EXAMINING THE RELATIONSHIP BETWEEN ECONOMIC GROWTH, ENERGY CONSUMPTION AND CO_2 EMISSION USING INVERSE FUNCTION REGRESSION

ZAIDI, I.[1] – AHMED, R. M. A.[*1] – SIOK, K. S.[2]

[1]School of Mathematical Sciences
National University Malaysia
43600 Bangi, Selangor, Malaysia

[2]School of Mathematical Sciences
University Science Malaysia
11800 Minden, Penang, Malaysia

**Corresponding author*
e-mail: ahmad8668@hotmail.com

(Received 4th Mar 2016; accepted 10th Nov 2016)

Abstract. Recently, the relationship between carbon dioxide emission (CO_2), aggregate energy consumption (EC) and economic growth (GDP) has been widely studied by many researchers using different approaches but the results were conflicting. Such controversy may due to the efficiency of the applied statistical approaches and using different dataset. The main objective of this experimental study is to examine the relationship between CO_2, EC, and GDP using different data transformation forms (natural logarithm versus inverse form) in reducing the heteroscedasticity in panel data. The panel data consist of 29 countries from two different economic levels of countries, 17 developed versus 12 developing countries. The data spanning from 1960 to 2008. A panel data approach is applied and estimations based on three models. First of all, the estimations are conducted by constructing three different models; First model is estimated by using the original data without any transformation, while the second and third model use the natural logarithm (Log) and inverse form to transform the data. Those two transformation forms are applied to reduce the heteroscedasticity problem. The main findings show a strong relationship between the three variables. The model with inverse function transformation is superior to the other two models using original data and Log transformation, as it has the highest R^2 which illustrates that more than 84% of CO_2 emission can be explained by GDP and EC. Since EC and GDP are influential on the CO_2 emissions, higher EC and lower GDP may lead to environmental problems such as air and water pollution. Therefore, prevention action should be taken to minimize the environmental degradation.
Keywords: *heteroscedasticity, panel data approach, economic growth, inverse form transformation*

Introduction

The relationship between carbon dioxide emissions (CO_2), aggregate energy consumption (EC) and economic growth (GDP) has been noticed growing attention in the recent energy economics literature ever afterward the crude oil prices had increased to double or ever more during the two energy crisis in the 1970s. Many researchers have examined that relationship by using different approaches but the results were conflicting. Such controversy may due to the efficiency of applied statistical approaches or using different dataset.

In the last few decades, rapid development has been observed plainly in many countries, and that is due to technology progress and industrialization etc. Besides, the energy resources such as oil, gasses and petrol are consumed in large scales as they are the main components need in the production of many goods especially in transportation,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

manufacturing and technology industry. A consequence, there are serious impacts towards the environmental degradation and in reducing the non-renewable energy resources. Thus it is very important to get a clear trend of that relationship to policymaker in monitoring the energy consumption/ efficiency and designing such a policy to minimize the trade-off effects of rapidly economic growth.

In light of the aforementioned literature, some of those studies used a bivariate framework or they included common variables in a single country or in a short panel of countries without considering the internal effects, and that has done by applying common methods. Therefore, this study is designed to overcome the shortcoming in the previous studies. To do that; first, we survey some of the related studies. Then, we detect the relationship between EC, GDP and CO_2 into two different groups of countries; developed and developing countries by using panel data approach with considering the data transformation by natural logarithm and inverse function to reduce the heteroscedasticity problem in the dataset.

To best of our knowledge this experimental study differs from earlier literature in several points; firstly, it is the first study uses original data without any transformation in analysis against (natural logarithm and inverse function transformation) in reducing the heteroscedasticity problem in the panel data which could provide more robust output. Secondly, it includes larger panel data in the analysis than that in previous studies, as it covers two groups of countries; (17) developed countries and (12) developing countries for the long time period from 1960 to 2008 in the multivariate framework, as the bivariate framework may suffer from omitted variable bias. Finally, it detects the different effects of (developed versus developing countries) into CO_2 emissions.

The remaining parts are organized as following; Section 2 overviews the strands of economic-energy literature. Section 3 provides data description. Section 4 explains the approach of panel data, and it provides the discussion of the empirical results. Section 5 recommends some suggestions to policymakers.

Literature Review

Seemly, there are three literature research strands which are interesting in the relationship between economic growth (GDP), energy consumption (EC) and environmental degradation, but some of them added other factors in the model such as; energy prices, capital, employment, foreign direct investment, industrial value added, agricultural value added and so on. The first strand is focusing on the relationship between GDP and environmental degradation which could be tested by environmental Kuznets curve (EKC) hypothesis. While the second strand is concentrating on causality relationship between EC and GDP. Finally, the third strand is exploring the relationship between GDP, EC and emissions. *Table 1* outlined some of the related literature.

The first strand of research is focusing on testing the EKC hypothesis. EKC is derived from original Kuznets Curve (KC) which is proposed by Simon Kuznets in 1955. EKC illustrates that in early stages of GDP the environmental quality is improving until a certain level (peak/turning point), then that case is reversed beyond the turning point, as it declines when GDP increase. This strand of literature is started by Grossman and Krueger (1991) who have applied EKC in path-breaking study of the potential influence of North American Free Trade Agreement (NAFTA) in the USA. The model includes SO_2, dark matter, and suspended particulate matter (SPM). The

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

main findings support the existence of EKC for both SO_2 and dark matter, while there is a negative relationship between GDP and SPM. The turning points for SO_2 and dark matter are about 4000-5000 USD$, while the concentration of SMP appeared to decline even at low-income levels (negative relationship). Then this strand of literature followed by others. Majority studies support the EKC hypothesis (He and Richard, 2010), (Millimet et al., 2003), (Selden and Song, 1994), (Orubu and Omotor, 2011), (Alsayed and Sek, 2013), (Stern and Common, 2001), (Coondoo and Dinda, 2002), but some papers found there is no EKC existence (Liu, 2005), (Ghosh, 2010), (Fodha and Zaghdoud, 2010).

Table 1*. The survey of some related studies to the relationship between GDP, EC and other variables*

Author	Methodology	Year	Scope	Additional variables	Findings and Results
Yu and Hwang (1984)	Sims and Granger causality	1947-1979 A	USA	EMP	GNP — EC EC → EMP
Masih and Masih (1997)	JJ, VDC and IRF	1961-1990 A	Korea Taiwan	Consumer prices	GDP ↔ EC GDP ↔ EC
Ghali and El-Sakka (2004)	JJ, VDC and VEC	1961-1997 A	Canada	Capital and EMP	EC ↔ GDP
Jobert and Karanfil (2007)	JJ	1960-2003 A	Turkey	IVA	EC — GNP EC — IVA
Odhiambo (2010)	Co-integration, ARDL and ECM.	1972-2006 A	South Africa Kenya Congo	energy prices	EC → GDP EC → GDP GDP → EC
Kaplan et al. (2011)	VECM	1971-2006 A	Turkey	Energy price, capital and labour.	EC ↔ GDP
Zaidi et, al. (2015)	Panel data	1960-2011 A	Austria, Sweden, Norway, France and Finland	GHG	GDP → EC GDP→GHG
Zaidi et, al. (2015)	Panel data and Granger causality	1950-2010 A	Austria, Sweden, Norway, France and Finland	SO_2	SO_2 ↔EC
Zaidi et, al. (2015)	Panel data	1960-2011 A	Europe countries	PM_{10}	GDP↔PM_{10}
Yang and Zhao (2014)	Granger causality	1979-2008 A	India	CO_2	EC → GDP EC → CO_2

Notes: The unidirectional causality, bidirectional causality and no causality between EC and GDP are represented by the symbols →, ↔ and — respectively. For the Abbreviations of methods; JJ: Johansen-Juselius causality test, VECM: vector error correction model. ARDL: autoregressive distributed lag bounds test. VDC: forecast error variance decomposition. ECM: error correction model. While the abbreviation of main variables and scope; GNP or GDP represent the economic growth. EC: energy consumption. IVA: Industrial value added. CO_2: carbon dioxide emissions. PM_{10}: particulate matter micrograms. GHG: greenhouse gases. SO_2: Sulphur dioxide. EMP: Employment.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

Moreover, the second strand of literature is concentrating on causality relationship between EC and GDP. The findings are restricted within four hypotheses; Feedback hypothesis which illustrates bidirectional causality between EC and GDP, that means there is a significant effect of EC into GDP and vice versa. Growth hypothesis which describes unidirectional causality running from EC to GDP, it suggests that EC may have an important role into GDP. Conservation hypothesis which supports the existence of unidirectional causality running from GDP to EC, as GDP may have influence into EC. Neutrality hypothesis which emphasizes that there is no significant effect between EC and GDP (Zaidi et al., 2015). An early study of this strand is conducted by Kraft and Kraft (1978) in the USA. The findings support the existence of unidirectional causality running from GDP to EC. Then it followed by others. Majority studies support the feedback hypothesis (Belke et al., 2011), (Eggoh et al., 2011), (Mahadevan and Asafu, 2007), but some support the growth hypothesis (Hossain and Saeki, 2011), while others support the Conservation hypothesis (Ozturk et al., 2010).

Furthermore, the third strand compiles the two above strands. This strand covers the related studies to the relationship between GDP, EC, and CO_2; (Arouri et al., 2012), (Omri, 2013), (Wang et al., 2011) and others. Most of those studies have report significant relationship between GDP, EC, and CO_2.

On the other hand, there are some studies focus on developed or developing countries. The studies based on single or panel of developed countries include (He and Richard, 2010), (Liu, 2005), (Millimet et al., 2003), (Selden and Song, 1994), (Belke et al., 2011), but some studies concentrates on developing countries; (Ghosh, 2010), (Fodha and Zaghdoud, 2010), (Orubu and Omotor, 2011), (Eggoh et al., 2011), whilst there are several studies have compared between developed and developing countries group; (Alsayed and Sek, 2013), (Stern and Common, 2001), (Coondoo and Dinda, 2002), (Mahadevan and Asafu, 2007), (Ozturk et al., 2010). By comparing the results, majority of studies support the existence of EKC hypothesis and bidirectional causality relationship in both of developed and developing group (Alsayed and Sek, 2013), (Stern and Common, 2001), (Ozturk et al., 2010), (Arouri et. al., 2012), (Omri, 2013). However, some results do not support a significant relationship between CO_2 and GDP in developing countries, but it existed in developed countries (Coondoo and Dinda, 2002). Moreover, there is bidirectional causality between GDP and EC in developed countries but it is not existed in developing countries (Mahadevan and Asafu-Adjaye, 2007).

Material and Methods

Scope of the study

This study contains several variables; the dependent variable is Carbon dioxide emission (CO_2) which measured by metric tons per capita. However, the independent variables are; Gross domestic product (GDP) per capita which measured by USD$, and Aggregate energy consumption (EC) which measured by kiloton of oil equivalent per capita. The study focuses on 29 countries which are divided into two groups; developed countries and developing countries, the classification is made based on World Bank definition. Developed countries group includes 17 countries; Austria, Belgium, Canada, Denmark, Finland, France, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain and Sweden. Developing countries group consists of 12 countries; Bulgaria, Eritrea, Ethiopia, Hungary, Iran, Jordan, Korea,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

Oman, Poland, Romania, South Africa, and Turkey. The panel data is obtained from World Bank website for annual data over the period 1960 to 2008.

Methodology

The heteroscedasticity problem in cross-section data exists when the variance of the unobserved error is not constant over a specific amount of time. The heteroscedasticity does not affect the estimated coefficients but it biases the variance of those coefficients. The Modified Wald test is applied to check the presence of heteroscedasticity as this test is more accurate even in the case of normality assumption is violated.

Panel data approach

The construction of Panel data is a combination of longitudinal data observed over a period of time. Panel data approach is applied to detect the relationship between the variables; GDP, EC and CO_2 by constructing three different models; First model is estimated by using the original data without any transformation, while second and third model transform the data by natural logarithm and inverse form, respectively. The best model fits the data is decided based on Coefficient of determination (R^2) and Root mean square error (RMSE).

One advantage of panel data analysis is to consider the spatial (individual) and temporal (time period) dimensions of the data, which allows to control the variation of time series and cross sections simultaneously, and it gives more robust regression. It could overcome the heteroscedasticity problems. Also, it allows covering more observations by pooling the time series data and cross sections which leads to the higher power of the test. Another advantage of panel data is controlling the individual heterogeneity which gives more informative data, less collinearity among the variables, more variability, more degree of freedom, more efficiency of estimate and broaden the scope of inference (Baltagi, 2005).

Panel data analysis follows several steps; First step is to estimate fixed effects models (FE) and Random effects model (RE), then compare them by Hausman test. After that, if the result is significant in favour to FE, we continue the analysis to compare FE with pooled model by the redundant test. If the later test is significant we opt for FE. If not, then the test suggests opting the pooled model. Finally, using White's robust estimation of the standard errors for FE could be performed to get a robust model for standard error against the heterogeneity.

The static panel model (pooled model) takes the form:

$$y_{it} = \alpha + x_{it}^{'}\beta + u_{it} \quad \text{(Eq. 1)}$$

Where x_{it} is the independent variables with coefficients β , y_{it} is the dependent variable, i represent the county on cross section, t stands for time series dimension, α is both a time and an individual-invariant constant term, β is slope and u_{it} is the disturbance term.

Fixed effects model (FE) has the following formula:

$$y_{it} = \alpha_i + x_{it}^{'}\beta + u_{it} \quad \text{(Eq. 2)}$$

$$u_{it} = \mu_i + v_{it}$$

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

Where α_i is countries effects, taking into account the heterogeneity impact from unobserved variables and it may vary across countries, μ_i represents the unobserved countries effects for N cross sections, and v_{it} represents random disturbances.

On the other hand, the random effects model (RE) model is constructed as:

$$y_{it} = \alpha_i + x_{it}'\beta + u_{it}$$
$$u_{it} = (\mu_i + \lambda_t) + v_{it} \quad \text{(Eq. 3)}$$

Where λ_t represents unobserved time-series effects for T time periods.

The estimated models have the following formula based on the type of panel data effect; cross section and period effects after the transformation by natural logarithm and inverse form. The purpose of transforming the data is to induce the stationarity in data, and to reduce heteroscedasticity problem, so the estimated coefficients can be interpreted as elasticity estimates /percent of change. However, in case if the sample has zero or negative values, then there is no way to use the natural logarithmic transformation, which can be solved by applying the inverse form transformation to overcome the heteroscedasticity problem.

Cross section effect models:

$$CO_{2\,it} = \alpha_i + \beta_1\, EC_{it} + \beta_2 GDP_{it} + \varepsilon_{it}$$
$$\text{Ln}\, CO_{2\,it} = \alpha_i + \beta_1\, \text{Ln}\, EC_{it} + \beta_2 \text{Ln}(GDP_{it}) + \varepsilon_{it} \quad \text{(Eq. 4)}$$
$$(1/CO_{2it}) = \alpha_i + \beta_1\, (1/EC_{it}) + \beta_2\, (1/GDP_{it}) + \varepsilon_{it}$$

Period effect models:

$$CO_{2\,it} = \gamma_t + \beta_1\, EC_{it} + \beta_2 GDP_{it} + \varepsilon_{it}$$
$$\text{Ln}\, CO_{2\,it} = \gamma_t + \beta_1\, \text{Ln}\, EC_{it} + \beta_2 \text{Ln}(GDP_{it}) + \varepsilon_{it} \quad \text{(Eq. 5)}$$
$$(1/CO_{2\,it}) = \gamma_t + \beta_1\, (1/EC_{it}) + \beta_2\, (1/GDP_{it}) + \varepsilon_{it}$$

The coefficients (β_1 and β_2) represent the elasticity estimates of CO_2 emissions with respect to EC and GDP respectively.

Diagnostic tests

There are two diagnostic tests; Hausman and Redundant test to compare between the estimated models (FE, RE and Pooled model). Hausman test is used to compare between FE and RE which is based on Wald χ^2 statistics with degrees of freedom (k-1). If the results show a correlation between FE and RE, then it means that there is significant evidence in favor to choose FE model. Hausman statistics has the following formula:

$$h = \mathbf{q}'\left[\text{var}\,(\beta_{FE}) - \text{var}\,(\beta_{RE})\right]^{-1}\mathbf{q} \quad \text{(Eq. 6)}$$

Where, $\boldsymbol{q} = \beta_{FE} - \beta_{RE}$, FE and RE models are consistent under the assumption of the null hypothesis, and RE is more appropriate. However, in the alternative hypothesis FE is more appropriate than RE.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

In additional of that, Redundant test is used to compare between FE and pooled model. Pooled model assumed to be baseline for comparison. Rejection of the hypothesis illustrates that FE model fits the data better than pooled model (Baltagi, 2005). The formula of Redundant test is:

$$F_{(n-1,nT-n-K)} = \frac{(R^2_{FE} - R^2_{Pooled})/(n-1)}{(1-R^2_{FE})/(nT-n-K)} \qquad \text{(Eq. 7)}$$

Where n is number of countries. K is number of independent variables in model.

Discussion and Results

Descriptive statistics

Some of the descriptive statistics of the original data values for each variables GDP, EC, and CO_2 of the developed and developing countries are summarized in *Table 2*. We can note that the standard deviation for each of GDP and EC has high values, which due to the differences in people's incomes, while the variations in EC is due to the availability of the energy resources in the country. On the other hand, the results of Modified Wald test using the original data indicates the existence of heteroscedasticity in the panel data, as the test's value is (74.07) at 1% significant level. However, after transforming the data by using log and inverse form, the results of Modified Wald test support that the data have constant variance (homogenous).

Table 2. *Descriptive statistics*

Variables	Variance type	Mean	Median	Std. Dev	Minimum	Maximum
Developed countries (17)						
	overall			6021.5		
CO_2	between	9330.7	7982.1	1029.6	911.1	40457.8
	within			5934.5		
	overall			15224.6		
GDP	between	15,241.5	10,736.72	13207.1	360.5	118218.8
	within			7791.2		
	overall			1637.5		
EC	between	3,444.7	3,251.1	1460.5	411.4	12124.7
	within			767.5		
Developing countries (12)						
	overall			3429.7		
CO_2	between	5387.1	5584.7	1145.3	14.7	17349.3
	within			3241.4		
	overall			3520.8		
GDP	between	3,069.1	1,962.73	2258.6	79.3	22968.5
	within			2688.0		
	overall			2623.4		
EC	between	2,546.2	1,967.1	1227.9	119.7	13023.9
	within			2323.7		

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

The results of the diagnostic tests

After estimation of both Random effects model (RE) and fixed effects model (FE), the comparison between them is performed by employing Hasuman test. The results of Hausman test suggest that FE model is more appropriate than RE model in most cases. The results are summarized in *Table 3*.

Table 3. *Results of Hausman test*

Model of data	Developed countries group		Developing countries group	
	Cross-section effects	Period effects	Cross-section effects	Period effects
1st model CO_2	17.8**	4.05	43.35***	26.74***
2nd model Ln CO_2	3.29	1.47	265.16***	140.65***
3rd model 1/ CO_2	3.80	11.04**	852.24***	168.81***

***, ** and * indicate the significant level of χ^2 test at 1%, 5% and 10% respectively

However, in case if the results show that FE model is appropriate more than RE, then the next step is to apply Redundant test to compare between FE model and Pooled model. Whilst some cases which have supported the using of RE model, will not be included in redundant test (dash line in table). The results of redundant test suggest that the FE models are more appropriate than the pooled model at 1% level in all remaining cases except in one model estimated by period effect using inverse form transformation. The results of redundant test are summarized in *Table 4*.

Table 4. *Redundant test*

Model of data	Developed countries group		Developing countries group	
	Cross-section effects	Period effects	Cross-section effects	Period effects
1st model CO_2	171.2***	----------	23.97***	4.48**
2nd model Ln CO_2	----------	----------	103.11***	5.23***
3rd model 1/CO_2	----------	0.43	93.93***	4.24***

***, ** and * indicate the significant level of F-test at 1%, 5% and 10% respectively.

Estimation models

This section illustrates the best model which fits the data with high accuracy among the three estimated models; 1^{st} model against 2^{nd} model and 3^{rd} model. The results of estimated models is summarized in *Table 5*.

Generally, the results show that all of the coefficients are significant in all models. Moreover, the estimated models in cross section effects are accurate more than the estimated model in period effects according to the values of R^2 and RMSE. On the other hand, by comparing the cross section models among the three patterns, the results show that the models with data transformation (2^{nd} and 3^{rd} model) outperform than the model

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

without data transformation (1st model) according to the scales, whereas the constant and RMSE are too large in the 1st model. However, in 2nd and 3rd model, we obtain more significant results according to R^2, RMSE and significance coefficients. Therefore, the discussion is based on the results of 3rd model which transformed the data by inverse form, as the models have higher R^2 in both developed and developing countries.

In the 1st model of cross section effects, CO_2 can be explained about 77% and 67% by the explanatory variables (GDP and EC) for developed and developing countries group, respectively. Whilst 2nd model supports that CO_2 can be explained almost 78% and 86% by GDP and EC for developed and developing countries. The 3rd model illustrates that CO_2 can be explained more than 84% by GDP and EC for developed and developing countries respectively.

In additional of that, it is clear in the 3rd model the coefficient of inverse GDP are (0.37) and (-0.65) in developed and developing countries respectively, which show that developing countries has larger effect than developed countries into CO_2, but it has a negative sign which illustrates that GDP has a negative effects towards the CO_2, the coefficient implies that in each one unit increase in (1/GDP) in developing countries leads to 0.65 unit decline in CO_2 compare to the case in developed countries. This implies that economic growth has negative environmental consequences, and the higher GDP ratio, the lower level of CO_2. This is particularly in developing countries due to their high levels of dependence on natural energy resources. As when developing countries start to develop their economic level by raising standards of living and improving quality of life, it results the depletion of energy resources and environmental degradation. After that, they start to mitigate the adverse environmental impacts through generating renewable energy, and induce waste management techniques etc.

In contrast, the coefficient of the inverse EC is (2.83) in developing countries which is about two times higher than that in developed countries (1.48). It has a positive sign which illustrates that the EC has a positive relationship with CO_2, with each 1 unit of kiloton oil per capita increase in the EC leads to the increase of 1.48 and 2.83 unit increase in CO_2 emission for developed and developing countries respectively.

In summary, based on the findings in *Table 5*, the elasticity of EC causes to higher pollutions and elasticity of GDP leads to improvement in pollution problem. So we can conclude that higher (elasticity) growth does not lead to higher pollution but higher (elasticity) energy consumption may cause to higher pollution in developed and developing countries. The increasing volume of CO_2 emissions has a significant effect on the environment. It could achieve the lower level of CO_2 emissions by reducing the consumption of fossil fuels, but that may result in a trouble to economic growth where the development relies on the cost of utilizing the fossil fuels.

Table 5. *Estimated Models of Panel Data Regression*

The Estimated Models	Developed countries group		Developing countries group	
	Cross-section effects	**Period effects**	**Cross-section effects**	**Period effects**
	Best Model Fitted The Panel Data			
1st Model	Robust	RE	Robust	Robust
α	4504.8*	3920.2*	2898.2*	660.12**
β_1 GDP	-0.21***	-0.11***	-0.18***	-0.21**
β_2 EC	2.31**	2.07***	1.73***	3.10***
Statistics Tests				

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

R^2	0.77	0.62	0.67	0.39
RMSE	2037.3	5744.5	1945.4	2780.2
2nd model	RE	RE	Robust	Robust
α	3.25***	1.06**	2.81***	-6.79*
β_1 ln(GDP)	-0.41***	-0.40**	-0.34*	-0.44**
β_3 ln(EC)	1.06***	1.44***	1.09***	2.52**
Statistics Tests				
R^2	0.78	0.69	0.86	0.67
RMSE	0.21	0.31	0.49	0.81
3rd model	RE	Pooled	Robust	Robust
α	0.0013**	0.0019**	0.0015***	-0.0023***
β_1 1/(GDP)	-0.37***	-0.83***	-0.65***	-1.02***
β_2 1/(EC)	1.48***	2.12***	2.83***	2.37***
Statistics Tests				
R^2	0.84	0.81	0.86	0.89
RMSE	0.0025	0.0033	0.0029	0.0041

***, ** and * indicate the Coefficient significant level from zero at 1%, 5%, and 10%. β_1 and β_2 are coefficients for EC and GDP. 1st model is estimated by using the original data without any transformation, 2nd and 3rd models use the natural logarithm and inverse form to transform the data, respectively.

Conclusions and policy implications

A number of challenges existed in detecting the relationship between energy and economic growth as energy is essential role for economic growth and development of a country. Therefore, the interest to investigate the relationship between energy consumption, economic growth and environment quality has been raised notably, especially with regards to the negative impact of energy consumption towards environmental degradation and climate change. These findings should become the framework that concerns competent authorities to take those issues into account.

The main objective in this experimental study is to examine the relationship between CO_2, EC and GDP using different data transformation forms (natural logarithm versus inverse form) in reducing the heteroskedasticity in panel data. The panel data consist of 29 countries from two different economic levels of countries, 17 developed versus 12 developing countries. The data spanning from 1960 to 2008. A panel data approach is applied and estimations based on three models. To achieve this objective, the panel data approach was applied by estimating three different models. The first model used the original data without any transformation, while the second and the third model used the data with transformation by natural logarithm and inverse form respectively. On the other hand, the results of Modified Wald test using the original data indicates the existence of heteroscedasticity. However, after transforming the data by using log and inverse form, the results support that the data have constant variance (homogenous). The main findings support that, the estimated models in cross section effects are accurate more than the estimated model in period effects. On the other hand, by comparing the cross section models among the three patterns, the results show that the models with data transformation outperform than the model without data transformation according to R^2,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

RMSE and significance coefficients. Therefore, the discussion is based on the results of the model which transformed the data by inverse form, as it has the highest R^2 which illustrates that more than 84% CO_2 emission can be explained by GDP and EC.

In conclusion GDP and EC might play an important role into environmental degradation particularly CO_2 emissions, thus it is recommended to policy makers to consider them as an effected factors, especially the developed countries, as the results support that the latter effects the environmental degradation (CO_2) more than that in developing countries group, that appear clearly as the developed counties assuming more energy resources than the developing countries, which most likely the main recourse to emits the CO_2 emissions.

Acknowledgments. I would like to express my sincere gratitude to the anonymous referee and editor who constructive comments and suggestions have improved the earlier version of this paper. Authors gratefully acknowledge the financial support of National University of Malaysia, Project code. GGPM-2016-001.

REFERENCES

[1] Al Sayed, A. R., Sek, S. K. (2013): Environmental Kuznets Curve: Evidences from Developed and Developing Economies. – Applied Mathematical Sciences 7(22): 1081-1092.

[2] Arouri, M. E. H., Ben, Y. A., M'henni, H., Rault, C. (2012): Energy consumption, economic growth and CO2 emissions in Middle East and North African countries. – Energy Policy 45: 342-349.

[3] Baltagi, B. H. (2005): Econometric Analysis of Panel Data (3rd ed.). – John Wiley and Sons Ltd, England.

[4] Belke, A., Dobnik, F., Dreger, C. (2011): Energy consumption and economic growth: new insights into the cointegration relationship. – Energy Economic 33(5): 782-789.

[5] Coondoo, D., Dinda, S. (2002): Causality between income and emission: a country group-specific econometric analysis. – Ecological Economics 40: 351-367.

[6] Eggoh, J. C., Bangake, C., Rault, C. (2011): Energy consumption and economic growth revisited in African countries. – Energy Policy 39(11): 7408-7421.

[7] Fodha, M., Zaghdoud, O. (2010): Economic growth and environmental degradation in Tunisia: an empirical analysis of the environmental Kuznets curve. – Energy Policy 38: 1150-1156.

[8] Ghali, K. H., El-Sakka, M. I. T. (2004): Energy and output growth in Canada: a multivariate cointegration analysis. – Energy Economics 26(2): 225-238.

[9] Ghosh, S. (2010): Examining carbon emissions economic growth nexus for India: a multivariate cointegration approach. – Energy Policy 38: 3008-3014.

[10] Grossman, G., Krueger, A. (1991): Environmental impacts of a North American free trade agreement. – In: Garber, P. (ed.) National Bureau of Economics Research Working Paper, No. 3194. MIT Press, Cambridge.

[11] He, J., Richard, P. (2010): Environmental Kuznets curve for CO2 in Canada. – Ecological Economics 69(5): 1083-1093.

[12] Hossain, M. D. S., Saeki, C. (2011): Does electricity consumption panel granger cause economic growth in South Asia? Evidence from Bangladesh, India, Iran, Nepal, Pakistan and Sri-Lanka. – European Journal of Social Sciences 25(3): 316-328.

[13] Jobert, T., Karanfil, F. (2007): Sectoral energy consumption by source and economic growth in Turkey. – Energy Policy 35(11): 5447-5456.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484

[14] Kaplan, M., Ozturk, I., Kalyoncu, H. (2011): Energy consumption and economic growth in Turkey: cointegration and causality analysis. – Romanian Journal of economic forecasting 2: 31-41.
[15] Kraft, J., Kraft, A., (1978): On the relationship between energy and GNP. – Journal of Energy and Development 3: 401 403.
[16] Liu, X. (2005): Explaining the relationship between CO2 emissions and national income, The role of energy consumption. – Economics Letters 87(3): 325-328.
[17] Mahadevan, R., Asafu-Adjaye, J. (2007): Energy consumption, economic growth and prices: a reassessment using panel VECM for developed and developing countries. – Energy Policy 35(4): 2481-2490.
[18] Masih, A. M. M., Masih, R. (1997): On temporal causal relationship between energy consumption, real income, and prices: some new evidence from Asian-energy dependent NICs based on a multivariate cointegration/vector error correction approach. – Journal of Policy Modeling 19(4): 417-440.
[19] Millimet, D. L., List, J. A., Stengos, T. (2003): The environmental Kuznets curve: real progress or misspecified models? – The Review of Economics and Statistics 85(4): 1038–1047.
[20] Odhiambo, N. M., (2010): Energy consumption, prices and economic growth in three SSA countries: a comparative study. – Energ Policy 38(5): 2463–2469.
[21] Omri, A. (2013): CO2emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. – Energy Economics 40: 657-664.
[22] Orubu, C. U., Omotor, D. G. (2011) Environmental quality and economic growth: Searching for environmental Kuznets curves for air and water pollutants in Africa. Energy Policy.
[23] Ozturk, I., Aslan, A., Kalyoncu, H. (2010): Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. – Energy Policy 38(8): 4422-4428.
[24] Selden, T. M., Song, D. (1994): Environmental quality and development: Is there a Kuznets curve for air pollution? – Journal of Environmental Economics and Environmental Management 27: 147-162.
[25] Stern, D. I., Common, M. S. (2001): Is there an environmental Kuznets curve for sulfur? – Journal of Environmental Economics and Environmental Management 41: 162-178.
[26] Wang, S. D., Zhou, P., Zhou, Q. W. (2011): CO2 emissions, energy consumption and economic growth in China: A panel data analysis. – Energy Policy 39(9): 4870-4875.
[27] Yang, Z., Zhao, Y. (2014): Energy consumption, carbon emissions, and economic growth in India: Evidence from directed acyclic graphs. – Economic Modelling 38: 533-540.
[28] Yu, E. S. H., Hwang, B. (1984): The relationship between energy and GNP: further results. – Energy Economics 6(3): 186-190.
[29] Zaidi, I., Ahmed, R. M. A. S., Sek, S. K. (2015): Review paper on economic growth-aggregate energy consumption nexus. – International Journal of Energy Economics and Policy 5(2): 2146-4553.
[30] Zaidi i. and. Al Sayed, A. R and Sek, S. K. (2015): Detect the relationship among Energy Consumption, Economic Growth and Greenhouse Gases by Panel Data Analysis. – Applied Mathematical Sciences 9 (54): 2645 - 2656.
[31] Zaidi i. and. Al Sayed, A. R and Sek, S. K. (2015): The relationship between Energy Consumption, Economic Growth and Sulphur Emissions by Panel Data approach.– Global Journal of Pure and Applied Mathematics 11(6): 4603-4616.
[32] Zaidi i. and. Al Sayed, A. R and Sek, S. K. (2015): Does the Particulate Matter PM10 have a Significant Effect in the Relationship between Economic Growth, and Energy Consumption? –Advanced Science Letters, 21(6), 1995-1998.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1501_473484