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Threshold Effects of Economic Growth on Air Pollution under Regimes of Corruption

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Abstract

This study uses the data from 57 countries during 1995 to 2005 to investigate the effects of economic growth on air pollution under regimes of corruption. A threshold and bootstrap approach is used to test whether the threshold effects exist in a pollution model. Our results show that economic growth has a single threshold effect on CO2 and N2O emissions, while having linear effect on PM10 and CH4 emissions. Increasing in economic growth would raise CO2 emissions in all sample countries, but could decline N2O emissions. Moreover, the effects in countries with high-corruption are greater than those in countries with low-corruption.

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1. Introduction

The relationship between economic growth and environmental quality has been extensively explored in recent years. Economists have found a negative relationship between economic growth and environmental quality in the short term, and a positive relationship in the long term. In other words, at the first stage of economic development, environmental quality deteriorates with economic growth. After reaching a peak point, environmental quality improves with increasing economic growth. In the above economic development, the relationship between economic growth and environmental quality has an inverted-U shape, which is called an environmental Kuznets curve (EKC) (Dachraoui and Harchaoui, 2006; Grossman and Krueger, 1995; Halkos and Tsionas, 2001; Holtz-Eakin and Selden, 1995; Selden and Song, 1994). The EKC illustrates that most developed countries have stringent environmental regulations as well as mature environmental protection technology to reduce environmental pollution. However, most developing countries lack strict environmental regulations and advanced technologies for environmental protection to reduce pollution.

Previous studies (López and Mitra, 2000; Leitão, 2006) have presented evidence showing that the relationship between economic growth and environmental quality is based on corruption. High-corruption countries lack stringent environmental policy and regulation because environmental pollution is assumed as a normal good. Thus, in these countries, there is a negative effect between environmental quality and economic growth. However, in low-corruption countries, there is a positive effect between environmental quality and economic growth because pollution is assumed as an inferior good. The above discussion suggests that corruption plays an important role in an inverted-U shaped relationship between economic growth and environmental pollution.

Previous studies related to the EKC model have used linear, quadratic, or cubic polynomial models rather than a threshold model. In addition, Chang and Chang (2010) proposed the hypothesis of a nonlinear long-run relationship between pollution and corruption. If researchers use a linear model to estimate the environmental effects of economic growth on pollution, they need more restrictions. In addition, the estimated results of previous studies show biases as compared to the threshold model.

Therefore, this study has two goals: to determine the number of thresholds and to estimate the marginal impact of economic growth on environmental pollution in these regimes. The difference from previous studies is to consider the threshold effects in pollution of economic growth, and use one of the four pollutants including CO_2, N_2O, PM_{10} and CH_4 as a proxy for environmental pollution in turn.

2. Literature overview on environmental pollution and corruption

The relationship between economic growth and pollution has been widely discussed in many previous studies. This relation may also be influenced by corruption. The relationship between corruption and environmental quality was discussed by Chang and Chang (2010), Cole (2006), Farzin and Bond (2006), Leitão (2006), López and Mitra (2000), and Zugravu et al. (2008). In addition, previous studies found that corruption would induce lower economic growth rates and laxer environmental policies (Pellegrini and Gerlagh, 2006).

In López and Mitra's (2000) study, they found that corruption could be part of the observed relationship between development and environmental quality. Their results showed that the turning point of the environmental Kuznets curve takes place at income and pollution levels above those corresponding to the social optimum. Cole (2006) found that corruption has a positive and direct effect on per capita emissions of SO_2 and CO_2. It was also found that corruption has an indirect impact on pollutants, and a negative relationship with per capita income.

Previous studies (Fredriksson and Svensson, 2003; Zugravu et al., 2008; Chang and Chang, 2010) supported the finding that corruption could reduce the stringency of environmental policy, but the strength of stringency depends on political instability. In other words, the relationship between environmental regulation and political instability is a negative effect as corruption levels are low, but is a positive effect as corruption levels are high. Although Chang and Chang's (2010) study pointed out that a long-run nonlinear relationship exists between pollution and corruption, their model mainly takes account of threshold effects in the error-correction term and omits economic growth and other macroeconomics variables.

3. The panel threshold regression model

The effect of economic growth on environmental pollution under different regimes of corruptibility can be written as follows:

$$\mathrm{E}_{it} = \mu_i + \mathrm{GDP}_{it} \mathrm{I}(\mathrm{CP}_{it} \le \gamma)\alpha_1 + \mathrm{GDP}_{it} \mathrm{I}(\mathrm{CP}_{it} > \gamma)\alpha_2 + \mathrm{B}'\mathrm{X}_{it} + \varepsilon_{it} \tag{1}$$

$$\mathrm{X}_{it} = \left(\mathrm{EP}_{it} \quad \mathrm{EU}_{it} \quad \mathrm{PO}_{it} \quad \mathrm{AL}_{it} \quad \mathrm{FA}_{it} \quad \mathrm{IV}_{it} \quad \mathrm{LP}_{it}\right)',$$

$$\mathrm{B} = \left(\beta_1 \quad \beta_2 \quad \beta_3 \quad \beta_4 \quad \beta_5 \quad \beta_6 \quad \beta_7\right)'$$

where subscripts *i* and *t* refer to country and year, respectively. E_{it} is an endogenous variable used as a proxy for pollution, which is measured by one of four pollutants such as carbon dioxide (CO_2), suspended particulate matte (PM_{10}), methane (CH_4) and nitrous oxide (N_2O). The GDP variable denotes the economic growth. CP_{it} is an exogenous threshold variable, which is used as a corruption index. X_{it} is a set of control variables, including electric power (EP_{it}), energy use (EU_{it}), total population (PO_{it}), agricultural land (AL_{it}), forest area (FA_{it}), industry value added (IV_{it}), and livestock production index (LP_{it}). $I(\cdot)$ is an indicator function. Variable γ is the threshold value to be estimated; ε_{it} is an error term and is generated as i.i.d. $N(0, \sigma^2)$; α_1, α_2 and β_j are parameters to be estimated.

This study adopts Hansen's (1999) approach to determine whether threshold effects exist in the pollution model, and the number of thresholds. If multiple thresholds exist in Equation (1), then Equation (1) can be extended to multiple thresholds and written as follows

$$E_{it} = \mu_i + GDP_{it} I(CP_{it} \le \gamma_1)\alpha_1 + GDP_{it} I(\gamma_1 < CP_{it} < \gamma_2)\alpha_2 + GDPI(CP_{it} \ge \gamma_2)\alpha_3 + B'X_{it} + \varepsilon_{it} \quad (2)$$

This paper tests the null hypotheses of nonlinearity and single threshold effect by the likelihood ratio (LR) statistic. The distribution of the LR statistic is nonstandard since the pollution model contains unidentified nuisance parameter γ. In this study, Hansen's (1999) bootstrap approach was applied to calculate the asymptotic distribution and *p*-values based on 1000 iterations.

4. Data sources and results

4.1 Data sources

This study adopts the data from 57 countries (in Table A of the Appendix) which are observed over the period from 1995 to 2005. GDP and control variables are obtained from the World Development Indicators of World Bank. Air pollution variables are obtained from United Nations Statistics Division. In addition, corruption is obtained from American Heritage Foundation, and scaled from 0 (defined as almost corrupt) to 100 (defined as almost clean). All variables are summarized in Table 1, and their descriptive statistics are reported in Table 2.

<Tables 1 and 2 here>

4.2 Results of unit root test

The stationarity test in this study used Levin, Lin, and Chu's (2002) panel unit root test. This approach overcomes the low-power problem of the conventional test because Levin, Lin, and Chu's (2002) test considers the cross-section trend. The results of unit root test are reported in Table 3, which shows that the null hypothesis of stationarity can be rejected in level and difference at the 1% significance level. This implies that the variables in the level are stationary.

<Table 3 here>

4.3 Results of GDP on CO_2 emissions

The threshold tests are shown in Table 4 in which null hypothesis of no threshold is rejected at the 1% significance level. By contrast, null hypotheses of single and double thresholds could not be rejected at the same level. This implies that the effect of economic growth on CO_2 emissions has a single threshold effect. In a single-threshold effect, threshold value is 88.7 and its asymptotic 90% confidence interval is between 88.6 and 88.9. Such a finding shows that there are two regimes (i.e. $CP_{it} > 88.7$ and $CP_{it} \leq 88.7$) in CO_2 emissions effect. Regimes $CP_{it} > 88.7$ and $CP_{it} \leq 88.7$ are referred to low-corruption and high-corruption, respectively.

<Table 4 here>

In Table 5, electric power consumption, energy use, agricultural land and industry value added are statistically significant at the 1% significance level. However, livestock production index, forest area, and population are statistically insignificant at the same level. Although the effects of GDP per capita on CO_2 emission have a positive and significant at the 1% significance level in all regimes, these effects have different sizes depending on corruption levels. It implies that increases in economic growth will increase CO_2 emissions, but this effect in high-corruption countries is greater than that in low-corruption countries. This finding shows that low-corruption countries pay more attention to environment problem when economic growth increases.

<Table 5 here>

4.4 Results of GDP on N_2O emissions

The threshold tests are shown in Table 6, where null hypothesis of no threshold could be rejected at the 10% significance level while null hypotheses of single and double thresholds could not be rejected at the same level. This implies that the effect of economic growth on N_2O emissions has a single threshold effect. The threshold value is 83.0 and the asymptotic 90% confidence interval is between 77.9 and 90. Such a finding shows that there are two regimes (i.e. $CP_{it} > 83.0$ and $CP_{it} \leq 83.0$) in N_2O emissions effect. Regimes $CP_{it} > 83.0$ and $CP_{it} \leq 83.0$ are referred to low-corruption and high-corruption, respectively.

<Table 6 here>

In Table 7, population has a significant and positive effect on N_2O emissions at 1% significance level while other variables have insignificant effect at the same level. Moreover, effects of GDP per capita on N_2O emissions have a significant and negative effect at the 5% significance level in all regimes. However, these effects have different sizes depending on different corruption levels. Countries with low corruption have smaller effect than countries with high corruption. The finding of N_2O emissions is the same as CO_2, in which low-corruption countries pay more attention to environment problem as economic growth increases. Thus, the results confirm Fredriksson and Svensson's (2003) and Zugravu et al.'s (2008) findings.

<Table 7 here>

4.5 Results of GDP on PM_{10} and CH_4 emissions

In Table 8, the hypotheses of no threshold, as well as single and double thresholds could not be rejected at the 10% significance level. It implies that the effect of economic growth on PM_{10} and CH_4 emissions is linearity. This study applies ordinary least squares to estimate the effect of GDP on PM_{10} and CH_4 emissions, and reports the result in Table 9. In this table, the effects of corruption and industry value added on PM_{10} emissions have insignificant at the 10% significance level while corruption has a significant and negative effect at the same level. It implies that decreases in corruption can reduce PM_{10} emissions.

<Tables 8 and 9 here>

Energy use and population has a significant and positive effect on PM_{10} and CH_4 emissions at the 1% significance level. It implies that increases in energy use and population may increase PM_{10} emission. However, agricultural land, livestock production index, forest area, electric power consumption and GDP per capita have significant and negative effects on PM_{10} emissions at the 1% significance level. This finding shows that increases in agricultural land, livestock production and electric power consumption could reduce PM_{10} emission. In addition, increase in GDP per capita also reduces PM_{10} emissions.

On the other hand, electric power consumption and corruption have a significant and negative effect on CH_4 emissions at the 1% significance level. This indicates the more corrupt countries may decrease CH_4 emissions. Increases in electric power consumption could reduce CH_4 emissions while increases in forest area would increase its emissions. The reason is that electric power consumption includes solar power, wind power, wave power, geothermal power, and tidal power. Thus, if we increase renewable electricity consumption, energy use can be replaced by renewable electricity and air pollution can be reduced subsequently.

5. Conclusion

This study has the following results for effects of economic growth on air pollution under regimes of corruption levels. First, there is a single-threshold effect of economic growth on CO_2 and N_2O emissions based on our sample that is split into two regimes identified as high- and low-corruption countries. However, PM_{10} and CH_4 emissions have no threshold effect, implying linear effects of economic growth on PM_{10} and CH_4 emissions. Second, increasing in economic growth will rise CO_2 emissions in all sample countries. However, increasing in economic growth will decline N_2O emissions in all sample countries. Although increasing economic growth will decline N_2O emissions, the effect in high-corruption countries is greater than that in low-corruption countries. The limitations of this study are that the available data is limited, and that the model excludes endogeneity of the threshold variable.

Appendix

Table A: Sample countries

Albania, Argentina, Australia, Austria, Botswana, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Cote d'Ivoire, Czech Republic, Denmark, Egypt, El Salvador, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, India, Indonesia, Ireland, Italy, Japan, Jordan, Kenya, Korea, Rep., Malaysia, Netherlands, Nicaragua, Norway, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Senegal, Singapore, Slovak Republic, Slovenia, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Trinidad and Tobago, Tunisia, United Kingdom, United States of America, Vietnam.

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Table 1 Variables description

Variables	Definition	Units
PM_{10}	Particulate matter is used to describe particles of 10 micrometers [a]	Micrograms per cubic meter
CH_4	Methane [a]	Gg (Giga gram)
N_2O	Nitrous oxide [a]	Gg (Giga gram)
CO_2	Carbon dioxide which is a major greenhouse gas emissions [b]	Metric tons per capita
EP	Electric power consumption [b]	Kilowatt hour per capita
EU	Energy use [b]	Kg of oil equivalent per capita
PO	Total population [b]	People
AL	Agricultural land [b]	% (in total land area)
FA	Forest area [b]	% (in total land area)
IV	Industry value added [b]	% (in GDP)
LP	Livestock production index which includes meat and milk [b]	An integration index
GDP	Gross domestic product [b]	Metric tons per capita
CP	The degree of corruption [c]	This index is scaled from 0 (defined as almost corrupt) to 100 (defined as almost clean).

Notes: a. Data source is from United Nations Statistics Division. b. Data source is from World Development Indicators of World Bank. c. Data source is from American Heritage Foundation.

Table 2 Descriptive statistics

Variables	Observations	Mean	Standard error	Minimum	Maximum
CO_2	627	5.81	4.96	0.18	24.67
PM_{10}	627	48.47	30.26	11.87	175.03
CH_4	627	3978.50	9027.16	15.46	61326.9
N_2O	627	107.69	225.57	0.48	1338.05
EP	627	4593.79	5260.70	97.25	28213.31
EU	627	2694.81	2298.00	222.87	12219.03
PO	627	75528346	211060774	268000	1304500000
AL	627	40.99	19.60	1.16	82.23
FA	627	33.27	18.89	0.05	73.86
IV	627	30.78	8.73	0.35	59.34
LP	627	100.99	11.69	63.64	178.48
GDP	627	10480.05	11451.17	305.24	40617.83
CP	627	51.68	25.18	10.00	100.00

Table 3 Results of panel unit root test

Variable	Level	Difference
	Test-statistic (*p*-value)	Test-statistic (*p*-value)
CO_2	-6.85 (0.0000) ***	-11.12 (0.0000) ***
PM_{10}	-8.65 (0.0000) ***	-13.51 (0.0000) ***
CH_4	-15.04 (0.0000) ***	-23.38 (0.0000) ***
N_2O	-9.85 (0.0000) ***	-23.08 (0.0000) ***
EP	-4.08 (0.0000) ***	-14.19 (0.0000) ***
EU	-6.04 (0.0000) ***	-11.52 (0.0000) ***
PO	-20.70 (0.0000) ***	-20.23 (0.0000) ***
AL	-3.00×10^{12} (0.0000) ***	-4.18 (0.0000) ***
FA	-5.79 (0.0000) ***	-4.93 (0.0000) ***
IV	-6.16 (0.0000) ***	-9.77 (0.0000) ***
LP	-15.29 (0.0000) ***	-15.34 (0.0000) ***
GDP	-6.02 (0.0022) ***	-17.91 (0.0000) ***

Notes: The *** denotes significant at the 1% significance level. The test equations include constant and linear trend. Null hypothesis: series has a unit root.

Table 4 Threshold test of CO_2 emissions

Test for no threshold	
F1	62.6060
p-value	0.007***
Critical values (10%, 5%, 1%)	(25.57, 33.24, 49.66)
Test for single threshold	
F2	21.3998
p-value	0.1567
Critical values (10%, 5%, 1%)	(25.81, 33.70, 46.77)
Threshold value	88.70
Test for double threshold	
F3	15.6289
p-value	0.247
Critical values (10%, 5%, 1%)	(23.82, 40.24, 54.98)
Threshold values	(88.70, 92.60)

Notes: The null hypothesis of nonlinearity is tested by the likelihood ratio (LR) statistic. The *** denotes significant at the 1% significance level. Bootstrap *p*-value is generated on the basis of 300 iterations.

Table 5 Results of threshold effect on CO_2 emissions

Variables	Coefficient	White standard error
EP_{it}	$-6.6\times10^{-4***}$	1.0×10^{-4}
EU_{it}	$2.2\times10^{-3***}$	2.6×10^{-4}
AL_{it}	$4.5\times10^{-2***}$	1.7×10^{-2}
LP_{it}	7.3×10^{-4}	5.0×10^{-3}
IV_{it}	$6.7\times10^{-2***}$	2.2×10^{-2}
FA_{it}	1.5×10^{-2}	1.7×10^{-2}
PO_{it}	1.0×10^{-5}	1.7×10^{-5}
$GDP_{it}I(CP_{it} \leq 88.7)$	$1.7\times10^{-4***}$	5.5×10^{-5}
$GDP_{it}I(CP_{it} > 88.7)$	$1.3\times10^{-4***}$	5.6×10^{-5}

Note: The *** denotes significant at the 1% significance level.

Table 6 Threshold test of N_2O emissions

Test for no threshold	
F1	15.4970
p-value	0.09^{*}
(10%, 5%, 1% critical values)	(15.45, 22.04, 257.53)
Test for single threshold	
F2	2.1161
p-value	0.88
(10%, 5%, 1% critical values)	(28.40, 31.08, 44.84)
Threshold value	83.0
Test for double threshold	
F3	1.8607
p-value	0.84
(10%, 5%, 1% critical values)	(12.71, 16.96, 24.48)
Threshold values	(19.40, 83.0)

Notes: The null hypothesis of nonlinearity is tested by the LR statistic. * denotes significant at the 10% significance level. Bootstrap *p*-value is generated on the basis of 300 iterations.

Table 7：Results of threshold effect on N_2O emissions

Variables	Coefficient	White standard error
EP_{it}	2.3×10^{-3}	7.5×10^{-4}
EU_{it}	-6.4×10^{-4}	2.2×10^{-3}
AL_{it}	-2.1×10^{-1}	5.3×10^{-1}
LP_{it}	-6.2×10^{-2}	2.3×10^{-1}
IV_{it}	1.1×10^{-1}	8.1×10^{-2}
FA_{it}	1.0×10^{-1}	4.2×10^{-1}
PO_{it}	2.4^{***}	2.8
$GDP_{it}I(CP_{it} \leq 83)$	$-3.2\times10^{-3**}$	8.4×10^{-4}
$GDP_{it}I(CP_{it} > 83)$	$-2.2\times10^{-3**}$	8.2×10^{-4}

Note: *** and ** denote significance at the 1% and 5% significance level, respectively.

Table 8 Threshold tests of PM_{10} and CH_4 emissions

Test for no threshold	PM_{10}	CH_4
F1	4.2118	7.8477
p-value	0.956	0.697
(10%, 5%, 1% critical values)	(31.16, 42.66, 62.55)	(33.41, 47.80, 110.52)
Test for single threshold	PM_{10}	CH_4
F2	2.6874	4.3169
p-value	0.99	0.871
(10%, 5%, 1% critical values)	(22.59, 27.47, 38.40)	(103.56, 192.35, 448.89)
Threshold value	91.20	81.40
Test for double threshold	PM_{10}	CH_4
F3	3.0973	3.0145
p-value	0.98	0.925
(10%, 5%, 1% critical values)	(17.13, 19.44, 29.67)	(37.21, 69.54, 233.69)
Threshold values	(27.30, 91.20)	(50.80, 81.40)

Notes: The null hypothesis of nonlinearity is tested by the LR statistic. Bootstrap *p*-value is generated on the basis of 300 iterations.

Table 9 Results of PM_{10} and CH_4 emissions

	Dependent variable: PM_{10} emissions		Dependent variable: CH_4 emissions	
Variables	Coefficient	Standard error	Coefficient	Standard error
Constant	$1.7\times10^{2***}$	1.2×10^{1}	1.7×10^{3}	1.6×10^{3}
EP	$-3.2\times10^{-2***}$	3.6×10^{-3}	$-2.1\times10^{-1***}$	7.1×10^{-2}
EU	$3.7\times10^{-3***}$	9.0×10^{-4}	1.2^{***}	1.4×10^{-1}
AL	$-6.2\times10^{-1***}$	5.3×10^{-2}	-1.2×10^{1}	9.6
LP	$-2.4\times10^{-1***}$	7.6×10^{-2}	-5.3×10^{-1}	1.4×10^{1}
IV	2.3	1.5	-3.3×10^{1}	2.0×10^{1}
FA	$-3.3\times10^{-1***}$	5.1×10^{-2}	$2.8\times10^{1***}$	9.0
GDP	-7.6^{***}	1.4	1.0×10^{-4}	3.1×10^{-2}
PO	$2.0\times10^{-4***}$	4.2×10^{-5}	3.8^{***}	7.9×10^{-2}
CP	-3.3×10^{-3}	7.0×10^{-4}	$-4.4\times10^{1***}$	1.1×10^{1}

Note: *** denotes significance at the 1% significance level.