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Foreign Direct Investment and Environmental Pollution: New Evidence from China

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Abstract

This paper investigates the relationship between FDI and environmental pollution based on 30 provincial capital cities data from China and exploits the possible mechanisms that cause specific pattern between FDI and environmental pollution. According to panel data model with and without technological progress, the relationship between FDI and sulfur dioxide exhibits inverted U-shaped pattern, yet there is no certain pattern between FDI and PM10 under two circumstances, in the meanwhile, the quadratic relationship between FDI and nitrogen dioxide disappears once incorporating technological progress. This paper further estimates such relationship by utilizing panel threshold model and concludes the impact of FDI on the emission of PM10 exhibits N-shaped pattern rather than usual U-shaped pattern, the relationship between FDI and sulfur dioxide may exist inverted V or U-shaped pattern and there is no any specific relationship between FDI and nitrogen dioxide. Theoretically, production scale effect, technique effect and regulation effect brought by FDI jointly determine the impact of FDI on environmental pollution and latter two effects will relieve the environmental deterioration in the long run.

Keywords: Economic Growth; FDI; Environmental pollution; Panel Threshold Model.

JEL Codes: Q56; F21; C23.

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1. Introduction

Rapid economic growth has sustained three decades in China since Reform and Opening-up in the 1980s, in the meanwhile, China also experienced significant environmental deterioration over the past 20 years and the side effect of environmental pollution has gradually emerged. China becomes the largest sulfur dioxide (SO_2) and carbon dioxide (CO_2) emission country. Chen et al. (2013) point out that the life expectancy per capita declines 5.5 year owing to the coal burning boiler in north of the Huai river of China. Facing the contradiction between economic growth and environmental pollution, an important question that we should solve urgently is whether persistent economic growth in China will eventually improve environmental quality. Economists view such environmental issue through Environmental Kuznets Curve (EKC), which indicates the environmental problems worsen during the early stage of economic growth and then improve with the development of economy after reaching the threshold value of GDP (or per capita GDP).

According to the 2015 World Investment Report published by UNCTAD, China has become the world's largest foreign direct investment (FDI) recipient. Specifically speaking, on the one hand, FDI fills up the financial gap for industrial development in China, on the other hand, large amounts of FDI are received by low-technological and high-pollution industries (Fed Reserve of Minneapolis, 2016). During the international trade activities, it is difficult to export products with high pollution to the less stringent environmental regulation country, one possible channel is multinational enterprises invest in building factories which yield products with high pollution. Hence, there will be a close relationship between foreign direct investment and environmental pollution.

In this paper, I will integrate economic growth, foreign direct investment and environmental pollution in a unified empirical framework and use 30 panel data of provincial capital cities in China from 2005-2015 to estimate the relationship between FDI and environmental pollution. In addition, I further use Panel Threshold model proposed by Hansen (1999) to find the threshold effect of economic growth and/or FDI on environmental pollution, which is different from the existing literature that most rely on incorporating squared term in regression models.

This paper concludes that panel data model with and without technological progress, the relationship between FDI and sulfur dioxide both exhibits inverted U-shaped pattern, yet there is no certain pattern between FDI and PM10 under two circumstances, in the meanwhile, the quadratic relationship between FDI and NO_2 disappears once considering technological progress. This paper further estimates their relationship based on panel threshold model and obtains the following conclusions: the impact of FDI on the emission of PM10 exhibits N-shaped pattern rather than usual U-shaped pattern, the relationship between FDI and SO_2 may exist inverted V or U-shaped pattern and there doesn't exist any specific relationship between FDI and NO_2. production scale effect, technique effect and regulation effect brought by FDI jointly determine the impact of FDI on environmental pollution and latter two effects will relieve the environmental deterioration in the long run.

The remaining paper is organized as follows: Section 2 is literature review which summarizes the literature on economic growth and environmental pollution as well as FDI and environmental pollution. Section 3 is data description. Section 4 introduces econometrical methodology used in this paper. Section 5 is empirical result and discussion. Section 6 is conclusion and policy implication.

2. Literature Review

Study on the relationship between economic growth and environmental pollution can trace back to Grossman and Krueger (1995), their conclusion exhibits environmental pollution and income per capita exist inverted U-shape pattern which is popular as Environmental Kuznets Curve (EKC), in other words, environmental quality doesn't be worsen with economic growth once beyond the turning point. In line with Grossman and Krueger (1995) study, some studies (e.g. Selden and Song, 1995; Jones and Manuelli, 2001; Hartman and Kwon, 2005; Brock and Taylor, 2010 etc.) construct different theoretical models (e.g. overlapping generations model, infinitely lived agent model etc.) to find the possible reasons for the inverted U shape between economic growth and economic pollution. In these models, they assume individual utility is a function of normal goods and environmental quality, hence there is a tradeoff between normal goods and environmental quality to maximize utility level when given resource constraints. One significant difference among these theoretical models is they propose different mechanisms to explain the existence of inverted U-shape pattern. For example, Stocky (1998) pointed out the choice of optimal production technology in different development period resulted in the EKC. Jones and Manuelli (2001) shifted the perspective from technology to policy factors, they demonstrated that pollution tax and/or regulation may interpret the formation of EKC.

Some scholars (Cole et al., 1997; Hilton and Levinson, 1998) used empirical methods to examine the relationship between economic growth and environmental pollution and their empirical results support the inverted U-shape relationship. However, Stern and Common (2001) and Harbaugh et al. (2002) indicated sample selection, control variables, even different econometric methods will obscure the relationship between economic growth and environmental pollution.

As for the relationship between FDI and environmental, a lot of literature also concentrate on their potential connection. For example, Hoffmann et al. (2005) used Granger causality test based on 112 countries data to verify the relationship between FDI and pollution relies on the development of host country. Cole et al. (2006) developed a political economy model and concluded that when the degree of government corruptibility is low, then FDI leads to a higher stringent environmental policy and less pollution. Hitam and Borhan (2012) used data of Malaysia from 1965 to 2010 to examine the impact of FDI on environmental quality and concluded that FDI will increase environmental pollution. Therefore, FDI should be incorporated as an independent variable in EKC regression model, otherwise, the coefficients estimated from EKC regression equation will be biased because of omitted variable.

Furthermore, with the deterioration of environmental quality, more and more literature turns to focus on economic growth and environmental pollution in China. De Groot et al. (2004) used the sample of 30 regions from 1982-1997 in China to discuss the impact of economic growth on three different types of pollution, they concluded that the relationship between wastewater (waste gas, solid waste) and per capita GDP displays negative (positive, constant). However, Song et al. (2008) concluded that the relationship between pollution and per capita GDP is inverted U-shape pattern which is uncorrelated with types of pollution. He and Wang (2012) pointed out that the capital abundance increases the concentration of TSP and decreased the concentration of NO_2 by using data from 74 cities from 1991 to 2001 in China. In addition to economic growth and environmental pollution, some studies also discuss the relationship between foreign direct investment and environmental pollution. He (2006) estimated that with 1% increase in FDI capital stock, then industrial SO_2 emission will increase by 0.098%, therefore the empirical conclusion in this paper provided convincing evidence for pollution haven hypothesis. Dean et al. (2009) estimated conditional and nested logit model and further indicate that FDI mainly from OECD countries in highly polluting industries significantly decreases in provinces with relatively stringent pollution regulation.

For most existing literature, they neglect an important characteristic that the impact of FDI on environmental pollution depends on the economic development level, in other words, the effect of FDI on environmental quality varies in different development period, therefore, the impact of FDI on environmental pollution relies on GDP and should be regarded as a function of GDP. Besides, most empirical researches use the quadratic term and cube term to capture the nonlinear effect of GDP and/or FDI on environmental, the prior specification of regression function form may make the results biased as mentioned by Common (2001) and Harbaugh et al. (2002). In this paper, I use panel threshold model proposed by Hansen (1999) to solve possible model misspecification in usual EKC empirical model, on the one hand, panel threshold model regards FDI as a function of GDP, on the other hand, panel threshold model doesn't assume specific pattern between FDI and environmental pollution.

3. Data and Descriptive Statistics

To empirically examine the relationship between economic growth, FDI and environmental quality, the data used in this paper are 30 provincial capital cities from China. Considering the availability of our data, the dependent variables that measure the environmental pollution are nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and PM_{10}. The independent variables include GDP per capita, FDI, export, industry value added over GDP, precipitation. The Data are collected from CEIC database, China Environment Yearbook and China City Statistical Yearbook. The time length of our data in 30 provincial capital cities is from 2004-2013. Besides, All the variables are taken natural logarithm form, this transformation not only eliminates the possible outliers and heteroskedasticity in our regression model, but also directly gives the elasticity through estimated coefficients.

Table1 reports the descriptive statistics of the variables used in our estimation. The mean of Nitrogen dioxide, sulfur dioxide and PM10 from 2004 to 2013 are 42.02 $\mu g/m^3$, 47.44 $\mu g/m^3$ and 103.92 $\mu g/m^3$, respectively. Moreover, Figure 1 exhibits the time trend of nitrogen dioxide, sulfur dioxide and PM10 in different provinces. From Figure 1, the emission amount of PM10 is apparently larger than the emission amounts of nitrogen dioxide and sulfur dioxide in 30 provincial capital cities. Therefore, total suspended particles are the main source of polluting gas, which also causes the smog and haze days in most areas of China in recent years. Figure 2 further displays the scatter plots between the emission amount of nitrogen dioxide, sulfur dioxide, PM10 and GDP per capita by pooling all the observations, it is difficult to identify the quadratic relationship from the graph. The similar phenomenon exists in Figure 3 that we can't identify a clear quadratic relationship between nitrogen dioxide, sulfur dioxide, PM10 and FDI.

Table 1. Descriptive Statistics

Variable	Sample	Mean	S.D.	Max	Min
Nitrogen dioxide	300	42.02	12.80	12	73
Sulfur dioxide	300	47.44	20.29	6	116
PM10	300	103.92	30.13	33	305
GDP	300	43.27	22.11	8.48	119.70
FDI	300	21.76	30.12	0.07	168.28
Industry value added	300	167.83	155.97	8.59	792.79
Export	300	147.54	306.76	2.15	2097.89

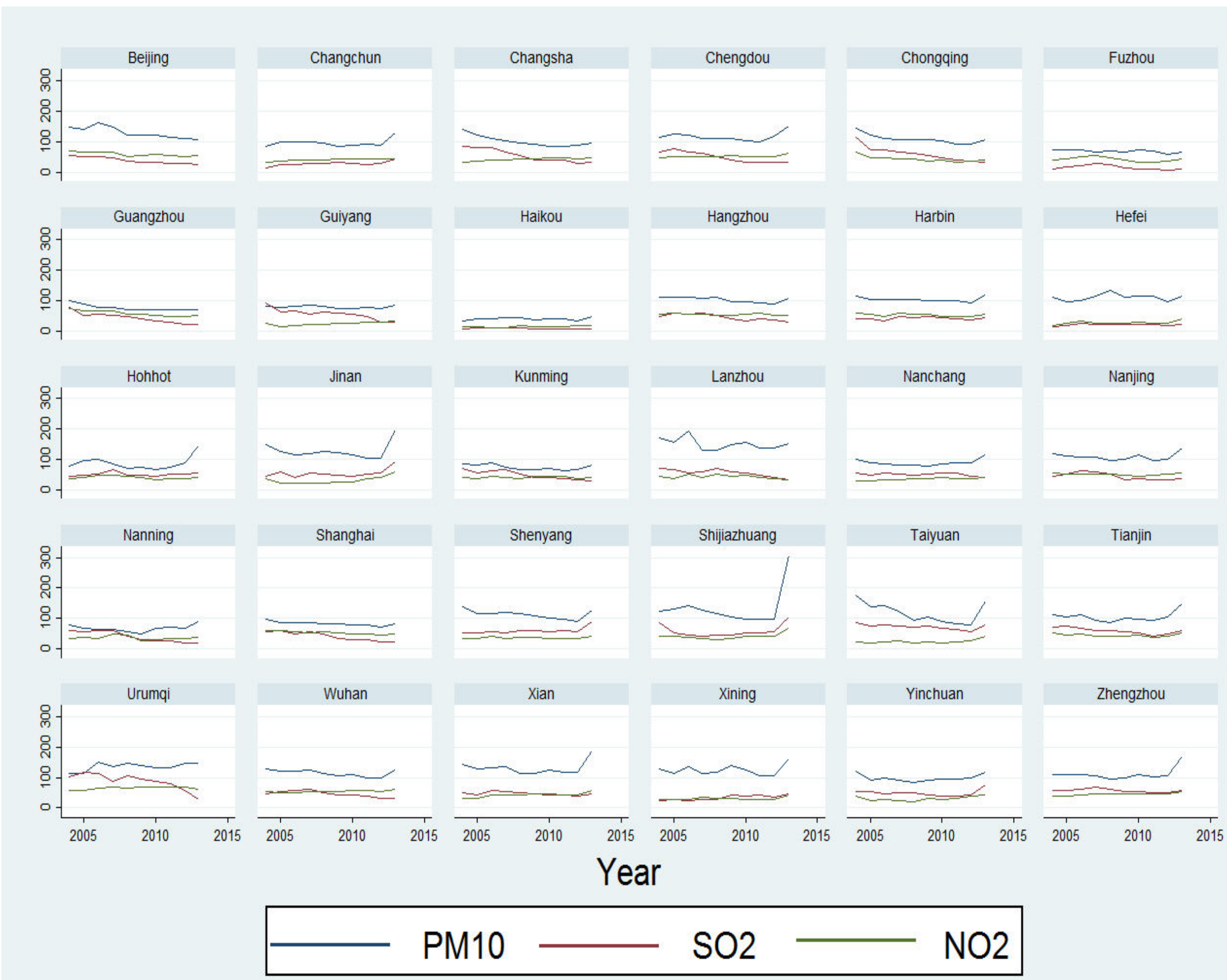

Figure 1 Time Trend in Different Provincial Capital Cities

Therefore, to verify whether there exists a significant relationship between FDI and environmental pollution, especially considering the impact of FDI may be determined by the threshold value of GDP. In next section, I will give a detailed illustration of traditional panel data model and panel threshold model, and then answer the above question based on the regression results.

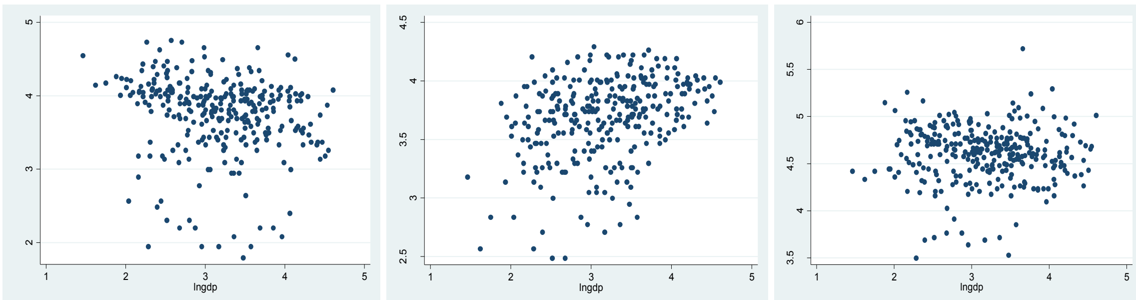

Figure 2 Environmental Pollution and GDP

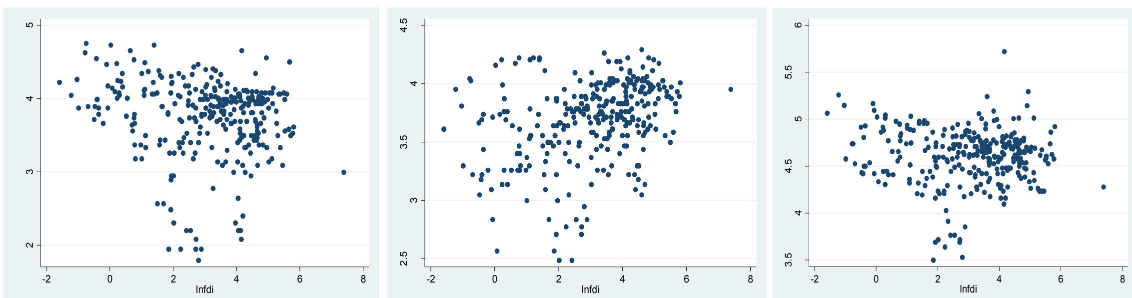

Figure 3 Environmental Pollution and FDI

4. Econometrical Methodology

4.1 Panel data model with quadratic term

Following Hoffmann et al. (2005), Hitam and Borhan (2012), I incorporate FDI and quadratic term as potential variable in panel data model. Besides, in order to capture technological progress with time, I also use correlated random trend model (Wooldridge, 2002) to estimate EKC based on 30 provincial cities in China. The model 1 is expressed as follows:

$$\ln\left(Pollution_{it}\right) = \alpha_i + \beta_1 \ln\left(GDP_{it}\right) + \beta_2 \left[\ln\left(GDP_{it}\right)\right]^2 + \beta_3 \ln\left(FDI_{it}\right) + \beta_4 \left[\ln\left(FDI_{it}\right)\right]^2 + \boldsymbol{Z'\beta} + \varepsilon_{it} \quad (1)$$

where α_i is province fixed effects and Z represents control variables which incorporate export and industry value added.

The Model 2 which incorporates technological progress is given by

$$\ln(Pollution_{it}) = \alpha_i + \rho_i t + \beta_1 \ln(GDP_{it}) + \beta_2[\ln(GDP_{it})]^2 + \beta_3 \ln(FDI_{it}) + \beta_4[\ln(FDI_{it})]^2 + \boldsymbol{Z'\beta} + \varepsilon_{it} \quad (2)$$

where ρ_i characterizes the average technological progress rate, Z has the same implication with model 1. However, I can't estimate the ρ_i directly because ρ_i varies with different time period.

One possible approach to estimate ρ_i is taking first-order difference firstly, then using fixed effects model to estimate the difference regression model given by

$$\ln\left(\Delta Pollution_{it}\right) = \gamma_i + \rho_i + \beta_1 \ln\left(\Delta GDP_{it}\right) + \beta_2 \left[\ln\left(\Delta GDP_{it}\right)\right]^2 + \beta_3 \ln\left(\Delta FDI_{it}\right) + \beta_4 \left[\ln\left(\Delta FDI_{it}\right)\right]^2 + \Delta \boldsymbol{Z}'\boldsymbol{\beta} + \Delta\varepsilon_{it} \quad (2')$$

Here, I will first discuss the coefficients and explain its economic meaning. The possible pattern between environmental pollution and GDP per capita or FDI is summarized as follows: i) $\beta_1 > 0$ and $\beta_2 > 0$, the relationship between environmental pollution and GDP per capita exhibits U-shaped pattern; ii) $\beta_1 > 0$ and $\beta_2 < 0$, the relationship between environmental pollution and GDP exhibits inverted U-shaped pattern and the turning point of GDP per capita is $-\frac{\beta_1}{2\beta_2}$; iii) $\beta_3 > 0$ and $\beta_4 > 0$, the relationship between environmental pollution and FDI displays U-shaped pattern; iv) $\beta_1 > 0$ and $\beta_2 < 0$, the relationship between environmental pollution and FDI exhibits inverted U-shaped pattern and the turning point of FDI is $-\frac{\beta_3}{2\beta_4}$.

4.2 Panel threshold model

Panel threshold model proposed by Hansen (1999) aims at estimating the regression model with potential structural break (threshold variable)[3]. Actually, the impact of FDI on environmental pollution will rely on the economic development period which can be characterized by GDP per capita, in other words, GDP per capita will be a potential threshold variable when exploring the relationship between FDI and environment pollution, therefore, panel threshold model will describe and estimate such possible potential relationship. The panel threshold regression model with individual heterogeneous effects is given by the following equation 3:

$$\ln\left(Pollution_{it}\right) = \alpha_i + \beta_1 \ln\left(FDI_{it}\right) I\left(GDP_{it} \le \gamma\right) + \beta_2 \ln\left(FDI_{it}\right) I\left(GDP_{it} \ge \gamma\right) + \boldsymbol{Z'\beta} + \varepsilon_{it} \quad (3)$$

where I(.) denotes indicator function, GDP_{it} represents threshold variable, γrepresents threshold values. Denote $x_{it} = \ln(FDI_{it})$ and $q_{it} = GDP_{it}$, then Equation 3 can be written in a compact form, that is:

$$y_{it} = \alpha_i + \beta' x\left(\gamma\right) + \varepsilon_{it} \quad (4)$$

$$x_{it}\left(\gamma\right) = \begin{pmatrix} x_{it} I\left(q_{it} \le \gamma\right) \\ x_{it} I(q_{it} > \gamma) \end{pmatrix}$$

where $\beta = (\beta_1' \ \beta_2')'$.

Following Hansen (1999), taking the average of equation 4 over the time period t and taking difference between (3) and (4), then:

$$y_{it}^* = \beta' x_{it}^* + \varepsilon_{it}^* \quad (5)$$

[3] For further readings about the threshold estimation and the misspecification tests, see Omay (2014) and Omay et al. (2017).

where $y_{it}^* = y_{it} - \bar{y}$, $x_{it}^* = x_{it} - \bar{x}$, $\varepsilon_{it}^* = \varepsilon_{it} - \bar{\varepsilon}$. Then, we can use pooled regression method to estimate β given specific value of the threshold parameter γ. Therefore, the sum of squared errors relies on the specific value of γ, that is:

$$SSE_1 = \hat{\varepsilon}^*(\gamma)'\hat{\varepsilon}^*(\gamma) \tag{6}$$

Next, according to Hansen (1999), the approach to estimating the value of γ is minimizing the sum of squared errors:

$$\hat{\gamma} = arg \min_{\gamma} SSE_1(\gamma) \tag{7}$$

Besides, to determine whether the threshold effect is statistically significant, we can test the null hypothesis $H_0: \beta_1 = \beta_2$ which means there is no threshold effect. However, under the null hypothesis, the threshold value γ can't be identified and the asymptotic distribution of F doesn't follow the standard F distribution. Hence, Hansen (1999) suggested us to obtain the asymptotic distribution of the likelihood ratio test of H_0 through bootstrap approach, namely:

$$F = (SSE_0 - SSE_1(\gamma)) / \hat{\sigma}^2 \tag{8}$$

where $\hat{\sigma}^2$ is the residual variance from estimating panel threshold model, and SSE_0 is the sum of squared errors estimated from the linear regression model. So, the p-values constructed from the bootstrap are asymptotically valid, then we can reject the null hypothesis if the p-value is smaller than the desired critical value. When there is a threshold effect, we can further test the null hypothesis that $H_0: \gamma_1 = \gamma_2$, the likelihood ratio test to reject for large values of $LR_1(\gamma_0)$ where

$$LR_1(\gamma_0) = \left(SSE_1(\gamma) - SSE_1(\hat{\gamma})\right) / \hat{\sigma}^2 \tag{9}$$

Note that statistic (9) tests different hypothesis from statistic (8) introduced before.

Similarly, we can also estimate the panel threshold model with two different threshold values as follows:

$$\begin{aligned} \ln\left(Pollution_{it}\right) = \alpha_i + \beta_1 \ln\left(FDI_{it}\right) I\left(GDP_{it} \leq \gamma_1\right) + \beta_2 \ln\left(FDI_{it}\right) I\left(\gamma_2 \geq GDP_{it} \geq \gamma_1\right) \\ + \beta_3 \ln\left(FDI_{it}\right) I\left(GDP_{it} \geq \gamma_3\right) + \boldsymbol{Z'\beta} + \varepsilon_{it} \end{aligned} \tag{10}$$

where γ_1 and γ_2 are two different threshold values. In single threshold model, if $\beta_1 > 0$ and $\beta_2 < 0$, the relationship between FDI and environmental pollution exhibits near inverted V(or U) -shaped pattern, if $\beta_1 < 0$ and $\beta_2 > 0$, the relationship exhibits near U-shaped pattern. In double threshold model, FDI and environmental pollution may exist more complicated relationship, such as near N-shaped pattern when $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$.

To sum up, regression equation 1 and 2 are panel data model which incorporate quadratic term, the difference between them is regression equation 2 considers the average technological progress, like clean technology. Regression equation 3 and 10 are panel threshold model with single threshold and double threshold value, respectively. In particular, panel threshold model allows the exogenous variable to have different regression slopes depending on whether the threshold variable is above or below the threshold value.

5. Empirical Analysis

Table 2 reports the estimation results of the environmental Kuznets curve without technological progress and robust standard error is used here to overcome the potential heteroskedasticity among different provincial cities. The estimated chi-squared values of Hausman test are 9.99, 6.40 and 7.49 respectively, we can't reject the null hypothesis that there is no correlation between independent variables and unobserved heterogeneity, hence we prefer to choose random effects model. Furthermore, we can't find any significant relationship between GDP and environmental pollution in Table 2, in the meanwhile, there exists inverted U-shaped pattern between FDI and SO_2 or NO_2, although such pattern doesn't exhibit in the PM10 regression equation.

Table 2. Panel Data: Without Technological Progress

	PM10		SO_2		NO_2	
	FE (1)	**RE (2)**	**FE (3)**	**RE (4)**	**FE (5)**	**RE (6)**
Intercept	5.79***	5.50***	3.60**	4.02***	3.62***	3.76***
	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)
GDP per capita	**-0.48***	-0.39	0.55	0.42	-0.03	-0.09
	(0.09)	(0.13)	(0.51)	(0.62)	(0.93)	(0.83)
GDP per capita squared	**0.08***	0.06	-0.08	-0.05	0.02	0.03
	(0.08)	(0.12)	(0.48)	(0.65)	(0.72)	(0.61)
FDI	0.01	-0.00	-0.06	-0.06	0.03	0.02
	(0.68)	(0.94)	(0.18)	(0.18)	(0.28)	(0.37)
FDI squared	-0.01	-0.01	**-0.02****	**-0.02****	-0.02	**-0.02***
	(0.13)	(0.15)	(0.03)	(0.04)	(0.06)	(0.06)
Industry value added	**-0.14***	**-0.08****	-0.06	**-0.17****	-0.04	**-0.07****
	(0.03)	(0.02)	(0.66)	(0.04)	(0.60)	(0.04)
Export	0.08	0.04	-0.06	-0.02	0.04	**0.07****
	(0.09)	(0.21)	(0.38)	(0.71)	(0.14)	(0.02)
F statistics	2.48**	19.19***	10.59***	75.21***	1.95	17.31
	(0.04)	(0.00)	(0.00)	(0.00)	(0.11)	(0.00)
R-squared	0.05	0.02	0.32	0.32	0.08	0.08
Hausman Test	9.99 (0.19)		6.40 (0.49)		7.49 (0.38)	

Note: ***, **, * denote significance level at 1%, 5% and 10%, respectively. P-value in parenthesis.

Considering general technological progress may result in the change of industrial structure and improvement of clean energy, introducing the technological factors into regression model is required. According to the Table 3, the inverted U-shaped pattern only exists in sulfur dioxide equation and such pattern disappears in nitrogen dioxide equation. However, there exists inverted U-shaped pattern between GDP and PM10, which is insignificant in PM10 equation without technological progress. Obviously, the previous estimation results support the following conclusion: the relationship between FDI and sulfur dioxide both exhibits inverted U-shaped pattern under two different circumstances; there is no certain pattern between FDI and PM10; as for nitrogen dioxide, once incorporating technological progress, the quadratic relationship between FDI and NO_2 disappears. Grossman and Krueger (1995) demonstrated that economic growth can't improve environmental quality automatically, inverted U-shaped pattern relied on clear technologies, structural transformation and more severe environmental regulation with economic development.

Table 3. Panel Data: With Technological Progress

	$PM10$		SO_2		NO_2	
	FE (1)	**RE (2)**	**FE (3)**	**RE (4)**	**FE (5)**	**RE (6)**
Intercept	0.08** (0.03)	0.08** (0.02)	0.03 (0.39)	0.01 (0.78)	0.04 (0.29)	0.04 (0.21)
GDP per capita	**-2.56***** (0.00)	**-1.54***** (0.00)	0.48 (0.49)	0.28 (0.64)	-0.60 (0.29)	-0.18 (0.66)
GDP per capita squared	**0.35***** (0.00)	**0.20***** (0.00)	-0.12 (0.26)	-0.08 (0.37)	0.08 (0.36)	0.02 (0.70)
FDI	**0.03**** (0.04)	0.02 (0.12)	-0.02 (0.37)	-0.02 (0.12)	-0.03 (0.19)	-0.02 (0.12)
FDI squared	0.01 (0.24)	0.00 (0.56)	-0.01 (0.14)	**-0.02**** (0.02)	-0.00 (0.69)	-0.10 (0.62)
Industry value added	**-0.49**** (0.01)	**-0.41***** (0.00)	-0.04 (0.81)	0.11 (0.95)	-0.08 (0.69)	0.00 (0.51)
Export	-0.00 (0.87)	-0.00 (0.87)	0.05 (0.23)	0.04 (0.40)	0.01 (0.84)	0.04 (0.95)
F-statistics	8.81*** (0.00)	29.12*** (0.00)	1.47 (0.22)	10.25 (0.11)	1.07 (0.40)	4.60 (0.60)
R squared	0.14	0.13	0.03	0.03	0.01	0.01
Hausman Test	11.89* (0.07)		7.67 (0.36)		4.38 (0.63)	

Note: ***, **, * denotes significance level at 1%, 5% and 10%, respectively. P-value in parenthesis. The intercept term here represents the average technological progress rate.

Regression results of the panel threshold model are presented in Table 4, Table 5 and Table 6, in which Table 4 examines whether the threshold effects are significant through F statistics, Table 5 estimates threshold value for PM10 and SO_2, Table 6 further reports all coefficients of explanatory variables.

The first step of the estimation is to examine the threshold effect. Repeating the bootstrap procedures 400 times, we obtain the approximation of the F-statistic and associated p-value. When the dependent variable is PM10, the reported F-statistic assessing the null hypothesis of no single threshold is 23.17 with a bootstrap p-value of 0.01 allowing us to clearly reject the linear structure of the model. The F-statistic that testing the null hypothesis of no double threshold is 14.09 with a bootstrap p-value of 0.09 which also rejects the null hypothesis, hence there exists two threshold values for PM10 equation. When the dependent variable is SO_2, the F-statistic of no single threshold is 17.10 with a bootstrap p-value of 0.06, and the F-statistic of no double threshold is 6.25 with a bootstrap p-value of 0.63, so there exists only on the threshold value for

SO_2 equation. Finally, when the dependent variable is NO_2, there doesn't exist any threshold effects by examining all the p-values which are consistent with the result of panel data model.

Table 4. Test for Threshold Effects

	PM10	SO_2	NO_2
Test for single threshold			
F_1	**23.17*** **	**17.10***	9.59
P-value	0.01	0.06	0.33
CV	(14.41, 17.18, 23.15)	(15.15, 18.63, 24.84)	(14.15, 17.77, 26.76)
Test for double threshold			
F_2	**14.04***	6.35	5.67
P-value	0.09	0.63	0.69
CV	(13.53, 16.16, 19.63)	(14.94, 17.23, 23.13)	(12.97, 14.83, 19.42)
Test for triple threshold			
F_3	2.11	3.56	2.96
P-value	0.97	0.81	0.81
CV	(11.64, 13.08, 15.24)	(10.10, 11.83, 16.49)	(8.81, 11.08, 13.44)

Note 1: The null hypothesis of test for threshold effects is there is no threshold effect. ***, **, * denotes significance level at 1%, 5% and 10%, respectively. P-value in parenthesis is calculated by 400 bootstrap replications.
Note 2: CV denotes the critical values for 1%, 5% and 10%,

The estimated threshold values of GDP presented in Table 5, and Figure 4 and Figure 5 allow us to clearly check the threshold values which correspond to the $LR(\cdot)$ equals zero. Therefore, the first and second threshold value of PM10 are 2.85 and 4.58 respectively; the threshold value of SO_2 is 2.89 which is close to the first threshold value of PM10. Considering the GDP is taken logarithm before estimating regression model, hence the level values of threshold variable for PM10 are 17287 yuan (approximately 2542 US dollars) and 97514 yuan (approximately 14340 US dollars), and the level value of threshold variable for SO_2 is 17993 yuan (approximately 2646 US dollars). Further analyzing according to Table 6, before GDP reaches the first threshold, the impact of FDI on emission of PM10 is positive (0.096), after GDP locates between 2.85 and 4.58, the impact of FDI on emission of PM10 is negative (-0.0029), then when GDP crosses the second threshold, the impact of FDI on PM10 becomes positive once again, in other words, the impact of FDI on the emission of PM10 exhibits N-shaped pattern rather than U-shaped pattern. Actually, this result is similar to Grossman and Krueger (1995) in which they added cube term in regression equation which implied cube relationship may exist between environmental pollution and GDP per capita. The dependent variable SO_2 only exists single threshold effect, before GDP reaches the threshold value, the impact of FDI on the emission of SO_2 is positive, after GDP reaches the threshold value, the impact of FDI on the emission of SO_2 is negative, this means the relationship between FDI and SO_2 may exist inverted V or U-shaped pattern, which is in accordance with our previous results estimated from two different panel data models.

Table 5. Threshold Estimates

	PM10	SO_2
1st Threshold Value-γ_1	2.85	2.89
2nd Threshold Value-γ_2	4.58	

Next, we will exploit the potential mechanism of FDI on environmental pollution from different channels. Firstly, there is no significant relationship between FDI and nitrogen dioxide, hence the results based on nitrogen dioxide doesn't provide any proofs for Pollution Haven Hypothesis in China. Secondly, our empirical conclusions show that inverted U (or V) -shaped pattern exists between FDI and sulfur dioxide, which also means there doesn't exist Pollution Haven Hypothesis in China. However, the conclusion obtained here is opposite with He (2006) in which the emission of sulfur dioxide increases with the increase of FDI capital stock. Thirdly, the relationship between FDI and emission of PM10 exhibits N-shaped pattern, which means the air quality deteriorates with more inflows of foreign direct investment in the long run, therefore, the Pollution Have Hypothesis may be verified in China under the third scenario.

Table 6. Threshold Effects Estimation

	PM10			SO_2	
	Coefficient	**White SE**		**Coefficient**	**White SE**
GDP per capita	-0.136	0.05	GDP per capita	-0.186	0.10
Industry value added	0.038	0.02	Industry value added	-0.087	0.03
Export	0.041	0.02	Export	0.096	0.04
FDI (GDP≤2.85)	0.096	0.04	FDI (GDP≤2.89)	0.099	0.09
FDI (2.85<GDP≤4.58)	-0.029	0.02	FDI (2.89<GDP)	-0.117	0.03
FDI (4.58<GDP)	0.062	0.02			

Theoretically, the impact of FDI on environmental pollution mainly depends on three aspects: production scale effect, technique effect and regulation effect[4] (He, 2006), in which the impact of production scale effect on environmental pollution is positive, namely production scale enlargement causes more pollution; the impact of technique effect on environmental pollution is negative, besides, the impact of regulation effect on environmental pollution is also negative. So, the impact of FDI on environmental pollution depends on the resultant of three different factors, and the production scale effect dominates in explaining the N-shaped patter of PM10 and other two effects may dominate in explaining SO_2 and NO_2. The main emission sources of SO_2 and NO_2 are industrial emission in China, therefore the Ministry of Environmental Protection has already used the emission of SO_2 and NO_2 as monitor control index since 1995, this may explain

[4] Regulation effect means government enacts law and regulation to guide the investment direction of FDI and avoid FDI flows into highly pollution industries.

why the regulation effect dominates in explaining the emission of SO_2 and NO_2. However, the emission source of PM10 or total suspended particles are multi-faceted, in addition to industrial emission, coal-burning and construction industry both result in a large number of PM10 emission, in the meanwhile, PM10 is still not incorporate as monitor indicator in China, which also explains the occurrence of haze and smog days more frequently in recent years.

Table 7. Summary

Estimation Method	Variables	*PM10*	SO_2	NO_2
Panel Threshold Model	FDI	N-shaped	V (or U)-shaped	-
Panel Data Model	GDP	-	-	-
	FDI	-	Inverted U-shaped	Inverted U-shaped
Correlated Random Trend Model	GDP	U-shaped	-	-
	FDI	-	Inverted U-shaped	-

Note: - represents there doesn't exist significant relationship between environmental pollution and GDP (or FDI).

6. Conclusions

This paper investigates the relationship between FDI and environmental pollution based on 30 provincial capital cities data from China and exploits the possible mechanisms that cause specific pattern between FDI and environmental pollution. According to panel data model with and without technological progress, the relationship between FDI and SO_2 exhibits inverted U-shaped pattern, yet there is no certain pattern between FDI and PM10 under two circumstances, in the meanwhile, the quadratic relationship between FDI and NO_2 disappears once incorporating technological progress. This paper further estimates such relationship by utilizing panel threshold model and concludes the impact of FDI on the emission of PM10 exhibits N-shaped pattern rather than usual U-shaped pattern, the relationship between FDI and SO_2 may exist inverted V or U-shaped pattern and there is no any specific relationship between FDI and NO_2. Theoretically, production scale effect, technique effect and regulation effect brought by FDI jointly determine the impact of FDI on environmental pollution and latter two effects will relieve the environmental deterioration in the long run.

The policy implications here are very clear. Understanding the validity and relationship between FDI and environmental pollution will enforce government to enact more stringent environmental policy by incorporating the FDI as a potential factor. Besides, according to the turning point estimated from panel threshold model, we find out the income per capita in China is still located on the middle level, this may explain the disappearance of EKC. China doesn't reach the turning point estimated by Grossman and Krueger (1995) and Millimet et al. (2003), so the government should take more stringent environmental regulation to avoid environmental deterioration and blindness of flowing foreign direct investment.

In closing, although the estimated relationships between FDI and environmental pollution based on different regression models have a significant distinguish (Table 7), the inverted U-shaped pattern exhibited in EKC only is statistical relationship, it varies with different countries and different datasets, therefore there is no necessary to expect inverted U-shaped relationship will exist under any circumstances. As Common (2001) and Harbaugh et al. (2002) point out, sample selection, control variables and econometric models will obtain different estimated result. In particular, Millimet et al. (2003) also emphasized that EKC is quite sensitive to modeling assumptions, therefore examining such relationship through different methods is necessary.

Appendix

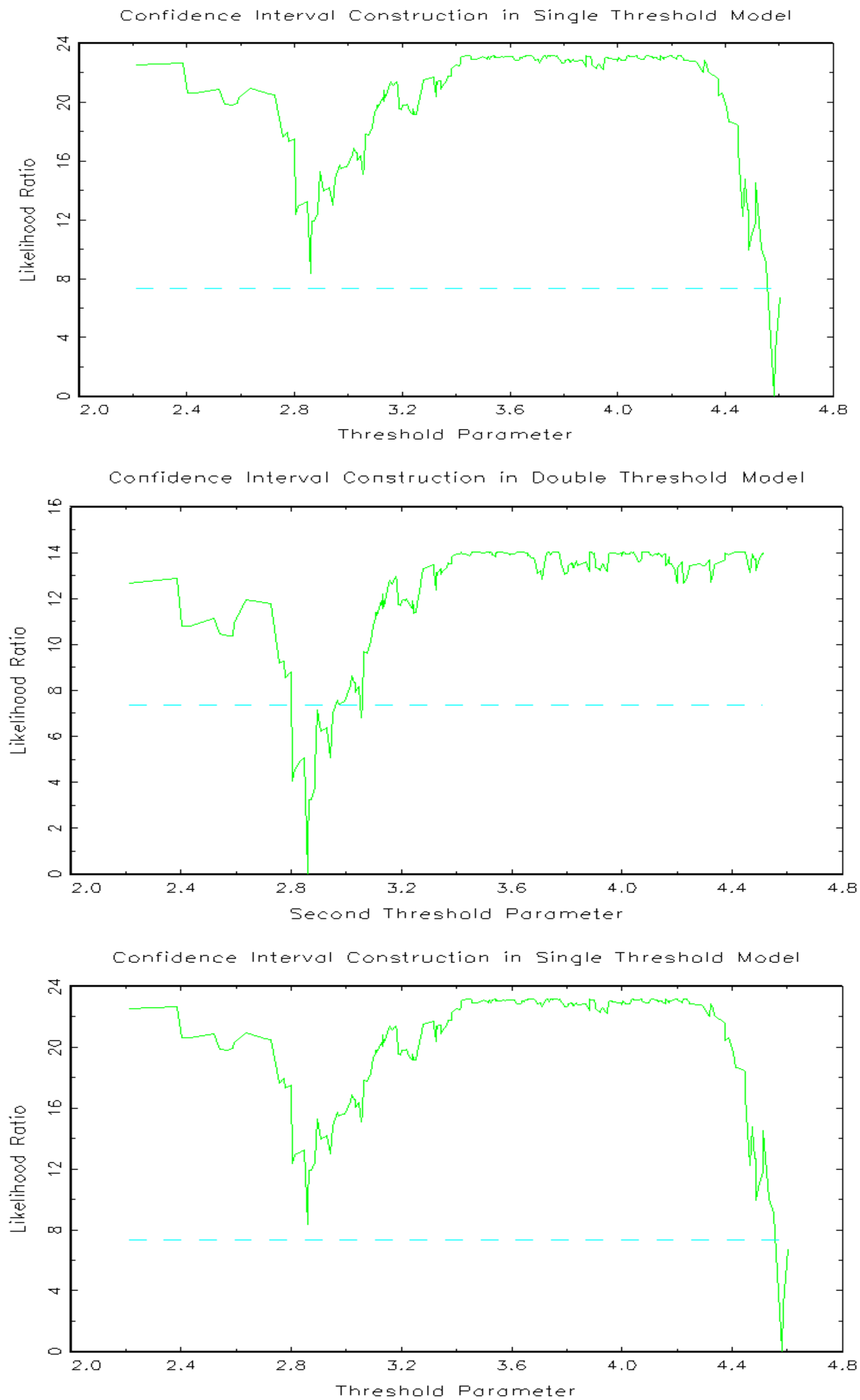

Figure 4 Confidence interval in single, double and triple threshold model (PM10)

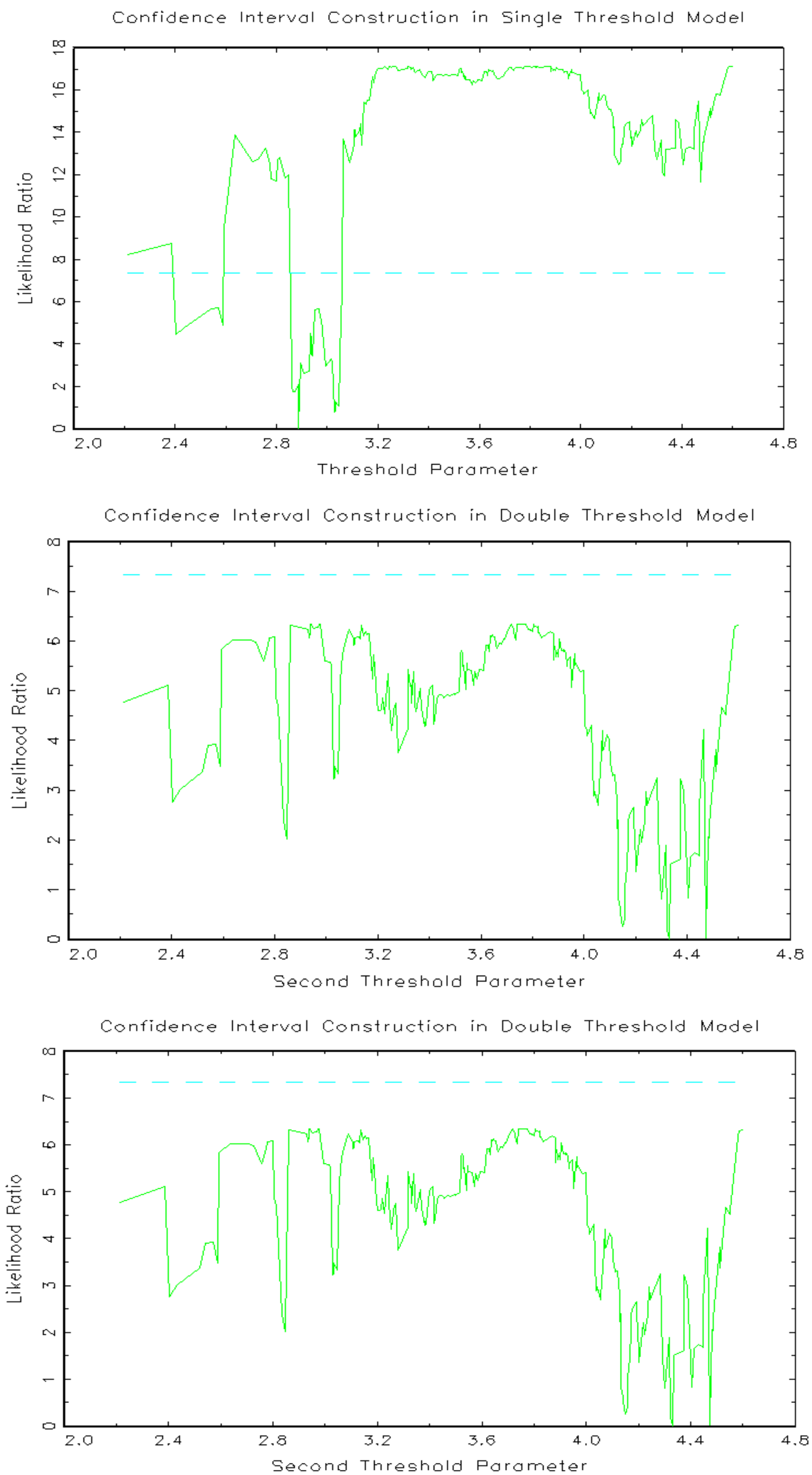

Figure 5 Confidence interval in single, double and triple threshold model (SO_2)

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