Research on the Mechanism of Foreign direct investment on environmental pollution-Based on regression model of threshold effect

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Abstract. The panel data of all provinces in China from 2010 to 2018 were selected and the threshold effect regression model of FDI impact on China's carbon emissions was constructed by taking urbanization level as the threshold variable. The results showed that FDI's impact on China's carbon emissions had obvious double threshold effect of urbanization level. Therefore, according to the urbanization development level, each region should introduce foreign direct investment according to local conditions, give full play to its positive effect on carbon emission reduction, and realize green, low-carbon and sustainable development.

1. Introduction
After the reform and opening up, China has accelerated its economic exchanges with the outside world for its own rapid economic development. In order to make up for its capital and technology gap, China has begun to attract large amounts of foreign investment to develop an export-oriented economy. Foreign direct investment (FDI)'s contribution to China's economic growth is unquestionable, but it comes at the cost of the environment. In recent years, China's carbon emissions have increased rapidly and environmental quality has been deteriorating, so the situation of carbon emission reduction in China is extremely severe[1].

In the context of frequent cross-border investments and rising environmental concerns, the impact of FDI on the environment of host countries has become the focus of many scholars. One view is that the inflow of FDI will promote carbon emissions, that is, the “pollution paradise” hypothesis. Because companies consider cost, when two countries have similar development conditions except environmental policies, polluters from countries with stricter environmental policies tend to shift to countries with looser environmental policies, thus leading to environmental deterioration in the host country[2]. Another argument is that FDI inflows through technology spillover effect to reduce carbon emissions, the hypothesis of "pollution halo", due to the FDI introduction of advanced technology, imitate the demonstration sample for the host country enterprise, promoting technology and access to upgrade their advanced management experience, ensuring the rational allocation of resources[3]. With the continuous deepening of research, some scholars have begun to pay attention to the nonlinear relationship between FDI and carbon emissions. Unfortunately, few scholars analyzed the mechanism of FDI's threshold effect on carbon emissions from the perspective of urbanization level. In view of this, based on the panel data of 30 provinces in China from 2010 to 2019, this paper intends to investigate the threshold effect of FDI on China's carbon emissions from the perspective of different stages of urbanization, so as to provide certain theoretical reference for the rational introduction of foreign direct investment in the region and the realization of green, low-carbon and sustainable development.
2. Study design
Based on the panel data of all provinces in China from 2010 to 2018, this paper intends to establish an equation with carbon emissions as the explained variable, FDI as the core explanatory variable (threshold dependent variable), and urbanization level as the threshold variable. At the same time, the industrial structure adjustment index, fixed asset investment scale and degree of national economic regulation are added as three control variables. The specific model was constructed as follows:

\[ \ln \text{CO}_2 = \beta_0 + \beta_1 \ln \text{FDI} + \beta_2 \ln \text{IND} + \beta_3 \ln \text{SCALE} + \beta_4 \ln \text{EP} + \epsilon \]

In formula (1), \( i \) is the province, \( t \) denotes the time, \( \text{IND} \) is the industrial structure adjustment index, \( \text{SCALE} \) is fixed asset investment scale, \( \text{EP} \) is the degree of national economic regulation, \( \epsilon \) is the random perturbation term, \( LN \) is the logarithm, \( \beta_0 \) is the constant term, \( \beta_1 \), \( \beta_2 \), \( \beta_3 \), \( \beta_4 \) is the parameter to be estimated.

2.1. Explained variable: Carbon emission (CO2)
China’s carbon emissions mainly come from fossil fuel combustion and industrial production process[4]. The formula for calculating carbon emissions from fossil fuel combustion is as follows:

\[ T\text{CO}_2 = \sum_{i=1}^{7} \text{CO}_2 = \sum_{i=1}^{7} Q_i \times CF_i \times CC_i \times COF_i \times \frac{44}{22} \]

In formula (2), \( T\text{CO}_2 \) is the total amount of carbon dioxide released by various fossil energy consumption, \( Q_i \) is 30 provinces the first kind of the final consumption of energy, \( CF_i \) is the energy consumption of calorific value of the release, \( CC_i \) is the energy of the carbon content, \( COF_i \) is carbon oxidation factor. \( CF_i \times CC_i \times COF_i \times \frac{44}{22} \) is the carbon dioxide emission factor.

The calculation formula of carbon emission in cement production process is as follows:

\[ C\text{CO}_2 = QC \times EC\text{cement} \]

In formula (3), \( C\text{CO}_2 \) is the total amount of \( \text{CO}_2 \) released during cement production, \( QC \) is the total amount of cement produced by industry, and \( EC\text{cement} \) is the discharge coefficient of \( \text{CO}_2 \) during cement production.

Figure 1 only lists the estimated values of the variation trends of carbon emissions in China’s provinces in 2010, 2015 and 2018.

As can be seen from the figure above, carbon dioxide emissions of all Chinese provinces showed a rising trend during the study period.
2.2. Explanatory Variables: Foreign Direct Investment
At present, many scholars at home and abroad dispute the role of FDI in the green development of China's economy and the green adjustment of industrial structure. Therefore, FDI is taken as the core explanatory variable to analyze its impact on carbon emissions in the process of urbanization development.

2.3. Control variables
Industrial Structure Adjustment Index: the optimization of industrial structure is conducive to the improvement of environmental quality. Therefore, this paper selects the ratio of the added value of the secondary and tertiary industries in each province to measure the status of industrial adjustment[5]. The larger the industrial structure adjustment index is, the higher the carbon dioxide emission will be.
Fixed Asset Investment Scale: Fixed asset investment activities will consume a large amount of fossil energy, resulting in the surge of carbon dioxide emissions; Degree Of National Economic Regulation: Whether the goal of energy conservation and emission reduction can be truly achieved depends largely on the effectiveness of the degree of national economic policy regulation.

2.4. Threshold variable: Urbanization level
The objective existence of regional difference in urbanization level makes the influence of FDI on carbon emissions vary in different regions. In this study, the urbanization level was selected as the threshold variable to test the spatial heterogeneity of FDI's impact on carbon emissions. The descriptive statistics of the variables are shown in Table 1.

![Figure 1. Carbon emissions of 30 Provinces in China in some years (unit: tons)](image)

Table 1. Statistical description of variables
| Variable         | Symbol | Mean value | Standard deviation | Maximum value | Minimum value |
|------------------|--------|------------|--------------------|---------------|---------------|
| Carbon emissions | CO2    | 2.62       | 1.79               | 8.75          | 0.19          |
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direct investmen

FDI 485.79 726.83 3839.34 4

Urbanization level POC 51.22 14.2 89.6 26.87

Industrial structure adjustment index IND 1.22 0.32 2.01 0.27

Fixed asset investment scale SCALE 8683.5 7587.86 42495.55 329.81

Degree of national economic regulation EP 0.31 0.1 0.58 0.11

3. Threshold effect analysis

The model in this paper is based on Hansen panel threshold regression model[6]:

\[ y_{it} = \beta_0 + \beta_1 x_{it} I(q_{it} \leq \gamma) + \beta_2 x_{it} I(q_{it} > \gamma) + \epsilon_{it} \]  

(4)

In formula (4), \( i \) is the region, \( t \) is the year, \( q_{it} \) is the threshold variable, \( \gamma \) is the specific threshold value, \( \epsilon_{it} \sim iid(0, \sigma^2) \) is the random error term, and \( I(\cdot) \) is the indicator function.

Formula (4) is also equivalent to:

\[ y_{it} = \begin{cases} 
\beta_0 + \beta_1 x_{it} + \epsilon_{it}, & q_{it} \leq \gamma \\
\beta_0 + \beta_2 x_{it} + \epsilon_{it}, & q_{it} > \gamma 
\end{cases} \]  

(5)

Therefore, formula (1) is further modified as:

\[ LNCO_2 = \beta_0 + \beta_1 LNFDI_{it} \times I(q_{it} \leq \gamma_1) + \beta_2 LNFDI_{it} \times I(q_{it} > \gamma_2) + \beta_3 LNIND_{it} \]

\[ + \beta_4 LNSCALE_{it} + \beta_5 LNEP_{it} + \epsilon_{it} \]  

(6)

4. Measurement results and empirical analysis

Using stata14.0 threshold regression from sampling method in single threshold, double threshold, and triple the threshold conditions for POC threshold effect of significance test, the results show that (see table 2) : for different POC, single threshold effect in the 5% significance level, and the double threshold effect are 1% significance level, so the level of urbanization double threshold model.

Table 2. Threshold effect self-sampling test

| Threshold variable | Model       | F value | P values | BS number | Critical value |
|-------------------|-------------|---------|----------|-----------|----------------|
|                   | A single threshold | 7.87** | 0.02     | 300       | 9.34 6.76 4.95 |
|                   | Double threshold  | 35.01** | 0.00     | 300       | 8.29 3.89 1.53 |
|                   | Triple threshold  | 0.00    | 0.13     | 300       | 0.00 0.00 0.00 |

Note: *** , ** , * are significant at 1%, 5%, and 10% levels, respectively (the same below).

Table 3 reports the estimated threshold value and its confidence interval for the urbanization level, with the first threshold value being 49.2 and the second threshold value being 70.1.

Table 3. Threshold estimates and their confidence intervals

| Threshold variable | Model         | Threshold estimate | 95% confidence interval |
|-------------------|---------------|--------------------|-------------------------|
|                   | Double threshold model | 70.10              | [70.10,71.06]           |
|                   |                | 49.22              | [47.64,51.42]           |

According to the value of threshold variable, the urbanization level of 30 provinces was divided into the initial stage (POC < 49.22), the middle stage (49.22 ≤ POC < 70.10) and the later stage (POC ≥ 70.10). With different urbanization levels as the threshold variables, the model estimation results are shown in Table 4.

Table 4. Regression results of threshold model

| Explained variable | CO2           |
|--------------------|---------------|
| Explatory variables| coefficient   | Standard deviation | 95% confidence interval |
| LNIND              | 0.32**        | 0.091              | 0.057 0.409             |
5. Conclusions and Implications

The results show that FDI has a significant double threshold effect on China's carbon emissions: when the urbanization level is low and the minimum threshold value has not been crossed, FDI has a significant positive impact on carbon emissions; when the urbanization level crosses the first threshold and enters the second stage, the effect of FDI on carbon emissions is positive, but the coefficient is lower than that of the first stage and is not significant. When the urbanization level crosses the second threshold and enters the third stage, FDI will significantly inhibit the increase of carbon emissions.

The above conclusions have the following inspirations for China to achieve the goal of energy conservation and emission reduction: First, for regions that have not yet crossed the minimum threshold, increase government investment, optimize the investment environment in this region, and accelerate the pace of urbanization development; Secondly, for the regions that cross the threshold of the lowest urbanization level, the strategy of industrial structure transformation and upgrading should be actively promoted, the development of high-tech industries should be accelerated, the proportion of enterprises with high energy consumption, high pollution and high emission should be reduced, and the introduction of capital, technology-intensive and clean FDI should be emphasized. Finally, for the cities that cross the second threshold, the distribution of FDI investment fields should be reasonably guided to maximize the direct and indirect effects of FDI in promoting energy conservation and emission reduction in China.

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