Investigating the Relationship on CO_2, Energy Consumption and Economic Growth: A Panel Data Approach

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Abstract: In this study, empirical analysis is conducted to reveal the relationship between three variables: energy consumption, GDP and CO_2. The analysis is based on 13 oil importing countries and 11 oil exporting countries. The main objectives are (1) to reveal the long-run relationship based on three different models using second generation panel unit-root and panel cointegration tests and (2) to investigate the short-run relationship between pairs of variables using VAR Granger causality test. The panel unit root tests indicate that each variable is integrated of order one, I(1). Based on cointegration tests, the results reveal a long-run relationship in one of the models in both countries. The VAR Granger Causality shows evidence of a short-run relationship between the variables in both groups of countries.

Keywords: CO_2, energy, growth, panel data.

1. INTRODUCTION

Examining the relationships that describe how energy, carbon dioxide (CO_2) emissions and economic growth are interrelated has inspired a high interest among researchers. As economy and population increases, the use of energy is expected to increase. In most countries, energy as a non-substitutable resource has been used extensively to promote their industrial productions and activities. The world has produced nearly 130 quadrillion BTU (British thermal unit) of energy from oil in 1997. Recent data from U.S. Energy Information Administration reported that United States used energy about 97.4 BTU in 2016. Dubai and Abu Dhabi are two cities benefitted from the oil and energy sector.

There are consequences faced by many countries due to the progress of development. At this phase, roads, railways, factories, and facilities are developed progressively. This leaves a positive impact on economic growth but not necessarily to the environment in the long term. Energy is essential to stimulate the economic growth. However, inefficient use of energy contributes to the environmental degradation. Most of developing countries have progressively increased their use of energy and this has contributed to an increase in GHG emissions. Apart CO_2, other dangerous gasses produced into the atmosphere are sulphur dioxide (SO_2), particulate (pm) nitrogen oxides (NO_x) (Qian and Zhang, 1998). CO_2 emissions contribute for more than half of GHG emissions which are likely to be linked to climate change (The World Bank, 2007). Other negative effects caused by unsustainable development are global warming and climate change and resulting in the rise of sea levels due to the ice caps and glaciers, and extreme weather conditions such as droughts, massive floods and tornadoes. The most populated country like China consumes a huge amount of coal as an energy source. It is reported that in 2015, China and the United States had produced about 45% of the total world CO_2 emissions. The Intergovernmental Panel on Climate Change revealed that GHG emissions have increased estimated 1.6% yearly, while CO_2 increased about 2% yearly over the past three decades. Recently, the IMF's World Economic Outlook Database 2016 reported that these two countries are the top two economies in the world.

To date, the relationship between energy consumption, environmental degradation and economic growth have been widely studied. However, there is no any precise answer and there is still no consensus on the relationship. Thus, in this paper, we extend the existing literature by examining the relationship and direction between these three variables for two different groups of countries (oil exporting and importing countries). This investigation has been applied using second generation panel unit root tests to relax the restrictive assumption of cross-sectional independence. The objective is twofold: to examine the short-run relationship (one-way or bidirectional) for each pair of variables and to reveal the long-run relationship using different models.

2. LITERATURE REVIEW

The inconsistent results obtained from the past studies on the direction of causality have inspired many

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researchers to analyses and discuss the nature of the variables using different techniques. For example, Vaona (2012) revealed the different results after using different methods of analysis; Toda and Yamamoto and Johansen technique.

Literature shows that various of economic modelling techniques have been applied to analyze the relationship between the variables. Environmental Kuznets Curve (EKC) had been applied employed in the analysis of environmental-economic. According to EKC, the curve describes the environmental degraded will initially increase with respect to the economic growth before the direction change once the desired level of economic is achieved, described as an inverted-U curve. The reverse in the direction means degradation starts to decline. Sun (1999) supports this theory and argues that the pollution can be avoided when the country's economy is developing. Moreover, Dasgupa and Heal (1979) and Coondou and Dinda (2002) argued it is impossible to protect the environment in both developed and developing countries when the economy grows rapidly. Tang and Tan (2016) revealed that CO_2 emissions, energy consumption and economic growth are cointegrated and takes 11 years before reaching a long-run equilibrium. Using data from 106 countries, Antonakakis *et al*. (2016) concluded that this situation brings dilemma in many countries, between high economic growth rates and unsustainable environment. Grossman and Kruger (1991) suggested that the implementation of high technology and machining would lead to the reduction of pollution once advancement has been achieved. The reasons why the EKC theory has been criticized because the sample was taken from the middle-income countries (Latin America) that experiencing unequal economic distribution during the study period. Secondly, this theory has opposite results in many countries. On the other hand, Ang (2007) research produced both shapes of curves in distinct groups of countries. He found a U-shaped EKC in five Middle East countries, but an inverted U-shaped curve was found in other three countries. Studies conducted by Grossman and Kruger (1995), Cinar *et al*. (2012), Yin *et al*. (2015), Saatci and Yasemin (2011) and Jalil and Mahmud (2009) supported the inverted U-shaped EKC hypothesis.

Bozkurt and Akan (2014) suggested that the environment will improve if the economy grows more rapidly. Rothman (1998) claimed that when countries become richer, they are more protective of the environment and the current economic growth is not sustainable due to the trade-off effect from production activities (Haywood, 1995). Hundie (2017) reported that in the long-run, energy consumption and economic growth have statistically significant impact on environmental degradation.

Solow's (1956) introduced an original growth model (neoclassical growth model). He believed an economy must reach stationary phase in which there is no more additional investment needed. This theory claimed that technological progress is crucial to achieving continuing economic growth.

Stern (1999) in his Biophysical Models of the economy proposed that energy is the main source of production. Likewise, environmental degradation-economic growth relationship, the relationship between energy consumption and economic growth has become as an interesting topic being discussed by researchers too. Energy consumption is closely related to economic growth by providing inputs to industries help to stimulate economic development (Ang, 2007).

Kahia *et al*. (2017) used data from 11 MENA Net oil importing countries for the period 1980 to 2012. They found evidence of a long-run and short-run relationship between GDP and energy. The results are positive and have significant elasticities. Hasanov *et al*. (2017) analyzed 10 oil exporting developing Eurasian countries from 1997 to 2014. They suggested policymakers to take action on inefficient of energy use that brings disadvantages on economic growth.

Empirical studies revealed inconsistent results due to the different sample used, various model and the time period examined (Ozturk, 2010). Bozkurt and Akan (2014) investigated the long-run relationship of CO_2 and energy consumption on economic growth in Turkey from 1960-2010. The study concluded that CO_2 emission is negatively related to economic growth. As expected, energy consumption contributes a positive effect on economic growth. Moreover, Ozturk (2010) used panel data from 1971-2005 in 3 distinct groups of countries, low, middle and upper middle-income group of countries to study the correlation and causality. He failed to find evidence of a strong correlation between energy consumption and economic growth in all the income groups. For low-income countries, the results indicated that there is long-run Granger causality running from GDP to energy consumption while a bidirectional Granger causality between these variables in the lower and the upper middle-income countries.

Apergis (2009) extended the study by Ang (2007) on panel framework. Based on data from 1971-2004 for six Central American countries and found that there is a positive relationship between energy and CO_2 emissions. Obradovic and Lojanica (2017), Odularu and Chinedu (2009) and Chebbi and Boujelbebe (2008) found evidence of a long-run relationship between energy consumption and economic growth. These results are similar to Naser (2015) and Chen *et al*. (2016). Naser studied four emerging economies named: Rusia, China, South Korea and India and Chen *et al*. used data from 3 different groups of countries. Other studies detected a long-run relationship between these studies include Suocheng *et al*. (2011) and Amin *et al*. (2012).

Among the recent longitudinal studies, which is conducted by Kang *et al*. (2016) involved thirty provinces of China, reported that economic growth and CO_2 as an inverted-N trajectory. This result opposite to the traditional inverted-U and N-shaped relationship.

Pala (2016) and Mercan and Karakaya (2015) analyzed data from OECD countries; Pala detected the presence of a long-run relationship between economic growth and energy consumption and there is a two-way relationship between the variables in the short-run. Using data from 1970-2011, Kaka and Zervas (2013) found that the results are similar to that in Bozkurt and Akan (2014), while Karakas (2014) compared the relationship between OECD and non-OECD countries using data from 1990-2011. The study showed that there is a positive relationship between economic growth and CO_2 emissions both groups of counties. Similarly, Wang *et al*. (2017) found relationship between these two variables although it is not linear in China.

3. DATA AND METHODOLOGY

In this study, we used annual panel data-set from 1975 to 2013 for two group of countries; oil importing countries and oil exporting countries. The variables used are ENC (energy consumption in kg of oil equivalent per capita), CO2 (carbon dioxide emissions in metric tons per capita) and GDP (per capita in current US$) as the proxies for energy consumption, environmental degradation and economic growth respectively. The data are extracted from the World Bank Development Indicators. All data are transformed into natural logarithm form for consistency.

The data consists of 13 and 11 countries from oil importing and exporting countries respectively. The countries are:

(i) Oil importing countries: Belgium, China, France, Indian, Italy, Japan, Korea, Netherlands, Singapore, Spain, Thailand, United Kingdom and the United States

(ii) Oil exporting countries: Algeria, Canada, Columbia, Mexico, Nigeria, Norway, Oman, Saudi Arabia, United Arab Emirates, United Kingdom, Venezuela

Three empirical models considered in this study are:

Model 1: $ENC_{it} = \alpha_o + \beta_1 GDP_{it} + \beta_2 CO2_{it} + \varepsilon_{it}$

Model 2: $GDP_{it} = \alpha_o + \beta_1 CO2_{it} + \beta_2 ENC_{it} + \varepsilon_{it}$

Model 3: $CO2_{it} = \alpha_o + \beta_1 ENC_{it} + \beta_2 GDP_{2it} + \varepsilon_{it}$

where α_o is a constant term, B_1 and B_2 are parameters to be estimated in the models. i indicates to the cross-section, i.e. countries, *t* is the time in years and ε is the error term.

The analysis part begins with examining the cross-sectional dependency in fitting the panel data models. In this study, we employed Lagrange Multiplier (LM) test developed by Breusch-Pagan (1980).

The LM statistic is given by

$$LM = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^2$$

where $\hat{\rho}_{ij}$ is the sample estimate of the pairwise correlation residuals

$$\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T}\hat{\mu}_{it}\hat{\mu}_{jt}}{\left(\sum_{t=1}^{T}\hat{\mu}_{it}^2\right)^{1/2}\left(\sum_{t=1}^{T}\hat{\mu}_{jt}^2\right)^{1/2}}$$

and $\hat{\mu}_{it}^2$ is the estimate of μ_{it}.

Secondly, before conducting cointegration analysis, stationary tests are essential to be conducted. The second -generation unit root test of Pesaran (2003) is used to check for the stationarity of the series. If the residuals are not serially correlated, the regression is employed for the i^{th} country is given by

$$\Delta Y_{it} = \alpha_i + \rho_i Y_{1,t-1} + c_i \bar{Y}_{t-1} + d_i \Delta\bar{Y}_t + \vartheta_{it}$$

where $\bar{Y}_{it} = \left(\frac{1}{N}\right)\sum_{i=1}^{N} Y_{it-1}$ and $\Delta\bar{Y}_{it} = \left(\frac{1}{N}\right)\sum_{i=1}^{N}\Delta Y_{it}$

The null hypothesis is nonstationary series and the alternative hypothesis is stationary series.

Once all variables are integrated of the same order, panel cointegration test can be performed to examine the existence of long-run relationship(s) among series. This study used the second generation cointegration test of Westerlund (2007). This test is based on the error-correction approach (ECM) which aims to examine whether an ECM does or does not have error correction.

$$\Delta y_{it} = c_i + a_{0i}(y_{it-1} - b_i x_{it-1}) + \sum_{j=1}^{K_{1i}} a_{1ij}\Delta y_{it-j} + \sum_{j=-K_{2i}}^{K_{3i}} a_{2ij}\Delta x_{it-j} + \mu_{it}$$

where a_{0i} is the error correction or speed of adjustment term. The variables are not cointegrated if $a_{0i} = 0$. In contrast, if $a_{0i} < 0$, then there is an error correction term, which implies that the variables are cointegrated.

Finally, we proceed with short-run causality test using VAR Granger causality. The decision is whether to reject the null hypothesis of variable X does not Granger cause variable Y versus alternative hypothesis of variable X does Granger cause variable Y.

4. RESULTS AND FINDINGS

To determine whether the variables are characterized by cross-sectional dependency, we used Breush-Pagan LM test. Table **1** shows that the test rejects the null hypothesis of no cross-sectional dependence for all the models in both countries. This means all the series are cross-sectionally correlated. Thus, the second-generation tests can be employed.

Table 1: Results of Breush-Pagan LM Test for Cross-Sectional Dependency

Model	Importing Countries	Exporting Countries
1	1190.433***	678.239***
2	1610.173***	837.061***
3	1106.146***	225.137***

Notes: ***, ** and * indicate significance at 1%, 5% and 10% levels respectively.

The results of panel unit root tests using Pesaran (2003) reported in Tables **2** and **3** indicate that all variables are integrated with first order, I(1) in both countries. This evidence of I(1) of all variables allow us to check the hypothesis of cointegration among energy consumption, GDP and carbon dioxide emission by employing second generation cointegration test; Westerlund (2007). This test uses four panel cointegration test statistics (Gt, Ga, Pa and Pt) based on Error Correction Model. For oil importing countries, there is a long-run relationship among variables as shown in Model 2 (see Table **4**). Meanwhile, the long-run relationship exists in Model 1 for exporting countries (see Table **5**).

Table 2: Results of Panel Unit Root Test for Oil Importing Countries

Variables	without trend	with trend
Level		
ENC	-0.810	-1.884
GDP	-1.999	-2.191
CO_2	-0.685	-1.840
First difference		
ENC	-5.561***	-5.836***
GDP	-4.712***	-4.987***
CO_2	-5.344***	-5.475***

Table 3: Results of Panel Unit Root Test for Oil Exporting Countries

Variables	without trend	with trend
Level		
ENC	-1.996	-2.633
GDP	-1.386	-1.905
CO_2	-2.024	-2.719*
First difference		
ENC	-5.780***	-5.938***
GDP	-4.731***	-4.934***
CO_2	-5.926***	-6.121***

Table 4: Results of Panel Cointegration Test for Oil Importing Countries

Model	Gt	Ga	Pt	Pa
	Z-value			
1	2.174	2.262	-0.273	-0.958
2	-2.003**	0.328	-1.054	-1.993**
3	5.594	2.961	3.296	1.970

In examining for the short-run causality, we used the Wald test. Table **6** reports that there is a bidirectional relationship between ENC and GDP and two one-way causalities (ENC to CO2 and GDP to CO2) in oil importing countries. In oil exporting countries, the one-way short-run relationship is detected between CO2 to ENC and CO2 to GDP.

Table 5: Results of Panel Cointegration Test for Oil Exporting Countries

Model	Gt	Ga	Pt	Pa
	Z-value			
1	-2.718***	0.267	-5.641**	-1.994
2	0.016	2.462	3.136	2.498
3	-2.980**	0.032	-1.099	-0.686

Table 6: Results of VAR Granger Causality

Null Hypothesis	Oil Importing Countries	Oil Exporting Countries
	Chi-sq	
ENC does not Granger-cause CO2	48.8653***	5.3685
GDP does not Granger-cause CO2	15.1884*	1.3596
CO2 does not Granger-cause ENC	7.4796	19.1920***
GDP does not Granger-cause ENC	30.3837***	7.6086
CO2 does not Granger-cause GDP	10.3813	11.3417**
ENC does not Granger-cause GDP	22.0642***	1.7520

Notes: Lag order selected by the Akaike information criterion (AIC) and final predictor Error (FPE).

5. CONCLUSION

This study examined the correlation between three variables, namely energy consumption, CO_2 (proxy to environmental degradation) and GDP (proxy for economic growth) in oil importing and exporting countries using data from 1975-2013. The second-generation panel unit root and cointegration test were used in the analysis. The objectives are 1) to reveal the long-run relationship in three different models and 2) to examine the short-run relationship (one-way or bidirectional) in each pair of variables. The Breush-Pagan LM test suggests that there is cross-sectional dependence for all the models. This suggests that there is a cross-section effect in the series. All the data series used are integrated of order one, I(1). Cointegration test shows that there is a long-run relationship between the variables in both countries. This result is similar to Bozkut and Akan (2014), Obradovic and Lojanica (2017), Oduloru and Chinedu (2009), Chebbi and Boujelbebe (2008) and few others as stated in the literature. For importing countries, empirical results show that carbon dioxide emissions affected by the energy consumption and economic growth in the short-run. In exporting countries, we found a bidirectional relationship between energy consumption and economic growth. This result is consistent with Kahia *et al*. (2017) and Hasanov *et al*. (2017). In all, we can conclude that the three variables in both countries are interrelated in long-run and short-run. These findings intended to provide a deeper understanding of the interactions of energy consumption, environmental degradation and economic growth as an input in the process to develop effective policies. Effort must be taken to encourage industries to adapt machines and technologies that reduce pollution. It is recommended to oil importing countries to control their energy consumption and economic progress to protect the environmental quality. The renewal energy sources must be used as input in industrial development.

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