Comparative study on the impact of clean energy on carbon emissions in different regions of China

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Abstract. Using the panel data of 30 provinces in China from 2008 to 2018, this paper compares the impact of clean energy on carbon emissions in different regions of China on the basis of extending the STIRPAT model. The results show that the impacts of clean energy on carbon emissions are different in different regions. The eastern region is not significant due to its developed economy and many influencing factors. The carbon emissions in the central and western regions are significantly affected by the energy structure, which reflects the relatively low scale of clean energy development in China and the huge dependence on fossil energy. In the future, one is to continue to strengthen the construction of clean energy; the other is to improve the technological level of the central and western regions and reduce their dependence on fossil energy.

1. Introduction
With the development of economy, the speeding up of industrialization and urbanization, the fossil energy consumption increases year by year, rising CO₂ emissions, frequent the resulting environmental problems: acid rain, ozone depletion, extreme natural disasters phenomenon common occurrence, increasingly serious environmental crisis form, to control carbon dioxide emissions is imminent. On September 22, 2020, the Chinese government put forward at the 75th session of the UN General Assembly that "China will increase its nationally determined contributions, adopt more effective policies and measures, strive to peak its carbon dioxide emissions by 2030, and strive to achieve carbon neutrality by 2060".

In this context, the clean energy due to the increasingly favor can effectively reduce carbon dioxide emissions, on November 22, 2020, President Xi, general secretary at the G20 summit in Riyadh "protect the earth" theme and delivered a speech at the meeting, pointed out that want to build a clean energy industry energetically, and thorough going efforts to promote clean energy transformation, carbon dioxide emissions to peak in the 2030 years ago, strive to become carbon neutral 2060 years ago. According to the 14th Five-Year Plan and the long-term goals for 2035, China will promote clean, low-carbon, safe and efficient use of energy, speed up the development of new energy, green and environmental protection industries, and promote the comprehensive green transformation of economic and social development.
2. Literature review

With the rapid development of the national economy, the demand for energy has become increasingly urgent, but the current energy consumption structure in China is still dominated by fossil energy such as oil and coal. Although these energy sources have relatively low mining costs, a wide range of applications, and mature technology, fossil energy is a non-renewable resource, and excessive consumption will cause future generations to face the dilemma of no resources available. In addition, the use of fossil energy will be accompanied by the release of huge amounts of greenhouse gases. These greenhouse gases will irreversibly damage the earth's environment, change the earth's climate, and threaten the continued development of races. Since clean energy can avoid the above-mentioned two huge shortcomings of fossil energy, clean energy has been favored in recent years and has become a weapon to solve the climate problem.

Research on whether clean energy development can reduce carbon dioxide emissions. Wang (2020) through the establishment of vector autoregressive model (VAR) of green energy use, carbon emissions and the relationship between economic growth and empirical study, the results show that the clean energy in China, there is a long-term equilibrium relationship between carbon emissions and economic growth, the use of clean energy not only reduce carbon dioxide emissions, and promote the sustainable economic growth in China. Shi (2019) studied the impact of low-carbon technology innovation on carbon emissions and the response of energy consumption to low-carbon technology by constructing low-carbon technology innovation index, comprehensively applying carbon emission decomposition method and using panel data model. The results show that low-carbon technological innovation in the Yangtze River Economic Belt can restrain the increase of carbon emissions. However, Xu Bin et al. (2019) used a non-parametric additive regression model to show that the development of clean energy has not played a role in reducing carbon dioxide emissions in the three major regions in the eastern, central and western regions.

Eastern, central and western region is China's three major economic belt, the region between population, economic structure, factor endowments, development level, there is a huge difference between clearly in the three areas of clean energy development on carbon emissions influence difference is very big also, clean energy at the present stage of the three major regional carbon emissions influence degree, is an interesting question, but there is little literature on empirical analysis. Compared with existing literatures, the possible marginal contributions of this paper are as follows: First, empirical models are used to test and analyze the influencing factors of clean energy and carbon emissions in different regions, and the influencing factors of carbon emissions in different regions are explored. Second, based on STIRPAT model, a new explanatory model for carbon emissions and clean energy is constructed.

3. Model construction

The development of clean energy can not only optimize the economic structure and promote sustainable economic growth, but also optimize the energy consumption structure and promote carbon dioxide emission reduction. The STIRPAT model is a classic method to determine the influencing factors of environmental pollution. Its basic form is as follows:

\[ I_t = \alpha P_t^b A_t^c T_t^d + \mu_t \]  

In Model (1), \( I_t \) represents the emission level of certain environmental pollutants, \( P \) represents population size, \( A \) represents economic prosperity, and \( T \) represents technological factors. In addition, existing studies have confirmed that energy consumption structure and government environmental regulations are also important factors affecting China's carbon dioxide emissions (Lin and Li, 2015). Therefore, in order to investigate the impact of the development of clean energy on China's carbon dioxide emissions, this paper expands the model and constructs the influencing factor model of carbon dioxide emissions. All variables in the extended model were logarithmically treated to eliminate possible heteroscedasticity. In addition, in order to more intuitively display the variables of the model, model variables are expressed in a more concrete form in this paper. The extended model has the following specific form:

\[ LCO_2 = C + \beta_1 LP GDP_t + \beta_2 LDEPL_t + \beta_3 LTECH_t + \beta_4 LEV_t + \beta_5 LES_t + \beta_6 LURB_t + \mu_t \]  

(2)
In Model (2), $C$ is the constant term, $CO_2$ represents carbon dioxide emissions, and $POP$ represents the total population. $GDP$ stands for economic prosperity, as measured by GDP per person; $Tech$ is a measure of skill level; $CE$ stands for clean energy; $ENS$ represents energy consumption structure; $ER$ stands for environmental regulation; $URB$ is the level of urbanization; $\beta_i$ represents the parameter to be estimated.

In this paper, the total consumption of the three fossil energy sources (coal, oil and natural gas) is converted into tons of standard coal and multiplied by the carbon dioxide emission coefficient of standard coal to obtain the total carbon dioxide emission. The carbon dioxide emission coefficient of a ton of standard coal published by the United Nations Intergovernmental Panel on Climate Change (IPCC), the International Energy Agency (IEA) and the United States Energy Administration (EIA) is between 2.68 and 2.72 tons, and the conversion coefficient in this paper refers to 2.70. Explanatory variables include five: The first is clean energy (CE), which uses data representation of power generation from clean energy. According to the National Bureau of Statistics data released in 2018, thermal power generating capacity in China accounted for 73.32% of total generating capacity of hydropower generation accounted for 16.24%, nuclear power accounted for 4.33%, of wind power generating capacity accounted for 4.79%, obviously thermal power generating capacity to occupy most of total generating capacity, combining with the National Energy Administration on clean energy defined based on the total generating capacity data minus the thermal power generating capacity as a clean energy power generation. The second is the total population, expressed as the total population at the end of the year. The third is economic growth, measured by GDP per person. In order to eliminate the influence of price factors, this paper takes 2005 as the base period and uses the per capita GDP deflator to carry out price deflating on the per capita GDP index value. The fourth is technological progress, which is described by the number of patent applications of industrial enterprises above designated size. The fifth is the structure of energy consumption. The proportion of coal consumption in total energy consumption is used to represent the energy consumption structure. The sixth is environmental regulation. Considering that sulfur dioxide emissions are closely related to industrial production, this paper uses sulfur dioxide emissions to characterize environmental regulation. The seventh is urbanization, which is described by the ratio of urban population to total population.

The data period in this paper is from 2008 to 2018. The data of clean energy generation, carbon dioxide emissions and energy consumption structure are obtained from China Energy Statistical Yearbook by manual calculation. Data on the number of patent applications, total population, urbanization, sulfur dioxide emissions, per capita GDP and per capita GDP deflator are from the China Statistical Yearbook over the years.

4. **The empirical analysis**

Estimation Model (2), the estimated results are shown in Table 1. The following conclusions can be drawn from Table 1:

The clean energy has a distinct impact on carbon dioxide emissions in different regions. Although the impact results are different in different regions, the impact is all very weak, almost negligible, mainly because clean energy has not been developed on a large scale, which is in line with the fact that China's electricity generation is still dominated by thermal power generation.

For the eastern region, population, urbanization and economic development impact on $CO_2$ emissions most three indicators, this is also consistent with the economic status of the eastern region, the influence coefficient is not significant, however, shows that the eastern region of carbon dioxide emissions factors more complex, as the most developed area of economic development in our country, the region's huge car ownership, every car gas carbon dioxide emissions is also a factor can not be ignored.

For the central region, the urbanization level and technological progress and the influence factors of energy structure of carbon dioxide, the largest population instead affects on the contrary, in this paper, the population data is adopted by the National Bureau of Statistics released at the end of each year's permanent population, as a net outflow of population areas, the central region each year over the years a large number of population outflow to economically developed areas, at the end, and return home, although nominally these people in the central region population statistics list, but the first year of life,
consumption, production is not completed in the area. This leads to the phenomenon that the population size in the central region has a negative impact on carbon emissions.

For the western region, the population and energy structure have the greatest influence on carbon dioxide, while the urbanization level has the opposite effect. This is consistent with the fact that the western region is large and sparsely populated and has the largest amount of coal mining. Sparsely populated western regions, the distribution characteristics of formation of a number of large and small groups, and the urbanization rate is limited by the natural environment is not as high as eastern and central regions, so the region urbanization is negative effects on carbon emissions, which is relatively dispersed population lives has certain inhibitory effect on carbon dioxide emissions. The carbon emissions in western China are significantly affected by environmental regulation and energy structure. The technological conditions in western China are backward compared with other regions, which is reflected in specific measures. Industrial enterprises do not properly treat the exhaust gas, and the sulfur content in the exhaust gas is too high, so carbon emissions are accompanied by a large amount of sulfur emissions. At the same time, there is a huge amount of coal mining in the western region, which leads to the large use of coal as fuel for heating and power generation in the region, which further aggravates carbon emissions.

Table 1. Basic regression coefficients and significance

| Variable | East         | Central      | West         |
|----------|--------------|--------------|--------------|
| CE       | -0.0185      | 0.0418(**)   | 0.0517       |
| POP      | 0.5717(***)) | -0.0024      | 0.6437       |
| URB      | 0.5058       | 0.4091(**)   | -1.0244(**)  |
| TECH     | 0.0336       | 0.1503( *)   | 0.0394       |
| ER       | 0.0288       | 0.0507(**)   | 0.10(**)     |
| ECS      | 0.0546       | 0.1499(**)   | 0.2543(**)   |
| PGDP     | 0.2551       | -0.2004(***)| 1.0931(**)   |
| Cons     | -1.8951      | 2.3909(*)    | 1.4568       |

5. Conclusions and policy recommendations

Based on the panel data of 30 provinces in China from 2008 to 2018, this paper builds a carbon emission model to study the impact of clean energy on carbon emissions in east, central and west. The results show that the impact of clean energy development on carbon dioxide emission reduction in the eastern, central and western regions is not significant, which reflects that China's clean energy construction still has a long way to go.

Different regions should formulate differentiated energy structure transformation policies and carbon dioxide emission reduction policies according to their different stages of economic development:

For the eastern region, with the expansion of population scale, the improvement of urbanization level and the further increase of carbon dioxide emissions along with economic growth, we can further increase the investment in clean energy and carbon dioxide emission reduction technology, so as to achieve carbon dioxide emission reduction.

For the central region, the level of urbanization is an important variable affecting carbon emissions. While accelerating urbanization, measures should be taken to reduce carbon emissions in this process. For example, electricity is used as the driving force in the construction process to reduce fossil fuel consumption. High-pollution and high-emission enterprises in cities cannot be concentrated and may be far away from urban agglomerations to avoid the resulting environmental pollution.

For the western region, energy structure and environmental regulation are two important factors that lead to carbon emissions, which are reflected in specific measures. First, increase financial input, increase the construction of clean energy infrastructure, and fully tap the potential of hydropower, wind power and solar power generation in the western region. Second, to speed up the upgrading of the energy structure, vigorously build clean energy industry, reduce the proportion of coal direct use, reduce the dependence on coal; Third, to increase the intensity of technology upgrading, high pollution, high emission enterprises to upgrade the waste gas treatment technology.
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