

The Threshold Effect of Clean Energy Development on Carbon Dioxide Emission

—— From the Perspective of Financial Scale

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ABSTRACT

Based on the panel data of 30 provinces in China from 2014 to 2019, this paper tests the impact of the development of clean energy industry on carbon dioxide emission from the perspective of financial scale, and uses the threshold model to analyze the threshold effect of clean energy development on carbon dioxide emission. Empirical research shows that the development of clean energy promotes the reduction of total carbon dioxide emissions, and the impact of carbon dioxide emissions in regions with different financial scales on the ratio of clean energy to traditional energy is heterogeneous. From a regional perspective, there are regional differences in the impact of clean energy development on carbon dioxide emissions in different regions, which is reflected in the division of high clean energy production areas and low clean energy production areas according to the clean energy capacity of different regions. The impact of clean energy development on carbon dioxide emission reduction in low clean energy production areas is more significant. On the contrary, the impact of clean energy development on carbon dioxide emission reduction in high clean energy production areas are not obvious. According to the current differences in the production and use of clean energy between the East and the west of China, formulate clean energy development policies according to local conditions, improve the incentive mechanism of relevant policies, increase the proportion of clean energy in the total domestic energy consumption, advocate the development of green and low-carbon economy, and put forward relevant suggestions to relevant national departments on developing clean energy and reducing carbon dioxide emissions, Give full play to the role of clean energy in reducing carbon dioxide emissions and promoting economic development.

Keywords: Green Energy, Carbon Dioxide, Energy-Resource Structure, Threshold Effect Model, Financial scale

1. INTRODUCTION

The overall trend of global warming requires countries to accelerate the optimization of energy mix and develop green and low-carbon economy. China is the world's largest energy consumer. At present, China's energy structure is not reasonable, hydropower development is slow, nuclear, and geothermal energy development is slow, small thermal power still accounts for a large proportion, power distribution is not reasonable. This is mainly due to the uneven distribution of energy resources in the eastern, central, and western regions of China, as well as the excessive and intensive installation of coal-fired power plants in the eastern

coastal regions. The 19th National Congress of the Communist Party of China proposed to promote the revolution in energy production and consumption and build a clean, low-carbon, safe and efficient energy system. In the general debate of the 75th UN General Assembly in 2020, China announced that it would peak its carbon emissions by 2030 and achieve the goal of carbon neutralization. It put forward strict requirements for our energy system before 2060. On the one hand, energy in the production sector, on the other hand, it requires the continuous development of renewable and clean energy and reduce the proportion of traditional energy to achieve the goal of reducing carbon emissions. In recent years, China has formulated a series of policies and regulations to promote the development of clean

energy. From 1997 to 2016, the central government formulated and promulgated nearly 130 policies and regulations related to clean energy [1].

Hydropower, nuclear power, solar energy, wind energy, geothermal energy, ocean energy, biomass energy, and other new and renewable energy development research are the most rapid among all types of new and renewable energy development and usage in terms of global energy development trends. China has benefited from developed-country technology and experience, promoting water, wind, solar, nuclear, and other forms of energy generation aggressively, actively utilizing biomass energy as an important part of its energy security strategy, accelerating its development, and gradually reducing its over-dependence on petrochemical energy — oil and coal [3].

Based on this, the main contributions of this paper to clean energy research are as follows: first, the threshold effect model is used to bring the clean energy development, carbon dioxide emission and economic development scale of different regions into the same research framework, and to explore the impact of clean energy development on carbon dioxide emission. Secondly, the impact of clean energy development and use scale on carbon dioxide emission in different regions and the differences of clean energy production in different regions are considered. Based on the analysis of carbon dioxide emission mechanism produced by the development of clean energy industry, combined with China's provincial panel data, this paper discusses the relationship between clean energy development and carbon dioxide emission and regional financial scale.

2. LITERATURE REVIEW

As for the economic research in the field of clean energy, scholars pay more attention to the impact of clean energy consumption on carbon dioxide emission, economic growth, and energy efficiency [10]. This paper follows the research of previous scholars, based on studying the impact of clean energy on carbon dioxide emissions and studies the impact of financial scale on it. With the development of the global economy, energy and environmental issues have attracted more and more attention from all countries and people. Global warming, glacier melting, and other phenomena have promoted the formation of people's environmental awareness. At the same time, low-carbon economy and green economy have also become the development direction of all countries. As a large country of energy production and consumption, China's energy structure dominated by traditional energy has led to China's carbon dioxide emissions remain high. Therefore, the development of domestic clean energy and carbon dioxide emissions have always been the focus of domestic scholars.

Regarding the relationship between the development

of clean energy and carbon dioxide emissions, most studies believe that the development of clean energy industry has reduced the country's carbon dioxide emissions. According to Zhang, research shows that the development of clean energy drives the development of low-carbon economy in provinces and regions and helps to reduce carbon dioxide emissions and optimize energy structure [9]. However, at the same time, many different ideas are put forward for the factors affecting carbon dioxide emission, such as energy consumption structure, resource endowment, industrial structure and inter provincial transfer of carbon dioxide. However, some scholars believe that the development factor of single clean energy does not necessarily significantly affect the regional carbon dioxide emission. In view of this assumption, they put forward the case of Western China. Among the 30 provinces, Shanxi Province, Inner Mongolia Autonomous Region and Ningxia Hui Autonomous Region have a high comprehensive level of carbon dioxide emission, while Beijing has a better low-carbon development. Therefore, the development degree of clean energy does not necessarily show a linear correlation with carbon dioxide emissions. Therefore, it is of great significance to study the impact of clean energy on carbon dioxide emissions from the perspective of financial scale, that is, the difference of financial development in different regions.

The rapid development of clean energy not only drives the optimization and adjustment of energy structure, but also has an impact on carbon dioxide emissions. The rapid development of clean energy has led to the emergence of a variety of renewable clean energy, such as wind energy, water energy and solar energy, to reduce the proportion of traditional energy and reduce carbon dioxide emissions. In addition, the extent to which the development of clean energy industry affects carbon dioxide emissions is related to the scale of regional financial development. On the one hand, the western region of China is sparsely populated and has sufficient clean energy resources, but it faces the dilemma of small demand and high development cost. The southeast region of China has a dense population, large energy demand, but a single type of clean energy, Less use. Therefore, the difference of financial development scale between different regions has heterogeneity on the efficiency of carbon dioxide emission affected by clean energy development [11]. According to the degree of economic development, the difficulty of financial support for clean energy industry in different regions is also different. For the more developed areas in eastern China, when formulating policies, government departments will give more priority to factors other than economic factors, such as environmental factors, so they will increase capital investment to develop clean energy industry and promote the optimization of energy structure [12]. However, for the less developed areas in Western China, government departments may give priority to economic development,

we will vigorously develop the traditional energy industry, while the clean energy industry will not be promoted because of objective factors such as less energy demand and underdeveloped technology in underdeveloped areas [13]. Therefore, the development of clean energy is also affected by different financial scales.

3. EMPIRICAL RESEARCH

3.1 Empirical Research

3.1.1 Standard Model Setting

To research the impact of clean energy industry development on Carbon Dioxide Emission. In this paper, for panel data with a small time span relative to the number of sections, regression models such as Equations (1) ~ (2) are constructed. To alleviate heteroscedasticity, logarithmic processing is applied to relevant variables.

$$1) \ln \text{ total} = a_0 + a_1 \ln \text{ clean} + a_2 Z + V$$

$$2) \ln \text{ tradition} = b_0 + b_1 \ln \text{ clean} + b_2 Z + V + u + e$$

In the formula,

- $\ln \text{ total}$ represents the overall electricity price for the area m at time n .
- $\ln \text{ tradition}$ represents the amount of Carbon Dioxide Emission of traditional energy industry for the area m at time n .
- $\ln \text{ clean}$ represents the clean energy output of each region.
- Z represents a group of control variables, including other factors that may affect Carbon Dioxide Emission.
- V represents individual fixed effects.
- u represents time fixed effect.
- e represents the random error term.

3.1.2 Threshold Effect Model

To study the influence of financial scale on the relationship between core variables, this paper uses the panel threshold model proposed by Hansen to form a segmented interval by measuring a threshold value y_1 [9].

If the threshold variable is greater than y_1 and less than y_2 , and the regression coefficient of the core explanatory variable changes significantly. It indicates that the impact of clean energy development on Carbon Dioxide Emission is not a simple linear relationship but a nonlinear relationship.

According to the principle of the threshold model, the threshold variable can be either the explanatory variable in the regression model or other variables.

The double threshold regression model is shown in Equations (3) ~ (4)

$$3) \ln \text{ total} = c_0 + c_1 \ln \text{ clean} * E(\ln \text{ ft} \leq y_1) + c_2 \ln \text{ clean} * E(y_1 < \ln \text{ ft} \leq y_2) + c_3 \ln \text{ clean} * E(\ln \text{ ft} > y_2) + c * Z + V + u + e$$

$$4) \ln \text{ tradition} = d_0 + d_1 \ln \text{ clean} * E(\ln \text{ ft} \leq y_1) + d_2 \ln \text{ clean} * E(y_1 < \ln \text{ ft} \leq y_2) + d_3 \ln \text{ clean} * E(\ln \text{ ft} > y_2) + d * Z + V + u + e$$

In the formula □

- $\ln \text{ ft}$ is the threshold variable representing the financial scale.
- y_1, y_2 are the thresholds to be estimated.
- $E(*)$ is a characteristic function, which is equal to 1 if the conditions in parentheses are met, otherwise, it is equal to 0.
- c_1, c_2, c_3 will have different values if reasonable threshold variables are selected and the threshold estimates pass the significance test.
- The other variables are explained as above.

3.1.3 Variables Illustration

As for the index selection of overall carbon dioxide emissions, some studies use carbon dioxide calculation formula to calculate, but the calculation formula of carbon dioxide emissions usually only reflects a part, which is quite different from the international comprehensive carbon dioxide emissions statistics, so it is difficult to completely estimate the actual carbon dioxide emissions.

The carbon dioxide emission of the traditional energy industry is measured by summing up the consumption of fossil fuels including raw coal, crude oil, and natural gas [8] [14] [15]. This method is more suitable for the study of this paper than the carbon dioxide formula.

To be clear, there is no empirical test on carbon dioxide emissions from clean energy industry in this paper. One reason is that there are no systematic statistics on carbon dioxide emissions from the clean energy sector. Some scholars use the number of clean energy enterprises to measure. But it only looked at the number of listed companies, which ignoring the carbon dioxide emissions from the clean energy industry chain. This would result in a large underestimation of carbon dioxide emissions. On the other hand, clean energy development has direct carbon dioxide emissions. Reducing carbon dioxide emissions from clean energy-related industries is not controversial. Therefore, this paper does not make empirical analysis of carbon dioxide emissions from clean energy industry. Instead, focus on the impact on overall CO₂ emissions and the possible knock-on effects on CO₂ emissions from the traditional energy sector [5].

As for clean energy indicators, the scope of clean energy in this paper is based on the Energy Law of the People's Republic of China and the Strategic Action Plan for Energy Development (2014-2020), and hydropower, nuclear energy, wind energy, biomass energy, solar energy, geothermal energy, and Marine energy are defined as clean energy [2]. Consider the consumption problem after clean energy production. Using a measure of clean energy consumption may underestimate the extent of the clean-energy industry [6]. According to the total energy production and the proportion of primary electricity (hydropower) and other clean energy (nuclear energy, wind energy, geothermal energy, and other clean energy) in total energy production given by the statistical yearbook of each province, the total energy production in each province is multiplied by the proportion of clean energy to measure the output of clean energy.

Control variables

As for the index of financial scale, scholars use many ways to measure it. For example, the ratio of outstanding loans of financial institutions to GDP, M2 to GDP, social financing scale, etc. The scale of social financing refers to the overall financing obtained by the real economy from the financial system [4]. Because the financial development of our country has experienced the structural transformation from the bank's absolute dominant financial structure to the joint development of financing and direct financing [7]. With the rapid development of bond market and stock market, it is more

appropriate to measure the financial scale of Our country by the index of social financing scale.

3.1.4 Data Illustration

This paper takes the data of 30 provinces (autonomous regions) in China from 2014 to 2019 as the research object. Due to missing data of some variables, data of Hong Kong, Macao, Taiwan, and Tibet were excluded. The study samples were panel data from 150 observation sites in 30 cross sections over a period of 5 years. Data on carbon dioxide emissions, economic development level, wage level and clean energy production of each province (region) are collected from the annual statistical yearbook of each province. Clean energy data in statistical yearbooks of some provinces (autonomous regions) are incomplete. This paper uses the clean energy production data of hydropower, nuclear, wind and solar energy of each province (autonomous region) in China Energy Statistical Yearbook to make up for it. Data on social financing comes from the People's Bank of China website. Table 1 gives descriptive statistics for each variable.

4. EMPIRICAL RESULTS AND ANALYSIS

Preliminary estimation results of the impact of clean energy output scale on carbon dioxide emissions from different areas and periods in China.

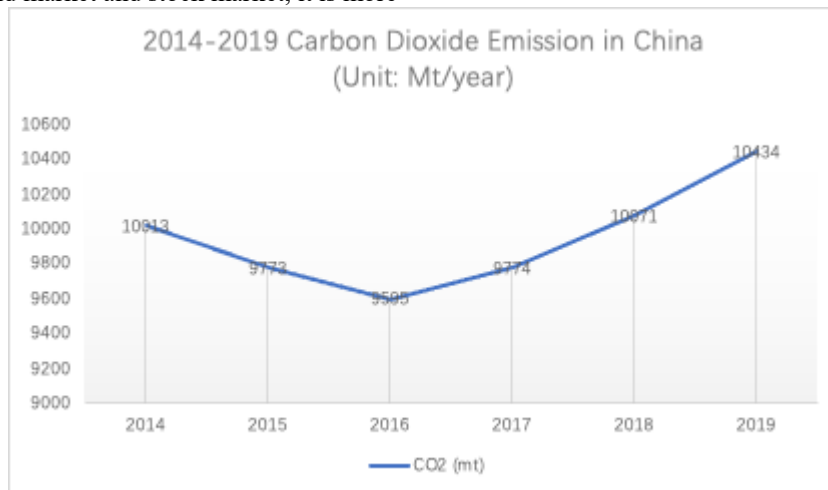


Figure 1. 2014 – 2019 Carbon Dioxide Emission in China.

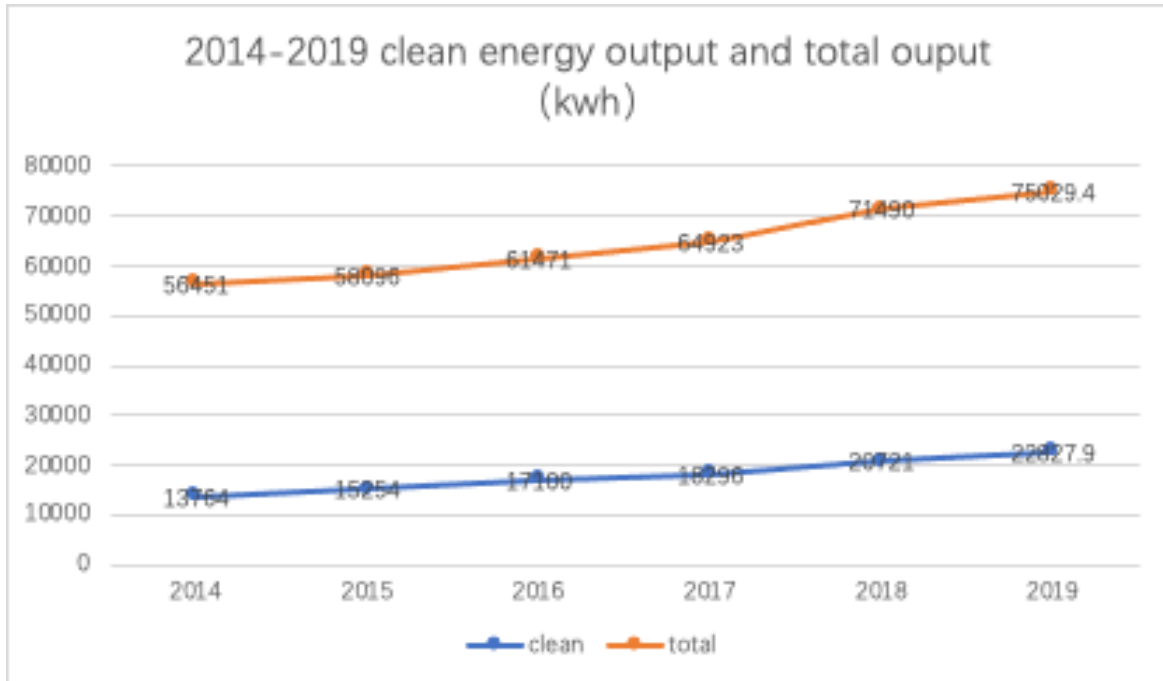


Figure 2. 2014 - 2019 clean energy output and total output.

The clean energy here includes water energy, wind energy, nuclear energy, and solar energy, but excluding thermoelectricity energy.

4.1 The development of clean energy industry affects the initial estimate of carbon dioxide emissions

In the case of panel data passing relevant tests, a preliminary regression is made to equations (1) ~ (2). Regional and temporal fixed effects are added to the model to reduce the possible influence of omitted variables on regression results.

At the same time, as mentioned above, there are obvious regional differences in clean energy resources and output in China. To distinguish between regions with different endowments of clean energy resources. Whether the development of clean energy industry has heterogeneous impact on employment scale. This paper is based on the distribution of clean energy resources and the actual output of each province in China. The 30 provinces in the sample were divided into high clean energy production areas and low clean energy production areas. Two panels were tested respectively.

Among them, 12 provinces with high clean energy output include Yunnan, Guangdong, Guangxi, Sichuan, Fujian, Guizhou, Hunan, Hubei, Qinghai, Gansu, Inner Mongolia, and Xinjiang. The remaining 18 provinces are low in clean energy production.

On a national scale, the coefficient of clean energy industry development is negative, not significant at the low-level percentage. It shows that the development of clean energy industry has a restraining effect on the

carbon dioxide emissions in China. The regression coefficient shows that the effect is not significant. The research results are basically consistent with those of other scholars.

From the perspective of other control variables, the level of economic development has a negative impact on the overall co2 emissions in areas with high clean energy production. It is speculated that areas with high clean energy production tend to migrate to more developed areas with the improvement of economic development.

Research and development level, human capital level, wage level and population size all have a positive impact on the overall carbon dioxide emissions, while foreign investment level has no significant impact on the overall carbon dioxide emissions. The main factors affecting carbon dioxide emission of traditional energy industry are R&D investment, population size, foreign direct investment and so on.

In areas with low clean energy production, the level of economic development and population size have a positive impact on overall CO2 emissions. The influence of economic development level, R&D investment, and population size on carbon dioxide emission of traditional energy industry is significantly positive.

4.2 Threshold effect model test results

According to the above analysis, the impact of the development of clean energy industry on the scale of carbon dioxide emissions is different in regions with different development degrees of clean energy industry.

In the regions with higher output of clean energy, most provinces (autonomous regions) and cities have low

level of economic development and less high-tech innovation. The industrial structure is still dominated by mining and manufacturing, and the industrial transformation is slow. The more prominent feature is that the development of financial market is relatively simple, and the business of financial market is mainly bank credit. Most provinces (autonomous regions) with low clean energy output are regions with developed economy, large financial scale, and abundant financial products.

In the context of transformation and upgrading of traditional industries, accelerated optimization of industrial structure, and rapid development of green finance, differences in financial scale in different regions may have different impacts on carbon dioxide emissions of the clean energy industry. Therefore, it is speculated that there may be non-linear relationship between the clean energy industry and carbon dioxide emissions

With the help of the panel threshold model proposed by Hansen [9], this paper takes the index of financial development scale as the threshold variable and uses provincial panel data to estimate equations (3) to (4)

Based on the mechanism analysis part, this paper focuses on testing how different threshold values will affect the relationship between financial scale and financial scale under the premise of threshold variables

The above analysis shows that there is a nonlinear relationship between the impact of the development of clean energy industry on the overall carbon dioxide emissions and the impact of the traditional energy industry on the carbon dioxide emissions under different financial development levels. This conclusion has enriched the research on carbon dioxide emissions of the development of clean energy industry to some extent

4.3 Further study

The distribution of clean energy resources in China has significant regional differences, showing obvious characteristics of "high in the West and low in the East".

According to the data of China energy statistical yearbook, the average output of clean energy in Western China is significantly greater than that in central and eastern China. From 2014 to 2019, the average annual output of clean energy in the western region was 31 billion kwh. The average annual clean energy output of the central and eastern regions is 21 billion kWh and 14 billion kwh respectively. At the same time, the development of the financial market in the western region is low, and the total scale and quality of finance need to be improved. As a result, the clean energy industry has some capital constraints in technology R & D and the introduction of high-precision equipment. In the eastern and central regions with a high degree of financial development, the amount of clean energy resources is

relatively small and single.

To further study the impact of regional heterogeneity on the relationship between clean energy industry and carbon dioxide emissions, this paper uses the grouping comparison method to empirically analyze the carbon dioxide emissions of clean energy industry development in different regions of China according to the classification of Eastern, central, and western regions.

5. CONCLUSION

By analyzing the relationship between clean energy industry, financial scale and carbon dioxide emission, this paper explores the action mechanism between different variables, obtains the problems that need further empirical test from the experiment, and constructs the threshold effect model on this basis. The research shows that there is a negative relationship between China's clean energy development and overall carbon dioxide emission, that is, the more developed the clean energy industry is, the less the overall carbon dioxide emission is. At the same time, the impact of the development of clean energy industry on the scale of carbon dioxide emission is different in regions with different levels of development of clean energy industry.

As a large country of energy production and consumption, China is still an energy structure dominated by traditional energy, and the environmental problems are not optimistic. We should develop a low-carbon economy to solve many environmental problems caused by excessive carbon dioxide emissions. Based on the conclusions of this paper, the following suggestions are put forward: first, government departments should formulate environmental policies suitable for local economic development according to local conditions, optimize energy structure and develop green and low-carbon economy according to the needs of local geographical environment and economic development. Second, government departments should establish and improve a sound incentive mechanism to encourage enterprises and individuals to practice the concept of green, low-carbon and environmental protection, and use marketization to manually promote the rapid development of clean energy industry.

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