Study on the threshold effect of China’s industrial structure on carbon emission

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Abstract. In recent years, carbon emission has become the focus of environmental governance and protection. Countries have made active efforts to reduce carbon emission while economic development. As the largest developing country and the second largest economy, China promises to reduce carbon emissions to the world in the critical period of industrial transformation, so the impact of industrial structure on carbon emissions has become an important problem to be solved. Based on the provincial panel data of China from 1999 to 2016, this paper estimates the influencing factors of carbon dioxide emissions, constructs threshold regression model, and studies the non-linear impact of industrial structure on carbon emissions in China. The results show that carbon emissions are increasing, while the industrial structure has a single threshold effect. And based on the empirical conclusion, according to the actual situation of our country, this paper put forward brief policy recommendations, including low-carbon technology development and the use of renewable clean energy, in order to better promote carbon emission reduction in our country.

1. Introduction

More and more attention has been paid to carbon emission. In recent years, countries around the world have made positive efforts to reduce carbon emissions, and signed a series of agreements to deal with climate change, such as the Kyoto Protocol and the Paris Agreement. As the largest developing country in the world and the second largest economy in the world, China’s economic growth has also brought a lot of greenhouse gas emissions, affecting the sustainable development of China’s economy. By 2030, China’s carbon emission intensity will drop by 60% - 65% from 2005, and the carbon dioxide emission will reach the peak around 2030. In the report of the 19th National Congress of 2017, it was also clearly pointed out that we should adhere to the development concept of innovation, coordination, green, opening and sharing, constantly emphasize and reaffirm the importance and urgency of green development and low-carbon development, protect ecology, reduce carbon emissions and curb climate warming. Extensive development mode relies heavily on primary energy in energy consumption, resulting in a substantial increase in carbon emissions.

2. Literature review

Around the influence factors and contribution rate of carbon emissions, scholars at home and abroad have conducted fruitful research. Using factor analysis method and input-output method, it can be concluded that industrial structure and energy structure have a certain impact on carbon emissions. Wang Feng used SDA to decompose the growth of carbon dioxide emissions in 1992-2007 from the perspectives of the whole economy, sub industry and industrial sub industry[1]. The analysis results show that the energy consumption intensity effect is always the most important factor of carbon
emission reduction, and the scale expansion effect of the final demand and the change effect of input-output coefficient are the main factors to promote the increase of carbon emissions. Zhan Hua used the generalized Fisher index (GFI) method to establish the factor decomposition model of China’s per capita carbon emissions from 2000 to 2008, and reached the same conclusion[2]. Zhang Hongyan studied the impact of industrial structure adjustment on Beijing’s carbon emission reduction target by using the method of logarithmic weight balance analysis[3]. The results show that both technological progress and energy structure have played a role in curbing carbon dioxide emissions. Based on the above-mentioned literature and the provincial panel data from 1999 to 2016 in China, this paper analyzes the dynamic impact of industrial structure on China’s carbon dioxide emissions by using the extended STIRPAT model and threshold regression model[4].

3. Model building

3.1 STIRPAT model

This paper combines the research of other scholars and uses the STIRPAT model proposed by York and Dietz for reference to analyze the non proportional impact of economic, technological, population, industrial structure and other factors on carbon emissions. The model can be expressed as: $I_t = AP$

In formula (1), $I$ is the carbon emission; $P$ is the population; $A$ is the economic level; $T$ is the technical level; $t$ is the year of investigation; $a, B, C, D, e$ and $G$ are regression coefficients, which are error terms. Therefore, in this model, the multiplication structure of "$I = pat$" model is preserved, and two variables are added on the basis of STIRPAT model, namely, economy ($A$), technology ($T$), population ($P$), industrial structure ($S$) and energy structure ($F$) are the decisive factors of carbon emission, which are expanded on the basis of STIRPAT model. After expansion, the model gram is shown as follows:

$$I_t = aP_t A_t^b T_t^c S_t^d F_t^e \epsilon_t$$

(2)

In order to reduce the possible heteroscedasticity, this paper takes the logarithm of the above model in the econometric analysis, which can also directly obtain the influence elasticity of various factors on carbon emissions, as follows:

$$\ln I_t = a + b \ln P_t + c \ln A_t + d \ln T_t + e \ln S_t + g \ln F_t + \epsilon_t$$

(3)

3.2 Panel threshold model

At present, China’s energy use is still dominated by traditional energy. Especially now, China is in the stage of accelerating the industrialization process. The demand for energy use is increasing, and the energy structure has a great impact on China’s carbon dioxide emissions. Therefore, this paper takes the primary energy consumption level, that is, the proportion of coal in primary energy ($Z$ here) as the threshold variable, and extends the above panel model with the help of Hansen panel threshold model. The specific form is as follows:

$$\ln I_t = a + b \ln P_t + c \ln A_t + d \ln T_t + e \ln S_t + g \ln F_t Q(z \leq m) + h \ln F_t Q(z > m) + h \epsilon_t$$

(4)

In formula (4), $Q(\cdot)$ is an explicit function with $Z$ as the threshold variable. When the condition in parentheses holds, the value is 1, otherwise it is 0. The model (4) can respectively measure the different effects of industrial structure on carbon dioxide emissions before and after the energy structure, the proportion of primary energy exceeds the estimated threshold from the traditional Chow test, the above model avoids the subjective setting of threshold parameters, and can determine the threshold endogenous according to the system characteristics of economic operation.
4. Empirical analysis

4.1 Variable selection and data processing

4.1.1 The variables selected in this paper include the following aspects:
- **Explained variable**
  - Carbon emissions (I): expressed in terms of carbon dioxide emissions over the years.
- **Explanatory variable**
  - Population scale (P): expressed by the total population over the years.
  - Economic level (A): expressed in per capita real GDP over the years.
  - Technical level (T): expressed by energy intensity over the years.
  - Energy structure (F): expressed by the proportion of coal consumption in primary energy over the years.
  - Industrial structure (S): expressed as the proportion of secondary industry over the years.

4.1.2 Threshold and other control variables
- **Threshold variable**
  - The energy structure will affect the economic development model to a great extent. According to previous studies, at present, China is in a century of unprecedented changes, and its economic development model has changed from extensive to intensive. In this process, the impact of industrial structure on carbon dioxide emissions may have nonlinear characteristics due to the different energy structure. Therefore, this paper uses energy structure as the threshold variable.
- **Other control variables**
  - According to the aforementioned STIRPAT model, other control variables include population size, industrial structure, and technical level. Based on the consistency between the availability of the above data and the statistical caliber, this paper selects panel data of 30 provinces and autonomous regions in China from 1999 to 2016, among which Tibet region is excluded from the sample due to the lack of data.

4.2 Model results and analysis

4.2.1 Panel model

First of all, a basic STIRPAT panel model is established to investigate the influencing factors of carbon dioxide emissions. When building the panel model, we need to consider the mixed effect, fixed effect and random effect model. Before regression, we need to determine the specific regression model. Regression tests are carried out for each model, and the commonly used methods include F test, LM test and human test. F test shows that fixed effect model should be used; LM test shows that random effect model should be used. On the whole, the regression coefficients of LNP, LNA, LNT, LNF and LNs are 1.0201, 1.0121, 1.0251, 0.1085 and 0.012, respectively. The influence degree is from technology level, population scale, economic level, energy structure and industrial structure. It shows that in the whole country, the energy consumption per unit of GDP promotes the emission of carbon dioxide to a great extent. The lower the energy intensity is, the less the energy consumption per unit of GDP is, and the higher the energy utilization efficiency is, the further carbon emission reduction can be promoted.

4.2.2 Threshold regression

In order to observe the impact of industrial structure changes on carbon dioxide emissions, the threshold model is used for empirical research. Based on the above panel model, this paper takes the energy structure as the threshold variable and discusses the possible non-linear emission reduction effect of industrial structure. Based on Hansen’s threshold regression model and the assumption of double threshold effect, this paper constructs the following threshold regression model to specifically
examine the threshold effect of energy structure on industrial adjustment on environmental impact.

According to Table 1, when one threshold is assumed, P value is 0.09, passing the significance test of 10%; when two thresholds are assumed, P value is 0.8200, did not pass the significance test, indicating that there is only one threshold.

Table 1: threshold test results

| hypothesis test | LR value | P value | critical value |
|-----------------|----------|---------|---------------|
|                 |          |         | 10%  | 5%  | 1%  |
| 1 Threshold     | 32.30    | 0.0900  | 31.4789 | 40.8745 | 57.6854 |
| 2 Threshold     | 5.07     | 0.8800  | 53.6344 | 66.0572 | 86.3657 |

Estimation results and analysis of threshold. The threshold value is 0.81, and the confidence interval is 0.803 to 0.8134. Table 2 is the panel threshold regression results. From the regression coefficient of LNF, when the energy structure is lower than 0.81, the industrial structure has a significant inhibitory effect on carbon dioxide emissions. In terms of the whole country, for every 1% increase in the proportion of the secondary industry in the industrial structure, its ability to curb carbon dioxide emissions has increased by 0.105%.

Table 2: panel threshold regression results

| variable | LnP  | LnA  | LnT  | LNF  | lnS(z<=0) | lnS(z=+) | cons | R2   |
|----------|------|------|------|------|----------|----------|------|------|
| Valuation| 1.009*** | 1.012*** | 1.023*** | -0.00155* | 0.105*** | -0.0552* | -9.751*** | 0.9982 |

Note: * * *, * are significant at the level of 1%, 5% and 10%, respectively.

5. Conclusions and policy recommendations

Based on the provincial panel data of China from 1999 to 2016, this paper constructs a provincial panel data model to conduct in-depth study on the factors affecting carbon dioxide emissions, and further constructs a threshold model on this basis, taking energy structure as the threshold variable, to test and analyze the non-linear characteristics of the emission reduction effect of industrial structure. The results show that: (1) the carbon dioxide emission is affected by many factors, and the order of its influence is technology level (T), population scale (P), economic level (A), energy structure (F) and industrial structure (S). (2) The results of threshold model analysis further show that the adjustment of industrial structure can effectively restrain carbon dioxide emissions. In the use of energy, traditional energy will produce more carbon dioxide, resulting in environmental pollution.

According to the research conclusion, this paper puts forward the following suggestions for carbon emission control and low-carbon development: (1) adjust the industrial structure and innovate the development. Empirical research shows that carbon emission mainly comes from the secondary industry, especially the industrial enterprises with high energy consumption and high pollution. (2) Change energy use and develop new energy. The essence of low-carbon economy is to improve energy efficiency technology, energy-saving technology, renewable energy technology and greenhouse gas emission reduction technology. (3) Strengthen publicity and raise awareness of environmental protection. It can effectively reduce carbon emissions to strengthen the propaganda of low-carbon life concept, guide the public to choose a low-carbon and environmental protection lifestyle, and enhance residents' awareness of environmental protection. (4) Strengthen communication and cooperation among regions. At present, the comprehensive evaluation system of carbon emission reduction efficiency in various regions of China only stays at the level of theoretical research, and there are few practical cases.
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