The Threshold Effect of Technological Innovation Ability on Environmental Pollution Level

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Abstract: According to environmental kuznets curve (EKC), there is a non-linear relationship between economic development and environment pollution. This paper aims to study on the threshold effect of technological ability on environmental pollution and uses nonlinear panel threshold regression to test the effect. An empirical study is made with 19 years panel data from 2000-2018 which are collected from 30 provinces. The study finds out that when taking technological innovation ability as threshold variable, the relationship between economic development and environment pollution is complicated. When technological innovation ability is below the first threshold value, the economic development has positive effect on environmental pollution level. When technological innovation ability ranges from the first threshold value to the second one, the economic development still has positive effect on environmental pollution level, but the effect becomes weak. When technological innovation ability is beyond the second threshold value, the economic development has negative effect on environmental pollution. This paper helps each province to understand the impact of their scientific innovation status on environmental quality and adhere to the concept of innovation and green development.

1. Introduction

In the past years, China's economy has developed at a high speed, but environmental pollution has increased at the same time. Although the government has attached a lot of importance to environment sustainable development, the present situation is not satisfying. The classical hypothesis about the impact of economic development on environmental pollution is Environmental Kuznets Curve (EKC). Scholars have also done many researches on EKC. According to their studies, most provinces of eastern China have reached the inflection point of the wasted-water kuznets curve, while the number of provinces which enter the right half of the wasted-gas kuznets curve are relatively low [1]. Economic growth and trade openness have both positive and negative impacts on regional pollution emissions [2]. The shapes and turning points of kuznets curves under different institutional arrangements in different regions differ significantly [3].

With the development of economy, environmental quality becomes worse and worse. At the same time, technological innovation ability becomes more and more important. However, the influence of technological ability on environmental pollution is uncertain according to existing study. From one thing, some researches show that technological progress has the dual effect on increasing enterprise productivity and improving the cleanliness of enterprise products, and the innovation compensation effect has reduced the pollution emission [4]. Scientific and technological innovation can reduce the emission intensity and total emission of sulfur dioxide from industry [5].

The technological innovation of enterprises is conducive to promoting the comprehensive utilization of the “three kinds of wastes” and improves the removal efficiency of industrial sulfur dioxide [6]. With the increase of industrial agglomeration, environmental pollution level increases at first and then decreases. Technological innovation plays a key role in determining the "inflection point" position [7]. From another, other scholars argue that technological innovation leads to a continuous increase in environmental pollution. The developed country considers more about the profit brought by technological innovation rather than the influence on society [8]. What’s more, the direction of technological process should be taken into consideration. We can improve the environmental quality through controlling urban land scale and the innovation method of clear technology [9].

Since most papers are focused on testing the EKC, people seldom study on the factors that influence the inflection point. In view of the ability of technological innovation may have threshold effect on the impact of economic development on environmental quality, this paper will use nonlinear panel threshold regression model to test the threshold effect of technological innovation ability. Nineteen years panel data from 2000-2018, which are collected from 30 provinces, will be used to make an empirical study.

2. Data and Methodology

2.1. Variable Selection

According to the research problem, we choose environmental pollution as the dependent variable, economic development as explanatory variable, technological innovation ability as threshold variable and industrial structure as control variable.

2.1.1. Dependent Variable

Environmental Pollution (pol). According to existing literature, scholars use three industrial wastes, which are liquid waste, solid waste and residue waste, to define how serious the environmental pollution is. However, there isn’t a standard about how to measure environmental pollution level. To make their study easy to be understood, most scholars use one indicator to define the environment quality. Considering that the proportion of sulfur dioxide is very high in industrial polluter and the data of sulfur dioxide emissions is easy to be found, this paper chooses sulfur dioxide emissions to be the measure of environmental pollution level.

2.1.2. Explanatory Variable

Economic development level (gdp). There are many indicators which can measure the economic development level of a country. Gross domestic product is one of the common indicators. It is used by many researches to measure the economic development level. Thus, this paper will use per capital GDP as the measure of economic development level.

2.1.3. Threshold Variable

Technological Innovation Ability (tia). Technological innovation is the application of new technologies and inventions in business. It is the driving force of economic development. Technological innovation capacity is closely linked to research and development activities. First, the number of patent is one of the vital outputs of innovation activities. Second, it indicates the ability of scientific innovation to some extends. Last, the number of patent in each province is easy to be collected. Therefore, we divided the the number of patent by ten thousand people, and use the answer to measure technological innovation capacity.

2.1.4. Control Variable

Industrial structure (inds). Theoretically, when a country's industrial structure is dominated by secondary industry, it will produce more waste [10]. Because industrial plants will produce a lot of wastes. When a country's industrial structure is tertiary industry dominated, it will release less pollute [10]. Because service industry is more environmental friendly than industry. Therefore, this paper will treat industrial structure as a control variable. This paper uses the proportion of tertiary industry divide secondary industry to measure industrial structure.

2.2. Data Source

This paper uses 19 years panel data from 2000 to 2018. Our sample contains data from 30 provinces. Data resources are China Statistical Yearbook form the year of 2001 to 2019. In addition, all variables are taken natural logarithm so as to reduce variance. But the relationship among data has not changed.

2.3. Model Settings

According to existing study, the impact of economic development level on environmental pollution may be affected by technological innovation ability. That is, technological innovation ability may have threshold effects on environmental kuznets curve.

Thus, this paper uses nonlinear panel threshold regression to test whether technological innovation ability has the effect we have mentioned above. The original equation of Hansen's threshold model is written like this [11]:

$$Y = \beta_1 X_i \cdot I_1(q_i \le \gamma) + \beta_2 X_i \cdot I_2(q_i > \gamma) + \varepsilon_i \tag{1}$$

In equation (1), Y represents dependent variable; X_i represents the factor which has influence on dependent variable. I_1 is 1 if $qi \leqslant \gamma$, otherwise, I_1 is 0. I_2 is 1 if $qi > \gamma$, otherwise, I_2 is 0.

In single threshold model, there is only one threshold value, which is γ. The form of single threshold model is shown in equation (2). In this equation, environmental pollution is the dependent variable, economic development level is the explanatory variable and industrial structure is the control variable.

$$\ln pol_{it} = \beta_0 + \beta_1 \ln gdp_{it} \cdot I(\ln tia \le \gamma) + \beta_2 \ln gdp_{it} \cdot I(\ln tia > \gamma) + \beta_k \ln inds_{it} + \varepsilon_{it} + \mu_{it} \tag{2}$$

In equation (2), β_0 is intercept term. β_1, β_2 and β_k are parameters which are supposed to be estimated. *pol* represents environment pollution level, *gdp* represents economic development level, *tia* represents technological innovation ability and *inds* represents industrial structure. ε_{it} is random interference term and μ_{it} is special effect of individuals. i represents different provinces in our sample. t represents the year of 2000 to 2018.

The double threshold panel model can be written at the same way. The only difference is that the double threshold model has two threshold values, which should be γ_1 and γ_2. So the form of double threshold model is omitted in this paper.

3. Results

In this part, we will show the descriptive statistics of variable and double threshold regression result. According to the descriptive statistics of variable, environmental pollution level, innovation ability, industrial structure and economic development level vary from time to space. Among them, the difference of technological innovation ability is the most obvious one. According to the threshold regression, we have verified that technological innovation ability certainly has threshold

effect on environmental kuznets curve.

3.1. Descriptive Statistics of Variables

We use stata15 analysis software to process the data and get the descriptive statistics of variables. The result is displayed in Table 1.

As it is shown in Table 1, there are 570 numbers of samples for each variable. There is a large gap between the minimum value and the maximum value of environmental pollution level. The standard deviation of lnpol is 0.969. It means that the environmental quality is totally different with the change of time and space. The standard deviation of lntia is the largest one. The maximum value of lntia is high but the minimum value is even a negative number. It means that the innovation ability is also different from time to space. The average value of inds is -0.094, which means the proportion of the secondary industry is higher than the tertiary industry in most province and years. Since industrial pollution is mainly from the secondary industrial, the high proportion of secondary is not environmental friendly. The maximum value of lngdp is much more higher than the minimum value. The minimum value of lngdp is a negative number, which means some region used to be very poor in the past. Generally speaking, the variables meet the requirements for further testing according to descriptive statistics.

Table 1. Descriptive statistics

Variables	Sample Number	Min	Mean	Max	Std.
lnpol	570	0.356	3.864	5.299	0.969
lntia	570	-2.041	0.652	4.049	1.409
lninds	570	-0.704	-0.094	1.469	0.357
lngdp	570	-1.266	0.861	2.637	0.857

3.2. Threshold Effect Test

The threshold effect test includes three parts: threshold effect significance test, threshold effect authenticity test and threshold regression estimation results. The significant test indicates that the threshold effect of technological innovation capacity is significant. The Authenticity test result shows the LR value of threshold parameter. And the threshold regression result shows that with the change of innovation ability, the economic development level has different impact on environmental pollution.

3.2.1. Significance Test Result

The significance test result is displayed in Table 2. The P value of the single threshold model is 0.000, and the P value of the double threshold model is also 0.000. We get the P value after 500 times bootstrap. The F value of two models are significant. The 95% confidence interval for the single threshold model is [1.033, 1.958]. The 95% confidence interval of the first threshold estimation for the double threshold model is [0.813, 2.773], and the 95% confidence interval of the second threshold estimation for the double threshold mode is [1. 958 , 2.773]. Generally speaking, both of the two models have passed the significance test.

Table 2. Significance test result

Model	F value	P value	0.01	0.05	0.1	Threshold estimation	95% Confidence interval
Single	77.042	0.000	50.479	30.560	22.656	1.662	[1.033 , 1.958]

threshold	(***)						
Double	42.714	0.000	12.962	-5.106	-11.586	0.834	[0.813 , 2.773]
threshold	(***)					2.334	[1.958 , 2.773]

Notes: (1) ***p<0.01; **p<0.05; *p<0.1.

3.2.2. Authenticity Test Result

A comparison of single and double threshold model shows that double threshold model is more relevant to real situation and gives more information about the function of technological innovation ability. Since the double threshold model has more practical significance, this paper will focus on double threshold model and omit the result of single model.

The first round test of double threshold model searches the first threshold estimate value and the second round test of double threshold model fixes the first threshold estimate value and searches the second threshold estimate value. The likelihood ratio value of the whole process is shown in Figure 1 and Figure 2.

When taking technological innovation as threshold variable, we get two threshold estimations for double threshold model. When likelihood ratio is 0, the two estimators are 0.834 and 2.334. The double threshold model passes the authenticity test. The estimators are nearly equal to true value.

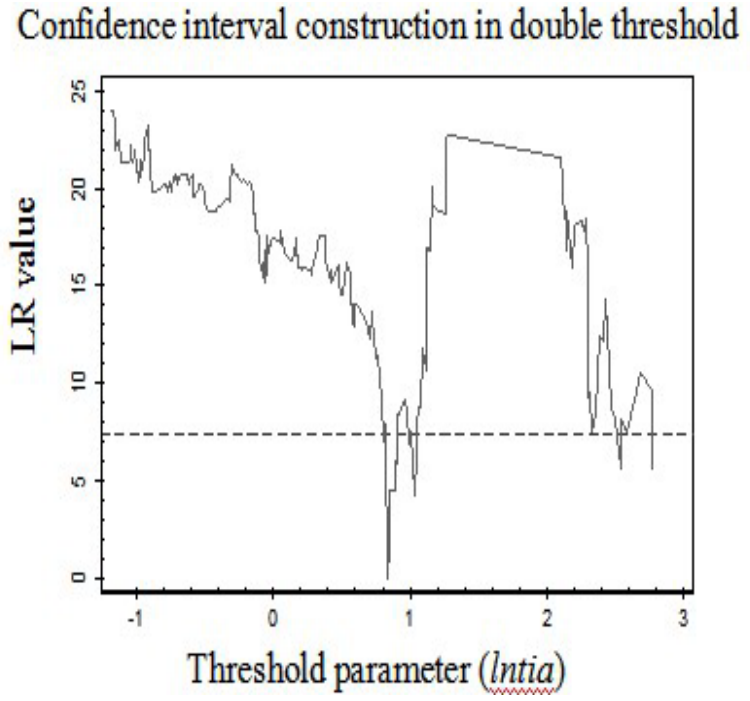

Figure 1. The first round test

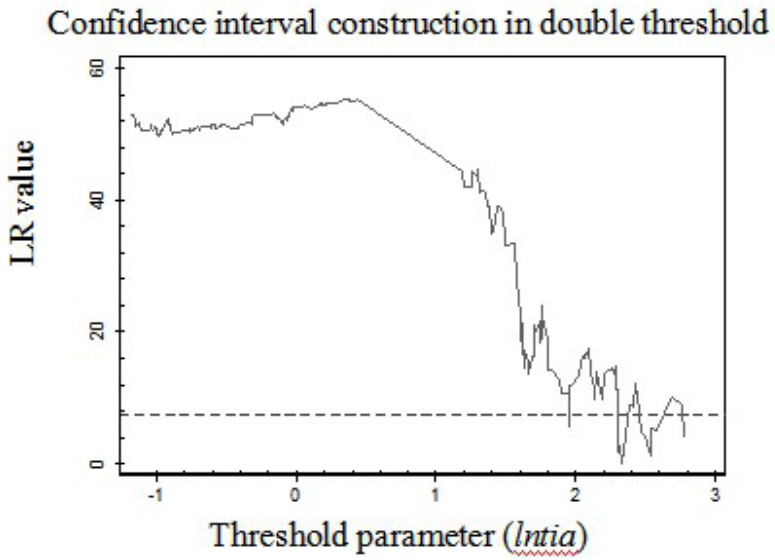

Figure 2. The second round test

3.2.3. Regression Estimation Result

The threshold regression estimation result is displayed in Table 3. The research result indicates that the economic development level has different impact on environmental pollution with the change of technological innovation ability. When technological innovation ability is less than 0.834, the economic development has positive effect on environmental pollution level. When technological innovation ability ranges from 0.834 to 2.334, the economic development still has positive effect on environmental pollution level, but the effect becomes weak. When technological innovation ability is higher than 2.334, the economic development has negative effect on environmental pollution. That means technological innovation ability has threshold effect on environmental pollution. It has impact on the turning point of EKC.

Regarding the control variable, industrial structure has negative influence on environmental pollution. That means the increasing proportion of tertiary industry and the upgrading of industrial structure is environmental friendly.

Table 3. Double threshold model estimation results.

lnpol	Coef.	Std. Err.	t	P>| t |	[95% Conf. Interval]
lngdp_1	.1245676	.0288564	4.32	0.000	[.0678822, .1812531]
lngdp_2	-.122635	.0240955	-5.09	0.000	[-.1699682, -.0753017]
lngdp_3	-.3217446	.030599	-10.51	0.000	[-.3818532, -.261636]
lninds	-.726196	.0749941	-9.68	0.000	[-.8735145, -.5788776]
_cons	3.91433	.025009	156.52	0.000	[3.865202 , 3.963457]

Conclusion

This paper use Hansen's nonlinear panel threshold regression model to test the threshold effect of technological innovation on environmental pollution. The result shows that the impact of economic development level on environmental pollution will be influenced by technological innovation ability. When technological innovation ability is below the first threshold value, the the environmental pollution will increase along with the increasing of economic development level. When technological innovation ability ranges from the first threshold value to the second one, environmental pollution level won't increase that fast, but it still increases. When technological

innovation ability is beyond the second threshold value, the environmental pollution level will decrease with the increasing of economic development level. Progress in technological innovation can offset part of the impact of economic development on environmental pollution. But technological innovation ability in most provinces do not step over the second threshold value by 2018. It means that we still need to improve the technological innovation capability so as to build a environmental friendly country and achieve green sustainable development.

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