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Energy Consumption and Economic Growth: A Panel Cointegration Analysis for Developing Countries

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Abstract: The aim of this paper is to examine the long-run relationship between energy consumption and economic growth for 80 developing countries from 1990 to 2009. For this purpose, methods of panel unit root test, panel cointegration test and panel dynamic ordinary least squares (DOLS) are applied. These 80 countries are divided into three income groups, namely, upper middle income countries, lower middle income countries and low income countries. The empirical results reveal a long-run cointegrated relationship between energy consumption and economic growth for the whole panel of countries as well as for each group of countries. We find the strong relation running from energy consumption to economic growth for upper middle income countries and lower middle income countries, and a strong relation which runs from economic growth to energy consumption for low income countries. These findings clearly indicate that energy consumption had a positive and statistically significant impact on economic growth in the long-run for these countries.

JEL Classifications: C23; Q43; O40

Keywords: Energy consumption, Economic growth, Panel cointegration, Developing countries

1. Introduction

Energy is an important contributor for global economy over the last four decades because of the scarcity of energy resources starting from first and second energy crisis in 1973 and 1979, respectively. According to the International Energy Agency (IEA, 2007, p.74) projections, world primary energy demand expected to exceed half between 2005 and 2030 with an average annual rate of 1.8%. In the twenty one century, energy consumption is increasing at fastest rate in developing nations due to the rapid population growth, growing standard of living, urbanization, industrialization and economic development. The IEA (2007, p.77) estimated that developing countries contribute approximately 74% of the increase in global primary energy consumption from 2005 to 2030.

Economic growth has become a major issue to transform the pattern of global energy consumption. In this respect, energy plays a crucial role in the process of development and economic growth in developing countries. Therefore, it is very important to understand the relationship between energy consumption and economic growth in order to design effective energy and environmental policies. Over the past years, energy consumption is well-liked subject of debate in the area of environment and economic growth. A large number of empirical studies analyzed the relationship between energy consumption and economic growth in the past years. The initial research in this area was conducted by Kraft and Kraft (1978) for the period 1947-1974 in the United States. Thereafter, numerous studies (see for example, Akarca and Long, 1980; Erol and Yu,

1987; Asafu-Adjaye, 2000; Ghali and El-Sakka, 2004; Soytas and Sari, 2006; Climent and Pardo, 2007; Sari and Soytas, 2007; Odhiambo, 2009; Tsani, 2010; among others) have investigated the relationship between energy consumption and economic growth in different countries or regions using various methods for different time periods. A cointegration method to test the long-run relationship was proposed by Engle and Granger (1987) and has become a widely used method to study the relationship between the variables in economic literatures. However, few researchers (see for example, Yu and Jin, 1992; Masih and Masih, 1996; Glasure and Lee, 1998; Stern, 2000; Oh and Lee, 2004a, b) have applied the cointegration technique to investigate the relationship between energy consumption and income or GDP. The results of previous empirical investigations have been mixed or conflicting due to the choice of data for different time periods and countries as well as the methods applied.

As noted above, most of the previous studies have mainly focused on single country or small sample group of countries using time series technique. The major problem in applying time series methods in individual countries with a relatively short time period reduces the power of the unit root and cointegration tests. In order to overcome such deficiencies in time series methods, the panel data approach can be used. Panel data sets enhance the degrees of freedom and reduce the colinearity among the explanatory variables thus improve the efficiency of econometric estimations (Hsiao, 1986, p.2). In panel data context, some recent empirical studies have investigated the relation between energy consumption and economic growth in developed and industrialized countries (see for example, Al-Iriani, 2006; Narayan *et al*., 2007; Lee *et al*., 2008; Narayan and Smyth, 2008; Lee and Lee, 2010; Belke *et al*., 2011; Hamit-Haggar, 2012). Likewise, few studies (see for example, Lee, 2005; Apergis and Payne, 2009; Ozturk *et al*., 2010; Eggoh *et al*., 2011; Kahsai *et al*., 2012) have also examined the relationship between the variables in developing countries. More recently, some authors have mainly focused on the panel cointegration relationship between energy consumption and economic growth using panel data technique. Aslan and Kum (2010) examined the long-run cointegration relationship between energy consumption and economic growth for sample of 11 East Asian countries and found the strong relation running from economic growth to energy consumption for most cases, except Indonesia and Philippines. Li *et al*. (2011) considered a sample of 30 provinces in China and tested the long-run cointegration relationship between real GDP per capita and energy consumption. They found a positive long-run cointegrated relationship between the variables. Similarly, Narayan *et al*. (2010) analyzed the long-run elasticities of energy consumption and GDP for 93 countries from 1980 to 2006 and found the positive relationship for only about 60 percent of the countries. In fact, such researches are absence for some developing countries using panel data techniques. Ideally, the use of panel data sets provide a well cointegrated relationship between the variables and give the more reliable and more statistically powerful results over time series data sets.

In this study, we use the panel data approach to investigate the long-run cointegrated relationship between energy consumption and economic growth for 80 developing countries from 1990 to 2009. The sign and magnitude between energy consumption and economic growth relation is vital for energy strategy and policy in developing countries.

The contributions of this work are as follows. First, we use panel data approaches to test for panel unit roots, and panel cointegration. We use the panel unit root tests to identify the order of integration of the variables. Then, we employ the heterogeneous panel cointegration technique to investigate the existence of a cointegration relationship between energy consumption and economic growth. Second, this study applies the Dynamic Ordinary Least Squares (DOLS) method to estimate the long-run relationship between the variables. The DOLS estimator allows correcting standard OLS for bias induced by endogeneity and serial correlation. Third, this study considers not only the whole set of 80 developing countries but also we divide the whole set of countries into three income groups: upper middle income countries, lower middle income countries and low

income countries. Most of the previous empirical investigations have given less consideration to classify the countries according to their levels of income.

The rest of the paper is organized as follows. Section 2 describes the variables and data source. Section 3 presents the econometric methods and the empirical findings of the study. Final section gives the conclusions.

2. Variables Description and Data Source

We use annual data of 80 developing countries for the period 1990-2009. All the data are obtained from the World Bank, World Development Indicators (WDI, 2012). The annual data on gross domestic product (GDP) in constant 2000 US dollars are used as a proxy for economic growth (*Y*), and energy use in kilotons of equivalent oil are used as a proxy for energy consumption (*E*). All variables are transformed into natural logarithms. The countries and specified period are selected according to the data availability of energy consumption. Based on the Gross National Income (GNI) per capita in 2011, the World Bank (WB, 2012) has classified countries into four income groups: high income group ($12,476 or more), upper middle income group ($4,036-$12,475), lower middle income group ($1,026-$4,035) and low income group ($1,025 or less). In this study, we select three income groups that consist of 80 developing countries. To make more homogeneity in the panel study, these 80 developing countries are classified as upper middle income group (37 Countries), lower middle income group (31 Countries) and low income group (12 Countries). The detailed description of the listed grouping countries is shown in table 1A (in Appendix).

Table 1. Descriptive statistics

Variables	Mean	Std. Dev.	Maximum	Minimum
All sample countries				
Y	23.59	1.60	28.71	20.39
E	9.48	1.54	14.63	6.58
Observations	1600	1600	1600	1600
Upper middle income countries				
Y	24.26	1.55	28.71	21.40
E	9.86	1.62	14.63	7.07
Observations	740	740	740	740
Lower middle income countries				
Y	23.29	1.41	27.51	20.63
E	9.25	1.52	13.42	6.58
Observations	620	620	620	620
Low income countries				
Y	22.30	1.08	25.08	20.39
E	8.88	0.87	10.39	7.14
Observations	240	240	240	240

Notes: All variables are in natural logarithms. Std. Dev. denotes the Standard Deviation. *Y* is the GDP (in constant 2000 US$) and *E* is the energy consumption (in kilotons oil equivalent). Balanced panel data on all sample (80 countries) and three income group countries: upper middle income (37 countries), lower middle income (31 countries) and low income (12 countries) for the period 1990-2009.

The above Table 1 reports the descriptive statistics of the economic growth and energy consumption variables, for all the 80 countries and three different income groups during the period 1990-2009. The comparisons of descriptive statistics results among the three income group countries reveal that the means of GDP (24.26) and energy consumption (9.86) are highest for upper middle income countries. The lowest means of GDP (22.30) and energy consumption (8.88) are found for low income countries. Overall, among these income group countries, upper middle income countries have the greatest means of GDP and energy consumption for the period 1990-2009.

3. Methodology and Results

In the present study, we use the panel data approach to investigate the long-run relationship between energy consumption and economic growth. The econometric methods and results of the present study are discussed in this sub-section. We follow three empirical methods, namely, panel unit root tests, panel cointegration test and panel dynamic OLS (DOLS) estimator.

3.1 Panel Unit Root Tests

Panel unit root test is one of the most popular tests in economic community because of its higher power rather than unit root tests for individual time series. We use the panel unit root tests to identify the order of integration of each variable. We perform four different statistics proposed by Levin *et al*. (2002, LLC), Im *et al*. (2003, IPS) and Fisher-type tests using ADF and PP tests of Maddala and Wu (1999) and Choi (2001). The LLC test assumes that there is a common unit root process across the cross-sections. This test has null hypothesis of unit root, whereas the alternative hypothesis does not have a unit root. The IPS, Fisher-ADF and Fisher-PP tests assume that there are individual unit root processes across the cross-sections. These three tests have null hypothesis of unit root, whereas the alternative hypothesis of some cross sections do not contain a unit root.

The results of the LLC, IPS, Fisher-ADF and Fisher-PP panel unit root tests for each of the variable are shown in table 2. We perform each test for the level and first difference of energy consumption and economic growth variables. For all variables, the null hypothesis of unit roots cannot be rejected in their level. However, when applying each variable at first difference of the panel unit root test, all tests reject the null hypothesis at the 1% level of significance. Moreover, we find similar results for three income group countries: upper middle income countries, lower middle income countries and low income countries. Thus, we conclude that two variables are non-stationary and integrated of order one process, i.e. *I* (1).

Table 2. Panel unit root test results

	Y Intercept	Y Intercept & Trend	ΔY Intercept	ΔY Intercept & Trend	E Intercept	E Intercept & Trend	ΔE Intercept	ΔE Intercept & Trend
All sample countries								
LLC	2.76	-9.29	-14.80***	-8.49***	-3.29	-6.30	-22.23***	-19.21***
IPS	9.07	-5.91	-14.11***	-8.58***	1.24	-3.42	-22.33***	-18.89***
ADF	110.71	299.79	502.66***	358.79***	226.80	231.42	761.67***	619.18***
PP	344.42	218.67	706.79***	418.72***	194.86	190.44	898.05***	816.13***
Upper middle income countries								
LLC	-1.70	-6.52	-8.58***	-5.30***	-5.01	-3.91	-13.79***	-12.16***

IPS	3.50	-4.27	-8.86***	-3.65***	-1.68	-2.91	-14.95***	-13.12***
ADF	58.61	140.21	216.41***	132.41***	132.81	115.10	349.01***	285.09***
PP	38.89	92.06	200.90***	131.82***	107.47	99.03	393.09***	343.96***
Lower middle income countries								
LLC	0.98	-4.76	-10.23***	-3.32***	-2.32	-3.99	-14.65***	-12.91***
IPS	7.07	-3.09	-9.35***	-6.44***	1.82	-2.29	-14.20***	-12.05***
ADF	44.15	106.80	206.98***	155.65***	58.72	92.75	300.27***	253.48***
PP	290.86	91.23	437.42***	212.44***	63.01	58.14	360.86***	340.31***
Low income countries								
LLC	4.73	-4.30	-6.48***	-7.77***	1.24	-3.07	-9.67***	-7.54***
IPS	5.86	-2.80	-5.83***	-5.30***	3.33	0.03	-8.61***	-6.37***
ADF	7.95	52.78	79.36***	70.74***	35.27	23.57	112.40***	80.61***
PP	14.67	35.38	68.47***	74.47***	24.38	33.27	144.09***	131.86***

Notes: Δ denotes the first difference. LLC represents the panel unit root test of Levin *et al*. (2002). IPS represents the panel unit root test of Im *et al*. (2003). Fisher-ADF and Fisher-PP represent the panel unit root tests of Maddala and Wu (1999) and Choi (2001). All tests examine the null hypothesis of non-stationary and *** indicates statistical significance at the 1% level. The optimal lag length is selected automatically using the Schwarz information criteria (SIC). Probabilities for the ADF (Fisher Chi-square) and PP (Fisher chi-square) tests are computed using an asymptotic $\chi 2$ distribution. All other tests assume asymptotic normality.

3.2 Panel Cointegration Test

Panel cointergation test is mainly used to confirm whether there exists a long-run equilibrium relationship between two or more variables. From the statistical perspective, the long-run equilibrium relationship defines the variables move together over time. If the series contain a panel unit root, then we use panel cointegration test technique. Indeed, panel cointegration test can be used in various ways; here we apply the most popular panel cointegration test developed by Pedroni (1999, 2004) to determine whether a relationship exists between energy consumption and economic growth. The panel cointegration test allows for cross-sectional interdependence with both different individual effects and deterministic trends can be defined as follows:

$$\ln Y_{it} = \alpha_{it} + \delta_i t + \beta_i \ln E_{it} + \varepsilon_{it} \qquad (1)$$

$$\varepsilon_{it} = \rho_{it} \varepsilon_{it-1} + u_{it} \qquad (2)$$

where $i = 1,\ldots\ldots N$ represents the panel member, $t = 1,\ldots\ldots T$ refers to the time period, Y represents the GDP, E represents the total energy consumption and β_i represents the slope coefficient. The parameters α_{it} and δ_i allow for possibility of country-specific effects and deterministic trend effects, respectively. ε_{it} represent the estimated residual deviations from the long-run relationship. To test the null hypothesis of no cointegration (i.e. $\rho_i = 1$), Pedroni (1999, 2004) proposed two types of cointegration tests: panel tests and group tests. First, the panel tests based on the within dimension method (i.e. panel cointegration statistics test) which includes four statistics, namely, panel v-statistic, panel rho-statistic, panel PP-statistic and panel ADF-statistic. Second, the group tests based on the between dimension method (i.e. group mean panel cointegration statistics test) which includes three statistics, namely, group rho-statistic, group PP-statistic and group ADF-statistic. These seven statistics are asymptotically distributed as standard normal and the detailed description of panel cointegration test statistics can be found in Pedroni (1999, 2004).

Table 3 presents the results of the panel cointegration test statistics. Five statistics significantly reject the null-hypothesis of no cointegration, with the exception of the panel rho-statistic and group pp-statistic for all sample countries. In addition, we find different results among the three income group countries. For the upper middle income countries, the panel v-statistic and group ADF-statistic most strongly reject the null-hypothesis of no cointegration. In the lower middle income countries, the panel v-statistic and group rho-statistic strongly reject the null-hypothesis of no cointegration. The group ADF-statistic very strongly rejects the null-hypothesis of no cointegration for the low income countries. In general, the majority of the statistic tests reject the null hypothesis of no cointegration at the 1% significance level. We find existence of a cointegration relationship between energy consumption and economic growth variables, implying that these variables move together in the long-run. Thus, it is concluded that there is a long-run relationship between energy consumption and economic growth for all sample countries as well as three income group countries.

Table 3. Panel cointegration test results

	Y to E		E to Y	
	Individual Intercept	Individual Intercept & Individual Trend	Individual Intercept	Individual Intercept & Individual Trend
All sample countries				
Panel v-statistic	-1.95**	10.52***	-3.17***	5.71***
Panel rho-statistic	4.54***	1.09	1.96**	0.36
Panel PP-statistic	5.52***	-2.23**	-2.88***	-3.22***
Panel ADF-statistic	1.36*	-2.16**	-7.40***	-7.90***
Group rho-statistic	3.35***	4.34***	1.46*	2.38***
Group PP-statistic	2.11**	-0.78	-3.79***	-3.88***
Group ADF-statistic	-3.05***	-5.81***	-7.18***	-8.65***
Upper middle income countries				
Panel v-statistic	-1.46*	7.84***	-1.33*	1.47*
Panel rho-statistic	3.15***	0.93	-0.40	0.70
Panel PP-statistic	3.83***	-0.81	-4.44***	-2.04**
Panel ADF-statistic	0.02	-0.37	-5.71***	-3.32***
Group rho-statistic	2.21**	3.18***	0.42	1.84**
Group PP-statistic	1.27	0.02	-4.19***	-2.71***
Group ADF-statistic	-2.36***	-3.66***	-6.10***	-5.66***
Lower middle income countries				
Panel v-statistic	-1.34*	8.12***	-2.16**	4.68***
Panel rho-statistic	2.96***	-0.33	1.80**	0.24
Panel PP-statistic	3.56***	-3.54***	-0.95	-1.65**
Panel ADF-statistic	1.17	-4.25***	-5.80***	-6.78***
Group rho-statistic	2.64***	2.43***	1.71**	1.40*

Group PP-statistic	1.95**	-1.16	-0.66	-2.12**
Group ADF-statistic	-0.74	-3.55***	-3.46***	-5.85***
Low income countries				
Panel v-statistic	-0.03	1.05	-1.87**	6.60***
Panel rho-statistic	1.27	1.32*	1.70**	-1.56*
Panel PP-statistic	1.64**	0.50	0.61	-3.17***
Panel ADF-statistic	2.01**	0.01	-0.09	-4.25***
Group rho-statistic	0.80	1.73**	0.30	0.66
Group PP-statistic	0.09	-0.45	-1.38*	-1.85**
Group ADF-statistic	-2.53***	-2.88***	-2.26**	-3.03***

Notes: The test statistics asymptotically distributed as standard normal. *, ** and *** indicate rejection of the null hypothesis of no cointegration at the 10%, 5% and 1% levels of significance, respectively. Automatic lag length selected according to the Schwarz Information Criteria (SIC).

3.3 Panel Cointegration Estimation

After establishing the panel cointegration, the long-run cointegration vector could be tested by using many methods, for instance, the panel fully modified ordinary least squares (FMOLS) developed by McCoskey and Kao (1998), Phillips and Moon (1999) and Pedroni (2000) and the panel dynamic ordinary least squares (DOLS) developed by McCoskey and Kao (1998) and Kao and Chiang (2000). The selection of the appropriate methods is discussed thoroughly in papers (McCoskey and Kao, 1998; Kao and Chiang, 2000). The authors noted that the panel DOLS is less bias than the panel OLS and FMOLS estimators in small samples using Monte Carlo simulations. Moreover, the panel DOLS estimator has better sample properties rather than the panel OLS and FMOLS estimators (Kao and Chiang, 2000).

To estimate the long-run cointegrating vector between energy consumption and economic growth, we employ the panel DOLS method proposed by Kao and Chiang (2000) that consists of lags and leads of the independent variables. The DOLS estimation is given by the following equation:

$$y_{it} = \alpha_i + x_{it}\beta + \sum_{j=-q_1}^{q_2} c_{ij}\Delta x_{it+j} + v_{it} \qquad (3)$$

where $i = 1,\ldots\ldots N$ for each country in the panel, $t = 1,\ldots\ldots T$ denotes the time period, q_1 represents the maximum lag length, q_2 represents the maximum lead length and v_{it} denotes the Gaussian vector error terms process.

The long-run relationship between energy consumption and economic growth variables are examined using the panel OLS and DOLS methods. Tables 4-7 summarize the results of the panel OLS and DOLS estimators for all sample countries, and separately for upper middle income countries, for lower middle income countries and for low income countries. We perform a panel data model with fixed (both individual and time specific) effects. The panel DOLS estimator values are determined following the assumption of two lags and one lead ($DOLS_{2,1}$) in the change of the regressors. It is important to note that the results of the DOLS estimator are very sensitive to the choice of number of lags and leads. However, we find that all coefficient estimates vary small in this study when changing the lags and leads.

Table 4 presents the results of the panel OLS and DOLS estimators for all sample countries.

For each variable, the panel OLS and DOLS estimators produce the similar results in terms of the sign and statistical significance, whereas the magnitudes of the estimated coefficients are slightly different. All the coefficients are statistically significant at the 1% level of significance. We find a positive relationship between energy consumption and economic growth. The panel DOLS results suggest that a 1% increase in energy consumption increases GDP by 0.89%. A 1% increase in GDP increases energy consumption by 0.85%. The highest energy consumption coefficient (0.89%) is observed when using GDP as the dependent variable. This implies a strong relationship which runs from GDP to energy consumption.

Table 4. Panel OLS and DOLS results for all sample countries

	Y		E	
	Panel OLS	Panel DOLS	Panel OLS	Panel DOLS
E	0.47***	0.89***		
	(25.85)	(17.92)		
Y			0.65***	0.85***
			(25.85)	(25.79)

Notes: The t-values are in parentheses. *** denotes statistical significance at the 1% level.

The results of the panel OLS and DOLS estimators for upper middle income countries are shown in table 5. We observe that all the coefficients produce the similar outcome in terms of the sign and statistical significance for panel OLS and DOLS estimators, but the magnitudes of the coefficients are very different. For each approach, the estimated coefficients are positive and statistically significant at the 1% level of significance. For the panel DOLS results, a 1% increase in energy consumption increases GDP by 0.82%. An increase of 1% in GDP increases energy consumption by 0.91%. The GDP coefficient (0.91%) is highest when considering energy consumption as the dependent variable. It implies a strong long-run relationship running from energy consumption to GDP.

Table 5. Panel OLS and DOLS results for upper middle income countries

	Y		E	
	Panel OLS	Panel DOLS	Panel OLS	Panel DOLS
E	0.47***	0.82***		
	(15.82)	(9.87)		
Y			0.57***	0.91***
			(15.82)	(20.03)

Notes: The t-values are in parentheses. *** denotes statistical significance at the 1% level.

Table 6 displays the results of the panel OLS and DOLS estimators for lower middle income countries. We observe that two estimators produce similar results in term of the sign and statistically significance of the coefficients. However, the magnitudes of the coefficients are very different from each other. The panel results show that all the coefficients are positive and statistically significant at the 1% level of significance. The panel DOLS results suggest that a 1% increase in energy consumption increases GDP by 0.81%. A 1% increase in GDP increases energy consumption by 0.98%. The maximum GDP coefficient (0.98%) is found when using energy consumption as the dependent variable. It means that there is a strong relationship which runs from energy consumption to GDP.

Table 6. Panel OLS and DOLS results for lower middle income countries

	Y		E	
	Panel OLS	Panel DOLS	Panel OLS	Panel DOLS
E	0.42*** (18.11)	0.81*** (11.70)		
Y			0.87*** (18.11)	0.98*** (17.56)

Notes: The t-values are in parentheses. *** denotes statistical significance at the 1% level.

The results of the panel OLS and DOLS estimators for low income countries are reported in Table 7. For each estimator, all the coefficients produce the similar results in terms of the sign and statistical significance, whereas the magnitudes of the coefficients are very different. The results of the panel OLS and DOLS indicate that all the coefficients are positive and statistically significant at the 1% level of significance. The panel DOLS results indicate that a 1% increase in energy consumption increases GDP by 1.05%. A 1% increase in GDP increases energy consumption by 0.73%. The highest energy consumption coefficient (1.05%) is obtained when considering GDP as the dependent variable. This means a strong relationship which runs from GDP to energy consumption.

Table 7. Panel OLS and DOLS results for low income countries

	Y		E	
	Panel OLS	Panel DOLS	Panel OLS	Panel DOLS
E	0.65*** (10.92)	1.05*** (8.77)		
Y			0.56*** (10.92)	0.73*** (8.96)

Notes: The t-values are in parentheses. *** denotes statistical significance at the 1% level.

Our analysis shows that the panel DOLS estimator has better performance than panel OLS estimator for a panel of 80 developing countries as well as for the subset of upper middle, lower middle and low income countries. Based on the panel DOLS estimator, we find similar results for the upper middle and lower middle income countries and different results for the low income countries. In the long-term, there exists the strong relation running from energy consumption to economic growth for the upper middle income countries and lower middle income countries, whereas there is a strong relation running from economic growth to energy consumption for the low income countries. The economy of upper middle income countries and lower middle income countries are energy dependent to a large degree and strongly relies on the consumption of the energy. The consumption of energy in these countries, not only related to rapid urbanization, industrialization, infrastructures building but also effect of policies, laws and regulations.

In sum, we find that energy consumption has a positive and statistically significant impact on economic growth in the long-run. Therefore, energy is an important contributing factor to economic growth for developing countries. It is important to note that energy serves as an engine of economic growth and changes in energy consumption bring a significant impact on economic activity (Lee and Chiang, 2008). Our empirical results are consistent with those of Mishra *et al*. (2009), Imran and Siddiqui (2010), Eggoh *et al*. (2011) and Kahsai *et al*. (2012) who found that there is a strong long-run relationship between energy consumption and economic growth. Similar results are also found by Li *et al*. (2011) for a panel of 30 provinces of China. In addition, our findings support the results of Lee (2005) for 18 developing countries and Lee and Chang (2008) for 16 Asian countries.

However, our results contradict the findings of Ozturk *et al*. (2010) who concluded that there is no strong long-run relationship between energy consumption and economic growth for low and middle income countries.

4. Conclusions

In this paper, we investigate the long-run relationship between energy consumption and economic growth for 80 developing countries during the period 1990-2009 using the panel unit root tests, panel cointegration test and dynamic ordinary least squares (DOLS) estimator. In addition, the present study not only investigate the whole panel of countries but also divide the sample countries into three income groups, namely, upper middle income countries, lower middle income countries and low income countries. The panel cointegration test results demonstrate that energy consumption and economic growth are cointegrated for the whole panel of countries and three income group countries. Moreover, the results of the panel OLS and DOLS estimators reveal that there is a strong long-run relationship between energy consumption and economic growth in these countries. It is also found that energy consumption and economic growth has a positive and statistically significant impact on each other in the long-run.

Our empirical results suggest that energy is an essential factor for economic growth in developing countries. This implies that the relation between energy consumption and economic growth are an integral part of development process. Thus, the link between energy consumption and economic growth provide useful information to policymakers in these countries for designing effective energy policies. The findings suggest that all sampled developing countries should focus on making long-term energy policy, increase the investment in energy infrastructure to boost energy efficiency and continue to promote renewable energy sources. Furthermore, the upper middle income countries and lower middle income countries are energy dependent and their policymakers should continue to promote the development of energy infrastructure with the aim to gain higher economic growth in making effective energy policies. The low income countries are economy dependent and energy infrastructure and technology development has great challenge to economic growth, therefore, their policymakers should consider level of energy infrastructure, technology and degree of economic growth in making appropriate energy policy.

In this study we have not incorporated energy consumption and its relation to the impact on environment and other economic factors. Future research will be needed to incorporate the other economic factors (such as labor force, net fixed capital stock and energy price etc.) and carbon dioxide emission within the relation between energy consumption and economic growth.

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Appendix

Table 1A. Sampled Countries based on GNI per capita

Income	GNI	Country Names
Upper middle income group (37 countries)	$4,036 - $12,475	Algeria, Angola, Argentina, Azerbaijan, Belarus, Botswana, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Gabon, Iran, Islamic Rep., Jamaica, Jordan, Kazakhstan, Latvia, Lebanon, Lithuania, Macedonia, FYR, Malaysia, Mexico, Panama, Peru, Romania, Russian Federation, Serbia, South Africa, Thailand, Tunisia, Turkey, Turkmenistan, Uruguay and Venezuela, RB.
Lower middle income group (31 countries)	$1,026 - $4,035	Albania, Armenia, Bolivia, Cameroon, Congo Rep., Cote d'Ivoire, Egypt, Arab Rep., El Salvador, Georgia, Ghana, Guatemala, Honduras, India, Indonesia, Moldova, Mongolia, Morocco, Nicaragua, Nigeria, Pakistan, Paraguay, Philippines, Senegal, Sri Lanka, Sudan, Syrian Arab Republic, Ukraine, Uzbekistan, Vietnam, Yemen, Rep. and Zambia.
Low income group(12 countries)	$1,025 or less	Bangladesh, Benin, Congo Dem. Rep., Ethiopia, Kenya, Kyrgyz Republic, Mozambique, Nepal, Tajikistan, Tanzania, Togo and Zimbabwe.

Note: Country classification by World Bank based on GNI (Gross National Income) per capita, 2011.