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Sustainable Economic Growth: An Empirical Study for the Asia-Pacific Economic Cooperation Forum

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ABSTRACT

This study analyses the validity of environmental Kuznets curve (EKC) hypothesis for the Asia-pacific Economic Cooperation Forum (APEC), within the period 1992-2012. Three econometric models are performed, which use different environmental quality indicators as dependent variable. Model 1: Uses carbon dioxide (CO_2) total emissions in APEC, Model 2: Uses CO_2 emissions generated from coal consumption, and Model 3: Uses CO_2 emissions generate from petroleum consumption. Pedroni and Kao co-integration approach are applied for testing long-run relationship between variables for each model. Fully modified ordinary least squares method is employed for determining the elasticities of the long-run relationships. The analysis finds that an EKC is held under Model 1, and 3, but for Model 2 the relation between the variables does not show an inverted U shape behavior. Additionally descriptive analysis and Model 2 suggest that coal consumption has been increasing in last years, because of the effect in CO_2 emissions; even more in this specific indicator, economic activity is leading to an unsustainable growth scenario in APEC.

Keywords: Environmental Kuznets Curve, Carbon Dioxide Emissions, Economic Growth
JEL Classifications: Q5, Q56

1. INTRODUCTION

Over the last two decades it has been observed the growing interest in the issues of scientific research with environmental background. One of the main motivations is the study of the consequences that brings development, measured in its various forms, on the health of planet earth. To study these effects with their causes, it can serve as an important recommendation tool for policy makers that address to create a sustainable scenario for future generations.

One can say that one of the main problems in the issue of environmental pollution is the air pollution, which translates to creating a greenhouse effect. In air pollution they are involved a variety of gases, taking the name of greenhouse gases, where the main actor is carbon dioxide (CO_2), which has been attributed to be the cause of more than 50 % of greenhouse effect (Ozturk and Acaravci, 2010).

The causes of greenhouse gas emissions can be many, since the use of appliances and burning trash, to large farming and industrial production, so it is reasonable to expect that economic activity will present one of the main causes of pollution, hence it can be said that the solution is not to stop such economic activities, because it means the growth of nations, but rather seek the methods by which the growth of nations is maintained with sustainable levels of contamination.

Kuznets (1955) tested the relationship between income levels and inequality hypothesis in per capita terms. Under the assumption that higher income levels represent more development, it was observed that low levels of inequality levels were high, while with high levels of development, inequality tended to decline. This behavior took the name of Kuznets curve (KC), and is recognized by its inverted "U" shape. If we take the KC hypothesis, this time not applied to a measure of inequality, but an indicator of environmental degradation, and obtain similar behavior (inverted U-shape) then an environmental KC (EKC) hypothesis can be validate. Shafik and Bandyopadhyay (1992), Selden and Song (1994), Grossman and Krueger (1994), Holtz-Eakin and Selden (1995), Stern et al. (1996), Panayatou (1997) were some of the researchers who first developed the concept of the EKC, applied to a variety of specific issues such as estimating demand elasticities of environmental quality, effects of international trade, implementation case environmentally efficient technologies, improvements in government policies, etc.

2. THE EKC ACROSS ASIA-PACIFIC COUNTRIES

The Asia-Pacific Economic Cooperation (APEC) is an organization that currently has 21 member states (Australia, Brunei Darussalam, Canada, Chile, People's Republic of China, Chinese Taipei, USA, Philippines, Hong Kong, Indonesia, Japan, Republic of Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, Singapore, Russia, Thailand and Vietnam). APEC aims to increase opportunities of an inclusive, sustainable and secure balanced economic growth through regional economic integration of its members (APEC, 2015). It was created in 1989 by Australian initiative in response to multiple new blocks that have been marked new trends in economic cooperation and integration in the world, such as the consolidation of the European Union or the signing of trade agreements, such as NAFTA in America. The forum includes both developed economies and developing economies. In recent decades it has been reported a large increase in economic activity carried out by Asian countries, as China controlled its own 11% of world trade in 2013 (WTO, 2015), other economies such as South Korea and Japan are highly industrialized, in addition the sum of the gross domestic product (GDP) of the 21 forum members equal about 56% of total world production. As mentioned above, the link between economic activity and environmental quality of the countries where it is carried out is currently of great interest, and also is the aim of this study.

Many research has taken Asia-pacific countries as objects of study, and in the last 5 years have seen the implementation of a variety of econometric and analytical techniques that offer different points of view to researchers. Regarding Southeast Asia, Indonesia relatively recent studies of Narayan and Narayan (2010) and Saboori and Sulaiman (2013a) provide results do not support the hypothesis of an EKC. For Malaysia, Saboori et al. (2012), Saboori and Sulaiman (2013a), Shahbaz et al. (2013) and Lau et al. (2014) find sufficient evidence to prove the validity of the EKC using CO_2 as an indicator of environmental degradation. In contrast, other studies as Mugableh (2013) or Saboori and Sulaiman (2013b), which includes disaggregated variables of energy consumption, have no empirical evidence that holds an EKC. For the Philippines, Narayan and Narayan (2010) and Saboori and Sulaiman (2013a), using different methodologies, show no evidence to prove the existence of a EKC. Similarly to Thailand, Narayan and Narayan (2010) shows that the evidence does not support one EKC. In contrast Saboori and Sulaiman (2013a) determine that the evidence is sufficient to validate the EKC in Singapore and Thailand. Al-Mulali et al. (2015) argues that the evidence is not sufficient to prove the EKC hypothesis in Vietnam. For other Asia-Pacific countries, such as South Korea and Japan Onafowora and Owoy (2014) proves that there is sufficient evidence to validate the EKC hypothesis in both countries. In the case of China, we can say that is one of the countries that most studies have been conducted for, finding much evidence in favor of EKC (Jalil and Feridun, 2011; Jayanthakumaran and Liu, 2012; Wang et al., 2016), and also evidence that prevents assert the existence of a EKC (Onafowora and Owoy, 2014; Ozturk, 2015; Kang et al., 2016). In the other hand for Russia, Pao et al. (2011) and Ozturk (2015) determine that there is not an EKC. For American Pacific nations, in the case of Canada, Plassmann and Khanna (2006) and Hamit-Haggar (2012) find results in favor of EKC. Narayan and Narayan (2010) finds that in Mexico the existence of a EKC is validated, while in Chile and Peru it cannot be validate. In contrast Onafowora and Owoy (2014) argues that in Mexico there would be no EKC. The aforementioned studies have used different methodologies, different indicators of environmental degradation, and at different periods of study. The technique of autoregressive model with distributed lags (ARDL) has been perhaps the most common method applied to the analysis of individual countries. However, in countries like China, with the aim of buil studies based on their political or natural divisions, panel model methods are applied (Table 1). Considering that most recent studies using CO_2 as an indicator of environmental degradation, in the present study that fact is replicated, further disaggregation of two main sources of CO_2 emissions is taken, as is the CO_2 from the petroleum consumption, and CO_2 emissions from coal consumption.

3. DATA AND VARIABLES

In the present study 4 series are taken: (1) CO_2 emissions from petroleum consumption, (2) CO_2 emissions from coal consumption, (3) total CO_2 emissions from energy consumption, (4) real GDP at 2005 dollars adjusted for purchase power parity. Series 1, 2 and 3 are taken from the database of the U.S. Energy Information Administration (www.eia.gov) and are measured in millions of metric tons. Series 4 is taken from Penn Wordl Table 8.0[1], measured in millions of dollars. In order to obtain better comparable series, they are transformed in per capita terms, additionally expressed in their natural logarithm in order to estimate elasticities (Table 2). All series are evaluated within 1992-2012 period. Brunei and Papua New Guinea are excluded from the analysis, since the unavailability of certain data of some series would cause an unbalanced panel.

4. METHODOLOGY

4.1. Econometric Specification

An EKC generally can be expressed as: $E = f(Y,Y^2,W)$, where E denotes an environmental quality indicator, Y and Y^2 represent the level of income and its square respectively, and W is a set of additional variables which the researcher has evidence affect on environmental quality, either positively or negatively. In the present study three indicators of environmental quality are used, and the variable GDP per capita represents levels of income, on the other hand additional regressors variables are not included. Given the notation for panel data, three models are specified, one for each environmental indicator, as follows:

1 Developed by Robert, C.F., Inklaar, R. and Timmer, M.P. (2015), "The next generation of the penn world table" forthcoming American Economic Review. Available for download at www.ggdc.net/pwt.

Table 1: Literature review summary in Asia-pacific countries

Country	Study	Period	Methodology	Indicator	Inverted U-shape?
Canada	Plassmann and Khanna (2006)	1975-1999	Johansen co-integration-OLS model	CO_2	Yes
	Hamit-Haggar (2012)	1990-2007	Pedroni co-integration-FMOLS	CO_2	Yes
Chile	Narayan and Narayan (2010)	1980-2004	Pedroni co-integration – Panel model	CO_2	No
China	Jalil and Feridun (2011)	1975-2005	ARDL	CO_2	Yes
	Jayanthakumaran and Liu (2012)	1990-2007	Panel model and simultaneous equations	SO_2	Yes
	Onafowora and Owoy (2014)	1970-2010	ARDL	CO_2	No
	Ozturk (2015)	1980-2013	Generalized Method of Moments	CO_2	Yes
	Kang et al. (2016)	1997-2012	Spatial panel model	CO_2	No
	Wang et al. (2016)	1990-2012	Semi parametric panel model analysis	CO_2	No
Indonesia	Narayan and Narayan (2010)	1980-2004	Pedroni co-integration – Panel model	CO_2	No
	Saboori and Sulaiman (2013a)	1971-2009	ARDL	CO_2	No
Japan	Onafowora and Owoy (2014)	1970-2010	ARDL	CO_2	Yes
Korea	Onafowora and Owoy (2014)	1970-2010	ARDL	CO_2	Yes
Malaysia	Saboori et al. (2012)	1980-2009	ARDL	CO_2	Yes
	Saboori and Sulaiman (2013a)	1971-2009	ARDL	CO_2	Yes
	Saboori and Sulaiman (2013b)	1971-2009	ARDL	CO_2	No
	Mugableh (2013)	1971-2012	ARDL	CO_2	No
	Shahbaz et al. (2013)	1971-2011	ARDL	CO_2	Yes
	Lau et al. (2014)	1970-2008	ARDL	CO_2	Yes
Mexico	Narayan and Narayan (2010)	1980-2004	Pedroni co-integration – Panel model	CO_2	Yes
	Onafowora and Owoy (2014)	1970-2010	ARDL	CO_2	No
Peru	Narayan and Narayan (2010)	1980-2004	Pedroni co-integration – Panel model	CO_2	No
Philippines	Narayan and Narayan (2010)	1980-2004	Pedroni co-integration – Panel model	CO_2	No
	Saboori and Sulaiman (2013a)	1971-2009	ARDL	CO_2	No
Russia	Pao et al. (2011)	1990-2007	Johansen co-integration-OLS model	CO_2	No
	Ozturk (2015)	1980-2013	Generalized method of moments	CO_2	No
Singapore	Saboori and Sulaiman (2013a)	1971-2009	ARDL	CO_2	Yes
Thailand	Narayan and Narayan (2010)	1980-2004	Pedroni co-integration – Panel model	CO_2	No
	Saboori and Sulaiman (2013a)	1971-2009	ARDL	CO_2	Yes
Vietnam	Al-Mulali et al. (2015)	1981-2011	ARDL	CO_2	No

OLS: Ordinary least squares, ARDL: Autoregressive distributed lag, FMOLS: Fully modified ordinary least squares, CO_2: Carbon dioxide

Table 2: Variable transformations

Variable	Symbol	Unit of measurement
Natural logarithm of per capita CO_2 emissions from petroleum consumption	LCO_2P	Metric tons
Natural logarithm of per capita CO_2 emissions from coal consumption	LCO_2C	Metric tons
Natural logarithm of total per capita CO_2 emissions from energy consumption	LCO_2	Metric tons
Natural logarithm of real GDP per capita	$LGDP$	U.S.D. dollars
Squared natural logarithm of real GDP per capita	$LGDP_2$	U.S.D. dollars

GDP: Gross domestic product, CO_2: Carbon dioxide

$$\text{Model 1: } LCO_{2it} = \alpha_0 + \alpha_1 LGDP_{it} + \alpha_2 LGDP_{it}^2 + u_{it} \quad (1)$$

$$\text{Model 2: } LCO_2C_{it} = \beta_0 + \beta_1 LGDP_{it} + \beta_2 LGDP_{it}^2 + e_{it} \quad (2)$$

$$\text{Model 3: } LCO_2P_{it} = \gamma_0 + \gamma_1 LGDP_{it} + \gamma_2 LGDP_{it}^2 + \varepsilon_{it} \quad (3)$$

Where, α_j, β_j, γ_j for $j = 0, 1, 2$ are the elasticities to be estimated, and u_{it}, e_{it}, ε_{it} are random error term. The EKC hypothesis is validity when $\alpha_1 > 0$, $\beta_1 > 0$, $\gamma_1 > 0$ and $\alpha_2 < 0$, $\beta_2 < 0$, $\gamma_2 < 0$. If the elasticitities have the expected signs, then the Models (1), (2) and (3) will present an inverted U-shape.

4.2. Panel Unit Root Detection

In the present study, following Farhani et al. (2014), with the aim of verifying the stationary properties and intregración variables, three statistical test (1) are used Levin, Lin, and Chu t-statistics (Levin et al., 2002), (2) Breitung (2001) t-statictics, and (3) Im, Pesaram and Shin W-statistic (Im et al., 2003). While Levin et al. (2002) t-statistics and the Breitung (2001) t-statistics propose a null hypothesis of unit root presence, it is that it follow a common process on that root; Im et al. (2003) test proposed under the null hypothesis of unit root presecia following an individual process. Table 3 shows the detailed formulas used for the different tests.

4.3. Testing for Co-integration

The recent literature on studies of the EKC has been used extensively the model ARDL (Pesaran et al., 2001) bound testing approach, because the possibility of an individually comparative analysis between short- and long-run of the countries concerned. However, when it comes to data panels, say, groups of countries or economic blocs, recent studies apply based on co-integration panel methods either proposed by Pedroni (1999) (Hamit-Haggar, 2012; Farhani et al. 2014; Al-Mulali and Ozturk, 2015; Al-Mulali et al. 2015) and Kao (1999) co-integration test (Al-Mulali et al., 2015). In this study both co-integration test suggested by Pedroni (1999; 2004) and Kao (1999) are applied.

Pedroni (1999; 2004) co-integration test shows seven test divided into two dimensions. Within dimension has the following panel statistics: V-statistic, rho-statistic, PP-statistic and augmented Dickey-Fuller (ADF)-statistic; between dimension has the following group statistics: Rho-statistic, PP-statistic and ADF-statistic. If the P value of most of these statistics are significant, then we can say that the analyzed variables holds a long-run

Table 3: Panel unit root test summary

Test	Statistics	Parameters	Hyphotesis
Breitung (2001)	$\lambda_{UB} = \frac{\sum_{i=1}^{N} \sigma_i^{-2} y_i^{*\prime} x_i^*}{\sqrt{\sum_{i=1}^{N} \sigma_i^{-2} x_i^{*\prime} A'Ax_i^*}} \to \mathrm{N}(1,0)$	From the equation $y_{it} = \mu_i + \beta_{it} + x_{it}$ Where, $x_{it} = \sum_{k=1}^{p+1} \alpha_{ik} x_{i,t-k} + \mu_{it}$ $E(\Delta y_{it}) = \beta_i$, where Δy_{it} is white noise $\sigma_i^2 = E(\Delta y_{i1} - {}^2{}_i)^2$ $y_i = [\Delta y_{i1}, \ldots, \Delta y_{iT}]'$ $x_i = [y_{i0}, \ldots, y_{i,T-1}]'$ $y_i^* = Ay_i = [y_{i1}^*, \ldots, y_{iT}^*]'$ $x_i^* = Bx_i = [x_{i1}^*, \ldots, x_{iT}^*]'$ such that= $E\left(y_{it}^*, x_{it}^*\right) 0$ T=Time series dimention N=Total cross section units	$H_0 : \sum_{k=1}^{p+1} \alpha_{ik} - = 0$ (Unit root)
Levin et al. (2002)	$t_\delta^* = \frac{t_\delta - \tilde{T}\tilde{S}_N \hat{\sigma}_{\tilde{\varepsilon}}^{-2} STD(\hat{\delta}) \mu_{m\tilde{T}}^*}{\sigma_{m\tilde{T}}^*} \to \mathrm{N}(1,0)$	$\tilde{T}$ = Time series dimension $\mu_{m\tilde{T}}^*$ =Mean adjustment $\sigma_{m\tilde{T}}^*$ =Estandar deviation adjustment $t_\delta = \frac{\hat{\delta}}{STD(\hat{\delta})}$ where $\hat{\delta}$ and $STD(\hat{\delta})$ are taking by stamating: $\tilde{e}_{it} = \delta \tilde{v}_{it-1} + \hat{\varepsilon}_{it-1}$ And, $\hat{\sigma}_{\tilde{\varepsilon}}^2 = \left[\frac{1}{N\tilde{T}} \sum_{i=1}^{N} \sum_{t=2+p_i}^{T} (\tilde{e}_{it} - \hat{\delta} \tilde{v}_{it-1})^2 \right]$	H_0: $\delta = 0$ (Unit root)
Im et al. (2003)	$Z_{\tilde{t}bar} = \frac{\sqrt{N}\{\tilde{t} - bar_{NT} - E(\tilde{t}_T)\}}{Var(\tilde{t}_T)} \to N(1,0)$	$\tilde{t} - bar_{NT} = \frac{1}{N} \sum_{i=1}^{n} \tilde{t}_{iT}$ where, $\tilde{t}_{iT} = \frac{\Delta y_i' M_t y_{i,-1}}{\hat{\sigma}_{iT} (y_{i,-1}' M_\tau y_{i,-1})^{1/2}}$ and $\hat{\sigma}_{iT}^2 = \frac{\Delta y_i' M_\tau \Delta y_i}{T-1}$ $M_\tau = I_T - \tau_T (\tau_T' \tau_T)^{-1} \tau_T'$ $\tau_T = (1,1,\ldots,1)^t$ $\Delta y_i = (\Delta y_{i1}, \Delta y_{i2}, \ldots, \Delta y_{iT})'$ $y_{i,-1} = (y_{i0}, y_{i1}, \ldots, y_{i,T-1})'$ And I_T is an identity matrix of dimensions $T \times T$	H_0: Unit root

All test equation are according with the notatition used in the original papers.

relationship, so there is co-integration. Farhani et al. (2014) provides a review of the seven statistical formula proposed above.

Kao (1999) co-integration test is performed through the combined application of a DF test and ADF test for unit root based on residuals.

Assuming the residual $\hat{e}_{it} = \rho \hat{e}_{it-1} + v_{it}$ under a regression equation $y_{it} = \alpha_i + \beta x_{it} + e_{it}$ for $i = 1,\ldots,N$, $t = 1,\ldots,T$, estimated by fixed effects, it can be obtained:

$$t_\rho = \frac{(\hat{\rho} - 1)\sqrt{\sum_{i=1}^{N} \sum_{t=2}^{T} e_{it-1}^{*2}}}{s_e} = t_{DF} \quad (4)$$

And if we derive $\hat{\sigma}_v^2 = \widehat{\sum}_{yy} - \widehat{\sum}_{yx}\widehat{\sum}_{xx}^{-1}$ y $\hat{\sigma}_{0v}^2 = \hat{\Omega}_{yy} - \hat{\Omega}_{yx}\hat{\Omega}_{xx}^{-1}$, statistic (5) can be built.

$$DF_t^* = \frac{t_{ADF} + \frac{\sqrt{6N}\hat{\sigma}_v}{2\hat{\sigma}_{0v}}}{\sqrt{\frac{\hat{\sigma}_{0v}^2}{2\hat{\sigma}_v^2} + \frac{3\hat{\sigma}_v^2}{10\hat{\sigma}_v^2}}} \rightarrow N(0,1) \quad (5)$$

In a same way if one takes into account a residual equation of the form:

$$\hat{e}_{it} = \rho\hat{e}_{it-1} + \sum_{j=1}^{p}\varphi_j \Delta\hat{e}_{it-j} + v_{itp} \quad (6)$$

Statistic (7) can be constructed, on which the test co-integration is evaluated. The null hypothesis can be presented as: H_0: ρ = 0.

$$ADF = \frac{t_{ADF} + \frac{\sqrt{6N}\hat{\sigma}_v}{2\hat{\sigma}_{0u}}}{\sqrt{\frac{\hat{\sigma}_{0v}^2}{2\hat{\sigma}_v^2} + \frac{3\hat{\sigma}_v^2}{10\hat{\sigma}_v^2}}} \rightarrow N(0,1) \quad (7)$$

4.4. Fully Modified Ordinary Least Squares (FMOLS) Model

Having tested the existence of co-integration for the variables of the three econometric specifications, a regression is applied by FMOLS in line of Pedroni (2000). FMOLS is considered as an efficient estimation method, and offers other advantages, for example it can provide consistent estimators and can eliminate the correlation between the co-integration equation and stochastic regressor innovation as Al-Mulali et al. (2015) noted.

5. EMPIRICAL ANALYSIS AND RESULTS

As a descriptive analysis five ratios are performed (Table 4) in order to observe the participation and behavior of CO_2 emissions made by of APEC countries member.

Figure 1a shows the evolution of the share who of CO_2 emissions from the consumption of petroleum and from coal consumption relative to the total CO_2 emissions in APEC, it is observed that approximately from 1999, the CO_2 emissions caused by petroleum consumption has been decreasing. On the other hand roughly from the same year CO_2 emissions from the consumption of coal has meant greater weight within the total CO_2 emissions in APEC, for example in 1999, a 41.47% of total CO_2 emissions in APEC were due to coal consumption, in 2011 the figure was 51.40%. In contrast to 1999 when a 40.07% of total CO_2 emissions was due to petroleum consumption, while in 2011 the same proportion dropped to 31.34%. This seems to show greater intensive use of sources different from petroleum in APEC, such as coal, with sharply rising trends. The literal Figure 1b shows that CO_2 emissions from petroleum consumption does not exceed 1% of total global CO_2 emissions during the study period. On the other hand for 2011 CO_2 emissions from the consumption of APEC coal was equivalent to almost 33% of global CO_2 emissions. Literal Figure 1c shows globally the share of APEC CO_2 emissions relative to global emissions. In this aspect there is a growing trend, and throughout the study period more than 50% of global CO_2 emissions were produced by APEC members; by 2011 this figure reached a considerable 63.86%. Descriptively the input that within APEC generates more CO_2 emissions is coal, while total CO_2 emissions made by member countries highly contribute to global emission levels.

5.1. Panel Unit Root and Co-integration Test

Panel unit root test reveals that all the variables are not stationary at levels, taking in consideration the presence of individual stochastic intercept and trend. Since all variables are stationary at first differences, then all variables are integrate of degree one *I*(1), so the Pedroni and Kao co-integration test can be performed. Table 5 shows test details. Co-integration test ensures that exists an long-run relationship for each case of study (Table 6).

Having ensured the existence of cointegration, the three models are estimated by FMOLS (Table 7). Estimated Model 1 shows that data supports and EKC, meaning that for an increase of 1% in the GDP^2,

Table 4: Descriptive ratios

Ratios
$\frac{PET}{APEC} = \frac{CO_2 \text{ emissions from petroleum consumption made by APEC}}{\text{Total } CO_2 \text{ emissions made by countries in APEC}}$
$\frac{COAL}{APEC} = \frac{CO_2 \text{ emissions from coal consumption made by APEC}}{\text{Total } CO_2 \text{ emissions made by countries in APEC}}$
$\frac{PET}{WORLD} = \frac{CO_2 \text{ emissions from petroleum consumption made by APEC}}{\text{Total global } CO_2 \text{ emissions}}$
$\frac{COAL}{WORLD} = \frac{CO_2 \text{ emissions from coal consumption made by APEC}}{\text{Total global } CO_2 \text{ emissions}}$
$\frac{APEC}{WORLD} = \frac{\text{Total } CO_2 \text{ emissions made by countries in APEC}}{\text{Total global } CO_2 \text{ emissions}}$

APEC: Asia-pacific Economic Cooperation Forum

Table 5: Panel unit root test results

Test	Levels	First difference
Levin, Lin and Chu t		
LCO_2	−2.15856	−8.24620***
LCO_2P	−1.58323	−12.6722***
LCO_2C	−1.25479	−12.8990***
LGDP	−1.33934	−6.19789***
$LGDP^2$	−0.87369	−6.19626***
Im, Pesaram and Shin W-Stat		
LCO_2	−0.89458	−10.7874***
LCO_2P	−2.84733	−10.6073***
LCO_2C	1.19006	−12.4606***
LGDP	0.57526	−6.97100***
$LGDP^2$	1.40822	−6.96158***
Breitung t-statistics		
LCO_2	1.38792	−8.24620***
LCO_2P	0.81088	−5.84711***
LCO_2C	1.72899	−6.18701***
LGDP	−1.51210	−4.57727***
$LGDP^2$	−1.47126	−4.55783***

All tests consider individual intercept and trend for each variable, ***Significance level at 1%. GDP: Gross domestic product

Figure 1: Ratios behavior across time, (a) Carbon dioxide (CO_2) from petroleum versus CO_2 from coal (within Asia-pacific Economic Cooperation Forum [APEC]), (b) CO_2 emitted by petroleum and coal consumption (within APEC) against global CO_2 emissions, (c) influence of total CO_2 emissions of APEC in global CO_2 emissions

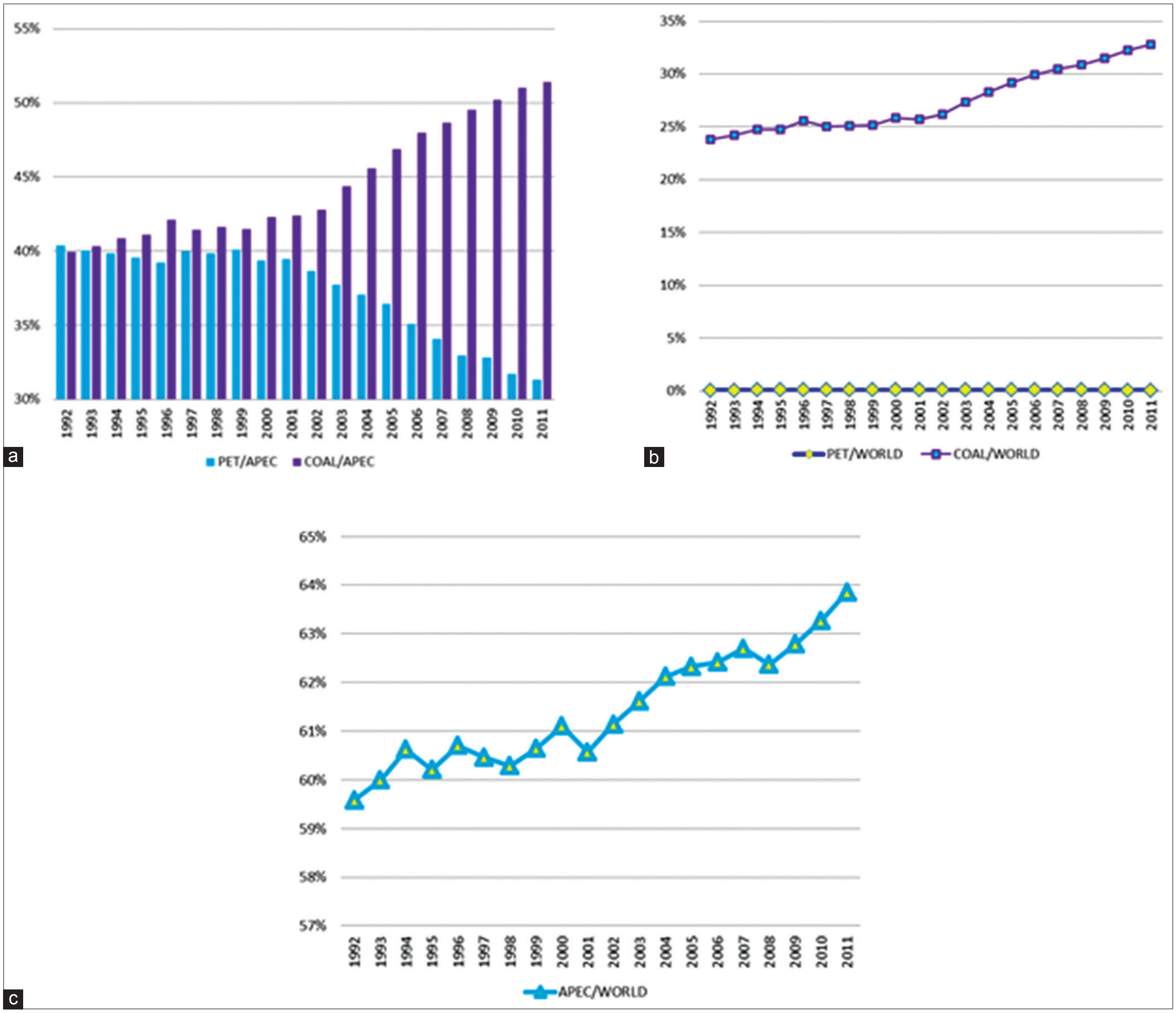

Table 6: Co-integration test results

Cases	$LCO_2=f\,(LGDP, LGDP^2)$	$LCO_2C=f\,(LGDP, LGDP^2)$	$LCO_2P=f\,(LGDP, LGDP^2)$
Pedroni co-integration test			
Within dimension			
Panel v-statistic	3.936650***	−1.376843	2.280060**
Panel rho-statistic	1.309713	1.116521	1.470787
Panel PP-statistic	−2.319541**	−2.596653***	−1.274924
Panel ADF-statistic	−2.054045**	−2.739713***	−2.786685***
Between dimension			
Group rho-statistic	2.279301	1.349947	2.933348
Group PP-statistic	−4.425428***	−4.952845***	−2.402021***
Group ADF-statistic	−4.454357***	−5.639495***	−3.586924***
Kao co-integration test			
ADF	−2.812177***	−3.316323***	−2.19522**
Residual variance	0.003419	0.253849	0.004107
HAC variance	0.004845	0.256623	0.004127

Deterministic trend and intercept have been assume for Pedroni co-integration test. *** and ** are significance levels at 1% and 5% respectively. ADF: Augmented Dickey-Fuller, HAC: Heteroskedasticity and autocorrelation consistent, GDP: Gross domestic product, CO_2: Carbon dioxide

Table 7: Long-run estimations

FMOLS method	Inverted U shape?
Model 1	Yes
LCO_2=3.004295$LGDP$−0.123044$LGDP^2$	
...............(6.916316)*** (−5.148474)***	
Model 2	No
LCO_2C=−3.477867$LGDP$+0.262781$LGDP^2$	
.....................(1.809123)* (2.640056)***	
Model 3	Yes
LCO_2P=3.865664$LGDP$−0.187931$LGDP^2$	
..................(1.809123)*** (2.640056)***	

Between parenthesis are t-statistics, *** and * are significance levels at 1% and 10% respectively. FMOLS: Fully modified ordinary least squares, GDP: Gross domestic product, CO_2: Carbon dioxide

will decrease the total CO_2 emissions 0.123044% in average. For Model 3 the reporter sing of the GDP^2 is negative, so an increase of 1% in GDP^2, will decrease the CO_2 emissions (of petroleum consumption) 0.123044% in average. In contrary form Model 2 shows an EKC cannot be held, it means that increases of GDP bring increases in CO_2 emissions (of coal consumption) levels.

6. CONCLUSIONS

The APEC is a block of contrasts. Several of its members are the most developed economies in the world, that have reached upper living standards (such as U.S.A., Canada, Korea or Japan), in the other hand some members are developing economies with high industrialization levels that still have low living standards (such as Mexico, Malaysia, Indonesia, Philippines or Taiwan).

The present analysis based on the EKC approach has considerated air pollution as the interest matter. Using total CO_2 emissions as environmental quality indicator, there are sufficient statistic evidence that ensures the existence of an EKC in APEC for the period 1992-2012. Taking into consideration that there is no a previous panel study for APEC, we can argue that this results are consistent with Plassmann and Khanna (2006), Hamit-Haggar (2012), Jalil and Feridun (2011), Ozturk (2015), Onafowora and Owoy, (2014), Saboori et al. (2012), Saboori and Sulaiman (2013a), Shahbaz et al. (2013), Lau et al. (2014), Narayan and Narayan (2010) since they have investigated and found EKC in some APEC members in an individual form. Despite an EKC exists for the total CO_2 emissions, when only CO_2 emissions generate by coal consumption is taken as dependent variable, the characteristic inverted "U" shape of EKC is not held, it means that the increasing levels of GDP (as an economic activity proxy) lead to proportional increasing levels of environmental degradation, and this degradation is linked to unsustainable coal consumption stage.

Policy makers have to take in consideration the trend of coal consumption, and focus on the develop of renewables energy sources, it could be the way that environmental degradation for CO_2 emissions start to slow down, in addition it reach a less dependent levels of the coal, even more when it is an highly polluting agent and nonrenewable mineral.

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