Dynamics of Electricity Consumption, Oil Price and Economic Growth: Global Perspective

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Abstract: This study uses the data from 157 countries from 1960 to 2014 to analyze the relationship between economic growth, electricity consumption, oil prices, capital, and labor. The economic growth of developing countries with industrial infrastructure has a more significant association with electricity consumption than oil prices. We use oil prices and electricity consumption jointly to study highly predictive observations for economic growth. The data are categorized by income, OECD and regional levels. The panel cointegration, long-run parameter estimation, and Pool Mean Group testsare used to analyze the cointegration and short-run and long-run relationships between the variables. The empirical results indicate the presence of cointegration between the variables. The presence of feedback effects between electricity consumption and economic growth, oil prices and economic growth is valid. These findings confirm that inspite of the oil prices, developing countries rely heavily on electricity consumption for economic growth. In the short run, growth and feedback effects suggest that more vigorous electricity policies should be implemented to attain sustainable economic growth for the long-term.

Keywords: Electricity Consumption, Oil Prices, GDP, Capital, Population
JEL Classification: Q43, Q48, O13

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1. Introduction

The economic progress of developing countries relies heavily on electricity. The production of manufacturing industries declines due to electricity shortages, which, in turn, destabilize an economy. Electricity consumption is a key component of economic growthand is directly or indirectly a complement to labor and capital as a factor of production (Costantini and Martini, 2010). Various studies have revealed the diverse impact of electricity consumption on economic growth (Yuan et al. 2007, Chen et al. 2007, Yuan et al. 2008, Narayan and Prasad 2008, Abosedra et al. 2009, Mutascu 2016, Ahmed and Azam 2016, Streimikiene and Kasperowicz 2016). For example, some studies suggest apositive impact of electricity consumption on economic growth (Shiu and Lam 2004, Yuan et al. 2007, Shahbaz and Lean 2012, Iyke 2015, Tang et al. 2016, Streimikiene and Kasperowicz 2016). Ozturk (2010) argues that if economic growth is inversely affected by energy consumption, then different arguments could justify the adverse impacts of energy consumption on economic growth. For example, we could imagine a situation in which a growing economy aims to reduce the level of energy consumption through production shifts to less energy-intensive sectors. Furthermore, the inefficient use of energy, such as constraints in capacity use or an inefficient supply of energy, may also have a negative impact on economic growth or growth in real GDP (Chontanawat et al. 2008, Payne 2010, Ozturk 2010). A large number of developing countries have concerns about electricity shortagesdue to scarce resources and infrastructure (Allcott et al. 2014, Shahbaz and Ali 2016). The relationship between electricity consumption and economic growth also varies across the income levels of countries (Yoo and Kwak, 2010). Similarly, Ferguson et al. (2000) reported that the relationship between electricity consumption and economic growth is stronger in high-income countries.

Oil prices are a key component of energy, and their importance in economic development has been recognized by economists, policy makers, businessmen, households, and researchers. After the 1973 oil crisis, several studies (Timilsina 2015, Kilian and Vigfusson 2011, Kilian 2008, Hamilton 1983, 1985, Gisser and Goodwin 1986, Mork 1989) affirmed an inverse relationship between oil prices and economic growth. Economists and researchers have reached a consensus that oil price volatility simultaneously reduces economic growth. However, the recent literature shows the negative relationship decreasing over time because of oil alternatives and preemptive governmental measures against sudden oil price shocks (Doroodian and Boyd 2003, Jbir and Zouari-Ghorbel 2009). Oil-importing developing economies are severely affected by oil price hikes because of a lower tax share on oil prices. Moreover, developed economies have a higher tax share on oil. Therefore, such oil price shocks may be mitigated to an extent by suspending the tax share as oil prices rise. Developing countries with less of a tax share on oil have less ability to absorb oil price shocks. Consequently, oil price hikes appear to have a more adverse impact on developing economies.

These dynamics between electricity consumption, oil prices and economic growth prompt researchers to conduct empirical research and provide diverse empirical evidence. This paper is a humble effort to provide comprehensive empirical evidence by covering data from 157 countries for the period from 1960 to 2014. This study contributes tothe existing energy literature in four ways: (i) The study employs the growth model developed by Solow (1956) by augmenting the production function to investigate the role of electricity consumption and oil prices on domestic production. The industrial infrastructure heavily relies on oil as an input to production operations and transportation. The increase in oil prices leads to higher costs of production and drives inflation, which adversely affects investment and purchasing power. Electricity supply is the basic element of industrial production, and countries facing an electricity shortage cannot sustain the pace of economic growth. The economic growth of developing countries with industrial infrastructure has a high and significant association with electricity consumption compared to oil prices. The production process can be slowed due to an electricity shortage (Shahbaz and Ali 2016). Such a decline in output has a direct influence on financial values. On the other hand, to mitigate such massive losses, many firms attempt to acquire alternative energy-producing plants, which also escalate production costs. The increase in electricity consumption in manufacturing economies may help to trigger economic growth (Kahane and Squitieri 1987). Therefore, this study has incorporated electricity consumption as a factor of domestic production along with oil prices in an augmented production function. The joint use of electricity consumption and oil prices in the augmented production function will also provide new guidelinesfor policy makers to design comprehensive growth policies while considering the role of electricity consumption and oil prices. The ignorance of relevant variables in the function of production may be a reason for the ambiguous results of previous studies in the existing literature (Shahbaz et al. 2016). (ii) The paper investigates the electricity-growth nexus using data from 157 countries, which are further categorized into sub-panels, such as regional, income, OECD and non-OECD levels, to mitigate heterogeneity in the data. (iii) This study applies the panel cointegration approach developed by Westerlund (2007). The Fully Modified Ordinary Least Square (FMOLS) and Pool Mean Group (PMG) tests have also been applied to scrutinize the short-run and long-run associations between the variables. (iv) The heterogeneous panel causality test originated by Dumitrescu and Hurlin (2012) is used to examine the causality relationship between electricity consumption and economic growth in heterogeneous panels. Our results show the existence of a feedback effect between electricity consumption and economic growth. The association between oil prices and economic growth is also bidirectional. Gross fixed capital formation and labor lead to economic growth. The findings show heavy reliance by developing countries on electricity consumption rather than oil prices for sustainable economic growth. This finding varies across income levels and regions.

The rest of the study is organized as follows: Section 2 provides a brief literature review of energy consumption, electricity consumption, oil prices and Pedroni panel cointegration. Section 3 discusses the data and methodology used for estimations. Section 4 reports the results and conclusion. Section 5 provides concluding remarks.

2.Literature Review

We have divided the literature review into two portions: (i) electricity consumption-economic growth nexus and (ii) oil price-economic growth nexus.

2.1. Electricity Consumption and Economic Growth[1]

Researchers and academics have researched the energy-growth nexus using time series and panel data sets but have reported conflicting empirical findings (Ozturk, 2010). These discrepancies may not help policy makers in designing comprehensive economic and energy policies touse electricity consumption as an economic tool to sustain economic growth in thelongrun (Payne, 2010)[2]. For example, Murray and Nan (1996) applied the causality test

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[1]A summary of electricity consumption-economic growth is given in Table-A1 (see Appendix)

[2]The existing literature on electricity consumption and the economic growth relationship provides four conflicting hypotheses: (i) The feedback effect reveals that electricity consumption causes economic growth and that economic growth causes electricity consumption. This hypothesis is empirically validated by Masih and Masih (1996), Constantini and Martini (2010), Shahbaz et al. (2012), Polemis and Dagoumas (2013), Mutascu (2016) and Sarwar et al. (2017). The feedback effect indicates that a decline in the electricity supply impedes economic growth and a reduction in economic growth will decrease electricity demand (ii) The growth hypothesis validates the presence of unidirectional causality running from electricity consumption to economic growth. This indicates that electricity consumption plays a vital role in enhancing domestic production and, hence, economic growth. Empirically, the growth hypothesis is empirically confirmed by Murry and Nan (1994), Khan et al. (2007), Pradhan (2010), Das et al. (2012), Tang and Shahbaz (2013), Wolde-Rufael (2014), Iyke (2015) and He et al. (2017). The feedback and growth hypothesis reveals the importance of energy-

developed by Granger (1969) to examine the relationship between electricity consumption and economic growth using data from 15 countries from 1970 to 1990. They found neutral effects between both variables in the cases of India, the Philippines, and Zambia. Furthermore, their analysis indicates that the conservation hypothesis is valid for Colombia, ElSalvador, Indonesia, and Kenya, whereas the growth effect is found in Mexico, Canada, Hong Kong, Pakistan, Singapore, Turkey, Malaysia, and South Korea. Wolde-Rufael (2006) applied the bounds testing approach developed by Pesaran et al. (2001) as well as the causality developed by Toda and Yamamoto (1995) to examine cointegration and causality between electricity consumption and economic growth in 17 African countries. The results reveal that economic growth causes electricity consumption in 6 countries (Cameroon, Ghana, Nigeria, Senegal, Zambia, Zimbabwe), whereas electricity consumption causes economic growth in 3 countries (Benin, Republic of Congo, Tunisia), and the feedback effect exists between both variables in 3 countries (Egypt, Gabon, Morocco)[3]. Yoo (2006) investigated the direction ofthe causal association between electricity consumption and economic growth for ASEAN countries and reported a feedback effect for Malaysia and Singapore and that economic growth causes electricity consumption in Indonesia and Thailand. In the case of the OPEC region, Squalli (2007) employed the bounds testing and causality approaches developed by Pesaran et al. (2001) and Toda and Yamamoto (1995), respectively, to examine cointegration and causality between electricity consumption and economic growth. The causality results indicate the dependence of economic growth on

(electricity) exploring policies to attain long-run economic growth. (iii) The conservation hypothesis reveals that unidirectional causality runs from economic growth to electricity consumption. This shows that electricity consumption does not play a vital role in stimulating economic growth. The conservation hypothesis is empirically validated by Cheng and Lai (1997), Aqeel and Butt (2001), Narayan and Singh (2007), Narayan et al. (2010), Mahmoodi and Mahmoodi (2011), Shahbaz and Feridun (2012) and Kasnan and Dunan (2015). (iv) The neutral effect indicates that electricity consumption does not lead economic growth and vice versa. This hypothesis is empirically confirmed by Yu and Hwang (1984), Chontanawat et al. (2008), Wolde-Rufael (2009) and Smiech and Papiez (2014).The conservation and neutral hypotheses reveal minor (or no) role of electricity consumption in promoting economic growth. In such circumstances, energy (electricity) conservation policies are suitable because they have no adverse effect on economic growth.

[3] A neutral effect also exists in the cases of Algeria, PR Congo, Kenya, South Africa, and Sudan.

electricity consumption. Chen et al. (2007) investigated the association between electricity consumption and economic growth in 10 industrialized countries from 1971to 2001. Their analysis showedthat electricity consumption causes economic growth, and as a result, economic growth causes electricity consumption.Narayana and Singh (2007) applied the multivariate production function by incorporating labor as an additional determinant of economic growth and electricity consumption for the Fiji Islands for the period from 1971 to 2002. Their results show the presence of unidirectional causality from economic growth and labor to electricity consumption[4].

Using data from 30 OECD countries, Narayan and Prasad (2008) used the bootstrap causality test to examine the causal relationship between electricity consumption and economic growth. They suggested that the implementation of energy conservation policies is not harmful to economic growth. Ciarreta and Zarraga (2008) investigated the causal association between electricity consumption and economic growth in European economies by applying panel cointegration and causality approaches. They found that electricity consumption predicts economic growth in the long run. Oztuek and Acaravci (2010) investigated the

[4]Cheng and Lai (1997) applied Hsiao's version of the Granger causality for Taiwan for the period from 1955 to 1993. Their results indicated the presence of unidirectional causality from economic growth to energy consumption. Asafu-Adjaye (2000) noted that energy consumption caused economic growth for India and Indonesia for the 1973-1995 period. By contrast, in Thailand and the Philippines, a feedback effect was noted between energy consumption and economic growth over the period from 1971 to 1995. Soytas and Sari (2003) used the data from G-7 and 10 emerging economies, but not PR China, for the period from 1950 to 1990 to examine the association between energy consumption and economic growth. They reported that energy consumption has a positive and significant effect on economic growth in Argentina, Italy and Korea and that unidirectional causality from economic growth to energy consumption also exists. Ghali and El-Sakka (2004) collected Canadian data for the period from 1961 to1997 to examine linkages between energy consumption and economics by applying the Johansen-Juselius (1990) and variance decomposition approaches. They confirmed the presence of bidirectional causality between energy consumption and economic growth. Mehrara (2007) attempted to investigate the relationship between energy consumption and economic growth for 11 oil-exporting countries over the period from 1971 to 2002 and found a positive impact of economic growth on energy consumption. Erdal, Erdal and Esengün (2008) also reported bidirectional causality between economic growth and energy consumption for the Turkish economy. Lee et al. (2008) studied the relationship between energy consumption and economic growth for 22 OECD countries by applying the Pedroni panel cointegration test. Their findings supported the presence of a feedback effect between energy consumption per capita and real GDP per capita. Bartleet and Gounder (2010) reported that economic growth stimulated energy consumption in New Zealand.

relationship between electricity consumption and economic growth in the cases of 15 transition economies using panel cointegration and causality approaches[5]. Their analysis indicated no cointegration between the variables and that the implementation of energy (electricity) conservation policies would affect economic growth.

Yoo and Kwak (2010) empirically examined the relationship between electricity consumption and economic growth using data from 7 South American countries for the period from 1975 to 2006. Their results showed that economic growth is the Granger cause of electricity consumption in Ecuador, Columbia, Chile, Brazil and Argentina, but a feedback effect also exists for Venezuela, whereas a neutral effect is valid for Peru. Apergis and Payne (2011) used a multivariate production function using a panel of 88 countries to examine the association between electricity consumption and economic growth. They used a panel error correction model and found a feedback effect between electricity consumption and economic growth for high-income and upper-middle-income country panels, whereas electricity consumption causes economic growth in the lower income country panel. Das et al. (2012) used data from 45 countries from 1971 to 2009 by applying the generalized method of moments (system GMMs) test developed by Blundell and Bond (1998) to examine the linkage between electricity consumption and economic growth. They found a positive and significant association between both variables.

Wolde-Rufael (2014) investigated the relationship between electricity consumption and economic growth for 15 transition countries by applyinga bootstrap panel cointegration test. The results indicated that electricity consumption significantly affects economic growth in

[5]Albania, Belarus, Bulgaria, Czech Republic, Estonia, Latvia,Lithuania, Macedonia, Moldova, Poland, Romania, Russian Federation, Serbia, Slovak Republic and Ukraine.

Bulgaria and Belarus; that economic growth causes energy consumption in the Czech Republic, Lithuania, Latvia; and that a feedback effect is valid for the Russian Federation and Ukraine. Similarly, Karanfil and Li(2015) investigated the relationship between electricity consumption and economic growth for 160 countries from 1980 to 2012. They reported that electricity consumption and economic growth relationship is sensitive to regional differences, income levels, urbanization levels and supply risks as well. Abdoli and Dastan (2015) examined the association between electricity consumption and economic growth by incorporating exports as a potential determinant of the production function for OPEC countries. They employed fully modified OLS (FMOLS) and found that electricity consumption and trade stimulate economic growth. Their causality analysis reveals the presence of a feedback effect between electricity consumption and economic growth in the short run. Kayikci and Bildirici (2015) applied the bounds testing approach to examine the relationship between economic growth, electricity consumption and oil rents for the GCC and MENA regions. They noted that the causality relationship with electricity consumption depends upon natural resource levels.

Osman et al. (2016) applied PMGE and demeaned the PMG, AMG, MGE and DFE approaches to investigate the association between electricity consumption and economic growth in the case of GCC countries. They found that electricity consumption and capitalization spur economic growth. Their analysis indicates the presence of a feedback effect between electricity consumption and economic growth. However, unidirectional causality is noted from capitalization to electricity consumption, whereas economic growth causes capitalization.

2.2. Oil Price and Economic Growth

The general perception about the correlation between oil price and GDP is that a decline in the prices of crude oil decreases inflation (Maeda, 2008). In fact, it is also responsible for the petroleum subsidy along with the interest rates and fiscal deficit; this increases the GDP growth rate and promotes economic development in the country. The relationship between oil price and economic growth was explored by Morey (1993) for the US economy. The empirical results show that oil price hikes decrease economic activity and hence economic growth. Later, Jimenez-Rodriguez and Sanchez (2005) collected data for OECD countries to examine the impact of oil price on economic growth. They found that oil price shocks positively and negatively affect economic growth in oil-exporting and oil-importing countries. Lardic and Mignon (2006) investigated the asymmetric relationship between oil price and economic growth by applying asymmetric cointegration. They found that cointegration exists between the variables and that an oil price increase impedes economic growth. Mehrara (2008) analyzed the relationship between oil price and economic growth for oil-exporting economies. The empirical evidence reported that the relationship between oil price and GDP is non-linear and asymmetric. Farzanegan and Markwardt (2009) investigated the relationship between oil price and macroeconomic variables for Iran. Their results confirmed that a positive shock in oil price has a significant and positive impact on industrial production. In contrast, negative shocks in oil prices have an adverse impact on industrial production. Jayaraman and Choong (2009) attempted to investigate the association between oil price and economic growth in oil-importing economies. Their empirical data reveal that oil price has a negative and significant effect on economic growth and the unidirectional causality exists running from oil price to economic growth. Ozlale and Pekkurnaz (2010) analyzed the linkages between oil price and macroeconomic variables for the Turkish economy. They applied a structural vector autoregression model (SVAR) and confirmed that oil price leadsto a current account deficit that leads to a decline in economic growth. In the case of China, Tang et al. (2010) reported that oil price shocks adversely affect economic growth and investment.

Using data from the G-7, OPEC economies, Russia, India and China, Ghalayini (2011) reinvestigated the association between oil price shocks and economic growth. The empirical exercise reveals that oil priceis negatively (positively) linked with economic growth in oil-importing (exporting) countries. Timilsina (2015) studied 25 economies to examine the empirical relationship between oil price and GDP. The results from the developing countries reported a negative and significant effect of oil price on GDP. The main cause for this negative relationship is the dependence of industries on oil. Moreover, the findings confirm that the increase in oil price helps to strengthen the economy for oil-exporting countries. Ftiti et al. (2016) examined the interdependence between oil price and economic growth using (selected) OPEC countries' monthly data for 2000-2010. They noted that oil price shocks affect the oil-growth nexus in global business cycle fluctuations and the financial crisis turmoil in the OPEC region. Sarwar et al. (2017) investigated 210 countries; they used the findings to show that oil price has a significant effect on economic growth in the short and long run.

3. The Model and Data

This study investigates the association between electricity consumption and economic growth by incorporating oil price in the augmented production function. We have included oil pricevariable into the production function due to its vital impact on economic activity. The impact of oil price hikes is sensitive in oil-exporting and oil-importing countries. Oil prices hike affect real economic activity via supply and demand channels and vice versa. The supply-side channel reveals that oil is a basic factor for production, and an increase in oil price lead to increase in the cost of production, which leads firms or industries to lower output (Morey 1993, Tang et al. 2010). The demand-side channel entails that oil price shocks affect not only consumption but also investment activities. Increase in oil prices will lower output, which lowers real wages due to the decline in demand for labor as a result of the decline in economic growth. A decline in economic growth is positively linked with less disposable income and consumption as well (Maeda 2008, Tang et al. 2010, Ftiti et al. 2016). Oil price hikes increase firms' costs, the result of which decreases investment activities. Indirectly, oil price shocks influence not only exchange rate but also inflation, which in turn affects real economic activity and, hence, economic growth. The general form of the augmented production function is modeled as follows:

$$Y_t = f(E, O, K, L) \tag{1}$$

All the variables have been transformed into natural-log. Shahbaz and Lean (2012) argued that a log-linear specification provides efficient and reliable empirical evidence relative to a simple linear specification. In doing so, all the variables are transformed into natural-log following Shahbaz et al. (2017). The empirical equation of the production function is modeled as follows:

$$\ln Y_t = \alpha_1 + \alpha_2 \ln E_t + \alpha_3 \ln O_t + \alpha_4 \ln K_t + \alpha_5 \ln L_t + \mu_i \tag{2}$$

where $\ln Y_t$, E_t, O_t, K_t and L_t are the natural-log of economic growth measured by real GDP per capita (constant 2010 US$), electricity consumption proxies by electric power consumption per capita (KWh), oil price, capitalization measured by gross fixed capital formation per capita (constant 2010 US$) and labor force per capita, respectively. μ_i is an error term with a normal distribution.

This study uses unbalanced panel data for 157 countries[6] over the period from 1960 to 2014. The data for the real gross domestic product (constant 2010 US$), electric power consumption (KWh), real gross fixed capital formation (constant 2010 US$) and total labor (population aged 15-64) were collected from World Development Indicators (CD-ROM, 2015)[7]. Crude oil price data are obtained from the Statistical Review of World Energy (http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html). The total population is used to convert all variables into per capita units except crude oil price.

3.1. Estimation Strategy

3.1.1. Cross-Sectional Dependence Test

Considering the globalization of the world economy, cross-sectional dependence may largely exist among countries and regional economies. However, cross-sectional dependency is an important factor that influences the result of panel unit root testing and cointegration testing. In doing so, we have applied first- and second-unit root and cointegration tests. The first-generation unit root and cointegration tests assumecross-sectional independence. The second-generation unit root and cointegration tests consider cross-sectional dependence. To decide which type of unit root and cointegration test is suitable, we test the null hypothesis of cross-sectional independence. Using the seemingly unrelated regression equation (SURE), Breusch

[6]Initially we used data for 210 countries. The countries with unavailable GDP data since 1960 are excluded.
[7] http://data.worldbank.org/

and Pagan (1980) proposed the Lagrange multiplier (LM) test, which is based on the average of squared pair-wise correlations of the residuals. The empirical equation of the LM cross-sectional dependence test is formulated as follows:

$$CD_{lm} = T\alpha_{i=1}^{N-1}\alpha_{j=i+1}^{N}S_{ij}^{2} \qquad (3)$$

where S_{ij} is the sample estimate of the pair-wise correlation of residuals and is defined as follows:

$$S_{ij} = S_{ji} = \frac{\alpha_{t=1}^{T} e_{it} e_{jt}}{(\alpha_{t=1}^{T} e_{it}^{2})^{1/2} (\alpha_{t=1}^{T} e_{jt}^{2})^{1/2}} \qquad (4)$$

where e_{it} is the Ordinary Least Squares (OLS) estimate of μ_{it} , defined as follows:

$$e_{it} = y_{it} - \alpha_{i} - b_{i}x_{it} \qquad (5)$$

Where *t* = 1……*T* and *i*= 1……*N* index the time-series and cross-sectional units, respectively. However, the Breusch and Pagan (1980) LM test is likely to exhibit size distortions when large N and small T exist, as in our data. Recognizing their shortcoming, Pesaran (2004) proposed simple tests of error in cross-section dependence thatare applied to a variety of panel data models. These tests include stationary and unit root dynamic heterogeneous panels with short T and large N and are robust to single and even multiple structural breaks in the slope coefficients and error variances of the individual regressions. His cross-sectional dependence statistic is based on pair-wise correlation coefficients rather than their squares, as used in the LM test:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \alpha_{i=1}^{N-1} \alpha_{j=i+1}^{N-1} S_{ij}^{2} \quad (6)$$

3.1.2.Panel Unit Root under Cross-Sectional Dependence

We apply the second-generation panel unit root test to examine the cross-sectional dependence developed by Pesaran (2007). The Pesaran panel unit root uses the cross-section mean to proxy the common factorand constructs the test statistics based on t-ratio of the OLS estimate of $b_i(\hat{b}_i)$ in the following cross-sectional augmented DF (CADF) regression:

$$Dy_{it} = \alpha_i + b_i y_{i,t-1} + c_i y_{t-1} + d_i Dy_t + e_{it} \quad (7)$$

One possibility would be to consider a cross-sectional augmented version of the IPS testbased on the formula given below:

$$CIPS(N,T) = t - bar = N^{-1} a_{i=1}^{N} t_i(N,T) \quad (8)$$

where $t_i(N,T)$ is the augmented Dicky-Fuller statistic across the cross-section for the ith cross-section unit set by the t-ratio of the coefficient ($y_i, t-1$) in the CADF regression.

3.1.3.Panel Cointegration Test

We apply the panel cointegration approach developed by Westerlund (2007), which generates samples through the bootstrap approach and usesa new sample to construct a two-group mean and two-panel statistics. This approach examines whether the model has an error correction (full panel or individual groups) based on the model as follows:

$$Dy_{it} = c_i + \alpha_i(y_{it} - 1 - b_i x_{it-1}) + \alpha_{j=1}^{p_i} \alpha_{ij} Dy_{it-j} + \alpha_{j=0}^{p_i} g_{ij} Dx_{it-j} + e_{it} \qquad (9)$$

where α_i is the speed of the adjustment term. H_0: $\alpha_i=0$ concludes no error correction, and the variables are not cointegrated. H_1: $\alpha_i<0$; the model shows the error correction and provides evidence of cointegration between variables[8].

3.1.4. Estimation of Panel Regression

After determining the existence of cointegration, we move tothe dynamic OLS (DOLS) technique based on a parametric panel developed by Kao and Chiang (2000) for long-run dynamics of the production function. The DOLS estimation ignores the significance of cross-sectional heterogeneity. Therefore, Pedroni (1999, 2000, 2001, 2004) introduced a fully modified OLS (FMOLS) heterogeneous panel cointegration approach. We apply the FMOLS estimation approach due to its consistent estimations. In the presence of endogeneity and heterogeneity, it does not suffer from large-sized distortion.

$$\widehat{\beta} = N^{-1} \sum_{i=1}^{N} (\sum_{t=1}^{T} (y_{it} - \bar{y})^2)^{-1} (\sum_{t=1}^{T} (y_{it} - \bar{y}) z_{it}^{*} - T\widehat{\eta}_i \qquad (10)$$

where $z_{it}^{*} = (z_{it} - \bar{z}) - \frac{\widehat{L}_{13i}}{\widehat{L}_{14i}} y_{it}$, $\widehat{\eta}_i \equiv \widehat{\Gamma}_{13i} + \widehat{\Omega}_{13i}^{\circ} - \frac{\widehat{L}_{13i}}{\widehat{L}_{14i}} (\widehat{\Gamma}_{14i} + \widehat{\Omega}_{14i}^{\circ})$ and $\widehat{L}_i$ is the lowest triangular decomposition of $\widehat{\Omega}_i$. The *t*-statistics are given as follows:

$$t_{\widehat{\beta}^{*}} = N^{-1/2} \sum_{i=1}^{N} t\widehat{\beta}^{*}, i \qquad (11)$$

[8]See Westerlund (2007)for more details.

where $t\widehat{\beta}^{*}, i = (\widehat{\beta}_{i}^{*} - \beta_{0}) \left[\widehat{\Omega}_{13i}^{-1} \sum_{t=1}^{T} (y_{it} - \overline{y})^{2} \right]^{1/2}$

3.1.5.Pool Mean Group (PMG) Test

We apply the Pool Mean Group (PMG) developed by Pesaran et al. (1999), which adopts a parametric model to estimate the cointegration vector based on an error correction model in which short-run dynamics are influenced by the deviation from the equilibrium. The autoregressive distributive lag (ARDL) ($p,q_1,..,q_k$) dynamic panel specification is modeled as follows:

$$x_{it} = \sum_{j=1}^{P} \lambda_{ij} x_{i,t-1} + \sum \delta_{ij} y_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (12)$$

where$y_{i,\,t\text{-}j}$ is the (k x 1) vector of explanatory variables for group *i,* and u_i presents the fixed effects. *p* and *q* can vary across countries, and the model is known as vector error correction model (VECM):

$$\Delta x_{it} = \theta(x_{i,t-1} - \beta_i^{'}(x_{i,t-1}) + \sum_{j=1}^{p-1} \gamma_{ij} \Delta x_{i,t-j} + \sum_{j=1}^{q-1} \gamma_{ij}^{'} \Delta y_{i,t-j} + \mu_i + \varepsilon_{i,t} \qquad (13)$$

Where$\beta\ '_i$ represents the long-run parameters and θ_i is the error correction term. The PMG uses β'_i, which is common across countries.

$$\Delta x_{it} = \theta(x_{i,t-1} - \beta^{'}(x_{i,t-1}) + \sum_{j=1}^{p-1} \gamma_{ij} \Delta x_{i,t-j} + \sum_{j=1}^{q-1} \gamma_{ij}^{'} \Delta y_{i,t-j} + \mu_i + \varepsilon_{i,t} \qquad (14)$$

where $\beta^{'}$ is the error correction speed of adjustment.

$$x_{it} = -(\frac{\theta_i}{\beta_i})x_{it} + \pi_{it} \tag{15}$$

where π_{it} presents the stationary process. If β'=0, the results do not confirm any long-run relationship, and β'<0 confirmsalong-run relationship between variables. The PMG test is intermediate between Mean Group (MG) estimations — in which slopes and coefficients are permitted to differ across countries —and the fixed effect method (FEM) — in which interceptsmay vary but slopes are fixed. In contrast, the PMG technique allows the coefficients to vary across countries in the short run. Furthermore, the MG that averages the coefficients of the country-specific regressions is also a consistent technique but is not a better estimator when either the number of countries orthe period is small (Hsiao et al. 1999). In comparison, the pool mean group estimator uses the combination of pooling and averaging of coefficients.

3.1.6.Heterogeneous Panel Causality Test

To test causality, we use the Dumitrescu and Hurlin (2012) panel causality test. It is a simplified version of the Granger (1969) non-causality test that is generally used for heterogeneous panel data models with fixed coefficients. It considers the two dimensions of heterogeneity: a) the heterogeneity of the regression model for testing the Granger causality and b) the heterogeneity of the causality relationships. The linear model is as follows:

$$z_{it} = \alpha_i + \sum_{m=1}^{M} \gamma_i^{(m)} z_{i,t-m} + \sum_{m=1}^{M} \beta_i^{(m)} y_{i,t-k} + \varepsilon_{it} \tag{16}$$

Equation-16 shows that y and z are two stationary variables for a number of individuals (*N*) in time periods (*T*). The intercept term α_i and coefficient $\beta_i = (\beta_i^{(1)}, \ldots\ldots., \beta_i^{(m)})'$ are consideredfixed in the time dimension, whereas the autoregressive parameter $\gamma_i^{(m)}$ and the regression coefficients $\beta_i^{(m)}$ are assumed to vary across cross-sections. The Homogenous Non-Causality (HNC) hypothesis is assumed to be the null hypothesis; it states no causal relationship for any of the cross-sections in the panel and is defined as follows:

$$H_0 : \beta_i = 0 \qquad \forall_i = 1, 2, \ldots\ldots., N$$

The Heterogeneous Non-Causality (HENC) assumed to be the alternative hypothesis specifies two sub-groups of cross-sectional units. For the first sub-group, from *y* to *z*, there is a causal relationship, which is not necessarily based on the same regression model. However, for the second sub-group, there is no causal relationship from*y* to *z* when considering a heterogeneous panel data model witha fixed coefficient. The alternative hypothesis is defined as follows:

$$H_a : \beta_i = 0 \qquad \forall_i = 1, 2, \ldots\ldots., N_1$$

$$\beta_i \neq 0 \qquad \forall_i = N_1 + 1, \ldots\ldots., N$$

It is assumed that β_i may vary across cross-sections having N_1 < N individual processes with no causal relationship from y to z. N_1 is unknown, but it provides the condition $0 \leq N_1 / N < 1$. Therefore, we propose the average statistic $W_{N,T}^{HNC}$, which is related to the Homogenous Non-Causality (HNC) hypothesis, as follows:

$$W_{N.T}^{HNC} = \frac{1}{N}\sum_{i=1}^{N} W_{i,T} \tag{17}$$

Each Wald statistic converges to a chi-squared distribution having M degrees of freedom $T \to \infty$ of the null hypothesis of the non-causal relationship. The standardized test statistic $Z_{N,T}^{HNC}$ for $T, N \to \infty$ is shown as follows:

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2M}}(W_{N,T}^{HNC} - M) \to N(0,1) \tag{18}$$

In equation18, $W_{N,T}^{HNC} = (1/N)\sum_{1=1}^{N} W_{i,T}$. The Dumitrescu and Hurlin (2012) study can be helpful in offering further information about the heterogeneous panel causality test.

4. Results and Discussion

Table-1 shows the results of the LM, CD, and CIPS cross-sectional dependence tests. We find that the empirical evidence provided by the LM and CD tests strongly supports rejectingthe null hypothesis of cross-sectional dependence. This result implies that the data are cross-sectionally dependent. The presence of cross-sectional dependence directs us to apply the second-generation unit root test to examine the unit root properties of the variables. In doing so, we have appliedthe CIPS unit root developed by Pesaran (2007). We note that all the variables are non-stationary in terms of the intercept and trend but are stationary interms of the first difference at the 1% level of significance. Moreover, we apply the Im, Pesaran and Shin (1997) (IPS) unit root test for a robust check. The findings of the IPS unit root are similar to the CIPS unit root test, which indicates the presence of a unit root process at level and stationarity at first difference. The results of the IPS unit root test are shown in Table-A2 (appendix). This observation shows that all the variables have a unique order of integration, i.e., I(1) in thefull panel.

Table-1: Cross-Sectional Dependence and Unit Root Analysis

Variable	$\ln Y_t$	$\ln E_t$	$\ln O_t$	$\ln K_t$	$\ln L_t$
Breush-Pagan(LM)	220450.5**	200883.6**	32373**	179432.9**	32373**
Pesaran CD	444.99**	276.038**	568.973**	379.754**	568.973**
Unit Root test with cross-sectional dependence					
CIPS Test (level)	-1.339	-1.795	1.273	-1.395	-0.942
CIPS Test (first) difference)	1.534**	1.492**	9.711**	5.137**	1.483**
Note: ** and *indicate significance at 1% and 5%, respectively					

After confirming that the variables are integrated at I(1), we proceed to apply thepanel cointegration approach developed by Westerlund (2007). The results are reported in Table-2. We note that the empirical findings of the panel and group statistics lead to rejection of the null hypothesis of no cointegration in the full panelor at the income, OECD or regional levels. This result implies the presence of cointegration between the variables over the period from 1960 to 2014. We may conclude that the long-run relationship between economic growth, electricity consumption, oil prices, gross fixed capital formation and labor is supported. For a robust check, we further apply (Pedroni, 1999, 2000, 2001, 2004) a panel cointegration test, and the results are reported in Table-A2. The panel cointegration test results confirm the findings of the Westerlund (2007) cointegration test.

For long-run dynamic linkages between the variables, we have applied FMOLS. The results are shown in Table-3. The empirical results indicate that electricity consumption has a positive and significant impact on economic growth in the case of the full panel as well as for lower-middle income, upper-middle income, OECD, East Asia & Pacific, Middle East & North Africa, South Asia and Sub-Saharan Africa regions. This finding is consistent with those of Streimikiene and Kasperowicz (2016), Tang et al. (2016), and Rafindadi and Ozturk (2016). Electricity consumption positively (negatively) but non-significantly affects economic growth in the cases of low-income countries, non-OECD countries, Europe & Central Asia and Latin America & the Caribbean (high-income countries and North America). These results show that oil is a more noteworthy energy component than electricity in these regions.

Table-2: Westerlund (2007) Panel Cointegration Analysis

Test	**Full panel**		**Income level**								**OECD level**			
			Low		**Lower-Middle**		**Upper-Middle**		**High**		**OECD**		**non-OECD**	
Statistic	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*
Gt	0.009	0.000	0.238	0.000	0.013	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.607	0.000
Ga	0.168	0.000	0.311	0.001	0.001	0.000	0.000	0.000	0.057	0.001	0.002	0.000	0.878	0.000
Pt	0.000	0.000	0.331	0.000	0.459	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.779	0.000
Pa	0.000	0.000	0.338	0.004	0.018	0.000	0.031	0.000	0.000	0.000	0.000	0.000	0.659	0.000

	Regional level													
	East Asia & Pacific		**Europe & Central Asia**		**Latin America & Caribbean**		**Middle East & North Africa**		**North America**		**South Asia**		**Sub-Saharan Africa**	
Statistic	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*	*P-value*	*Robust P-value*
Gt	0.495	0.000	0.000	0.000	0.001	0.000	0.107	0.000	0.040	0.000	0.003	0.000	0.177	0.000
Ga	0.062	0.000	0.001	0.000	0.000	0.000	0.096	0.001	0.009	0.000	0.028	0.001	0.657	0.000
Pt	0.534	0.000	0.000	0.000	0.001	0.000	0.279	0.000	0.105	0.000	0.002	0.000	0.495	0.000
Pa	0.331	0.031	0.000	0.000	0.000	0.000	0.175	0.000	0.006	0.000	0.002	0.000	0.373	0.000

Note: **and*indicate significance at 1% and 5%, respectively

Table-3: Fully Modified OLS Regression Analysis

Group	$\ln E_t$	$\ln O_t$	$\ln K_t$	$\ln L_t$
Full Panel	0.157**	0.241**	0.482**	2.840**
Income Level				
Low	0.914	1.223**	0.492***	1.526**
Lower-Middle	2.433**	1.541**	0.161***	0.691**
Upper-Middle	0.359**	1.882	1.141***	0.832
High	-0.194	1.704**	0.138***	0.057**
OECD				
OECD	0.159**	0.135**	0.448***	2.672**
Non-OECD	2.435	0.374**	0.649***	2.113**
Region				
East Asia & Pacific	1.065**	0.997**	0.276***	2.317**
Europe & Central Asia	1.143	1.521	0.493***	0.549
Latin America & Caribbean	0.612	0.428**	0.835***	0.581**
Middle East & North Africa	1.118**	0.627**	0.924***	1.217**
North America	-0.351	0.126**	0.611***	-0.058
South Asia	0.163**	1.507	0.329***	1.205
Sub-Saharan Africa	0.198**	0.127*	0.849***	0.242*
Note: ** and *****indicatesignificance at 1% and 5%, respectively.				

Oil price has a positive and significant effect on economic growth. This relationship shows that the increase in oil price positively affects economic growth in the full panel and in low-income, lower-middle income, high-income, OECD & non-OECD, East Asia & Pacific, Latin America & Caribbean, Middle East & North Africa, North America and Sub-Saharan Africa regions. The positive relationship indicates that energy price-saving and lower oil pricesmayalso curtail payments for imports (oil). North America is the only region adversely affected by an increase in oil price. These countries are oil-exporters as well as oil-importers, and the rapid decline in oil prices has both negative and positive effects on different sectors. In the case of Canada, real GDP increased by 2.4% in the last quarter of 2014. By contrast, real incomes contracted due to the value of exports (oil) (Isfeld, 2015). This finding is similar to that of Alquist and Guénette (2014). In the cases of upper-middle income countries, Europe & Central Asia and South Asia, oil price has a positive but non-significant impact on economic growth. This finding of non-significance is in line with Behmiri and Manso (2014), who argue that South Asia, i.e., Pakistan[9], India[10], Bangladesh, etc. consists of industrial economies in which oil consumption is continuously increasing regardless of whether oil price increases or decreases. The non-significance of oil price and the significance of electricity consumption confirm that electricity has a more prominent role than oil price in South Asia.

The relationship between gross fixed capital formation and economic growth is positive and significant in the full panel and in all regions, which implies that capitalization enhances economic growth significantly. Our empirical evidence is similar to that of Streimikiene and Kasperowicz (2016), Apergis and Payne (2010) and Satti et al. (2014), who reported that gross fixed capitalization plays a vital role in stimulating economic activity and hence stimulates economic growth. The association between labor growth and economic growth is positive and significant. Labor growth affects economic growth positively and non-significantly in the full panel and all regions except for upper-income countries, but in North America, labor growth adversely affects economic growth, albeit non-significantly.

Our empirical evidence indicates the significance of economic growth in all five developing country categories. Lower-middle income, upper-middle income, East Asia & Pacific, Middle East & North Africa and South Asia showa significant positive effect of electricity consumption on economic growth. Oil price is significant for only three of the five developing country categories. The upper-middle income and South Asia categories showsignificant results. In sum, the results confirm that developing countries rely heavily on electricity consumption for economic growthin spite of oil price. Proficient and sound fiscal

[9]Double-digit percentage increases in oil consumption were recorded by Pakistan between 2012 and 2013 (Rapier, 2014).
[10] India became the third-largest oil consumer in 2015 (Meyer and Hume, 2014).

policy, monetary policy and industrial infrastructure can mitigate the effect of oil price shocks on economic growth. Furthermore, we apply panel OLS and dynamic OLS for a robust check, and the results are reported in Table-A3. The empirical evidence corroborates the impact of electricity consumption, oil price, capital and labor on economic growth, which is in line with the FMOLS empirical results. This indicates that long-run empirical results are reliable and robust.

Table-1: Pool Mean Group Analysis

Dependent Variable	Source of causation (independent variable)					
	Short-run					Long-run
	$\Delta \ln Y_t$	$\Delta \ln E_t$	$\Delta \ln O_t$	$\Delta \ln K_t$	$\Delta \ln L_t$	ECT_{t-1}
Full Panel						
$\Delta \ln Y_t$		0.111**	0.063**	0.391**	0.128**	0.0015**
$\Delta \ln E_t$	1.242**		11.214**	0.953	2.528	0.0063**
$\Delta \ln O_t$	31.157**	2.059		0.153	41.250**	-0.0040*
$\Delta \ln K_t$	125.548	5.493*	5.846**		2.753**	-0.0010
$\Delta \ln L_t$	8.186	24.435**	5.753**	6.197**		0.0011**
Low-Income Panel						
$\Delta \ln Y_t$		4.872	1.559*	0.194	0.772	-0.0107
$\Delta \ln E_t$	0.547		1.183	6.717	0.326	-0.0021**
$\Delta \ln O_t$	8.359	0.141		0.943	1.971**	-0.0170
$\Delta \ln K_t$	6.105	4.008	0.513		1.209	0.0011
$\Delta \ln L_t$	2.973	2.466	3.157	0.013		-0.0529*
Low-Middle-Income Panel						
$\Delta \ln Y_t$		2.593**	1.854**	9.451*	8.937*	0.0081
$\Delta \ln E_t$	5.673		1.775	11.823	7.031	0.0004
$\Delta \ln O_t$	18.209**	3.82		7.106	98.435**	0.0031**
$\Delta \ln K_t$	10.815**	8.006**	9.651**		35.618**	-0.0683
$\Delta \ln L_t$	2.607	5.111	11.345**	5.715		0.0018**
Upper-Middle-Income Panel						
$\Delta \ln Y_t$		25.822*	2.485	12.765**	43.541**	-0.0064**
$\Delta \ln E_t$	25.654**		6.908	22.582	12.079	-0.0234*
$\Delta \ln O_t$	3.174**	8.907**		0.135	60.953**	-0.0006**
$\Delta \ln K_t$	23.765**	45.079**	4.124*		5.171**	0.0979**
$\Delta \ln L_t$	7.411	2.147	3.159	8.534**		-0.0554
High-Income Panel						

$\Delta \ln Y_t$		6.438**	9.022	4.212	16.108**	-0.0751**
$\Delta \ln E_t$	52.97**		15.4*	78.505**	0.316	-0.0834**
$\Delta \ln O_t$	11.66*	2.407		8.192	32.0541**	-0.0733*
$\Delta \ln K_t$	126.309	3.868	5.627		5.196**	0.0518*
$\Delta \ln L_t$	9.988	14.583**	9.642	6.152		0.0960
OECD						
$\Delta \ln Y_t$		9.915**	5.892	4.331	2.554**	0.0515*
$\Delta \ln E_t$	1.924**		25.109**	56.491**	6.477	-0.0301**
$\Delta \ln O_t$	75.35	9.774		9.182	8.815	-0.0845*
$\Delta \ln K_t$	65.431	5.706	7.204		5.613	0.0129
$\Delta \ln L_t$	9.007	95.806**	3.114	5.841		0.0015**
Non-OECD						
$\Delta \ln Y_t$		30.019**	9.082**	5.960	81.102*	0.0056
$\Delta \ln E_t$	5.609		56.806**	8.312	8.081	0.0110
$\Delta \ln O_t$	7.426**	8.185		9.444	99.107**	0.0451*
$\Delta \ln K_t$	14.901**	7.155	17.011**		73.215*	0.0009**
$\Delta \ln L_t$	11.152	0.106	5.131	4.016		0.0061
East Asia & Pacific						
$\Delta \ln Y_t$		17.151**	1.864**	5.091	2.87**	0.0010**
$\Delta \ln E_t$	53.609**		1.076	5.808**	4.631	-0.0013**
$\Delta \ln O_t$	1.441	3.127		23.514	30.011**	-0.0068*
$\Delta \ln K_t$	90.307*	6.936*	6.553		3.792	0.0718
$\Delta \ln L_t$	6.102	109.601*	5.321	2.047		-0.0089
Europe & Central Asia						
$\Delta \ln Y_t$		1.55*	11.045	32.306**	17.806	0.0020*
$\Delta \ln E_t$	6.609		97.564**	3.104	15.661	-0.0026**
$\Delta \ln O_t$	78.908**	6.342		8.791	52.906*	0.0048
$\Delta \ln K_t$	8.564**	89.013**	1.07		9.155*	0.0917*
$\Delta \ln L_t$	0.896	2.3067**	23.011**	7.155		-0.0806
Latin America & Caribbean						
$\Delta \ln Y_t$		2.097**	7.869**	15.506	42.807*	-0.0501
$\Delta \ln E_t$	4.927*		9.172	13.908	75.432**	-0.0001
$\Delta \ln O_t$	13.901**	3.412		54.021	68.195	-0.0047**
$\Delta \ln K_t$	16.071**	8.262	24.456		4.001	0.0098*
$\Delta \ln L_t$	4.051	7.095	34.774	11.092		0.0900*
Middle East& North Africa						
$\Delta \ln Y_t$		34.698**	1.556	16.201**	5.814*	0.0805
$\Delta \ln E_t$	6.432		6.098	5.816	3.607	0.0017**
$\Delta \ln O_t$	7.098	5.891		9.418	78.809**	0.0091**
$\Delta \ln K_t$	45.78**	6.085**	85.491*		45.293*	0.0035**

$\Delta \ln L_t$	2.051	7.119	14.23	3.163		0.0020
North America						
$\Delta \ln Y_t$		8.123	7.332**	2.613**	7.852	0.0090*
$\Delta \ln E_t$	7.884		8.793	7.133*	6.778	0.0031
$\Delta \ln O_t$	56.078	8.945		7.193	1.091	0.007
$\Delta \ln K_t$	65.901	11.456	9.056		6.093	-0.0057*
$\Delta \ln L_t$	0.186	5.809	0.006	3.654		0.0560
South Asia						
$\Delta \ln Y_t$		77.012**	3.198*	8.932	15.512**	-0.0045
$\Delta \ln E_t$	13.209		4.097	24.521**	3.314	-0.0130**
$\Delta \ln O_t$	57.305**	8.272		2.309	27.501*	0.0860*
$\Delta \ln K_t$	1.384	3.621	3.304		16.907*	0.0011
$\Delta \ln L_t$	6.907	9.174	4.201	7.002		0.0984
Sub-Saharan Africa						
$\Delta \ln Y_t$		1.089	2.647	6.097**	10.708**	0.0911
$\Delta \ln E_t$	11.078		6.789	4.132	3.776	0.0981
$\Delta \ln O_t$	84.476**	9.057**		5.004	22.986**	-0.0866*
$\Delta \ln K_t$	38.907**	8.103**	5.634		8.042	0.0540
$\Delta \ln L_t$	6.092	8.645	8.883	21.907		0.0046*
Note:** and *indicate significance at 1% and 5%, respectively.						

The short-run and long-run causality results obtained by the Pool Mean Group (PMG) test are reported in Table-4[11]. In the long run, we note that the feedback effect between electricity consumption and economic growth is valid for the full paneland for the upper-middle income, high income, OECD, East Asia & Pacific and Europe & Central Asia categories. This empirical evidence is similar to that of Ho and Siu (2007) and Yuan et al. (2008). The bidirectional relationship specifies that high economic growth stimulates industrial development and household living standards, which leads to an increase in electricity consumption. The unidirectional causality from economic growth to electricity consumption is confirmed inthe low-middle income, Middle East & North Africa and South Asia

[11]The long-run dynamics are illustrated by the error correction term (ECT) in Table5. The coefficient of the error correction term is significantly negative in the low-income, upper-middle-income, high-income, OECD, East Asia & Pacific, Europe & Central Asia and South Asia categories.

categories. Thisempirical evidence is consistent with Costantini and Martini (2010), Shahbaz and Feridun (2012), and Damette and Seghir (2013). Electricity consumption as the Granger cause of economic growth is noted in North America. Along similar lines, Masih and Masih (1996), Wolde-Rufael (2005) and Alam et al. (2015) also reported that economic growth is a cause of electricity consumption. A neutral effect is also noted in the cases of the low-middle income panel, non-OECD, Latin America & Caribbean and Sub-Saharan Africa categories. The bidirectional causality between labor growth and energy consumption is noted for thefull paneland for the upper-middle income, high-income, OECD, East Asia & Pacific, Middle East & North Africa and South Asia categories. Labor growth is the Granger cause of energy consumption in the low-middle income paneland in the Non-OECD, Latin America & Caribbean, North America and Sub-Saharan Africa categories. Capitalization causes electricity consumption, and thus, electricity consumption causes economic growth in the upper-middle income, high-income, Europe & Central Asia and the Middle East & North Africa categories. Electricity consumption is a cause of capitalization in the full panel as well as in the low-income, East Asia & Pacific, Europe & Central Asia and South Asia categories. In the case of the non-OECD, Latin America & Caribbean, and North America categories, we find that electricity consumption causes capitalization.

In the short run, a feedback effect exists between oil price, electricity consumption and economic growth in the full panel and in low-middle income, non-OECD, Latin America & Caribbean and South Asian countries. The unidirectional causality is found from oil price to economic growth in the low-income, East Asia &Pacific and North America categories, while economic growth influences oil price in upper-middle income, high income, OECD, European & Central Asian and Sub-Saharan countries. A neutral effect between oil price and economic growth is also noted in the Middle East & North Africa. In 2014, Colombia, Venezuela and Ecuador experienced a decline in economic growth due to the fall in oil price. Meanwhile, Mexico, Brazil, and Argentina experienced moderate economic growth. The International Monetary Fund (IMF) estimated that Latin America reacts in a mostly neutral manner, with no net gain from rising or declining oil price. Capital formation and labor force show a bidirectional relationship with economic growth in the full sample, whereas the subgroup level depicts different findings.

To examine the robustness of the PMG Granger causality test, we have applied the heterogeneous panel causality test. The results are reported in Table-5. We find that in the full sample panel, electricity consumption and economic growth have a confirmed bidirectional causality relationship. However, a unidirectional causal relationship exists from economic growth to oil price. These results also confirm the significant role of electricity consumption over oil price for the economy. A feedback effect exists between electricity consumption and economic growth for the low-income, upper-middle-income, high-income, non-OECD, East Asia & Pacific, Latin America & Caribbean, Middle East & North Africa, South Asia and Sub-Saharan Africa categories. This feedback effect indicates that a reduction in electricity supply will retard economic growth, and thus, a decline in economic growth will reduce electricity demand. The empirical evidence supports the implementation of energy-exploring policies to maintain economic development for the long run. The empirical evidence for the bidirectional causal association between electricity consumption and economic growth is similar to that ofHo and Siu (2007), Behmiri and Manso (2013), and Al-mulali and Sab (2012). Economic growth is the Granger cause of electricity consumption in the case of OECD, while the case of Europe & Central Asia reveals the importance of consistent electricity supply for long-run economic growth. The unidirectional causality from electricity consumption to economic growth is consistent with Narayan and Singh (2007), Damette and Seghir (2013), Streimikiene and Kasperowicz (2016) and Tang et al. (2016). Economic growth is the Granger cause ofelectricity consumption in the lower-middle-income and Europe & Central Asia categories. The unidirectional causality from economic growth to electricity consumption is similar to the results of Costantini and Martini (2010).

Table-5: Heterogeneous Panel Causality Test

Heterogeneous panel causality test	Full Panel	Income Level: Low Income	Income Level: Lower-Middle Income	Income Level: Upper Middle	Income Level: High Income	OECD Level: OECD	OECD Level: Non-OECD
Null Hypothesis:	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.
$\ln E_t$ does not homogeneously cause $\ln Y_t$	16.279**	3.296**	0.978	7.002**	64.687**	8.622**	81.046**
$\ln Y_t$ does not homogeneously cause $\ln E_t$	18.467**	5.649**	16.172**	27.558**	12.975*	-0.178	18.070**
$\ln O_t$ does not homogeneously cause $\ln Y_t$	1.737	3.9362**	5.516*	4.849**	8.287**	3.783**	7.837**
$\ln Y_t$ does not homogeneously cause $\ln O_t$	12.593**	3.587*	7.186**	7.649*	10.162**	11.266**	3.312**
$\ln K_t$ does not homogeneously cause $\ln Y_t$	9.215**	4.237**	1.660	3.948**	44.866**	26.345**	36.857**
$\ln Y_t$ does not homogeneously cause $\ln K_t$	31.684	7.214**	4.319**	7.982**	17.857**	9.234**	15.859**
$\ln L_t$ does not homogeneously cause $\ln Y_t$	9.638**	9.334**	15.388**	13.551**	13.103**	7.763**	10.699**
$\ln Y_t$ does not homogeneously cause $\ln L_t$	4.602	6.701**	13.550*	25.804*	13.052*	8.444**	9.980*
$\ln O_t$ does not homogeneously cause $\ln E_t$	15.097**	4.518**	8.253**	6.094**	10.039**	4.223**	9.835**
$\ln E_t$ does not homogeneously cause $\ln O_t$	7.385	0.274	-1.938	-0.666	-0.252	0.974	-1.274
$\ln K_t$ does not homogeneously cause $\ln E_t$	19.457**	7.884**	22.684**	20.621**	11.256**	1.213	14.375**
$\ln E_t$ does not homogeneously cause $\ln K_t$	17.359**	0.433	16.614**	25.040**	179.349**	256.343**	3.800**
$\ln L_t$ does not homogeneously cause $\ln E_t$	21.815**	12.444**	38.127**	19.105**	22.576**	7.402*	24.111**
$\ln E_t$ does not homogeneously cause $\ln L_t$	6.576	6.099**	20.386**	11.103**	16.703**	9.498**	14.016*
$\ln K_t$ does not homogeneously cause $\ln O_t$	8.378**	0.559	2.910**	4.241**	7.708*	7.557**	3.452**
$\ln O_t$ does not homogeneously cause $\ln K_t$	3.816*	4.796**	8.767*	3.623*	3.726**	-1.012	6.103**
$\ln L_t$ does not homogeneously cause $\ln O_t$	-0.150	3.841**	7.093	4.061**	8.493**	6.572**	5.471**
$\ln O_t$ does not homogeneously cause $\ln L_t$	-5.941	12.416**	19.381	35.499**	13.503**	7.515**	11.487**
$\ln L_t$ does not homogeneously cause $\ln K_t$	12.912*	8.283*	9.327	12.031**	10.563*	6.936**	7.980**
$\ln K_t$ does not homogeneously cause $\ln L_t$	1.066	11.382**	12.563**	17.387*	20.948**	21.205**	8.747**

Note: ** and * indicate significance at the 1% and 5% levels,respectively

Table 5: Heterogeneous Panel Causality Test (continued)

Null Hypothesis:	Regional Level						
	East Asia & Pacific	Europe & Central Asia	Latin America & Caribbean	Middle East& North Africa	North America	South Asia	Sub-Saharan Africa
	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.	Zbar-Stat.
$\ln E_t$ does not homogeneously cause $\ln Y_t$	2.492**	5.548**	84.012**	4.195**	0.856	2.250**	2.627**
$\ln Y_t$ does not homogeneously cause $\ln E_t$	12.577**	1.904	7.466**	17.113**	-0.801	2.063**	33.597**
$\ln O_t$ does not homogeneously cause $\ln Y_t$	3.528**	1.345	9.777**	5.501**	9.489**	2.861**	2.842**
$\ln Y_t$ does not homogeneously cause $\ln O_t$	6.181*	8.283**	4.077*	2.374**	-0.518	3.435**	10.808*
$\ln K_t$ does not homogeneously cause $\ln Y_t$	-0.340	26.383**	33.145**	7.404**	-0.274	3.516**	2.711**
$\ln Y_t$ does not homogeneously cause $\ln K_t$	11.895*	8.460**	6.960**	6.132**	-0.050	-0.607	12.199**
$\ln L_t$ does not homogeneously cause $\ln Y_t$	15.300**	8.523**	15.573*	6.978**	2.761**	2.848**	10.816**
$\ln Y_t$ does not homogeneously cause $\ln L_t$	17.431*	9.955**	14.965**	11.373**	1.892	0.839	14.913**
$\ln O_t$ does not homogeneously cause $\ln E_t$	9.882**	3.726**	6.903**	3.005*	0.910	2.524	9.116**
$\ln E_t$ does not homogeneously cause $\ln O_t$	-1.247	0.437	-2.043	0.351	-0.651	-1.346	0.295
$\ln K_t$ does not homogeneously cause $\ln E_t$	28.988**	1.346	5.643**	8.806**	1.536	7.470**	24.094
$\ln E_t$ does not homogeneously cause $\ln K_t$	110.233**	7.691*	11.259**	14.146	520.206**	4.661**	0.283
$\ln L_t$ does not homogeneously cause $\ln E_t$	49.978**	9.944**	13.644**	3.196*	0.440	5.188**	28.113**
$\ln E_t$ does not homogeneously cause $\ln L_t$	10.460**	20.070**	6.412**	17.670**	1.252	6.222**	7.880**
$\ln K_t$ does not homogeneously cause $\ln O_t$	0.929	6.836**	4.148**	2.976**	-0.988	0.765	4.028**
$\ln O_t$ does not homogeneously cause $\ln K_t$	2.768**	-0.197	6.580**	5.785**	0.619	-0.061	8.510**
$\ln L_t$ does not homogeneously cause $\ln O_t$	7.805	3.175**	5.720**	3.007*	4.239**	2.384**	5.804*
$\ln O_t$ does not homogeneously cause $\ln L_t$	23.436**	3.877*	38.501**	13.407**	1.608	2.649**	12.566**
$\ln L_t$ does not homogeneously cause $\ln K_t$	12.751**	7.045**	8.847**	5.669**	-0.209	3.614**	10.409*
$\ln K_t$ does not homogeneously cause $\ln L_t$	12.809*	12.945**	13.99**	9.539**	22.971**	-0.271	16.478**

Shahbaz and Feridun (2012), and Ahmed and Azam (2016). A neutral effect exists between electricity consumption and economic growth for North America, which suggests that the implementation of energy conservation policies will not retard economic growth. This lack of acausal relationship between electricity consumption and economic growth is consistent with Chontanawat et al. (2008), Zilio and Recalde (2011), Karanfil and Li (2015), and Ahmed and Azam (2016).

The relationship between oil prices and economic growth is bidirectional for the low-income, lower-middle-income, upper-middle-income, high-income, OECD, non-OECD, East Asia & Pacific, Latin America & Caribbean, Middle East & North Africa, South Asia and Sub-Saharan Africa panels. The unidirectional causality is found from oil price to economic growth in the case of North America. Similar results are reported by Elmezouar et al. (2014), who argued that most of these economies are in a transition phase and need oil to boost their economic growth. In such circumstances, an increase in oil price has no adverse effect on oil-importing and oil-exporting countries (Rasmussen and Roitman, 2011). Economic growth is the Granger cause of oil price for the full panel and for Europe & Central Asia. This result implies that economic growth of a country can be attained by a gradual boost in the industrial sector, which requires energy (oil). This higher demand for oil causes the oil priceto increase (Ali, 2016). The causality between gross fixed capitalization and economic growth is bidirectional for the low-income, upper-middle-income, high-income, OECD, Non-OECD, East Asia & Pacific, Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa and Sub-Saharan Africa categories. Capitalization is the Granger cause of economic growth in thecases of the full panel and South Asia. Economic growth is the Granger cause of capitalization in the lower-middle income and

East Asia & Pacific categories, while a neutral effect exists between gross fixed capitalization and economic growth in North America. A bidirectional causal relationship exists between labor growth and economic growth in the low-income, upper-middle-income, high income, OECD, non-OECD, East Asia & Pacific, Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa and Sub-Saharan Africa categories. In the case of the full panel, North America and South Asia, labor growth is the Granger cause of economic growth.

5. Summary and Conclusion

This study uses the data from 157 countries over the period from 1960 to 2014 to examine the empirical relationship between electricity consumption and economic growth by incorporating oil price as an additional factor of production. The data are categorized into income, OECD and regional levels. The cointegration approach developed by Westerlund (2007) is applied to examine cointegration between the variables. The pool mean group test is used to study the short-run and long-run relationships between variables. The robustness of the empirical analysis is also tested by applying alternative unit root, cointegration and causality approaches.

We find evidence of cointegration between the variables. Moreover, electricity consumption stimulates economic growth in the full panel and the lower-middle-income, upper-middle income, OECD, East Asia & Pacific, Middle East & North Africa, South Asia and Sub-Saharan Africa regions. A positive association between oil price and economic growth is confirmed for the full panelas well as for the low-income, lower-middle-income, high-income, OECD, Non-OECD, East Asia & Pacific, Latin America & Caribbean, Middle East & North Africa, North America and Sub-Saharan Africa panels. Capitalization and labor growth promote economic growth in the full panel and in all regions. Electricity consumption causes economic growth, and as a result, economic growth causes electricity consumption in the full panel as well as the upper-middle income, high income, OECD, East Asia & Pacific and Europe & Central Asia categories. The energy conservation hypothesis is valid for the lower-middle-income, Middle East & North Africa and South Asia groups. The growth hypothesis is noted for North America. There is no causality between economic growth and electricity consumption in the low-middle-income panelor in the non-OECD, Latin America & Caribbean and Sub-Saharan Africa categories.

These empirical findings have significant implications for countries across the regions in planning for energy conversion policies that help to trigger economic growth. It is suggested that countries where the growth hypothesis is confirmed find the best alternatives to electricity generation to enhance economic growth. The countries in which the conservation hypothesis is confirmed do not depend on electricity for economic growth. These countries should concentrate on means of economic growth other than electricity policies. For the countries confirming the feedback hypothesis, the implication is that economic growth and electricity consumption are mutually dependent; accordingly, policy makers should concentrate onelectricity generation policies and economic growth policies that stimulate each other. Countries in which the neutrality hypothesis is confirmed should not pursue economic growth but instead make electricity conservation policies.

In oil-importing countries, it has been found to be practically impossible to eliminate the detrimental role of energy prices for economic growth because the elimination of such energy prices, i.e., oil price, would restrain economic growth. Other than the elimination of energy prices, programs should be implemented to increase the yield, which leads to significantly increased benefits. Any increase in energy prices results in an increased cost of living for the citizens. However, addressing this problem is not a major issue because the governments of the countries can implement specific measures to address the problem. Additionally, it is the obligation of any government to lower the cost of living for its citizens, particularly the low-income group, by controlling energy prices.

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Appendix-A

Table A2: Literature Highlights

Author(s)	Countries	Time Period	Methodology	Conclusion(s)
Murray and Nan (1996)	Canada, Colombia, El Salvador, France, Germany, Hong Kong, India, Indonesia, Israel, Kenya, Luxembourg, Malaysia, Mexico, Norway, Pakistan, Philippines, Portugal, Singapore, South Korea, Turkey, UK, USA, Zambia	1970-1990	Granger Causality	EC↔GDP (Malaysia, South Korea) GDP→EC (Colombia, El Salvador, Indonesia, Kenya, Mexico) EC→GDP (Canada, Pakistan, Singapore, Turkey) EC≠GDP (France, Germany, India, Israel, Luxembourg, Norway, Philippines, Portugal, UK, USA, Zambia)
Wolde-Rufael (2006)	Algeria, Benin, Cameroon, Congo DR, Congo Rep, Egypt, Gabon, Ghana, Kenya, Morocco, Nigeria, Senegal, South Africa, Sudan, Tunisia, Zambia, Zimbabwe	1971-2001	Toda-Yamamoto causality	EC↔GDP (Egypt, Morocco) GDP→EC (Cameroon, Gabon, Ghana, Nigeria, Senegal, Zambia, Zimbabwe) EC→GDP (Benin, Congo DR, Gabon, Tunisia) EC≠GDP (Algeria, Congo Rep, Kenya, Sudan, South Africa)
Yoo (2006)	Indonesia, Malaysia, Singapore, Thailand	1971-2002	Johansen-Juselius	EC↔GDP (Malaysia, Singapore) GDP→EC (Thailand, Indonesia)
Chen et al. (2007)	China, Hong Kong, Indonesia, India, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand	1971-2001	Johansen-Juselius; Pedroni Panel Cointegration	EC↔GDP (Hong Kong) GDP→EC (India, Korea, Malaysia, Philippines, Singapore) EC→GDP (Indonesia) EC≠GDP (China, Taiwan, Thailand)
Narayan et al. (2010)	93 countries	1980-2006	Pedroni panel cointegration test	EC→GDP (Western Europe, Asia, Latin America, Global) EC≠GDP (Middle East)
Apergis and Payne (2011)	88 countries	1990-2006	Pedroni panel cointegration test	EC→GDP (high, upper middle-income panels, lower middle income (long-run) EC-GDP: lower middle-income panels, low-income panels

Karanfil and Li (2015)	160 countries	1980-2010	Panel cointegration test	EC and GDP relation varies across panels.
Osman et al. (2016)	GCC countries	1975-2012	PMGE, PMG, AMG, MGE and DFE	EC↔ GDP

Note: EC and GDP denote energy consumption and economic growth, respectively. ↔, →and ≠ indicate the feedback effect, unidirectional causality and neutral effect between the variables. PMGE, PMG, AMG, MGE and DFE represent the pooled mean group estimator, pooled mean group, average mean group, mean group estimator and dynamic fixed effect models.

Table A1: IPS Unit Root Test Analysis

IPS	at level	first difference
$\ln Y_t$	5.263	-49.848**
$\ln E_t$	3.57	-60.903**
$\ln O_t$	7.817	-50.426**
$\ln K_t$	3.921	-45.288**
$\ln L_t$	7.468	-23.218**
Note: ** and * indicate significance at the 1% and 5% levels, respectively		

Table A2: Pedroni Panel Cointegration

Test	Full panel	Income level				OECD level	
		Low	Lower-Middle	Upper-Middle	High	OECD	Non-OECD
Panel ν-statistics	8.897	0.272	4.264214	5.476	5.039	-0.184	3.911**
Panel ρ-statistics	-9.234**	-7.831**	-3.922871	-6.065**	-4.561**	-7.467**	-3.000*
Panel PP-statistics	-14.353**	-12.372**	-5.437567	-10.783**	-6.937**	-13.194**	-4.449**
Panel ADF-statistics	-8.544**	-6.562**	-3.940809	-10.796*	0.381**	-9.788**	1.033
Group ρ-statistics	-2.951**	-1.333	0.554735	-2.627**	-2.303*	-0.144	-3.040**
Group PP-statistics	-10.277**	-4.348**	-2.469**	-6.616	-6.775**	-3.826	-5.710**
Group ADF-statistics	-5.509**	-3.535**	-1.023679	-3.271	-3.358**	-3.163	-1.627
	Regional level						
	East Asia & Pacific	Europe & Central Asia	Latin America & Caribbean	Middle East& North Africa	North America	South Asia	Sub-Saharan Africa
Panel ν-statistics	3.791	3.139	6.260**	1.918	-1.416	1.441	4.336
Panel ρ-statistics	-3.546	-2.939	-5.487**	-3.909	-2.273*	-1.855	-9.391
Panel PP-statistics	-4.73	-4.422**	-9.881**	-6.850**	-4.857**	-4.212**	-14.790**
Panel ADF-statistics	-3.548	1.017	-12.091**	-2.743**	-4.577**	-1.529**	-6.152**
Group ρ-statistics	-0.364	-0.276	-2.294*	-2.127*	-1.888*	-1.380	-0.724
Group PP-statistics	-2.156*	-3.558**	-4.592**	-5.322**	-4.575**	-6.148**	-3.928**
Group ADF-statistics	-0.089	-1.252	-3.022**	-3.021**	-3.462**	-3.954**	-2.408**
Note: **and * indicate significance at 1% and 5%, respectively.							

Table A3: Panel Dynamic and Ordinary Least Square

Groups	Dynamic Ordinary Least Square (DOLS)				Ordinary Least Square (OLS)			
	$\ln E_t$	$\ln O_t$	$\ln K_t$	$\ln L_t$	$\ln E_t$	$\ln O_t$	$\ln K_t$	$\ln L_t$
Full Panel	0.354**	0.478**	0.180**	0.077	0.284**	0.158**	0.790**	-0.086**
Income Level								
Low	0.133**	0.035	0.021	1.682**	0.818**	-0.237**	0.564**	0.405**
Lower-Middle	0.237**	0.454**	-0.047**	0.421**	-0.446**	0.458**	0.508**	-0.121
Upper-Middle	0.415**	0.325**	0.174**	-0.035	0.923**	-0.038	0.631**	0.099
High	0.151**	0.315**	0.665**	0.507**	0.069*	0.158**	1.042**	0.062*
OECD								
OECD	-0.012	0.298**	0.522**	1.582**	0.202**	-0.020	1.091**	-0.056
Non-OECD	0.347**	0.449**	0.658**	0.073	-0.025	0.531**	0.770**	0.085
Region								
East Asia & Pacific	0.218**	-0.060	0.075**	2.492**	-0.144**	0.214**	0.719**	0.324**
Europe & Central Asia	0.294**	0.557**	0.177**	0.028	0.641**	0.209**	0.737**	0.069
Latin America & Caribbean	0.483**	0.356**	0.492**	-0.249	1.160**	-0.438**	0.915**	-0.040
Middle East & North Africa	0.327**	0.706**	0.024	0.256*	0.083**	0.684**	0.116**	0.397**
North America	0.893*	0.198	0.524**	-2.028*	0.159**	0.776**	0.118**	-3.354**
South Asia	-0.037	-0.008	0.557**	-0.121	-1.474	1.025**	0.790**	-1.135
Sub-Saharan Africa	0.046	0.207**	0.019*	1.612**	0.702**	-0.087	0.566**	0.622**

Note: ** and * indicate significance at 1% and 5%, respectively