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Environmental Kuznets Curve: Evidences from Developed and Developing Economies

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Abstract

Previous studies show that the environmental quality and economic growth can be represented by the inverted U curve called Environmental Kuznets Curve (EKC). In this study, we conduct empirical analyses on detecting the existence of EKC using the five common pollutants emissions (i.e. CO_2, SO_2, BOD, SPM_{10}, and GHG) as proxy for environmental quality. The data spanning from year 1961 to 2009 and cover 40 countries. We seek to investigate if the EKC hypothesis holds in two groups of economies, i.e. developed versus developing economies. Applying panel data approach, our results show that the EKC does not hold in all countries. We also detect the existence of U shape and increasing trend in other cases. The results reveal that CO_2 and SPM_{10} are good data to proxy for environmental pollutant and they can be explained well by GDP. Also, it is observed that the developed countries have higher turning points than the developing countries. Higher economic growth may lead to different impacts on environmental quality in different economies.

Keywords: Economic growth, environmental quality, Environmental Kuznets Curve (EKC).

1 Introduction

The environmental Kuznets curve (EKC) hypothesis indicates the inverted U-shape on the relationship between the incomes per capita or the gross domestic product (GDP) and the environmental degradation (emissions or pollutants). It is established by Kuznets in 1955's, and it has been referred to him since 1990's on the study of North American Free Trade Agreement (NAFTA), under the Environmental Kuznets Curve (EKC) (AkbostancI *et al* ., 2009).

There is a clear relationship between income level and the environmental quality reported by the World Development Report (World Bank, 1992). That relationship illustrates the inverted "U" shape, started with positive trend and levelled off in the peak, and then it will decline. A reasonably clear pattern has emerged from numerous empirical studies on the relationship between the income per capita and emission pollutions. (De Groot *et al*., 2004).

In this study, we intend to investigate if the EKC is detected in two groups of economies, i.e. developed and developing economies by using different data as proxy of environmental quality. The second purpose is to compare the influence of the emissions on the economic growth between developed and developing economies. Our results reveal that EKC does not hold in all countries and that using different data to proxy for environmental emissions produce different results. There are evidences of EKC in both groups of economies using CO_2 and SO_2 as proxy for environmental emissions. Higher economic growth may lead to different impacts on environmental quality in different economies/ countries.

The remaining parts of the paper are organized as follows: Section two is the literature review of EKC; Section three the theory and conception of EKC; Section four explains the methodology which we had applied; Section five discusses the findings and the final section is the conclusion.

2 The environmental Kuznets curve (EKC)

The environmental Kuznets curve is a curve that detects the relationship between the economic growth and the environmental equality. The inverse relationship between economic growth and environment shows that each increasing of income level leads to degradation of the environment.

Bai and Imura (2000) classify the urban environmental issues into three types. The first type of urban environmental issues shows a negative relationship between environmental quality and economic growth as shown in Figure 2.2 (a), and this trend remains negative until it reaches the significant low levels. The relationship between economic growth and environmental quality may be positive because the increasing income will lead to additional resources and provide new public service.

The second category of urban environmental issues is the so called industrial pollution-related issues which focused on air pollutants such as sulphur dioxide and suspended particular matter. The relationship of the industrial pollutant and growth can be represented by the inverted U curve or Environmental Kuznets curve (see Figure 2.2b). Most of the pollutants as (SO_2, CO_2, and SPM_{10}) support the environmental Kuznets curve hypothesis, while the turning points are different using different pollutants.

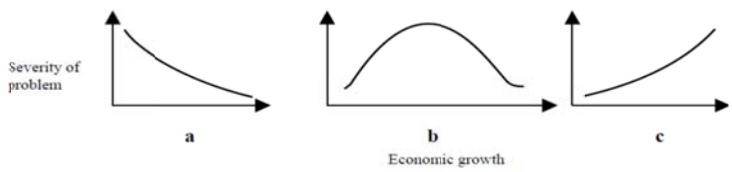

Figure 2.2 Behaviour of each type of urban environmental issue in relation with economic growth. **Source:** adapted from World Bank 1992, 11.

The third type of urban environmental issue shows worsening environmental condition trend with the raising of incomes (see Figure 2.2.c). The relationship was observed in many environmental indicators of consumption as council waste per capita, fuel and energy demand (World Bank, 1992). The future trend is unbounded and the turning point is not obvious (Bai and Imura, 2000).

Empirical findings

Many studies focused on environmental EKC. These results report different outcomes, some reveal EKC but some not. The studies reveal inverted U curve include Cialani (2007), Dinda, Coondoo and Pal (2000), Miah, Masum, and Koike (2010), Dinda (2004), Richard and He (2009), Shahbaz, Jalil and Dube (2010), Tamazian and Rao (2009),Omotor (2011), Diao, Zeng and Tam (2008), Halkos (2003), Dijkgraaf and Vollebergh (2005). On the other hand, some studies does not support the existence of EKC curve, such as Akbostanci (2008), Ghosh (2010), Clement and Meunie (2008), De-Groot, Withagen and Minliang (2004), Coondoo and Dinda (2001). These studies reveal different relationship other than inverted U curve. The studies that report negative relationship between economic growth and environmental quality include Liu, (2005), Roca *et al*., (2001). The studies that show the N-shaped curve between environmental quality and economic growth include AkbostancI *et al*., (2009), Martinez-Zarzoso and Bengochea-Morancho (2004).

He and Richard (2010) focused their study in Canada using annually data of carbon dioxide (CO_2) and gross domestic product (GDP) per capita for the period of 1948 to 2004. The result from semi parametric model reveals evidence of EKC (an inverted U) between GDP per capita and CO_2 emission per capita. However there is no evidence of EKC reported by flexible estimation methods. The relationship between GDP and CO_2 emissions per capita is monotonically increasing only when GDP is nonlinearly.

Moreover Orubu and Omotor (2011) focused the analysis in 47 African countries using annual data which spanned from 1990–2002. Their results support the EKC between the income per capita and the suspended particulate matter (SPM) pollutants. While by using other data to different pollutant such as the organic water pollutants (OWP), the output do not show an evidence of EKC, but a positive relationship between OWP and GDP (Orubu and Omotor, 2011).

Clement and Meunie (2008) focused their study in 83 countries. The data is spanning from 1988-2003. Applying the linear panel models, least squares with dummy variables estimator (LSDV) and the random-effects model, the results show that the decline of inequality does not have effect on the environment. The relationship between the social inequality and the pollution is not universal but it depends on both of the pollutant.

EKC – Model specification

The standard equation of EKC can be written as follows:

$$\ln\left(E/P\right)_{it} = \alpha_i + \gamma_t + \beta_1 \ln\left(GDP/P\right)_{it} + \beta_2 \left(\ln\left(GDP/P\right)\right)^2_{it} + \varepsilon_{it}$$

where ln(E/P) represents the natural logarithms of the emission per capita, E the emission pollutants, P the population, GDP/P the income per capita while β_1 & β_2 are the slopes of the model. α_i and γ_t are the intercept parameters. *i* represents the cross-section of countries or regions and *t* denotes the years or periods of time series. ε_{it} is the error occurred by cross-section (countries) or by years on time series, some studies called it a stochastic error term. The trend of the relationship between the pollutants and the GDP can be determined by the following forms (Dinda, 2004):

a) $\beta_1 = \beta_2 = 0$ Indicates that no relationship between GDP and E/P.
b) $\beta_1 > 0$ & $\beta_2 = 0$, represents increasing relationship or a linear relationship between GDP and E/P.
c) $\beta_1 < 0$ & $\beta_2 = 0$, refers decreasing relationship between GDP and E/P.

d) $\beta_1 > 0$ and $\beta_2 < 0$, denotes an inverted-U-shaped relationship, EKC curve.
e) $\beta_1 < 0$ and $\beta_2 > 0$, illustrate U-shaped relationship.

The turning points (*TP*) can be calculated by $Y(TP) = \exp(-\beta_1 / 2\beta_2)$.

3 Data and methodology

Source of data

In our study we are interested to examine the relationship between economic growth which is measured by GDP and five of the most popular pollutants (SO_2, CO_2, GHG, BOD, and SPM_{10}). The study is focused on 40 countries which can be divided into two categories, developed and developing economies as defined by World Bank. Developed economies consist of Austria, Belgium, Canada, Denmark, Estonia, Finland, France, Greece, Ireland, Italy, Japan, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Republic Slovak, Spain and Sweden. Developing economies include Azerbaijan, Bahamas, Bulgaria, Eritrea, Ethiopia, Hungary, Iran, Jordan, Korea, Republic Kyrgyz, Latvia, Lithuania, Mauritius, Moldova, Oman, Poland, Romania, South Africa, Tajikistan, and Turkey. The data take the range from 1960 to 2011. All data are collected from the World Bank website, except SO_2 emission is collected from Anthropogenic Sulfur Dioxide Emissions: 1850-2005 website.

The proxy of economic growth, gross domestic product per capita (GDP) is measured by USD$. Whilst the dependent variables are the pollutants consist of CO_2 emissions measured by metric tons per capita, SO_2 emissions collected using a bottom-up mass balance method, calibrated to country-level and SPM_{10} suspended particulate matter micrograms per cubic meter, refer to less than 10 microns in diameter. Other pollutants include GHG net greenhouse gases emissions/removals refer to changes in atmospheric levels of all greenhouse gases attributable to forest and land-use change activities. The data was collected in million metric tons. The other pollutant is BOD organic water pollutant kg per day which is measured by biochemical oxygen demand, refer to the amount of oxygen that bacteria in water will consume in breaking down waste. This is a standard water-treatment test for the presence of organic pollutants.

Estimation approach – panel data analysis

We apply the panel data analysis to detect the EKC curve between the pollutants and the economic growth. The turning points of the EKC curve is calculated based on the estimation result. Panel data helps to detect the dynamics of changes in short time series. It provides more powerful regression by considering the place (spatial) and the time (temporal) dimensions of the data (Schmidheiny and Basel, 2011). The standard panel data model can be written in a general form as:

$$y_{\text{it}} = \alpha + \beta' X_{it} + \varepsilon_{\text{it}}$$

i indicates the country and *t* indicates the temporal year. α is a constant term, β is a vector of coefficients and ε_{it} is the error term. There are two types of panel models, i.e. fixed effects (FE) model and the random effects (RE) model. The fixed effects model has the following form:

$$y_{it} = \alpha + \beta' X_{it} + \varepsilon_{it}$$
$$\varepsilon_{it} = \mu_i + u_{it}$$

where μ_i are time-invariant or fixed over time. On the other hand, under a random effects specification, the mean error μ_i and random error u_{it} are randomized. Both the error components are assumed to be random variables with normal distribution which is identically independent distributed (i.i.d.). These error components are uncorrelated with the independent variables (Yaffee, 2003

$$u_{it} \sim N\left(0, \sigma_u^2\right)$$
$$\mu_{it} \sim \left(0, \sigma_\mu^2\right)$$

Diagnostic tests

Hausman test is used to compare between the two estimated models, fixed effects model (FE) and random effects model (RE). It is considered as Wald χ^2 test with (k-1) degrees of freedom where k is the number of regressors in the model. The equation of Hausman statistic is

$$m = q' \left[\text{var}\ (\beta_{FE}) - \text{var}\ (\beta_{RE})\right]^{-1} q$$

where $q = \beta_{\text{FE}} - \beta_{\text{RE}}$. Under random effects model, the matrix difference in brackets is positive, as the random effects estimator is efficient and any other estimator has a larger variance. Under the null hypothesis, both FE and RE models are consistent with RE is more efficient. Under the alternative hypothesis, FE is more efficient than RE. Therefore, the rejection of null hypothesis will suggest for the choice of FE model (Yaffee, 2003).

Redundant test is used to compare between the fixed effects model and the pooled model. The main purpose to conduct this test is to identify if pooled OLS model is sufficient to apply or one should include the fixed effects in the model. We assume that the pooled regression model is the baseline for the comparison without any effect. The test statistic is defined by:

$$F_{(n-1, nT-n-K)} = \frac{\left(R_{LSDV}^2 - R_{pooled}^2\right) / (n-1)}{\left(1 - R_{LSDV}^2\right)(nT - n - K)}$$

where *LSDV* represents the fixed effect model (least square dummy variable model), *pooled* indicates the pooled model, *T* indicates the total number of temporal observation and n is the number of countries. K is the number of regressors. The rejection of the test will suggest for the opt of FE model (Greene and Zhang, 2003).

4 Results

Diagnostic tests

The results of Hausman test are summarized in Table 2. The results suggest for the adoption of FE model in most cases as the test is significant. The results suggest RE model for the pollutants of BOD and GHG in developed economies and SO_2 and GHG in developing economies.

Table 2 Hausman test

Environmental Variables	Developed countries		Developing countries	
	Cross-section effects	Period effects	Cross-section effects	Period effects
CO_2	15.871702***	337.103278***	24.338245***	158.342709***
SO_2	0.635109	23.451892***	4.556123	2.557216
BOD	4.174321	2.701149	7.212757**	9.435261**
Spm_{10}	13.033083***	23.415122***	12.080661***	56.234574***
GHG	1.980329	0.039276	4.152640	2.055772

The numerical values are the test statistics which are significant at 1% level ***; at 5% level ** and at 10% level *.

The next step after selecting the FE model is to compare between FE and pooled OLS model by using the redundant test which based on Chi-square value. In some cases the redundant test is omitted because the Hausman test has identified the practical case to apply the random effects model. The results of that test are summarized in Table 3. The results of CO_2 emission shows that all test values are significant at 1% level signifying the use of FE with exception of the use of SO_2 and SPM_{10} in period effects model for developed economies, and the use of BOD in period effects model for developing economies.

Table 3 Redundant Test

Environmental Variables	Developed countries		Developing countries	
	Cross-section effects	Period effects	Cross-section effects	Period effects
CO_2	1714.421505***	318.710888***	792.583429***	171.484652***
SO_2	--------------	31.347694	--------------	--------------
BOD	--------------	--------------	1028.089790***	14.433997
Spm_{10}	970.438523***	26.442816	865.974302***	59.749088***
GHG	--------------	--------------	--------------	--------------

The numerical values are the test statistics which are significant at 1% level ***; at 5% level ** and at 10% level *.

Estimation results

The EKC equations to be estimated are summarized as below:

Cross section effects

$$\ln(\text{emission})_{it} = \alpha_i + \beta_1 \ln(\text{GDP})_{it} + \beta_2 \left(\ln(\text{GDP})\right)^2_{it} + \varepsilon_{it}$$

Period effects

$$\ln(\text{emission})_{it} = \gamma_t + \beta_1 \ln(\text{GDP})_{it} + \beta_2 \left(\ln(\text{GDP})\right)^2_{it} + \varepsilon_{it}$$

After deciding the models, we continue with the estimation. The fixed effects model is estimated using GLS method, then it will call robust model. The results of estimations are summarized in Table 4. Cross section effects model can explain the data better than period effects specification as the R^2 and R^2 adjusted are higher. CO_2 and SPM_{10} are good proxies for environment variables in EKC analysis as these variables can be explained more than 90% by the explanatory variables of GDP for both developed and developing countries. BOD and GHG have weak relationship with GDP as the later has low explanation on the movement of these two variables.

It is observed in CO_2 estimated model that for each 1% increase in GDP leads to greater environmental degradation of about 2% and it followed by greater improvement in environmental quality of 0.1% in both developed and developing countries. However SPM_{10} has inverse situation. Using SO_2 and CO_2 as proxy for environmental variables, we detect the inverted U curve of EKC with higher turning point in EKC. GDP has the largest impact on SO_2. The relationship follows the inverted U curve of EKC. The impact of GDP on SO_2 is as high as double on CO_2 in the case of developed countries. In contrary, the impact of GDP is the highest on CO_2 in developing countries.

Table 4 Estimation Models

Environmental Variables	The Estimation	Developed countries		Developing countries	
		Cross-section effects	Period effects	Cross-section effects	Period effects
		Best Model Fitted The Panel Data			
CO_2	Coefficients	ROBUST	ROBUST	ROBUST	ROBUST
	α	-7.530004***	-16.52338***	-8.041289***	-18.33956***
	β1	2.037346***	3.557173***	2.301785***	4.533579***
	β2	-0.106182***	-0.163081***	-0.140111***	-0.250703***
	Statistics Tests				
	R-squared	0.928605	0.555073	0.932840	0.764520
	Adjusted R2	0.926907	0.529024	0.930486	0.743864
	D-W Test	0.180929	0.036579	0.155153	0.075373
SO_2	Coefficients	RE	Pooled Model	RE	RE
	α	-15.43884***	-13.64239***	-2.689747**	-19.84619
	β1	5.353396***	4.918876***	1.586990***	6.718175
	β2	-0.329871***	-0.303149***	-0.069812***	-0.438395
	Statistics Tests				
	R2	0.673952	0.138805	0.322622	0.197397
	R2 adjusted	0.673191	0.136795	0.320265	0.194605

Table 4 Estimation Models (continued)

	D-W Test	0.123431	0.009218	0.083423	0.015874
BOD	Coefficients	RE	RE	Robust	Pooled
	α	13.31355***	-50.36216***	11.19003***	-1.656949
	β1	-0.298448	12.60292***	-0.059833	2.976390***
	β2	0.009914	-0.641337***	-0.000472	-0.170236***
	Statistics tests				
	R2	0.044871	0.099278	0.995321	0.297270
	R2 adjusted	0.038168	0.092957	0.994964	0.291986
	D-W Test	0.336088	0.010086	0.352695	0.011655
SPM_{10}	Coefficients	Robust	Pooled	Robust	Robust
	α	12.25923***	-6.340482***	5.868402***	10.25727***
	β1	-1.394569***	2.172714***	-0.093243	-1.659663***
	β2	0.048445***	-0.121469***	-0.021575***	0.104239***
	Statistics tests				
	R2	0.981089	0.131876	0.962086	0.290582
	R2 adjusted	0.979973	0.126754	0.959778	0.249575
	D-W Test	0.553606	0.022820	0.368005	0.028588
GHG	Coefficients	RE	RE	RE	RE
	α	-180.4440***	489.9386**	-83.45567**	82.63598
	β1	36.48800***	-97.46292**	20.01014**	-23.62623
	β2	-2.039359***	4.619096**	-1.343144**	1.333800
	Statistics tests				
	R2	0.118222	0.062460	0.136834	0.017073
	R2 adjusted	0.113544	0.057486	0.127651	0.006617
	D-W Test	0.696192	0.023075	0.344574	0.017839

Coefficient estimate is significantly different from zero, * at 10%; ** at 5%. *** at 1%.

Turning points EKC Curve

Table 5 provides the results of turning points obtained from the estimation models in Table 4. EKC does not hold in all cases but it has detected in most of them. In certain case we detect U shape and other case with increasing trend without any turning point. In general, the turning point in developed countries is higher than that in developing countries. Among the developed countries the CO_2 and BOD have the higher turning points of inverted U shape. While in developing countries the higher turning points of inverted U shape is detected on the SO_2 emission.

Table 5 Turning Points

Environmental Variables	Developed countries		Developing countries	
	Cross-section effects	Period effects	Cross-section effects	Period effects
CO_2	14,890.68 [c]	67,846.3 [c]	3,719.81 [c]	8,673.26 [c]
SO_2	3,314.5 [c]	3,640.95 [c]	86,525.53 [c]	2,072.19 [c]
BOD	3,438,359.6 [a]	18,840.24 [c]	---------- [b]	6,404.18 [c]
Spm_{10}	1941,879 [a]	8,447.85 [c]	---------- [b]	2,924.18 [a]
GHG	7,690.7 [c]	38,086.7 [a]	1,748.3 [c]	7,211.7 [a]

a Represent the U shape.
b Increasing trend, no any turning points.
c Represent the inverted U shape.

6 Conclusions

This study aims to investigate if the EKC hypothesis the relationship between economic growth and environmental degradation in developing and developed economies holds by using different environmental variables (CO_2, SO_2, BOD, SPM_{10}, GHG) included in that models. In particular we compare the results between two groups of countries i.e. developed and developing countries. The analysis is conducted by applying the panel data analysis. The Hausman and redundant tests are conducted in ordered to determine the appropriate model for different cases (random effects, fixed effects and pooled model). The main findings of this study reveal evidences of the existing the inverted U shape in most cases. We rely on cross section effects model more than period effects specification which can explain the data better as the R^2 and R^2 adjusted are higher. CO_2 and SPM_{10} are good proxies for environment variables in EKC analysis as these variables can be explained more than 90% by the explanatory variables of GDP for both developed and developing countries. However the BOD and GHG have weak relationship with GDP. GDP has double effects higher on SO_2 than CO_2. The turning points in developed countries are higher than that in developing countries. Among the developed countries the CO_2 and BOD have the higher turning points of inverted U shape. While in developing countries the higher turning points of inverted U shape is detected on the SO_2 emission.

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