. Financial development can provide necessary financing support for renewable energy consumption. The introduction of green finance policies can guide and encourage financial institutions to provide loans and investments in renewable energy projects, providing financial support for the development of renewable energy. In addition, financial development can also promote the development and utilization of renewable energy by providing risk management and investment opportunities [18]. Through correlation analysis, Guo et al. explored the relationship between green innovation, energy investment, and environmental quality. Then, through regression analysis, explore the degree and mode of impact of green innovation and energy investment on environmental quality [19]. Renewable energy investment is an important driving force that can promote the development of a green economy. By improving energy efficiency, reducing energy consumption, and promoting the development of the environmental protection industry. These investments contribute to achieving sustainable development goals and driving the growth of the green economy [20].

Based on empirical research results, we can further explore the relationship between green finance, sustainable technological innovation, and energy efficiency. Firstly, green finance can promote sustainable technological innovation by providing financial support for environmental projects. This is because some environmental protection projects require significant investment, and green finance can provide a stable source of funding for these projects. Secondly, sustainable technological innovation can significantly improve energy efficiency. This is because new environmental technologies can improve the way energy is used, reduce energy consumption, and reduce environmental pollution. Finally, improving energy efficiency can also bring more opportunities for green finance. With the improvement of energy efficiency, the same energy consumption can achieve more economic output, which will bring more returns to investment in green finance. The existing literature on the relationship between this field is not yet complete. Although there have been numerous studies exploring the relationship between green finance, sustainable technological innovation, and energy efficiency, few studies have focused on their mutual influence. This article aims to explore the relationship between green finance, sustainable technological innovation, and energy efficiency. Through comprehensive analysis of relevant literature and empirical research, we have found that green finance and sustainable technological innovation have a positive impact on energy efficiency.

2 Literature Review

2.1 Green Finance Development Affects Energy Efficiency Through Sustainable Technological Innovation

The development of green finance can have a positive impact on energy efficiency, which is mainly achieved through innovation in sustainable energy technologies. Green finance is a financial tool designed to achieve sustainable development and environmental protection goals, focusing on environmental protection and effective utilization of resources. Specifically, green finance promotes the research and application of clean energy, energy efficiency improvement, and sustainable technologies by providing financial support, market mechanisms, and policy incentives.

On the one hand, green finance can guide the flow of funds to projects and enterprises that meet environmental standards by providing loans and credit support, which can improve energy efficiency. These projects typically include the development and utilization of renewable energy, research and development of energy storage technologies, and promotion of clean energy. Through the implementation of these projects, energy efficiency can be greatly improved, energy consumption and emissions can be reduced, and the development of a low-carbon economy can be promoted.

On the other hand, green finance can also promote energy efficiency by supporting the research and promotion of sustainable technologies. For example, providing financial support for the research and development of clean energy technologies and encouraging enterprises and institutions to explore and practice energy efficiency improvement. These measures can promote technological progress and innovation, further promoting the improvement of energy efficiency.

In addition, green finance has also played an important role in enhancing the environmental responsibility awareness of enterprises and institutions. Through environmental assessment and information disclosure requirements, enterprises and institutions need to understand their own environmental risks and impacts, and take corresponding improvement measures. This not only helps enterprises improve their own environmental management system, improve resource utilization efficiency, but also promotes the sustainable development of the entire society.

Overall, green finance has had a positive impact on the improvement of energy efficiency through the innovation and promotion of sustainable technologies. In the future, we need to further strengthen international cooperation, establish stricter standards and regulatory mechanisms, and encourage all parties to actively participate in the development of green finance to achieve a more sustainable and prosperous future.

2.2 Energy Efficiency Affects the Development of Green Finance Through Economic Restructuring

Economic structural adjustment can promote the improvement of energy efficiency, thereby having a positive impact on the development of green finance. Economic structural adjustment can promote the effective utilization of energy. In China's current energy consumption structure, coal is the main energy source, accounting for 75% of the market share. However, this high proportion of coal consumption has caused great pressure on the environment, with a large amount of mineral resources being mined and the exhaust emissions generated by coal combustion also having a significant negative impact on air pollution. Through energy structure adjustment, China can gradually reduce its dependence on traditional energy and shift towards the utilization of new and clean energy. For example, measures such as popularizing electric vehicles and improving the utilization of renewable energy can effectively adjust the energy consumption structure and reduce dependence on traditional energy.

Economic structural adjustment can promote the development of the new energy industry. With the upgrading of energy structure, China will gradually reduce its dependence on imported oil and natural gas, thereby reducing the cost of energy imports and promoting economic development. Technological research and development in new energy, clean energy, efficient and low-carbon areas will also be greatly strengthened, stimulating new drivers of economic growth. For example, the use of new energy sources create more job opportunities, and promote sustainable economic development.

Economic structural adjustment can also promote the development of a series of related industries. Traditional high energy consuming and high emission industries are restricted, while emerging and clean energy industries are developing. This will drive the growth of a series of related industries, provide more job opportunities, and accelerate the process of economic transformation and upgrading. The development of these emerging and clean energy industries will provide more investment opportunities and space for green finance. In summary, economic structural adjustment can promote the improvement of energy efficiency, thereby creating more opportunities and conditions for the development of green finance. Through the innovation and promotion of sustainable technologies, we can better promote the development of green finance and achieve a more sustainable and prosperous future..

2.3 Green Finance and Energy Conservation and Emission Reduction

Green finance is closely related to energy conservation and emission reduction, and the former is one of the important means to achieve the latter's goals. Green finance is a financial tool that promotes sustainable development and environmental protection by providing preferential credit, insurance, and securities issuance services for environmental protection projects and enterprises. Energy conservation and emission reduction are actions to reduce energy consumption and pollutant emissions.

Specifically, green finance can promote energy conservation and emission reduction through the following methods:

1. Provide financial support: Green finance can provide financial support for environmental protection projects and enterprises, promoting the rapid development of these fields and achieving the goal of energy conservation and emission reduction.
2. Innovative financial products: Green finance can develop innovative financial products, such as green bonds, green funds, green insurance, etc. These products can provide more funding sources for environmental protection projects and enterprises, while also reducing investment risks.
3. Guiding investment direction: Green finance can provide investors with environmental protection investment information and services, guide investment direction, and enable more funds to flow to environmental protection projects and enterprises, promoting energy conservation and emission reduction.
4. Promote industrial upgrading: Green finance can support the environmental upgrading and transformation of traditional industries, promote industrial structure adjustment and optimization, and promote the development of traditional industries towards a more environmentally friendly, efficient, and energy-saving direction.
5. Promote green consumption: Green finance can promote the concept of green consumption, encourage consumers to purchase environmentally friendly products and services, reduce negative impacts on the environment, and promote energy conservation and emission reduction.

In short, green finance is one of the important means to achieve energy conservation and emission reduction goals. It can provide financial support, innovate financial products, guide investment direction, promote industrial upgrading, and promote green consumption to promote energy conservation and emission reduction.

This paper mainly analyzes the dynamic sustainable technological innovation and energy efficiency from the perspective of green finance.

3 Methodology

Sustainable technological innovation can push optimization and upgrading of energy efficiency can provide a good energy environment for it and the collaborative innovation of financial enterprises have enhanced industry, driven the upgrading of consumer demand, and then promoted the development of green finance. At the same time, sustainable technological innovation will reduce energy consumption, promote the reduction of carbon emissions, and accelerate the development. As shown in Figure 1:

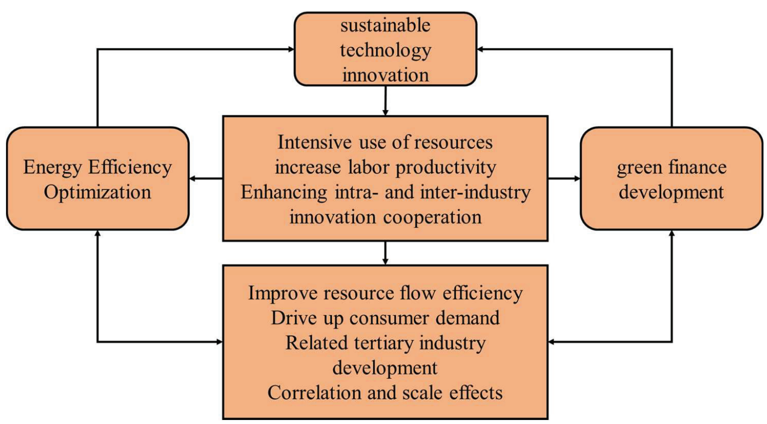


Figure 1 The relationship between green finance, sustainable technological innovation and energy efficiency.

3.1 Energy Efficiency

Regarding the measurement, it is more common to use the one, that is, energy consumption per unit of gross domestic product (GDP). For example, Wang Yingjie and Lu Zhengnan of the University of Chinese Academy of Sciences used this indicator when they studied the differences in the impact of factors such as energy efficiency and economic level on carbon emissions in the eastern and western regions. Although this method is simple and intuitive to calculate, as a single factor of energy efficiency, energy intensity itself includes changes in energy structure, changes in industrial structure, etc. that have nothing to do with energy technology efficiency, and the calculation results are too general. Therefore, the author selects the total factor energy efficiency considering the interaction of various input factors as the measurement index, adopts the data envelopment analysis method, calculates the Marquist production efficiency index, examines the dynamic generation efficiency of intertemporal energy input and output, and analyzes the dynamic generation efficiency of energy input and output. Calculate energy efficiency.

$$\begin{aligned} &\underset{\theta,\lambda}{Min\theta} \\ s.t \quad &-y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq O \\ &\lambda \geq 0 \end{aligned} \tag{1}$$

In formula (1), θ is a scalar, λ is a constant vector of N*l, and the value obtained is the efficiency value of decision-making unit i. Generally $\theta \leq 1$, when is $\theta = 1$, it means that the unit is located on the frontier of production and is technically effective.

In this study, each province (autonomous region, municipality directly under the central government) is used as a decision-making unit, and the specific ideas for the calculation of the Marquis index based on the data envelopment analysis method are as follows:

Assuming that the vector represents the factor input of each province (autonomous region, municipality directly under the Central Government), the vector $\mathrm{y} = (\mathrm{y}_1, \mathrm{y}_2, \ldots \mathrm{y}_m)$ represents its output, and P (x) represents the possible production set, that is, the input vector x can The set of all output vectors produced. Then the output distance function in period t is:

$$d_0^t(x_t, y_t) = \inf\{\theta_t : (\underset{\theta}{x_t}, y_t|\theta_t) \in P(X_t)\} \tag{2}$$

where $\theta_t \in [0, 1]$ is the rate of increase in output factors when reaching the production frontier.

At this time, the index with reference to technology T in period t is shown in formula (3):

$$M_0^t(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{d_0^t(x_{t+1}, y_{t+1}|C, S)}{d_0^t(x_t, y_t|C, S)} \tag{3}$$

In the same way, the Marquis exponent of the technology T. in the t+1 period is shown in formula (4):

$$M_0^{t+1}(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{d_0^{t+1}(x_{t+1}, y_{t+1}|C, S)}{d_0^t(x_t, y_t|C, S)}(x_{t+1}, y_{t+1}) \tag{4}$$

Among them, (x_{t+1}, y_{t+1}) and (x_t, y_t) are the inputs and outputs of the t+1 period and the t period, respectively, d_0^t and d_0^{t+1} are the distance functions between the t period and the t+1 period with the technology Tt in the t period as the reference, respectively; C, S indicate the situation of constant return to scale.

In order to avoid the differences that may be caused by the randomness of period selection, following the construction method of Fisher's ideal index, the geometric mean of formula (3) and formula (4) is used as the Marquee measure of productivity changes from period t to period t+1. Sturt exponent, as shown in formula (5):

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{d_0^t(x_{t+1}, y_{t+1}|C, S)}{d_0^t(x_t, y_t|C, S)} \times \frac{d_0^{t+1}(x_{t+1}, y_{t+1}|C, S)}{d_0^{t+1}(x_t, y_t|C, S)}\right]^{\frac{1}{2}} \tag{5}$$

3.2 Green Finance and Energy Efficiency

Green development is a sustainable development that promotes the mutual promotion of environment and economy. Green development requires it to develop an efficient circular economy. This article elaborates on China's green finance industry, including the ecological friendliness and sustainable development of the green economy. Representing the level of energy conservation, low-carbon, safety, and environmental protection in the financial industry, it reflects the requirements for reducing energy consumption and protecting the environment in green development. This paper uses the direct right method to measure the relationship between the development level of regional green finance and energy efficiency in China. The specific steps are as follows:

(1) Data standardization processing. Due to the inconsistent nature and dimension of each index, it is necessary to standardize each index separately.

Positive indicators:

$$T_{ij} = \frac{t_{ij} - \min(t_{ij})}{\max(t_{ij}) - \min(t_{ij})} \tag{6}$$

Negative indicators:

$$T_{ij} = \frac{\max(t_{ij}) - t_{ij}}{\max(t_{ij}) - \min(t_{ij})} \tag{7}$$

In Equations (1) and (2), T_{ij} is the index value after standardization, tij is the actual value of the jth index in the ith province, max(T_{ij}) and min(T_{ij}) are the jth index respectively. the maximum and minimum values.

(2) Calculate the inheritance rights of each indicator. The formula for calculating succession is:

$$\omega_j = \frac{(1 - E_j)}{\sum_{j=1}^{m}(1 - E_j)} \tag{8}$$

The information descendant value of the jth indicator:

$$E_j = -\frac{1}{\ln n}\sum_{i=1}^{n} g_{ij}\ln(g_{ij}) \tag{9}$$

The proportion of the j-th indicator in the i-th province:

$$g_{ij} = \frac{T_{ij}}{\sum_{i=1}^{n} T_{ij}} \tag{10}$$

(3) Calculate the comprehensive evaluation value of green finance development level and energy efficiency in each region:

$$Hq = \sum_{j=1}^{m} \omega_j T_{ij} \tag{11}$$

3.3 Sustainable Technology Innovation and Energy Efficiency

The power source of sustainable technological innovation is driven by a comprehensive model that integrates the pursuit of long-term growth of innovators' economic interests, technological development, social needs, and natural environment pressure, as shown in Figure 2.

The coefficient of sustainable technological innovation is used to measure the impact of sustainable technological innovation on energy efficiency. The calculation of this coefficient is based on the input and output data of sustainable technological innovation, as well as their impact on energy

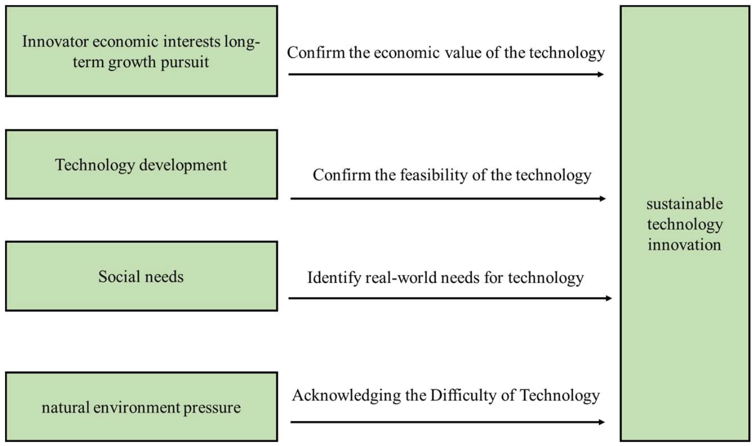


Figure 2 The power source model of sustainable technological innovation.

efficiency. Analyze the impact of input and output on energy efficiency through regression analysis or other statistical methods. Assign corresponding weight values based on the magnitude of the impact effect. Combine the weight values with input and output data to calculate the sustainable technological innovation coefficient. This coefficient can reflect the contribution of sustainable technological innovation to energy efficiency and provide reference for formulating relevant policies and investment decisions. The location direct index is used to measure the moderating effect of regional policies, market environment, and other factors on the relationship between green finance and energy efficiency. The calculation of this index is based on statistical analysis of regional policies, market environment, and other data. Analyze the moderating effect of factors on the relationship between green finance and energy efficiency through regression analysis or other statistical methods. Assign corresponding weight values based on the magnitude of the adjustment effect. Combine the weight values with the statistical analysis results of relevant data to calculate the location direct index. This index can reflect the regulatory effect of regional policies, market environment, and other factors on the relationship between green finance and energy efficiency, providing reference for formulating targeted policies. The sustainable technological innovation coefficient takes the region as the independent variable to examine the distribution of specific technological innovation, and it is divided into relative indicators and absolute indicators. The location direct index, industry concentration, Hirschman-Hafidel index and technology absolute geographic concentration index are all absolute indicators. Indices such as the spatial Gini coefficient, the Hoover-Barrassa coefficient, the industrial dynamic agglomeration index and the spatial separation index are all relative indicators. Different calculation methods of sustainable technological innovation coefficient have their own advantages, but because the location succession index is more in line with the basic requirements of technological structure changes and is widely used by sustainable technology organization scientists, the author adopts the location succession method to calculate Sustainable Technological Innovation Coefficient.

The locational succession index is usually certain one. In the study of sustainable technological innovation coefficient, it is usually used to analyze it and it will be shown in formula (12):

$$E_{ij} = \frac{\frac{q_{ij}}{Q_j}}{\frac{Y_i}{Y}} \tag{12}$$

In formula (12), Eij represents the locational succession index of j technology in the i region in the whole country, and the energy consumption of unsustainable technologies is the largest. Therefore, the author measures the degree of sustainable technological innovation by calculating the locational succession index of the secondary industry. is the gross production value of j industry in region i; 0; is the national gross production value of j industry, Yi is the production value of all industries in region i, and Y is the production value of all industries in all regions of the country. The larger the Eij value, the higher the degree of sustainable technological innovation. When Eij > 1, it means that the regional economy of region i has an advantage in the whole country; when Eij < 1, it means that the regional economy of region i has a disadvantage in the whole country.

Considering that the impact of sustainable technological innovation on energy efficiency may have both hysteresis effect and spatial effect, the author uses a dynamic spatial panel model to examine the relationship between the two, and the model is set as:

$$\ln \mathit{eff}_t = \tau \ln \mathit{eff}_{t-1} + \in \ln \mathit{eff}_{t-2} + \rho \sum_{j=1}^{N} W_{ij} \ln \mathit{eff}_t + \beta \ln X_{it} + \eta_{it} + \upsilon_{it} + \varepsilon_{it} \tag{13}$$

$$\varepsilon_{ij} = \lambda \sum_{j=1}^{N} W_{ij} \xi_{ij} + \mu_{ij} \tag{14}$$

In formula (1) and formula (2), τ and $\in$ represent the first-order lag and second-order lag regression coefficients of energy efficiency, respectively, ρ and λ represent the spatial lag regression coefficient and spatial error regression coefficient, respectively, η_{it} and υ_{it} represent the regional effect and time effect, respectively, represents the random interference term, ε_{it} represents the spatial weight matrix, W_{ij} represents the energy efficiency of the current period, and eff_t represents the energy efficiency of the first lag period eff_{t-1} and the second lag period eff_{t-2}, respectively, X is the control variable, referring to the existing research, the author selects the sustainable technological innovation coefficient, energy consumption structure as a control variable. Such large order of magnitude has the difference on the model analysis, the logarithm of all variables was measured. The author selects 30 provinces (autonomous regions and municipalities directly under the Central Government) in my country as the spatial weight matrix, so as to conduct a more comprehensive investigation of the spatial effect of sustainable technological innovation on energy effects.

The sustainable technological innovation and energy efficiency will be listed. The calculation formula is shown in formula (15):

$$Moran'I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(Y_i - \overline{Y})(Y_j - \overline{Y})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \tag{15}$$

Yi represents the GDP of the ith region, n is the total number of regions, and W_{ij} is the spatial weight matrix represented by the geographic adjacency matrix.

4 Result Analysis and Discussion

4.1 Energy Efficiency

This paper measures and deconstructs energy efficiency from the provincial level to note the changes. Considering that in 2006, the government first included targets into the outline of the national economic development plan, and the possible structural changes in the growth rate of regional energy efficiency in my country before and after the "Eleventh Five-Year Plan", in the empirical analysis, the investigation period is divided into 2006 as the node. In two stages, eliminating the impact of structural breakpoints caused by changes in national policies makes empirical analysis more reasonable and can also test the effect of policy implementation to a certain extent. As shown

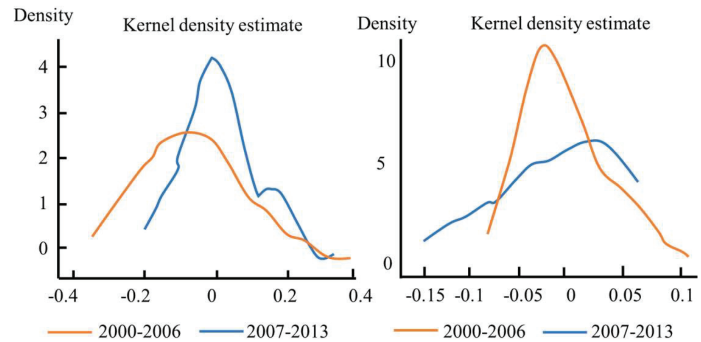


Figure 3 Distribution of regional energy efficiency and its decomposition terms in China.

in Figure 3, from left to right, the distribution of efficiency of 28 provinces in the two stages of the investigation period is depicted.

The growth rate of total factor energy productivity in my country has gradually evolved from a unipolar distribution to a bimodal distribution, and the position of the main peak has increased and shifted to the right, indicating that total factor energy productivity has shown a high level of growth. rate of accelerated convergence. In the first stage, from 2000 to 2006, the growth rate of total factor energy productivity showed a unimodal distribution in the range of -0.2 to 0. In the second stage, from 2007 to 2013, it appeared in the range of 0 to 0.1 and 0.15 to 0.2, respectively. The peaks and sub-peaks show that in the second stage, the growth rate of total factor energy productivity in China has converged in two poles, and a small number of provinces have agglomerated to a higher growth rate; the energy utilization efficiency, which mainly examines the impact of technological progress, has an opposite trend of change. The position of the main peak shifts to the right while falling, and a secondary peak appears at a lower position), indicating that there is a trend of polarization in energy utilization efficiency, and some provinces converge to a higher growth rate but converge The speed has slowed down, while some provinces have a tendency to agglomerate to a low level; for the growth rate of energy allocation efficiency, which has a greater impact on cost, the peak position moves to the upper right, indicating that allocation efficiency is positive The higher level accelerates the movement, and the second stage also has an obvious bimodal structure, which shows that the growth rate of energy allocation efficiency has converged in two poles, and a small number of provinces are clustered towards a higher growth rate.

Next, by stochastic kernel estimation for the two periods of the investigation period, the dynamic distribution three-dimensional map and density

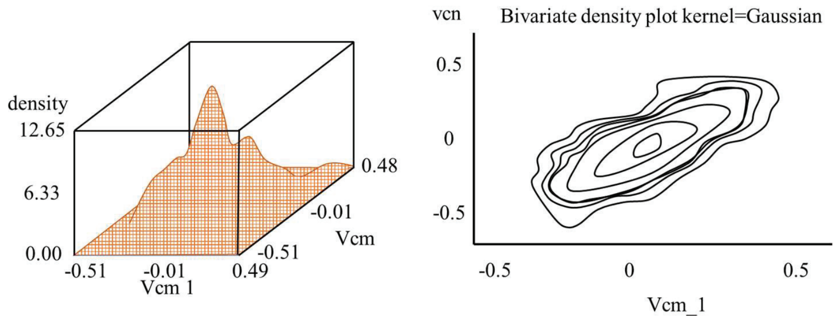


Figure 4 Random kernel and contour plots of energy efficiency.

contour map of the growth rate of total factor energy productivity, energy utilization efficiency and energy allocation efficiency in the two periods are drawn. The evolution law of total factor energy productivity and its influencing factors. The axis of the plane represents the growth rate in years t and t+1, and the axis perpendicular to the plane is the random kernel, representing the conditional probability of any point in the plane. The line parallel to the X-axis represents the transition probability from a point on the Y-axis to any point on the X-axis, describing the transition probability and trend of the distribution of total factor energy productivity and its decomposition in each province from year t to year t+1.

The transition probability groups of energy efficiency and its decomposition term mainly fall around the positive diagonal, indicating that both TFP and its decomposition term growth rate have certain mobility, as shown in Figure 4. Nevertheless, there is still a certain difference in the growth rates of energy efficiency and its decomposition terms between the two periods.

The main peak of the stochastic nuclear map in the first period is relatively steep, and the contour lines are more below the 45-degree line, indicating that the energy efficiency growth rate of more provinces in year t+1 has increased compared with year t. At the same time, etc. The high line crosses the second and fourth quadrants, indicating that some provincial energy efficiency growth has reversed, and the transitions of positive growth and decay may occur in parallel. In the second period, the main peak of the stochastic nuclear map was relatively flat, and the previous small peaks disappeared to form two more significant peaks, indicating that the growth rate of energy efficiency in this stage began to show the characteristics of club convergence; the contour line shifted to the upper right corner and The concentration range is more divergent, indicating that the growth rate of provincial energy efficiency has increased slightly, and the liquidity of distribution has been further enhanced; and the area of contour lines passing through the second and fourth quadrants has increased, indicating that the possibility of reversal of the growth rate of provincial energy efficiency has increased. The gap between the efficiency leading and the backward areas is gradually narrowing, and the possibility of the backward areas catching up and surpassing is further increased.

4.2 Green Finance and Energy Efficiency

From the perspective of the financing scale of the green financial market, from 2005 to 2014, the financing scale of the green market in my country has grown rapidly (see Figure 5). In 2005, the total financing scale of green financial markets in the seven major economic zones in the country was 285.047 billion yuan. In 2014, Figure 5 reached 8,066.267 billion yuan, which is about 28.3 times the total financing scale of green financial markets in 2005. At the same time, the financing scale of green finance markets in different economic zones varies greatly. In 2014, the total financing of green financial markets in the Beijing Delta and Yangtze River Delta regions reached 4,606.821-billion-yuan, accounting for 57.11% of the total financing of the green financial markets in the seven major economic zones that year. The total amount of financing from the green financial market in North-east China is only 320.492-billion-yuan, accounting for about 3.97% of the national total. In terms of relative proportions, the green financial markets in the Pearl River Delta, northwest, southwest and central regions still have

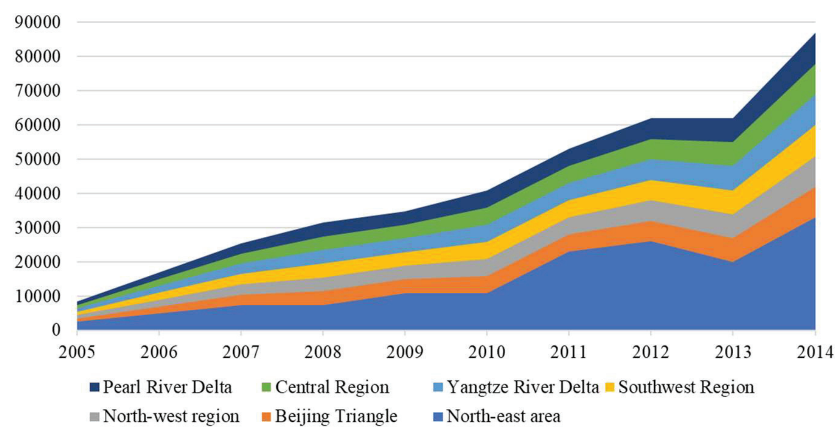


Figure 5 The financing scale of green financial markets in the seven economic zones from 2005 to 2014.

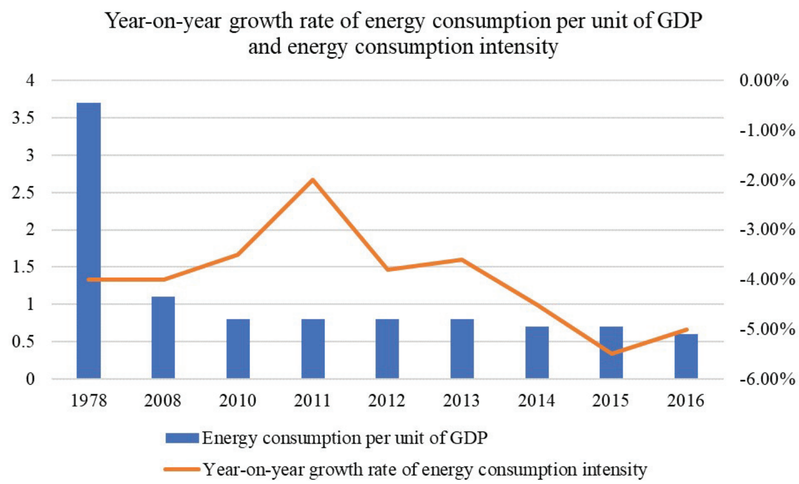


Figure 6 Chinese 1978–2016 unit GDP energy consumption level and year-on-year growth rate of energy consumption intensity.

great development. The seven economic zones have increased from 14.57% in 2005 to 2010. 31.47% in 2014, and 38.91% in 2014. Nevertheless, it is still difficult to change the huge differences in the development of financial markets in different economic zones.

The intensity, describes the energy efficiency and low-carbon capability. Some data show that Chinese energy consumption intensity continues to decline in the process of development, especially after 2008, the trend of energy consumption decline is more obvious. As shown in Figure 6, in the early stage of reform and opening up, Chinese economic development energy consumption was relatively high, close to 4, but since 2008, the energy consumption coefficient has been less than 1, which means that Chinese energy utilization efficiency has achieved a qualitative change and has entered to the mid-to-late stage of industrialization.

It examines the dynamic generation efficiency of intertemporal energy input and output, and calculates the energy efficiency. Differences and changes in green finance energy efficiency in different economic regions can be examined (see Figure 7). From 2005 to 2015, the energy utilization efficiency of the seven major economic regions improved significantly, and it has been continuously improved, followed by the Beijing Delta, the central region, the northeast region and the southwest region are again in terms of energy efficiency. Energy efficiency in different regions has a trend of gradual convergence.

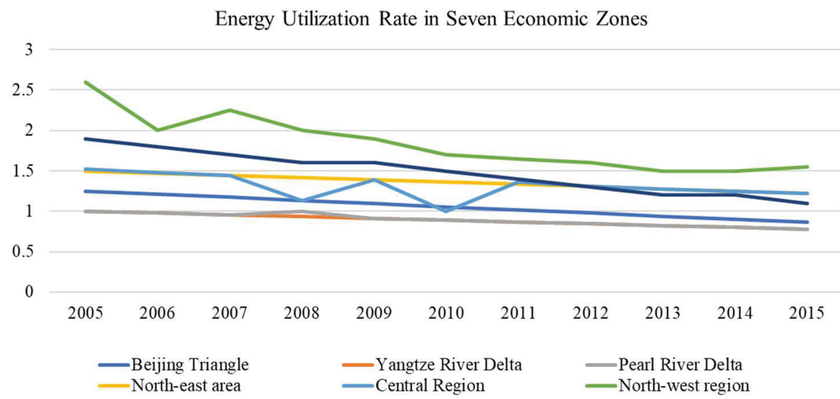


Figure 7 Green Finance Energy Efficiency in Seven Economic Zones from 2005 to 2015.

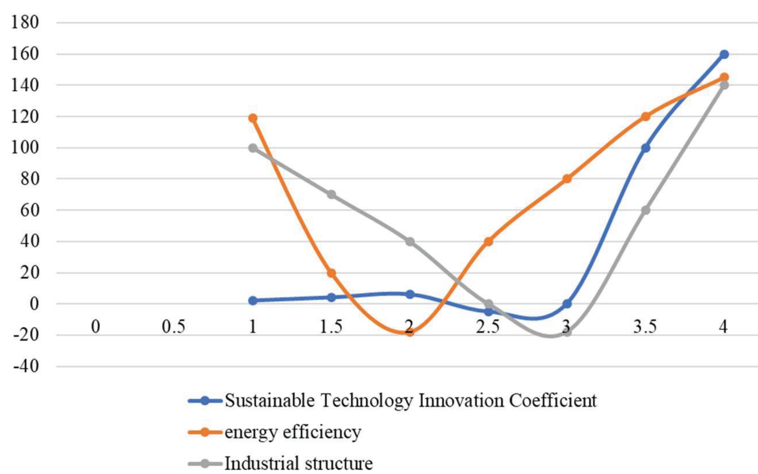
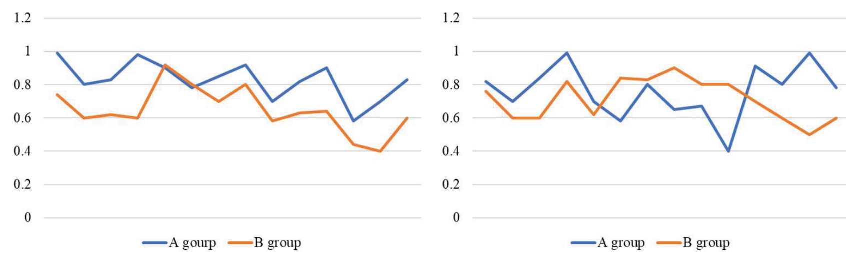


Figure 8 Values of variables such as sustainable technological innovation coefficient and energy efficiency.

4.3 Sustainable Technology Innovation and Energy Efficiency

The sustainable technological innovation will be in line with energy efficiency. According to the calculation formula, the values of each variable are obtained, as shown in Figure 8.

The spatial correlation of sustainable technological innovation coefficient and industrial structure to energy efficiency is shown in Figure 9. Group A represents a group with higher industrial structure indicators or a group with a higher level of sustainable technological innovation, and Group B represents



(a) Sustainable technological innovation coefficient (b) Industrial structure

Figure 9 Spatial correlation of sustainable technological innovation coefficient and industrial structure on energy efficiency.

a lower group. Provinces with better industrial structure have no obvious advantage in energy efficiency compared with provinces with relatively poor industrial structure, while provinces with higher level of technological innovation generally have relatively high energy efficiency. This phenomenon may be due to the fact that the secondary industry, especially the industrial production technology level, rather than the main factor affecting the energy efficiency of each region.

5 Conclusion

It can be seen that there are indeed differences and challenges in improving energy efficiency among different regions. The sustainable technological innovation coefficient and location direct index have significant contributions to the overall analysis. The coefficient of sustainable technological innovation can measure the impact of sustainable technological innovation on energy efficiency and reveal the role of technological innovation in improving energy efficiency. Sustainable technological innovation can optimize and improve energy efficiency, provide a good energy environment for green industries, drive the upgrading of consumer demand, and thus promote the development of green finance. Meanwhile, sustainable technological innovation will also increase consumption. This trend may indicate that with the continuous progress and innovation of technology, there will be greater development space in areas such as clean energy and energy storage technology, thereby providing more opportunities and space for the development of green finance. The differences in energy efficiency among different regions are gradually converging, which may indicate that a balance between technological and economic development is gradually being achieved. The regional energy efficiency is the highest and continuously improving, followed by the Beijing Delta. The energy efficiency of the central, northeastern, and southwestern regions has also improved. This trend may mean that various regions are constantly making progress in energy utilization and efficiency, and green finance can play a positive role in it.

Provinces with high levels of technological innovation typically have relatively high energy efficiency, while provinces with better industrial structures do not have significant advantages in energy efficiency compared to provinces with poorer industrial structures. This may indicate that the main factors affecting energy efficiency are not only industrial structure, but also other factors such as technological level and policy environment that need to be considered. This further reflects the importance of green finance in promoting energy efficiency and green development.

Therefore, it can be considered that there are differences and challenges in improving energy efficiency among different regions, and sustainable technological innovation and location direct index are important factors among them. Meanwhile, with the development of sustainable technological innovation and green finance, energy efficiency in various regions will gradually converge, and green finance plays a positive role in it.

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Biography

Miaomiao Zhu was born in Henan, China in 1989. From 2008 to 2012, she studied in Zhengzhou Shengda University and obtained a bachelor's degree in 2012. From 2012 to 2015, she studied in China West Normal University and obtained a master's degree in 2015. At present, she works in Zhengzhou college of Finance and Economics. Lecturer. Her research interests are the regional economic development, the theory and practice of commercial banks.