Online Publication Date: 10 March, 2012
Publisher: Asian Economic and Social Society

A Dynamic Causality Study between Electricity Consumption and Economic Growth for Global Panel: Evidence from 76 Countries

Md. Sharif Hossain (Department of Economic Engineering, Faculty of Economics, Kyushu University, Japan)

Chikayoshi Saeki (Department of Economic Engineering, Faculty of Economics, Kyushu University, Japan)

Citation: Md. Sharif Hossain, Chikayoshi Saeki (2012): "A Dynamic Causality Study between Electricity Consumption and Economic Growth for Global Panel: Evidence from 76 Countries" Asian Economic and Financial Review Vol.2, No.1, pp.1-13.

Asian Economic and Financial Review, 2(1),pp.1-13

A Dynamic Causality Study between Electricity Consumption and Economic Growth for Global Panel: Evidence from 76 Countries

Author (s)

Md. Sharif Hossain
Department of Economic Engineering, Faculty of Economics, Kyushu University, Japan.
E-mail:sharif@en.kyushu-ua.c.jp, sharif_hossain04@yahoo.com

Chikayoshi Saeki
Department of Economic Engineering, Faculty of Economics, Kyushu University, Japan.
E-mail: saeki@en.kyushu-u.ac.jp

Abstract

This paper empirically examines the dynamic causal relationships between electricity consumption and economic growth for five different panels (namely high income, upper middle income, lower middle income, low income based on World Bank income classification and global) using time series data from 1960 to 2008. Three panel unit root tests results support that both the variables are integrated of order 1 for all panels except low income panel. Only the variable economic growth is integrated of order 1 for low income panel. The Kao and Johansen Fisher panel conintegration tests results support that both the variables are cointegrated for high income, upper middle income and global panels but for lower middle income and low income panels are not cointegrated. Bidirectional causality between economic growth and electricity consumption both in the short-run and long-run is found for high income, upper middle income and global panels from the Granger causality test results. Unidirectional short-run causality is found from economic growth to electricity consumption for lower middle income panel and no causal relationship is found for low income panel. It is found that the long-run elasticity of economic growth with respect to electricity consumption is higher for high income, upper middle income and for global panels indicates that over times higher electricity consumption gives rise to more economic growth in these panels.

Keywords: Dynamic Causal Relationship, Panel Unit Root Test, Panel Cointegration Test, Granger Causality Test.
JEL Classification: C23, C32, C33, O50, O57, Q40.

Introduction

Due to rising energy demand around the word especially in the developed and developing countries, soaring oil prices concerns about energy supply security, the debate of rising GHGs and climate change, a common energy policy will become indispensable for future or near future all over the world. Now-a-days, energy efficiency measures will play a vital role as energy savings as a result most of the countries all over the world fear that such policy measure will harm their economic development especially higher income countries. Thus the most import question arises whether the new energy policy and policy for reducing the GHG's emissions will strike the world economy, especially in the developed and developing societies. One of the best known methods is to investigate the short-run and long-run causal relationship between energy consumption and economic growth for different panels using the time series data.

That is why in this paper the principal purpose has been made to investigate the dynamic causal relationships between electricity consumption and economic growth for five different panels namely high income, upper middle income, lower middle income, and low income panels based on World Bank income classification and also for global panel of 76 countries using the time series data from 1960 to 2008. For this study, the variable electricity consumption (kWh per capita) and per capita real GDP (constant 2000 US $) are considered as the proxies for energy consumption and economic growth respectively for all of these panels.

On the basis of the modern econometrics techniques, the dynamic causal relationships between electricity consumption and economic growth are examined. The testing procedure involves the following steps: At the first step whether each variable contains a unit root is examined using different panel unit root tests. If the variables contain a unit root the second step is to test whether there is a long run-cointegration relationship between the variables. If a long-run relationship between the variables is found, the final step is to estimate panel vector error correction model in order to infer the Granger causal relationship between the variables. Finally using the GMM technique the long-run and short-run elasticities of economic growth with respect to electricity consumption are estimated.

The direction and policy implications for the causal relationship between electricity consumption and economic growth can be classified as follows. If unidirectional causal relationship from electricity consumption to economic growth is found, any restriction on the use of energy leads to a reduction of economic growth. Thus about this negative effect on economic growth that caused by a policy of restriction of energy use in order to slow down the rate of climate change grows by reducing GHG's, many countries of the world will be worried especially high income countries. On the other hand if unidirectional causal relationship from economic growth to electricity consumption is found, any restriction on the use of electricity has very little or no adverse impacts on economic growth. A bi-directional causal relationship implies that both the variables are jointly determined and will affect at the same time. If no causal relationship between these two variables is found, the hypothesis of neutrality holds indicates that any restriction on energy use will not work as a barrier for economic development of the panel.

The organizational structure of the paper is as: Section 2 discusses the literature review; Section 3 discusses data sources and descriptive statistics; Section 4 provides econometric modeling framework with empirical analysis and finally section 5 concludes with a summary of the main findings and policy implications.

Literature Review

In the last three decades, the causal relationships between energy consumption and economic growth as well as economic growth and carbon dioxide emissions are investigated widely in economic literature. The enormous amount of empirical literatures to examine the causal relationship between energy consumption and economic growth fall into four categories; (i) no causal relationship between energy consumption and economic growth, (ii) unidirectional causality from energy consumption to economic growth, (iii) unidirectional causality from economic growth to energy consumption and (iii) bidirectional causality between energy consumption and economic growth.

A number of studies that found no causal relationship between energy consumption and economic growth are as; Akarca and Long (1980), Yu and Hwang (1984), Yu and Choi (1985), Erol and Yu (1988), Yu and Jin (1992), Stern (1993), Cheng (1995), Imran (2010), Hossain (2011), Hossain and Saeki (2011).

Studies that found unidirectional causality from economic growth to energy consumption are as; Cheng and Lai (1997), Glasure and Lee (1998), Cheng (1999), Chang and Wong (2001), Soytas and Sari (2003), Narayan and Smyth (2009), Hossain (2011), and Hossain and Saeki (2011). A number of studies that have found the unidirectional causality from energy consumption to economic growth are as; Yu and Choi (1985), Masih and Masih (1996), Asafu and Adjaye (2000), Yang (2000), Soytas and Sari (2003), Morimoto and Hope (2004), Shina and Lam (2004), Altinary and Karagol (2005), Narayan and Singh (2007), Squalli (2007), Hossain (2011) and Hossain and Saeki (2011).

The studies that have found two way causation are as; Masih and Masih (1997), Asafu and Adjaye (2000), Glasure (2002), Oh and Lee (2004).

In time series econometrics most recent studies have tended to focus on VAR and VEC models and cointegration approach. For example Asafu and Adjaye (2000) investigated the causal relationship between energy use and income in four Asian countries using cointegration and error correction mechanism. They found that causality runs from energy use to income in India and Indonesia and bi-directional causality in Thailand and Philippines. Yang (2000), found bi-directional causality between energy consumption and GDP in Taiwan and this results contradicts with Cheng and Lai (1997) results. Soytas and Sari (2003) found bidirectional causality in Argentina and unidirectional causality from GDP to energy consumption in Italy and South Korea, and from energy consumption to GDP in Turkey, France, Germany and Japan. Paul and Bhattacharya (2004) found bidirectional causality between energy consumption and economic growth in India. Using cointegration analysis Wietze and and Van (2007) found that unidirectional causality from GDP to energy consumption in Turkey. Dirck (2008) used the cointegartion approach to study the causal relationship between electricity consumption and economic growth for the panel of 15 European countries. He found the unidirectional causality from electricity consumption to economic growth for Greece, Italy, and Belgium, and from economic growth to electricity consumption for Great Britain, Ireland, Netherland, Spain and Portugal, no causality is found in Austria, Germany, Denmark, Finland, France, Luxembourg, and Switzerland. Narayan, Narayan and Popp (2010) used the cointegartion approach to study the causal relationship between electricity consumption and economic growth for six different panels of 93 countries. They found bidirectional causality relationship between these two variables except for the panel of Middle East. Unidirectional causality from GDP to electricity consumption is found for the panel of Middle East. Hossain (2011) used the cointegration approach and VEC model to investigate the causal relationship between economic growth and energy consumption for a panel of 9 newly industrialized countries and found unidirectional causality from economic growth to energy consumption for this panel. Hossain and Saeki (2011) investigated the causal relationship between electricity consumption and economic growth for a panel of six South Asian countries using cointegration and error correction mechanism. They found that causality runs from electricity consumption to economic growth in Bangladesh, from economic growth to electricity consumption in India, Nepal and Pakistan and no causal relationship is found between electricity consumption and economic growth in Iran and Sri-Lanka.

Thus the existing literature reveals that due to the application of different econometric methodologies and different sample sizes the empirical results are very mixed and even vary for the same panel and are not conclusive to present policy formulation that can be applied over the countries especially for lower middle income and low income countries. Thus this study tries to overcome the shortcoming literature related with the linkage between electricity consumption and economic growth. Also this empirical study will be important for policy recommendation from the point of view of electricity consumption and economic growth for high income, upper middle income, lower middle income and low income panels and also for global panel.

Data Sources and Descriptive Statistics

Annual data for electricity consumption (EC) (kWh per capita), and per capita GDP (PGDP) (constant 2000 US $), are downloaded from the World Bank's Development Indicators. The data is for the period from 1960 to 2008.

Table-1 Descriptive Statistics for the Individual and also for Panel

Different Panels	Per Capita GDP (constant 2000 USD)					
	Minimum	Maximum	Mean	Std. Dev.	CV	Obs.
High Income	941.062	56624.730	15679.910	9423.200	60.097	1470
Upper Middle Income	72.325	9893.811	3024.657	1819.418	60.153	980
Lower Middle Income	180.861	2672.456	827.271	456.979	55.239	980
Low Income	137.766	587.586	315.892	110.039	34.834	294
Global	72.325	56624.730	7228.043	9131.085	126.328	3724
	Electricity Consumption (kWh Per Capita)					
High Income	14.209	50067.110	6100.516	5271.246	86.407	1470
Upper Middle Income	89.824	4938.405	1096.446	901.364	82.208	980
Lowe Middle Income	15.755	1521.236	317.358	271.039	85.405	980
Low Income	5.808	1027.442	196.247	304.175	154.996	294
Global	5.808	50067.110	2795.645	4292.64	153.547	3724

Std. Dev.: indicates standard deviation; CV: indicates coefficient of variation, Obs.: indicates no. of observations

High income panel of 30 countries, upper middle income panel of 20 countries, lower middle income panel of 20 countries and low income panel of 6 countries are considered for this study [1]. Finally a global panel of 76 countries is considered for this study. At first we reported different descriptive statistics of the variables in order to compare the variability among different panels in Table (1)

In respect of economic growth it is found that high income countries are more volatile than low income countries. The volatility of global panel is highest which indicates the existence of huge differential among the countries in the world. In respect of per capita GDP the range is highest for high income panel and lowest for low income panel. The range of per capita GDP for global panel is 56552.4051 USD which indicates the significant differential between high income and low income countries in the world.

The mean electricity consumption recorded is highest for high income panel followed by upper middle income, lower middle income and low income panel indicates that high income countries are consuming more electricity than low income countries. The mean electricity consumption for global panel is 2795.645 kWh, which is lower than high income panel and higher than upper middle income, lower middle income and low income panels. In respect of electricity consumption the low income countries are more volatile than high income countries indicates that at the early stage of economic development the energy consumption will not be consistent. The volatility for global panel in respect of electricity consumption is 153.54% which indicates the existence of huge differentials in respect of per capita electricity consumption of high income and low income countries in the world. Since the average electricity consumption of high income countries is relatively higher thus a general question arises in our mind whether electricity consumption causes the economic growth. Thus to give the answer of the question, the principal purpose of this study is made to investigate empirically the dynamic causality relationships between electricity consumption and economic growth for five panels based on the modern econometric techniques.

[1] High income panel: Australia, Austria, Belgium, Canada, Switzerland, Denmark, Finland, France, Greece, Hungary, Ireland, Iceland, Israel, Italy, Japan, South Korea, Luxembourg, Malta, Netherlands, Norway, New Zealand, Oman, Portugal, Sweden, Trinidad and Tobago, UK, USA, Hong Kong, Singapore, Spain,
Upper middle income panel: Algeria, Argentina, Botswana, Brazil, Chile, China, Colombia, Costa Rica, Dominican Republic, Gabon, Malaysia, Mexico, Panama, Peru, Thailand, Tunisia, Turkey, Uruguay, Venezuela, South Africa, ,
Lower middle income panel: Bolivia, Cameroon, Congo, Cote d'Ivoire, Egypt, Ghana, Guatemala, Honduras, Indonesia, India, Morocco, Nicaragua, Nigeria, Pakistan, Philippine, Paraguay, Senegal, El Salvador, Syria, Zambia
Low income panel: Bangladesh, Benin, Kenya, Nepal, Togo, Zimbabwe.

Econometric Methodology

The empirical investigation of the dynamic causal relationship between electricity consumption and economic growth based on modern econometric techniques involves the following three steps. At the first step whether each panel variable contains a unit root is examined. If the variables contain a unit root, the second step is to test whether there is a long run-cointegration relationship between the panel variables. If a long-run relationship between the variables is found, the final step is to estimate panel vector error correction model in order to infer the Granger causal relationship between the variables. Finally using the GMM technique the long-run and short-run elasticities of economic growth with respect to electricity consumption are estimated for five different panels.

Panel Unit Root Tests

Since none of the panel unit root tests is free from some statistical shortcomings in terms of size and power properties, so it is better for us to perform several unit root tests to infer an overwhelming evidence to determine the order of integration of the variables. In this paper three panel unit root tests: Im, Peasaran and Shin (IPS, 2003), Maddala and Wu (1999), and Choi (2006) tests are applied. The IPS and MW tests are based on the assumption of cross-sectional independence. This assumption is likely to be violated for the income variable. It is found by Banerjee, Cockerill and Russell (2001) that these tests have poor size properties and have a tendency to over-reject the null hypothesis of unit root if the assumption of cross-section independence is not satisfied. Choi (2006) is derived another test statistic to solve this problem.

Im, Pesaran and Shin (2003) proposed the test statistics using the following model;

$$\Delta y_{it} = \alpha_i y_{it-1} + \sum_{j=1}^{p_i} \gamma_{ij} \Delta y_{it-j} + X'_{it}\delta + \varepsilon_{it} \quad (1)$$

where, $\Delta y_{it} = y_{it} - y_{i,t-1}$, y_{it} (i = 1, 2,………..,n; t = 1, 2,………..,T) is the series under investigation for country i over period t, p_i is the number of lags in the ADF regression and the ε_{it} errors are assumed to be independently and normally distributed random variables for all i's and t's with zero mean and finite heterogeneous variance σ_i^2 . Both α_i and p_i in equation (1) and are allowed to vary across countries. The null hypothesis to be tested is that each series in the panel contains a unit root, i. e. $H_0: \alpha_i = 0 \ \forall \ i$. Against the alternative hypothesis that some of the individual series to have unit root but not all

$$H_1: \begin{cases} \alpha_i = 0; \text{ for some i's} \\ \alpha_i < 0; \text{for at least one i} \end{cases}$$

There are two stages for constructing the t-bar statistic which is proposed by Im, Pesaran and Shin (2003). At the first stage the average value of the individual ADF t-statistic for each of the countries in the sample is calculated which is given by

$$\bar{t}_{nT} = \frac{1}{n}\sum_{i=1}^{n} t_{iT_i}(p_i) \qquad (2)$$

where $t_{iT_i}(p_i)$ is the calculated ADF test statistic for country i of the panel (i = 1, 2, ……,n). The second step is to calculate the standardized t-bar statistic which is given by;

$$Z_{\bar{t}_{nT}} = \frac{\sqrt{n}\left[\bar{t}_{nT} - \frac{1}{n}\sum_{i=1}^{n} E(t_{iT}(p_i))\right]}{\sqrt{\frac{1}{n}\sum_{i=1}^{n} var(t_{iT}(p_i))}} \sim N(0, 1) \qquad (3)$$

where n is the size of the panel, which indicates the no. of countries, $E(t_{iT}(p_i))$ and $var(t_{iT}(p_i))$ are provided by IPS for various values of T and p. However, Im, et al. (2003) suggested that in the presence of cross-sectional dependence, the data can be adjusted by demeaning and that the standardized demeaned t-bar statistic converges to the standard normal in the limit.

Maddala and Wu (1999) proposed a Fisher-type test which combines the p-values from unit root tests for each cross-section i. The test is non-parametric and has a chi-square distribution with 2n degrees of freedom, where n is the number of countries in the panel. The test statistic is given by;

$$\lambda=-2\sum_{i=1}^{n}\log_e(p_i)\sim\chi^2_{2n(d.f.)} \qquad (4)$$

where p_i is the p-value from the ADF unit root test for unit i. The Maddala and Wu (1999) test has the advantage over the Im, et al. (2003) test that it does not depend on different lag lengths in the individual ADF regressions. Maddala and Wu (1999) performed Monte Carlo simulations showing that their test is superior to that proposed by Im, et al. (2003). In addition Choi (2006) derived another test statistic which is given by;

$$Z = \frac{1}{\sqrt{n}}\sum_{i=1}^{n}\Phi^{-1}(p_i) \sim N(0, 1) \qquad (5)$$

where, Φ^{-1} is the inverse of the standard normal cumulative distribution function.

We know macroeconomic variables tend to exhibit a trend over time. As a result it is more appropriate to consider the regression equation with constant and trend terms at level form. Since first differencing is likely to remove any deterministic trend in the variables, regression should include only constant term. Therefore both constant and trend terms are included in the model for the test statistics while utilizing level form and only constant term is included for first differenced of the variables in their logarithmic form. The test results for five panels are given below in Table (2).

The tests results support that both the variables are integrated of order 1 for high income, upper middle income, and lower middle income panels and also for global panel but only the variable economic growth is integrated of order 1 for low income panel.

Panel Cointegration

From the panel unit root tests results it is found that both the series economic growth and electricity consumptions are integrated of order 1 for all panels except low income panel. For low income panel only the variable economic growth is integrated of order 1. Therefore the cointegration analysis is conducted to examine whether there is a long-run relationship between the variables using the Kao (1999) ADF type test and Johansen Fisher panel cointegration test proposed by Maddala and Wu (1999).

The Kao (1999) ADF type test can be computed from the following regression equation

$$e_{it}=\rho e_{it-1}+\sum_{j=1}^{p}\gamma_{ij}\Delta e_{it-j}+v_{it} \qquad (6)$$

where e_{it} 's are the estimated residuals from the panel static regression equation;

$$y_{it}=\mu_i+x'_{it}\beta+u_{it};\ i=1,2,\ldots\ldots,n;\ t=1,2,\ldots,T; \qquad (7)$$

Where

β: (m, 1) vector of the slope parameters

μ_i : intercepts, u_{it} : stationary disturbance terms. Here x_{it} is a (m, 1) integrated process of order 1 for all i, i.e. $x_{it}\sim I(1)\ \forall\ i,\ \Rightarrow\ x_{it}=x_{it-1}+\varepsilon_{it}$, $\{y_{it}, x_{it}\}$ are independent across cross-sectional units and $\omega_{it}=\left(u_{it},\varepsilon'_{it}\right)'$ is a linear process. Then, the long-run covariance matrix of $\{\omega_{it}\}$ is denoted by Ω and is given by; $\Omega=\sum_{j=-\infty}^{\infty}E(\omega_{ij},\omega'_{i0})=\begin{pmatrix}\Omega_u & \Omega_{u\varepsilon}\\ \Omega_{\varepsilon u} & \Omega_{\varepsilon}\end{pmatrix}$

and $\Sigma=E(\omega_{i0}\omega'_{i0})=\begin{pmatrix}\Sigma_u & \Sigma_{u\varepsilon}\\ \Sigma_{\varepsilon u} & \Sigma_{\varepsilon}\end{pmatrix}$

The null hypothesis of no cointegration can be written as

Table-2 IPS, MW , and Choi panel unit root tests results for five panels

	IPS Test	Prob.	MW Test	Prob.	Choi Test	Prob.
	[High Income Panel ; Constant and Trend Terms are Included in the Model [Level Form]					
lnPGDP	-1.4741	0.0712	46.8343	0.8927	1.3456	0.9108
lnEC	0.74169	0.7709	67.7152	0.2307	1.3273	0.9078
	Model with Only Constant Term [First Differenced Form]					
ΔlnPGDP	-18.5510*	0.0000	447.422*	0.0000	-17.099*	0.0000
ΔlnEC	-15.1447*	0.0000	365.974*	0.0000	-14.7413*	0.0000
	Upper Middle Income Panel; Constant and Trend Terms are Included in the Model [Level Form]					
lnPGDP	0.18274	0.5729	26.9947	0.9422	1.36183	0.9134
lnEC	-1.64503	0.0500	43.4734	0.3257	-0.7331	0.2318
	Model with Only Constant Term [First Differenced Form]					
ΔlnPGDP	-19.3034*	0.0000	390.064*	0.0000	-16.5037*	0.0000
ΔlnEC	-13.8171*	0.0000	291.839*	0.0000	-13.5598*	0.0000
	Lower Middle Income Panel; Constant and Trend Terms are Included in the Model [Level Form]					
lnPGDP	2.1013	0.9822	16.8526	0.9995	3.54398	0.9998
lnEC	-2.4278*	0.0076	48.5668	0.1660	-1.9675*	0.0246
	Model with Only Constant Term [First Differenced Form]					
ΔlnPGDP	-18.7508*	0.0000	397.672*	0.0000	-16.6208*	0.0000
ΔlnEC	-19.3710*	0.0000	419.841*	0.0000	-16.759*	0.0000
	Low Income Panel; Constant and Trend Terms are Included in the Model [Level Form]					
lnPGDP	1.5828	0.9433	8.9726	0.7053	2.4071	0.9920
lnEC	-3.5461*	0.0002	32.5079*	0.0012	-3.3349*	0.0004
	Model with Only Constant Term [First Differenced Form]					
ΔlnPGDP	-10.4517*	0.0000	120.762*	0.0000	-8.6467*	0.0000
ΔlnEC	-12.6833*	0.0000	146.074*	0.0000	-10.5931*	0.0000
	Global Panel; Constant and Trend Terms are Included in the Model [Level Form]					
lnPGDP	0.0592	0.5236	99.6542	0.9997	4.0383	1.000
lnEC	-2.6339*	0.0042	192.262*	0.0150	-1.4885	0.0683
	Model with Only Constant Term [First Differenced Form]					
ΔlnPGDP	-34.1038*	0.0000	1401.61*	0.0000	-31.1291*	0.0000
ΔlnEC	-30.1175*	0.0000	1265.29*	0.0000	-28.2836*	0.0000

*: indicates significant at 1% level, **: indicates significant at 5% level.

Table-3 Kao Cointegration Test Results for Five Panels

Different Panels	Kao cointegration test	Probability
High income panel	-7.1061*	0.0000
Upper middle income panel	-4.1765 *	0.0000
Lower middle income panel	-0.4343	0.3320
Low income panel	0.1025	0.4592
Global panel	-5.9069*	0.0000

$H_0: \rho = 1$

Against the alternative hypothesis is

$H_1: \rho < 1$

With the null hypothesis of no cointegration, the Kao (1999) ADF test statistics can be constructed as follows;

$$\text{ADF} = \frac{\dfrac{t_{\hat{\rho}} + \sqrt{6n}\hat{\sigma}_v / 2\hat{\sigma}_{0v}}{2\hat{\sigma}_{0v}}}{\sqrt{\hat{\sigma}_{0v}^2 \big/ 2\hat{\sigma}_v^2 + \left(3\hat{\sigma}_v^2 / 10\hat{\sigma}_{0v}^2\right)}} \sim N(0,1) \quad (8)$$

where, $\hat{\sigma}_v^2 = \hat{\Sigma}_u - \hat{\Sigma}_{u\varepsilon}\hat{\Sigma}_{\varepsilon}^{-1}$

and $\hat{\sigma}_{0v}^2 = \hat{\Omega}_u - \hat{\Omega}_{u\varepsilon}\hat{\Omega}_{\varepsilon}^{-1}$

The Johansen Fisher panel conintegration test is panel version of the individual Johansen conintegration test. The Johansen Fisher panel cointegration test is based on the aggregates of the p-values of the individual Johansen maximum eigenvalues and trace statistic. If p_i is the p-value from an individual cointegration test for cross-section i, under the null hypothesis for the panel

$$-2\sum_{i=1}^{n}\log(p_i) \sim \chi_{2n}^2 \quad (9)$$

The χ^2 value is based on *p*-values for Johansen's cointegration trace test and maximum eigenvalue test. In the Johansen type panel cointegration tests results heavily depends on the number of lags of the VAR system. The results are obtained here use one lag and are given below in Table (4).

Table -4 Results of the Johansen based Panel Conintegration Test for Five Panels

Number of Coint. Eqn.	Model 1 Trace Test	Prob.	Max-Eigen Value Test	Prob.	Model 2 Trace Test	Prob.	Max-Eigen Value Test	Prob.
	High Income Panel							
None	298.3*	0.0000	289.4*	0.0000	252.0*	0.0000	222.3*	0.0000
At Most 1	93.67*	0.0035	93.67*	0.0035	92.65*	0.0044	92.65*	0.0044
	Upper Middle Income Panel							
None	146.0*	0.0000	140.4*	0.0000	143.8*	0.0000	119.6*	0.0000
At Most 1	60.37*	0.0203	60.37*	0.0000	63.79*	0.0098	63.79*	0.0098
	Lower Middle Income Panel							
None	108.8*	0.0000	112.3*	0.0000	104.3*	0.0000	103.1*	0.0000
At Most 1	39.67	0.4849	39.67	0.4849	36.03	0.6377	39.03	0.6377
	Low Income Panel							
None	47.61*	0.0000	66.69*	0.0000	54.31*	0.0000	42.09*	0.0000
At Most 1	16.42	0.1730	16.42	0.1730	24.60**	0.0168	24.60**	0.0168
	Global Panel							
None	606.60*	0.0000	588.5*	0.0000	554.4*	0.0000	487.0*	0.0000
At Most 1	210.1*	0.0013	210.1*	0.0013	217.3*	0.0004	217.3*	0.0004

Model 1: Intercept and no trend in cointegration equation and VAR: Model 2: Intercept and trend in cointegration equation, no trend in VAR

From the tests results in Tables (3) and (4) it is found that there is a long-run relationship between electricity consumption and economic growth for high income, upper middle income and global panels but for lower middle income and low income panels both the variables are not cointegrated.

Granger Causality

The cointegration relationship indicates that the existence of causal relationship between the variables but it does not indicate the direction of causal relationship between variables. Therefore it is common to test for detecting the causal relationship between variables using the Engle and Granger test procedure. In the presence of cointegration relationship between the variable for high income, upper middle income and for global panels the Engle and Granger (1987) causality test takes the following VEC model;

$$\begin{bmatrix} \Delta \ln EC_{it} \\ \Delta \ln PGDP_{it} \end{bmatrix} = \begin{bmatrix} C_1 \\ C_2 \end{bmatrix} + \sum_{k=1}^{p} \begin{bmatrix} \beta_{11k} & \beta_{12k} \\ \beta_{21k} & \beta_{22k} \end{bmatrix} \begin{bmatrix} \Delta \ln EC_{it-k} \\ \Delta \ln PGDP_{it-k} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \end{bmatrix} ECM_{it-1} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \end{bmatrix} \quad (10)$$

And due to the absence of cointegration relationship in the lower middle income and low income panels the he Engle and Granger (1987) causality test takes the following VAR model;

$$\begin{bmatrix} \Delta \ln EC_{it} \\ \Delta \ln PGDP_{it} \end{bmatrix} = \begin{bmatrix} C_1 \\ C_2 \end{bmatrix} + \sum_{k=1}^{p} \begin{bmatrix} \beta_{11k} & \beta_{12k} \\ \beta_{21k} & \beta_{22k} \end{bmatrix} \begin{bmatrix} \Delta \ln EC_{it-k} \\ \Delta \ln PGDP_{it-k} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \end{bmatrix} \quad (11)$$

where i = 1, 2,….,n; t = p+2, p+3,……….,T; .The C's, β's and λ's are the parameters to be estimated., ECM_{it-1} represents the one period lagged error-term derived from the cointegration vector and ε's are serially independent with mean zero and finite covariance matrix. From the equations (10) and (11) given the use of a VEC and VAR structure, variables are treated as endogenous variables. The F test is applied here to examine the direction of any causal relationship between the variables. The electricity consumption does not Granger cause economic growth in the short run, if and only if all the coefficients β_{21k} 's $\forall$ k are not significantly different from zero in equations (10) and (11). Similarly the economic growth does not Granger cause electricity consumption in the short run if and only if all the coefficients β_{12k} 's $\forall$ k are not significantly different from zero in equations (10) and (11). There are referred to as the short-run Granger causality test. The coefficients on the ECM represent how fast deviations from the long-run equilibrium are eliminated. Another channel of causality can be studied by testing the significance of ECM's. This test is referred to as the long run causality test. The panel short-run and long-run Granger causality results are reported below in Table- (5). The findings in Table (5) indicate that there is bidirectional causality between economic growth and electricity consumption both in the short-run and long-run for high income, upper middle income and global panels. Unidirectional short-run causality is found from economic growth to electricity consumption in lower middle income panel and no short-run causal relationship is found between economic growth and electricity consumption for low income panel.

Short-run and Long-run Elasticity

The short run elasticity for high income, upper middle income and global panels can be obtained by estimating the following error correction model;

$$\Delta \ln PGDP_{it} = \alpha \Delta \ln EC_{it} + \lambda ECM_{it-1} + \varepsilon_{it} \quad (12)$$

But for lower middle income and low income panels the short-run elasticity can be obtained from the following model

$$\Delta \ln PGDP_{it} = \alpha \Delta \ln EC_{it} + \varepsilon_{it} \quad (13)$$

where ε_{it} is the random error terms, α and λ are the parameters to be estimated.

The long-run elasticity for five panels can be obtained from the following regression equation;

Table-5 Panel Granger F-test Results

Dependent Variables	ΔlnEC	ΔlnPGDP	ECM
	High Income Panel	[VEC Model]	
ΔlnPGDP	6.4359* (0.0000)		-2.80476* (0.0051)
ΔlnEC		31.6363* (0.0000)	1.87976** (0.0603)
	Upper Middle Income Panel	[VEC Model]	
ΔlnPGDP	1.9366** (0.0859)		-4.94594* (0.0000)
ΔlnEC		6.0683* (0.0000)	2.87282* (0.0042)
	Global Panel [VEC Model]		
ΔlnPGDP	2.4059 * (0.0000)		-2.54997* (0.0108)
ΔlnEC		9.5215*(0.0000)	6.19110* (0.0000)
	Lower Middle Income Panel	[VAR Model]	
ΔlnPGDP	0.3695 (0.775019)		
ΔlnEC		8.1278* (0.0000)	
	lnEC	ΔlnPGDP	
	Low Income Panel		
ΔlnPGDP	0.6602 (0.5175)		
lnEC		0.7740 (0.4621)	

*: indicates significant at 1% level; **: indicates significant at 10% level. Reported values in parentheses are the p-values of the tests

Table-6 Panel Long-run and Short-run Elasticities

Different Panels	Long-run Elasticity [lnPGDP is the Dependent variable]		Short-run Elasticity [ΔlnPGDP is the Dependent Variable]			
	lnEC		ΔlnEC		ECM	
	Coefficient	t-Test	Coefficient	t-test	Coefficient	t-Test
High income panel	0.5958*	12.1476	0.1429*	3.8152	-0.0072	-1.5674
Upper middle income	0.6027*	7.9218	0.2122*	5.5597	-0.0211*	-6.3097
Global panel	0.8125*	48.9068	0.1336*	7.2043	0.0009	0.4544
Lower middle income	0.2871*	8.8280	0.1288*	5.0831		
Low income panel	0.2145*	17.3557	0.00278*	4.4163		

*: indicates significant at 1% level.

$$\text{lnPGDP}_{it} = \mu_i + \beta_i \text{lnEC}_{it} + \sum_{j=-p_i}^{p_i} \lambda_{ij} \Delta\text{lnPGDP}_{it-j} + \sum_{j=-k_i}^{k_i} \gamma_{ij} \Delta\text{lnEC}_{it-j} + u_{it} \quad (14)$$

This equation (14) is augmented with lead and lagged differences of the dependent and explanatory variables to control for serial correlation and endogenous feedback effects. Here the GMM is applied to estimate both equation which control the problem of endogeneity and serial correlation of regressors. The estimated results are given in Table (6). From the estimated results in Table (6) it is found that in the long-run electricity consumption has significant positive impact on economic growth for all panels. The range of positive long-run elasticity of economic growth with respect to electricity consumption is from 0.8125 for global panel to 0.2145 for low income panel. It is also found that short-run elasticities are significant for all panels and ECM is significant only for upper middle income panel. The range of short-run elasticity is 0.2122 for high income panel to 0.00278 for low income panel. It is also found that the long-run elasticity is higher than short-run elasticity for all five panels which indicates that over times higher electricity consumption gives rise to more economic growth for all panels.

Conclusions and Policy Implications

This paper attempts to empirically examine the short-run and long-run causal relationships between electricity consumption and economic growth for five panels namely high income, upper middle income, lower middle income and low income panels based on World Bank income classification and for global panel of 76 countries using the time series data for the period from 1960 to 2008. Also this study attempts to estimate the long-run and short-run elasticities of economic growth with respect to electricity consumption in order to examine the Narayn and Narayn (2010) new approach.

Before testing for any causal relationship between the variables within a VEC model structure at the first stage panel unit root tests and at the second stage panel cointegration analysis are done. Three different panel unit root tests, IPS (2003), MW (1999), and Choi (2006) results support that both the panel variables are integrated of order one for high income, upper middle income, lower middle income and also for global panels but only the variable economic growth is integrated of order 1 for low income panel. The Kao (1999) and Johansen Fisher panel cointegration tests results support that both the panel variables are cointegrated for high income and upper middle income panels and also for global panel but for lower middle income and low income panels both the variables are not cointegrated.

Bidirectional short-run and long-run causal relationships are found between electricity consumption and economic growth for high income, upper middle income and for global panels. Unidirectional short-run causal relationship is found from economic growth to electricity consumption for lower middle income panel and no short-run causal relationship is found for low income panel. It is found that both the short-run and long-run elasticities of economic growth with respect to electricity consumption are positively significant for all panels. The error correction term for the upper middle income panel is statistically significant represents evidence about a long-run relationship between economic growth and electricity consumption. It is found that the long-run elasticity of economic growth with respect to energy consumption for high income, upper middle income and also for global panel is higher than short run elasticity indicates that over times higher electricity consumption in high income, upper middle income and global panels gives rise to more economic growth. Also it is found that in the long-run for 100% increases in electricity consumption for lower middle income and low income panels, the economic growth with be increased by 28.71% and 21.45% respectively and they are statistically significant.

Thus from the analytical results it can be easily concluded that any restriction on the use of energy will strike the economic development of high income and upper middle income countries as well as the countries of the global panel but the lower middle income and low income countries will not be affected. Thus from the analysis the following policies should be implemented to the panels of high income, upper middle and also for global panel to solve the problem. The research and investment in clean energy should be an integral part of the process of controlling the GHG's emissions in the high income and upper middle income countries for which the economy of these countries will not be negatively affected due to any restriction on energy use. The high income and upper middle income countries have to find the alternative sources like as solar energy of energy to oil for which any restriction on energy use will not strike the economic growth.

References

Akarca, A.T., & Long, I.T.V. (1980) "On the Relationship between Energy and GNP: A

Reexamination" Journal of Energy and Development, pp.326-331.

Altinay, G., & Karagol, E.,(2005) "Electricity Consumption and Economic Growth: Evidence from Turkey" Energy Economics, Vol.27, pp. 849–856.

Asafu, J., & Adjaye (2000) "The Relationship between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries". Energy Economics, Vol. 22, No.6, pp. 615-625.

Banerjee, A., Cockerill, L., & Russell, B. (2001) "An I(2) Analysis of Inflation and the Markup" Journal of Applied Econometrics, Vol.16, pp. 221-240.

Cheng, B.S. (1995) "An Investigation of Cointegration and Causality between Energy Consumption and Economic Growth" Journal of Energy and Development Vol. 21, pp.73–84.

Cheng, B.S., & Lai, T.W. (1997) "An Investigation of Co-integration and Causality between Energy Consumption and Economic Activity in Taiwan" Energy Economics, Vol.19, No.4, pp.435-444.

Cheng, B.S., (1999) "Causality between Energy Consumption and Economic Growth in India: An Application of Cointegration and Error Correction Modeling" Indian Economic Review Vol.34 , pp.39–49.

Chang,Y.,& Wong, J. F., (2001) Poverty, Energy, and Economic Growth in Singapore. Working Paper, Department of Economics, National University of Singapore, 37.

Choi, I., (2006) Combination Unit Root Tests for Cross-Sectionally Correlated Panels in Econometric Theory and Practice: Frontiers of Analysis and Applied Research: Essays in Honour of Peter C. B. Phillips by D. Corbae. S. N. Durlauf and B. Hansen, Cambridge University Press.

Dirk C. B., (2008) Electricity Consumption and Economic Growth in the European Union: A Causality Study Using Panel Unit Root Test and Cointegration Analysis, IEEE Xplore.

Erol, U., & Yu, E.S.H. (1987) On the Causal Relationship between Energy and Income for Industrialized Countries. Journal of Energy and Development, Vol.13, No.1, pp.113-122.

Glasure, Y.U., & Lee, A.R. (1998) "Cointegration, Error Correction and the Relationship between GDP and Energy: The Case of South Korea and Singapore" Resource and Energy Economics Vol.20, No.1, pp. 17-25

Glasure, Y.U., (2002) "Energy and National Income in Korea: Further Evidence on the Role of Omitted Variables" Energy Economics Vol.24, pp.355-365.

Hossain, Md. 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, Vol.25, No.3, pp.316-328.

Hossain Md. S. (2011) "Panel Estimation for CO_2 Emissions, Energy Consumption, Economic Growth, Trade Openness and Urbanization of Newly Industrialized Countries" Energy Policy, Vol.39, No.11, pp.6991-6999.

Im, K. S., Pesaran, M. H., Shin, Y. (2003) "Testing for unit roots in heterogeneous panels" Journal of Econometrics Vol.115, pp. 53-74.

Imran, K., (2010) "Energy Consumption and Economic Growth: A Case Study of Three SAARC Countries" European Journal of Social Sciences, Vol.16, No.2, pp.206-224.

Kao, C., (1999) "Spurious Regressions and Residual-Based Tests of Cointegration in Panel Data" Journal of Econometrics Vol.90, pp.1-44.

Maddala, G. S., & Wu, S., (1999) "A Comparative Study of Unit Root Tests with Panel Data and A New Simple Test" Oxford Bulletin of Economics and Statistics, Vol.61, pp.631-652.

Masih, A.M.M., & Masih, R. (1996) "Energy Consumption, Real Income and Temporal Causality: Results from Multi-country Study Based on Cointegration and Error-correction Modeling Techniques" Energy Economics, Vol.18, pp.165-183.

Masih, A.M.M., & Masih, R., (1997) "On the 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, Vol.19, No.4, pp.417-440.

Morimoto, R., &Hope, C., (2004) "The Impact of Electricity Supply on Economic Growth in Sri Lanka" Energy Economics, Vol.26, pp.77-85.

Narayan, P. K., & Singh, B. (2007) "The Electricity Consumption and GDP Nexus for the Fiji Islands" Energy Economics, Vol.29, pp.1141-50.

Narayan, P.K., & Smyth, R. (2009) "Multivariate Granger Causality between Electricity Consumption, Export and GDP: Evidence from a panel of Middle Eastern countries" Energy Policy Vol.37, pp. 229-36

Narayan, P.K. & Narayan, S., (2010) "Carbon Dioxide and Economic Growth: Panel Data Evidence from Developing Countries" Energy Policy, Vol.38, pp. 661-666.

Narayan, P.K., Narayan, S., & Popp S., (2010) "Does Electricity Consumption Panel Granger Cause GDP? A New Global Evidence" Applied Energy Vol.87, pp.3294-3298

Oh, W., & Lee, K., (2004a) "Causal Relationship between Energy Consumption and GDP Revisited: The Case of Korea 1970-1999" Energy Economics Vol.26, pp.51-59.

Oh, W., & Lee, K., (2004b) "Energy Consumption and Economic Growth in Korea: Testing the Causality Relation" Journal of Policy Modeling Vol.26, pp.973-981.

Paul, S., & Bhattacharya, R.N. (2004) "Causality between Energy Consumption and Economic Growth in India: A Note on Conflicting Results" Energy Economics, Vol.26, pp.977-983.

Soytas, U., & Sari, R. (2003) "Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets" Energy Economics, Vol.25, pp.33-37.

Stern, D. I. (1993) "Energy Growth in the USA: A Multivariate Approach" Energy Economics, Vol.15, pp.137-150.

Wietze, L., & Van, M. K., (2007) "Energy Consumption and GDP in Turkey: Is There a Co-integration Relationship?" Energy Economics, Vol.29, pp.1166-1178.

World Bank, (2010) World development indicators.

Yang, H., Y., (2000), "A Note on the Causal Relationship between Energy and GDP in Taiwan," Energy Economics, Vol.22, No.3, pp. 309-317.

Yu. E.S.H., & Choi, J.Y. (1985) "The Causal Relationship between Energy and GNP: An International Comparison" Journal of Energy and Development Vol.10, No.2, pp.249-272.

Yu, E.S.H., & Hwang, B.K., (1984) "The Relationship between Energy and GNP: Further Results" Energy Economics, Vol.6, No.3, pp. 186-190.