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Long Run Energy Demand and Its Determinants: A Panel Cointegration Analysis of the Association of Southeast Asian Nations-5

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ABSTRACT

Energy determinants continue to reinforce the sustained rise in energy demand (ED) over the coming years. Such concern has captured considerable attentions among the governments worldwide in the anticipation of its unabated rise to jeopardize a country's long term energy security. Specifically, this paper investigates the interplay between ED and its determinants notably world oil price, economic growth, population, urbanization and energy access in the Association of Southeast Asian Nations (ASEAN)-5 over the 2000–2016 period. At the aggregated level, the long run results reveal that economic growth, energy access and urbanization have significant effects on ED. However, the results vary by the disaggregated fuel type, respectively. Therefore, energy conservation policy is the viable option in the ASEAN-5 going forward. Also, the policy makers are suggested to secure for reliable and affordable energy supplies with minimal environmental impacts, promote a sustainable development and socio-economic growth and enhance the quality of life.

Keywords: Association of Southeast Asian Nations-5, Energy Conservation, Energy Demand, Energy Security
JEL Classifications: C33, Q41, Q43

1. INTRODUCTION

Energy is the lifeblood of a nation. Strategically, energy security constitutes as a key issue in most energy consuming nations. According to the International Energy Agency (IEA) (2013), the Southeast Asian's energy demand (ED) has posted a substantial growth by two-and-a-half folds increase since 1990 in line with a rapid expansion in the global ED. Together with China and India, the 10 countries of the Association of Southeast Asian Nations (ASEAN) namely Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam are collectively shifting the gravitational centre of the global ED to Asia (IEA, 2013). From the ASEAN-10, the five largest economies that make up the ASEAN-5 are comprised of Indonesia, Malaysia, Singapore, Thailand and the Philippines.

Figure 1 depicts that the ASEAN-5 has experienced rising ED since 2000. The ASEAN-5's ED has been on the upward trend, increased from 337 million tonne of oil equivalent (Mtoe) in 2000 to 577 Mtoe in 2016. Thus far, it has grown at the compound annual growth rate of 3.4% per year from 2000 to 2016. Equivalently, this constitutes as a 71% increase or an additional 240 Mtoe of energy sources through 2016. Between 2000 and 2016, the ASEAN-5's ED remains on the rise strongly underpinned by robust economic growth i.e. between 4% and 6%, rising population i.e. from 376 million to 468 million people, growing number of city dwellers i.e. from 163 million to 247 million people and high levels of access to the electricity on-the-grid in Malaysia, Singapore and Thailand (IEA, 2016). In term of the sectoral outlook, it is mainly driven by rising demand profiles for oil-based products in the transport and industrial sectors as well as coal and natural gas in the power generation sector notwithstanding there was a surge in inflation during the 2007–2008 period faced by many ASEAN countries. As such, the fluctuations in world oil price (WOP) notably within 2010–2014 timeframe have been considered as one of the primary causes that elevated the general energy price level regionally.

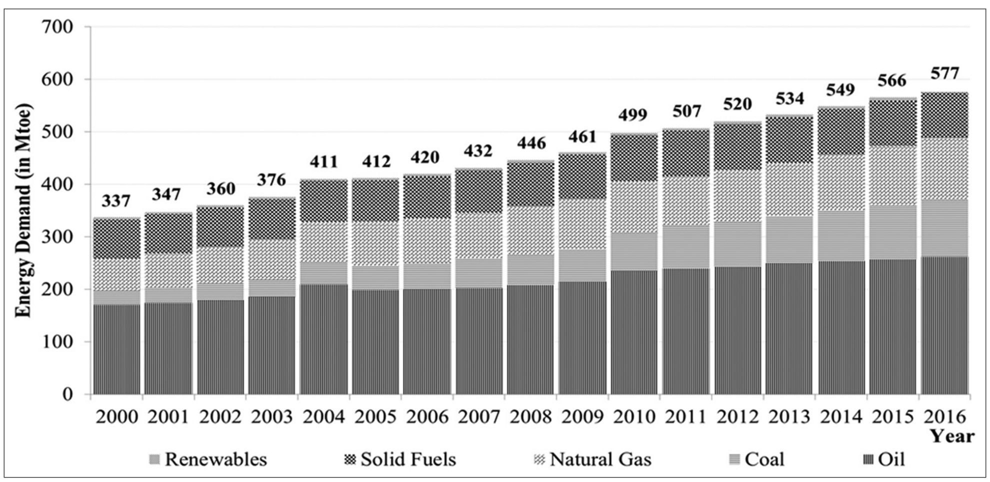
Furthermore, Figure 2 incorporates the total energy supply that is largely believed to accommodate for the sustained rise in ED across the ASEAN-5 over the period.

As shown in Figure 2, it is empirically observed that there is likelihood that the ASEAN-5, either collectively or on individual basis, encounters energy deficit locally. The situation is likely to occur as stemmed from the incapability of a country's total energy production and net imports combined to grapple with a problem of meeting the sustained rise in domestic ED through 2016. As a consequence, the uncurbed rise in ED potentially threatens the self-sufficiency rate of a country, broadens the energy supply – demand gap, induces a strong dependence on energy imports, creates energy deprived situations locally and shortens the estimated lifespan of proved natural energy reserves (Kanchana and Unesaki, 2014). Above all, it will cause detrimental effects in jeopardizing a country's long term energy security. Unfortunately, a country or countries will have hard times in putting together respective efforts to sustain energy security at the time when there are declining domestic oil and natural gas production and depleting natural energy reserves (Magazzino, 2014).

Possibly, one near-term solution to mitigate the severity of the issue is to slash certain numbers of coal export commitments especially by Indonesia as means to cope with acute energy insecurity (Jain, 2011). By doing so, the availability of accessible volumes could be diverted in order to prosper the nation's energy market for local use instead. Necessarily, maintaining energy security represents an utmost priority among the policy makers in the ASEAN-5. Nevertheless, there is a tendency that the priority overshadows the urgent need to address the climate change issues within the overall energy policy agenda in the region (Hong, 2010). To some extent, environmental problems, which are originated from excessive use of hydrocarbon-based energy in the implementation of various economic activities and development projects, have been taken for granted as well.

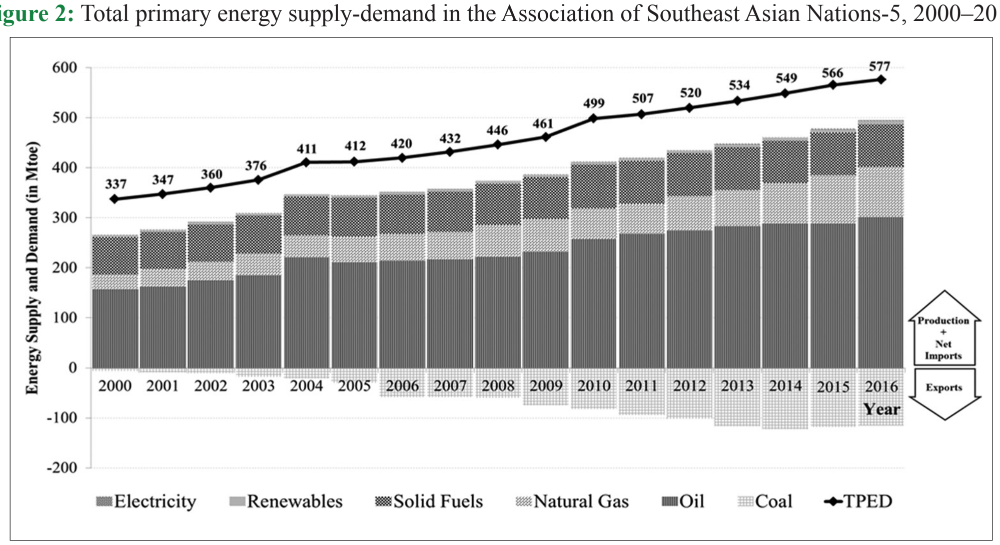
In essence, the motivation of this paper hinges upon the aim of filling a gap in the existing literature that measures the long run relationship among both ED levels and energy determinants notably WOP, economic growth, population, urbanization and energy access in the ASEAN-5. With the aggregated ED is set to

Figure 1: Total primary energy demand in the Association of Southeast Asian Nations-5, 2000–2016



Source: IEA (2016)

Figure 2: Total primary energy supply-demand in the Association of Southeast Asian Nations-5, 2000–2016



Source: IEA (2016)

rise in the post-2016, the policy makers can adopt strategic policy options to enhance the security of energy supply via reducing the dependency on imports of non-renewable energy sources e.g. coal and oil that have resulted in the environmental degradation, emphasizing energy efficiency and deploying technology and innovation to commercialize indigenous renewable energy sources e.g. hydro, solar, wind and geothermal. In consideration of the external costs to health and environment, natural gas, which is the cleanest of the fossil fuels, represents the preferred fuel relative to coal and oil. It is an environmentally friendly fuel and continues to play a key role for the sustainable development and socio-economic growth (International Gas Union [IGU], 2012). Ideally, good energy policy should balance energy security and pricing via optimal development of domestic fuels and strategic importation of external sources.

The rest of this paper is structured as follows. Section 2 reviews the existing literature on the relationship between ED and its determinants and Section 3 describes the data and methodology that are used in the analysis. While Section 4 reports various results, Section 5 wraps up with the policy implication and conclusion.

2. LITERATURE REVIEW

The study of ED modeling can be historically traced with the earliest author was Houthakker (1951) as cited in Madlener et al. (2011). Subsequently, following the works of Engle and Granger (1987) on the cointegration analysis, these have attracted numerous studies, which may adequately address the problem of spurious regressions in the empirical models, to be thrived in both developed and developing countries. The studies are not only limited to cover the long run relationship between ED (or energy consumption interchangeably) and economic growth but also increasingly extensive to include other relevant variables as well depending upon one's interest such as WOP, population, urbanization, carbon dioxide (CO_2) emissions and employment. Either undertaken via time series or panel data analyses, the studies employed various econometric techniques such as ordinary least square (OLS), Johansen cointegration, Pedroni panel cointegration, panel fully modified OLS (FMOLS), panel dynamic OLS and autoregressive distributed lag (ARDL). Because of disparities in adopted methodology and techniques, these have led the empirical results to be diverse and remain contentious (Karanfil, 2009).

Aziz et al. (2013) analyzed the determinants of ED by measuring the short and long run relationships among ED, real gross domestic product (GDP), real energy price, industrialization and CO_2 emissions for 16 developing countries over the 1978–2003 period. With the ARDL method, they manifested the findings, of which, one is the evidence of income, energy price, industrialization and CO_2 emissions to exert significant impacts on ED over the long run. Therefore, the study is found in parallel with Al-Azzam and Hawdon (1999) and Gately and Huntington (2002). Furthermore, there is a growing concern to capture the effect of demographic factors in order to raise an interesting discussion in the literature. Poumanyvong and Kaneko (2010) studied the long run relationship among energy use, population size, urbanization and CO_2 emissions in 99 countries that consist of 33 high income, 43 middle income and 23 low income nations over the 1975–2005 period, respectively. Using the Stochastic Impacts by Regression on Population, Affluence and Technology model, they revealed the findings. Of which, one is the influence of development stages over the impact of urbanization on energy use. Urbanization constitutes as a key demographic driver of ED. While it fosters energy use among the middle and high income nations, it reduces energy use in the low income group instead. Hence, the findings of Poumanyvong and Kaneko (2010) is found consistent with Pachauri (2012), Michieka and Fletcher (2014) and Bayramoglu and Sukruoglu (2016).

Moreover, access to the modern energy services cannot be disregarded when commencing an empirical study on ED modeling notably in the developing countries. Thus far, Pachauri and Spreng (2004), Bhattacharyya (2006), Nkomo (2007) and Pachauri and Jiang (2008) incorporated energy access as one of the variables in their empirical models. For instance, Nkomo (2007) focused on the long run relationship among economic growth, energy use, human development, poverty levels and energy access in the Southern African Development Community countries over the 1994–2003 period. He argued that modern energy services could represent invaluable means to improve social equality if household access to electricity increases. In turn, the services will help to accelerate economic growth by improving productivity, promoting job creations and generating local incomes.

Increasingly, the literature is also enriched with rigorous studies that put emphasis on the real impact of WOP fluctuations. From the early work of Hamilton (1983) as quoted in Kilian (2014), the effect of WOP fluctuations can be measured either from the perspective of economic growth or the financial sector. Of the earliest authors, Mehra and Peterson (2005) analyzed the likelihood of the fluctuations in WOP to directly affect ED in the residential sector notably in the aspect of consumption expenditure that represents the consumer's side of the economy. In recent years, Abubakar et al. (2013) investigated the determinants of aggregated ED via measuring the long run relationship among ED, economic growth and WOP in two economic blocs namely the Organization for Economic Cooperation and Development (OECD) and the Organization of the Petroleum Exporting Countries (OPEC) over the 1987–2011 period. By employing the OLS method, they disclosed the findings in which one of them is that WOP and economic growth have significant effects on the variations of ED in the long run for the OECD member countries relative to the OPEC nations. On the contrary, Saibu (2013) claimed that the fluctuations in WOP have statistically insignificant effects on ED, economic growth and domestic investment in Nigeria between 1970 and 2009.

Empirically, it is evident from the past studies that have been reviewed on the long run relationship among ED, WOP, economic growth, population, urbanization and energy access remains inconclusive with mixed results at the aggregated and disaggregated levels. Based on the commercial perspective, this inevitably provides the credence to examine the issue in the ASEAN-5.

3. DATA AND ESTIMATION TECHNIQUE

3.1. Data

Secondary data are utilized to measure the long run relationship among ED, coal demand, natural gas demand, oil demand, renewables demand, solid fuels demand, WOP, economic growth, population, urbanization and energy access in the ASEAN-5 for a-17 year period i.e. from 2000 to 2016. The annual data on demand for fuel sources (e.g. aggregated, coal, natural gas, oil, renewables and solid fuels), economic growth, population, urbanization and energy access were taken from the IEA's website. The annual data on Brent spot prices reflecting WOP, which also constitute as a reference point for bulk of crude oil volumes destined for the Asian markets, were obtained from the Energy Information Administration's website.

3.2. Model Specification

Following the works of Olsen and Roland (1988), the functional form for the ASEAN-5 at the aggregated level, which consists of ED, WOP, economic growth (RGDP), population (POP), urbanization (URBAN) and energy access (EA), is given by Equation (1):

$$ED=f(WOP, RGDP, POP, URBAN, EA) \quad (1)$$

Likewise, the expressions for the disaggregated types of fuel are listed in Equation (2)–Equation (6):

$$Coal=f(WOP, RGDP, POP, URBAN, EA) \quad (2)$$

$$Gas=f(WOP, RGDP, POP, URBAN, EA) \quad (3)$$

$$Oil=f(WOP, RGDP, POP, URBAN, EA) \quad (4)$$

$$Renew=f(WOP, RGDP, POP, URBAN, EA) \quad (5)$$

$$Solid=f(WOP, RGDP, POP, URBAN, EA) \quad (6)$$

Subsequently, Equation (1)–Equation (6) are transformed into the double natural log specifications to become the empirical models as shown in Equation (7)–Equation (12):

$$LED_{i,t} = \beta_0 + \beta_1 LWOP_{i,t} + \beta_2 LRGDP_{i,t} + \beta_3 LPOP_{i,t} + \beta_4 LURBAN_{i,t} + \beta_5 LEA_{i,t} + \varepsilon_{i,t}^{LED} \quad (7)$$

$$LCoal_{i\,t} \quad LWOP_{i\,t} \quad LRGDP_{i\,t} \quad LPOP_{i\,t} \quad LURBAN_{i\,t} \quad L \quad (8)$$

$$LGas_{i,t} \quad LWOP_{i,t} \quad LRGDP_{i,t} \quad LPOP_{i,t} \quad LURBAN_{i,t} \quad LE \quad (9)$$

$$LOil_{i,t} = \varphi_0 + \varphi_1 LWOP_{i,t} + \varphi_2 LRGDP_{i,t} + \varphi_3 LPOP_{i,t} + \varphi_4 LURBAN_{i,t} + \varphi_5 LEA_{i,t} + \varepsilon_{i,t}^{LOil} \quad (10)$$

$$LRenew_{i,t} = \psi_0 + \psi_1 LWOP_{i,t} + \psi_2 LRGDP_{i,t} + \psi_3 LPOP_{i,t} + \psi_4 LURBAN_{i,t} + \psi_5 LEA_{i,t} + \varepsilon_{i,t}^{LRenew} \quad (11)$$

$$LSolid_{i,t} = \theta_0 + \theta_1 LWOP_{i,t} + \theta_2 LRGDP_{i,t} + \theta_3 LPOP_{i,t} + \theta_4 LURBAN_{i,t} + \theta_5 LEA_{i,t} + \varepsilon_{i,t}^{LSolid} \quad (12)$$

where LED is natural log of ED (in Mtoe), LCoal is natural log of coal demand (in Mtoe), LGas is natural log of natural gas demand (in Mtoe), LOil is natural log of oil demand (in Mtoe), LRenew is natural log of renewables demand (in Mtoe), LSolid is natural log of solid fuels demand (in Mtoe), LWOP is natural log of WOP (in USD per barrel), LRGDP is natural log of economic growth (in USD billion – constant 2005), LPOP is natural log of population (in million people), LURBAN is natural log of urbanization (in million people) and LEA is natural log of energy access (in percentage of population). β_0, α_0, γ_0, ϕ_0, Ψ_0 and Θ_0 are constant terms and β_1 to β_5, α_1 to α_5, γ_1 to γ_5, ϕ_1 to ϕ_5, Ψ_1 to Ψ_5, and Θ_1 to Θ_5 are estimated parameters of the models, respectively. Also, i is a cross-section data for countries, t is a time series data and $\varepsilon_{i,t}$ is a random disturbance term.

3.3. Method of Analysis

In a panel analysis, the first step is to check the stationary properties of the data. To do so, the IPS method from Im et al. (2003) is employed for the analysis. Similar to the LLC method from Levin et al. (2002), both are originated from the augmented Dickey-Fuller (ADF) approach in Dickey and Fuller (1979) as given in Equation (13):

$$\Delta Y_{it} = \alpha_i + \rho_i Y_{i,t-1} + \sum_{j=1}^{k} \theta_{ij} \Delta Y_{i,t-j} + \gamma_i t + \varepsilon_{it}\ ;\ i = 1, 2, \ldots, N \text{ and } t = 1, 2, \ldots, T \quad (13)$$

where Y = LED, LCoal, LGas, LOil, LRenew, LSolid, LWOP, LRGDP, LPOP, LURBAN and LEA. Also, Δ is the first difference operator, ρ is autoregressive coefficient, α_i is the country-specific fixed effect, γ_i is an individual trend and ε_{it} is a white-noise error term.

On the contrary, the IPS method considers both heterogeneity in intercepts and slope coefficients across countries. In particular, the alternative hypothesis under the IPS method is that some (but not all) of the series are stationary i.e. H_1: $\rho_i < 0$ for at least one i.

Its t-bar statistic, $\bar{t}$, which is a simple average of the individual ADF τ-statistics, is expressed in Equation (14):

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} \tau_i \text{ and } \tau_i = \frac{\hat{\rho}_i}{s.e.\left(\hat{\rho}_i\right)} \quad (14)$$

Thus, the standardized $\bar{t}$ statistic, which is known as $\bar{z}$ statistic, is stated in Equation (15):

$$\bar{z}=\frac{\sqrt{N}}{\sqrt{\mathrm{var}\left(\bar{t}\right)}}\left(\bar{t}-E\left(\bar{t}\right)\right) \quad (15)$$

Where $E(\bar{t})$ and $\mathrm{var}(\bar{t})$ denote the moments of mean and variance as tabulated in Im et al. (2003). The $\bar{z}$ statistic approaches a standard normal distribution as N and T $\to \infty$.

In the case of each variable is stationary and integrated at order one, I(1), the panel cointegration test by Pedroni (2004) can be employed thereafter. The test permits both intercept and slope terms of the cointegrating equations to be heterogeneous. Hence, seven statistics were developed to test the null of no cointegration in heterogeneous panels (Pedroni, 2004). As such, one group is classified under the panel cointegration statistics in Equation (16–19):

$$\nu\text{-stat: } Z_V=\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1} \quad (16)$$

$$\rho\text{-stat: } Z_\rho=\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}\left(\hat{\varepsilon}_{i,t-1}\,''\,\hat{\varepsilon}_{i,t}-\hat{\lambda}_i\right) \quad (17)$$

Non-parametric (PP) t-stat:

$$Z_{PP}=\left(\tilde{\sigma}^{2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t}-\hat{\lambda}_i\right) \quad (18)$$

Parametric (ADF) t-stat:

$$Z_{ADF}=\left(\hat{S}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{*2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{*}\Delta\hat{\varepsilon}_{i,t}^{*} \quad (19)$$

The other group is under the group mean panel cointegration statistics as provided in Equation (20–22):

$$\rho\text{-stat: } \tilde{Z}_\rho=\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1}\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t}-\hat{\lambda}_i\right) \quad (20)$$

Non-parametric (PP) t-stat:

$$\tilde{Z}_{PP}=\sum_{i=1}^{N}\left(\hat{\sigma}^{2}\sum_{t=1}^{T}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t}-\hat{\lambda}_i\right) \quad (21)$$

$$\text{Parametric (ADF) t-stat: } \tilde{Z}_{ADF}=\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{S}_i^{-2}\hat{\varepsilon}_{i,t-1}^{*2}\right)^{-1/2}\sum_{t=1}^{T}\hat{\varepsilon}_{i,t-1}^{*}\Delta\hat{\varepsilon}_{i,t}^{*} \quad (22)$$

With the definitions of several supporting terms as follow:

- $\hat{\lambda}_i=\frac{1}{T}\sum_{s=1}^{K}\left[1-\frac{s}{K_i+1}\right]\sum_{t=s+1}^{T}\hat{u}_i\hat{u}_{i,t-s}$, where $\hat{\varepsilon}_{i,t}=\hat{\varepsilon}_{i,t}-\hat{\rho}_i\hat{\varepsilon}_{i,t-1}$;
- $\hat{L}_{11i}^{-2}=\frac{1}{T}\sum_{t=1}^{K}\hat{\eta}_{i,t}^{2}+\frac{2}{T}\sum_{s=1}^{K}\left[1-\frac{s}{K_i+1}\right]\sum_{t=s+1}^{T}\hat{\eta}_{i,t}\hat{\eta}_{i,t-s}$, where

  $\hat{\eta}_{i,t}=\Delta Y_{it}-\sum_{m=1}^{M}\hat{b}_{m,i}\Delta X_{m,it}$;
- $\hat{\sigma}^{2}=\frac{1}{N}\sum_{i=1}^{N}\hat{L}_{11i}^{-2}\hat{\sigma}_i^{2}$, where $\hat{\sigma}_i^{2}=\hat{S}_i^{2}+2\hat{\lambda}_i$ and $\hat{S}_i^{2}=\frac{1}{T}\sum_{t=1}^{T}\hat{u}_{i,t}^{2}$; and
- $\hat{S}_i^{*2}=\frac{1}{T}\sum_{t=1}^{T}\hat{u}_{i,t}^{*2}$, where $\hat{u}_{i,t}^{*}=\hat{\varepsilon}_{i,t}-\hat{\rho}_i\hat{\varepsilon}_{i,t-1}-\sum_{k=1}^{K_i}\hat{\rho}_{i,k}\Delta\hat{\varepsilon}_{i,t-k}$.

While the group mean panel cointegration statistics enable parameters across countries to be heterogeneous, the panel cointegration statistics look into common time factors and also allow them to heterogeneous across countries. In addition, seven statistics from Pedroni (2004) are based on the null of no cointegration i.e. H_0: $\rho_i = 0$ for all i in which ρ_i is the autoregressive term from the estimated residuals as exhibited in Equation (23):

$$\hat{\varepsilon}_{i,t}=\rho_i\hat{\varepsilon}_{i,t-1}+u_{i,t} \quad (23)$$

The null of no cointegration is rejected given the test statistics exceed the critical values that can be found in Pedroni (2004). Hence, there exist long run cointegrating relationships among the variables in respective models.

With the variables are proven to be cointegrated at I(1), the next step is to employ the panel FMOLS procedure. Accordingly, the equilibrium estimates will be obtained for the long run cointegrating relationships among the variables in all models. As such, the procedure allows for a larger flexibility in the presence of heterogeneity both in the transitional serial correlation dynamics and in the long run cointegrating relationship. Following the work of Pedroni (2000), the cointegrated system for panel data takes on the specific forms as expressed in Equation (24 and 25), respectively:

$$Y_{it}=\alpha_i+\beta_i X_{it}+e_{it} \quad (24)$$

$$X_{it}=X_{i,t-1}+\varepsilon_{it} \quad (25)$$

For i = 1, 2,…, N and t = 1, 2,…, T where $\mu_{it}=(e_{it}, \varepsilon_{it})' \sim I(0)$ and $Z_{it}=(Y_{it}, X_{it})' \sim I(1)$.

Thus, the panel group mean FMOLS estimator for coefficient β is given in Equation (26):

$$\hat{\beta}_{FMOLS}^{*}=\frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T}\left(X_{i,t}-\bar{X}_i\right)^{2}\right)^{-1}\left(\sum_{t=1}^{T}\left(X_{i,t}-\bar{X}_i\right)Y_{i,t}^{*}-T\hat{\lambda}_i\right)\right] \quad (26)$$

In which $Y_{i,t}^{*}=(Y_{i,t}-\bar{Y}_i)-\frac{\hat{L}_{21i}}{\hat{L}_{22i}}\Delta X_{i,t}$ and $\hat{\gamma}_i=\hat{\Gamma}_{21i}+\hat{\Omega}_{21i}^{0}-\frac{\hat{L}_{21i}}{\hat{L}_{22i}}\left(\hat{\Gamma}_{22i}+\hat{\Omega}_{22i}^{0}\right)$ where covariance matrix, $\Omega=\Omega^0+\Gamma_i+\Gamma_i'$ with Ω_0 is the contemporaneous covariance matrix, Γ_i is the weighted sum of autocovariances, $\Omega=L_i L$ with L_i is the lower triangular decomposition of Ω and $\hat{\Omega}_i^0$ that denotes as an appropriate estimator of Ω_i^0. In term of the hypothesis testing, the null hypothesis, H_0: $\beta_i=\beta_0$ for all i against the alternative hypothesis, H_1: $\beta_i\neq\beta_0$. The main difference is that the heterogeneity effects are allowed for all values of β_i under the alternative hypothesis.

Hence, the associated t-statistics for the estimator can be obtained from Equation (27):

$$\hat{t}^{*}_{\beta_{FMOLS}} = \frac{1}{N^{1/2}}\sum_{i=1}^{N}\hat{t}^{*}_{\beta_{FMOLS,i}} \text{where}$$

$$\hat{t}^{*}_{\beta_{FMOLS,i}} = \left(\hat{\beta}^{*}_{FMOLS,i} - \beta_0\right)\left(\hat{\Omega}^{-1}_{11i}\sum_{t=1}^{T}\left(X_{i,t} - X_i\right)^2\right)^{1/2} \quad (27)$$

4. EMPIRICAL RESULTS

As reported in Table 1, the variables are found to have non-stationary properties at level. This is due to relatively high in their P values that are over than the 10% significance level. However, at first order difference, the variables are proven to be stationary with their P values becoming statistically significant at the 5% and 10% significance levels, accordingly. Hence, it can be concluded that the non-stationary variables at level are successfully converted into stationary series at first order difference and integrated of same order one, I(1).

Furthermore, Table 2 summarizes the results of cointegration analyses at the aggregated and disaggregated types of fuel. At the constant level, all models, which exclude LOil, contain four of seven statistics that collectively reject the null hypothesis of no cointegration at the 5% and 10% significance levels. Meanwhile, at the constant plus trend level, only the LED model, validates that there is no long run cointegrating relationship among the variables. With the panel-ADF and group-ADF statistics being as part of the results in which both tests have small-sample properties and more reliable than other statistics according to Pedroni (2004), it can be concluded that the variables are cointegrated in the long run relationships in all models.

By proving the long run cointegrating relationships do exist among the variables, the estimated parameters of each model are then measured via the FMOLS technique. As such, Table 3 provides the long run relationship estimation results by model.

From the Table 3, it is observed that the variations of aggregated and disaggregated ED are largely explained by the changes in the five understudied energy determinants. As such, the associated R^2 and adjusted R^2 indicate the values of over 75% for all models.

For the aggregated ED i.e. LED model, the coefficients of LRGDP, LURBAN and LEA are found statistically significant at the 5% and 10% significance levels and have positive and negative signs, accordingly. Thus, the results imply that a percent hike in economic growth would lead to about 1.34% rise in the aggregated ED whereas increases in a percent of urbanization and energy access would scale down the aggregated ED by −0.99% and −2.32%, respectively.

In other words, accelerated economic growth positively triggers the variations in aggregated ED over the long run. In contrast, urbanization and energy access adversely affect the aggregated ED in the long run by causing an inevitable drop notably in the rural residential sector. Since the effect of urbanization on ED varies by the phases of development, there is a tendency by urbanization to cause a decline in energy use notably among the low-to-middle income groups of countries (Poumanyvong and Kaneko, 2010). However, on individual basis, Singapore should be singled out from the group since the country is classified as a high income nation. In term of energy access, it is expected that

Table 1. Results of the IPS' panel unit root test

Variable	Level		First order difference	
	Constant	Constant plus trend	Constant	Constant plus trend
LED	1.600	0.489	−2.572	−2.893
	(0.945)	(0.688)	(0.005)*	(0.002)*
LCoal	1.203	1.662	−2.284	−2.252
	(0.886)	(0.952)	(0.011)*	(0.012)*
LGas	−1.221	−1.014	−7.527	−4.769
	(0.111)	(0.155)	(0.000)*	(0.000)*
LOil	−0.071	−0.693	−2.614	−1.567
	(0.472)	(0.244)	(0.005)*	(0.059)**
LRenew	0.157	−0.824	−4.103	−2.763
	(0.562)	(0.205)	(0.000)*	(0.003)*
LSolid	−1.042	0.517	−5.415	−5.631
	(0.149)	(0.698)	(0.000)*	(0.000)*
LWOP	0.112	1.183	−2.668	−1.738
	(0.544)	(0.882)	(0.004)*	(0.041)*
LRGDP	2.625	0.249	−2.349	−3.998
	(0.996)	(0.598)	(0.009)*	(0.000)*
LPOP	−0.772	−0.984	−3.699	−5.127
	(0.220)	(0.163)	(0.000)*	(0.000)*
LURBAN	1.387	0.237	−2.762	−1.339
	(0.917)	(0.594)	(0.003)*	(0.090)**
LEA	1.147	−0.722	−2.260	−2.124
	(0.874)	(0.235)	(0.012)*	(0.017)*

Figures in the parentheses are P values. * and **indicate rejections of the null of non-stationary at the 5% and 10% levels of significance, respectively

Table 2: Results of the Pedroni panel cointegration test

Model	Type	Test	Constant	Constant plus trend	Conclusion
LED	Panel statistics	ν-stat	−0.983	−2.205	Cointegrated
		ρ-stat	0.427	1.344	
		PP t-stat	−1.999*	0.062	
		ADF t-stat	−2.214*	−1.371	
	Group mean panel statistics	ρ-stat	1.472	2.397	
		PP t-stat	−2.612*	−0.842	
		ADF t-stat	−2.817*	−1.428	
LCoal	Panel statistics	ν-stat	−1.321	−2.120	Cointegrated
		ρ-stat	1.286	1.797	
		PP t-stat	−3.007*	−3.806*	
		ADF t-stat	−2.435*	−2.773*	
	Group mean panel statistics	ρ-stat	2.161	2.287	
		PP t-stat	−5.261*	−6.360*	
		ADF t-stat	−1.986*	−3.228*	
LGas	Panel statistics	ν-stat	−0.143	−1.112	Cointegrated
		ρ-stat	0.468	1.508	
		PP t-stat	−5.146*	−2.842*	
		ADF t-stat	−6.046*	−3.432*	
	Group Mean panel statistics	ρ-stat	1.470	2.198	
		PP t-stat	−4.161*	−4.103*	
		ADF t-stat	−4.513*	−4.236*	
LOil	Panel statistics	ν-stat	−0.816	−1.541	Cointegrated
		ρ-stat	1.467	1.960	
		PP t-stat	−1.648*	−2.686*	
		ADF t-stat	−1.609	−2.391*	
	Group mean panel statistics	ρ-stat	2.141	2.598	
		PP t-stat	−1.982*	−4.571*	
		ADF t-stat	−1.718*	−3.260*	
LRenew	Panel statistics	ν-stat	−1.721	−2.122	Cointegrated
		ρ-stat	1.494	1.970	
		PP t-stat	−6.910*	−6.528*	
		ADF t-stat	−2.532*	−2.462*	
	Group mean panel statistics	ρ-stat	2.158	2.563	
		PP t-stat	−8.657*	−6.598*	
		ADF t-stat	−4.557*	−3.321*	
LSolid	Panel statistics	ν-stat	−1.447	−2.087	Cointegrated
		ρ-stat	1.412	2.171	
		PP t-stat	−1.612**	−2.793*	
		ADF t-stat	−3.779*	−1.801*	
	Group mean panel statistics	ρ-stat	2.138	2.825	
		PP t-stat	−2.390*	−2.037*	
		ADF t-stat	−3.531*	−1.331**	

Statistics from Pedroni (2004) are one-sided tests with a critical value of −1.64 (k<−1.64 means the rejection of the null) except the ν-statistic that has a critical value of 1.64 (k>1.64 means the rejection of the null). * and **mean the null of no cointegration being rejected at the 5% and 10% significance levels.

fuel switching activities gradually take place i.e. shifting from intermittent renewables e.g. hydro, solar and wind, inefficient solid fuels e.g. wood and charcoal and carbon intensive fuels e.g. coal and oil to modern fuels e.g. electricity and gas that are more secure and reliable supplies (Pachauri and Jiang, 2008). Therefore, the long run results on economic growth, urbanization and energy access being key determinants for the aggregated ED are aligned with Pachauri and Jiang (2008) and Poumanyvong and Kaneko (2010).

Meanwhile, certain discrepancies are spotted in the results when looking at the disaggregated types of fuel. One example is can be seen from the case of coal demand i.e. the LCoal model. Of the variables, the coefficients of LPOP and LEA, which are statistically significant at the 5% significance level, have positive and negative impacts on the long run variations of coal demand. Empirically, the results explain that a percent rise in population would induce about 20.96% boosts in coal demand whereas a percent increase in energy access would lessen the total amount of coal demand by −13.39%. Conversely stated, population constitutes as the driving force that will induce major portion of growing needs to demand for more coal from the primary energy mix of a country over the long term. On the contrary, improved access to modern, more secure and reliable energy supplies e.g. electricity and gas would reduce in-home burning of low-cost albeit environmental unacceptable fuel e.g. coal (Gohlke et al., 2011). For this reason, fuel switching activities become essential and may take place whenever permissible as means to address severe health and environmental concerns especially among the groups of rural and impoverished people as a consequence of excessive coal use.

Table 3: Results of the panel FMOLS estimates

Model	Variable	Coefficient	Standard Error	t statistic	P value	Summary statistics
LED	LWOP	0.027	0.040	0.664	0.510	R^2: 0.897 Adjusted R^2: 0.895
	LRGDP	1.336	0.258	5.181	0.000*	
	LPOP	0.061	0.642	0.095	0.925	
	LURBAN	−0.988	0.509	−1.942	0.058**	
	LEA	−2.316	0.540	−4.290	0.000*	
LCoal	LWOP	−0.198	0.375	−0.528	0.600	R^2: 0.887 Adjusted R^2: 0.882
	LRGDP	0.953	2.390	0.399	0.692	
	LPOP	20.955	5.948	3.523	0.001*	
	LURBAN	−4.708	4.713	−0.999	0.323	
	LEA	−13.386	5.003	−2.675	0.010*	
LGas	LWOP	0.297	0.399	0.745	0.460	R^2: 0.822 Adjusted R^2: 0.783
	LRGDP	−0.011	2.542	−0.004	0.997	
	LPOP	11.805	6.326	1.866	0.068**	
	LURBAN	−6.029	5.012	−1.203	0.235	
	LEA	1.938	5.321	0.364	0.717	
LOil	LWOP	−0.064	0.050	−1.282	0.206	R^2: 0.893 Adjusted R^2: 0.889
	LRGDP	1.605	0.319	5.036	0.000*	
	LPOP	−1.029	0.793	−1.298	0.201	
	LURBAN	−0.897	0.628	−1.428	0.160	
	LEA	−2.590	0.667	−3.882	0.000*	
LRenew	LWOP	−0.038	0.095	−0.400	0.691	R^2: 0.850 Adjusted R^2: 0.841
	LRGDP	−0.302	0.607	−0.498	0.621	
	LPOP	2.145	1.511	1.420	0.162	
	LURBAN	1.251	1.197	1.045	0.301	
	LEA	−2.294	1.271	−1.805	0.078**	
LSolid	LWOP	0.010	0.114	0.087	0.931	R^2: 0.897 Adjusted R^2: 0.895
	LRGDP	3.412	0.730	4.677	0.000*	
	LPOP	−0.613	1.816	−0.337	0.737	
	LURBAN	−4.656	1.439	−3.236	0.002*	
	LEA	−4.912	1.527	−3.217	0.002*	

* and **indicate rejections of the null hypothesis of zero coefficient at the 5% and 10% levels of significance, respectively. FMOLS: Fully modified ordinary least square

Thus, the long run results on population and energy access serving as key determinants for coal demand are in tandem with Gohlke et al. (2011) and Lei et al. (2014).

Furthermore, natural gas demand i.e. LGas model reveals the results slightly different than the LCoal model. Among the variables, only the coefficient of LPOP, which is statistically significant at the 10% significance level, contributes a positive effect to the growth in natural gas demand over the long term. In this regard, a percent escalation in population would render to about 11.81% upsurges in natural gas demand. As matched with the LCoal model, the notion on population to drive changes in ED remains valid in the case of natural gas. Accordingly, the long run results on population constituting as the key determinant for natural gas demand are consistent with Alshehry and Belloumi (2014) and Zhu et al. (2014).

Moreover, oil demand i.e. LOil model unveils the results that closely resemble the case of aggregated ED but empirically verifies that LURBAN is statistically insignificant at the reasonable significance levels. Similar to the LED model, apart from LRGDP, the coefficient of LEA, which is a negative sign and statistically significant, has an adverse effect on oil demand in the long run. To simply put, a percent expansion in energy access would cause −2.59% losses in the changes of oil demand. As such, this opposing proposition proves to be the case, in which Pachauri and Jiang (2008) pointed out the economic sense that is previously mentioned in the LED and LCoal model. With economic growth and energy access representing key determinants for oil demand, the past studies such as Narayan and Smyth (2007) and Farhani and Ben (2015) discovered such long run relationships, respectively.

Slightly dissimilar to the LOil model, renewables demand i.e. LRenew model discloses only coefficient of LEA that is statistically significant at the 10% significance level. Explicitly, energy access would pose a negative implication to the long run demand profiles of renewable energy sources. In this respect, a percent improvement in energy access would lead to about −2.29% reductions in the total demand content of renewable energy sources. Interestingly, the presence of a negative sign and statistically significant coefficient of LEA, in which the economic sense is enlightened by Pachauri and Jiang (2008), has prominently appeared in the LED, LCoal and LOil models. Fuel substitutions, which may be termed as 'energy transition' i.e. shifting from intermittent renewables to modern fuels e.g. electricity and gas are crucial to ensure that there is no interruption in gaining access to energy supplies or everlasting access to energy flows given that the long term energy security is maintained by a country. Thus far, the long run results on energy access as a key determinant for renewables demand are in line with Leach (1992) and Pachauri and Jiang (2008).

By and large, a close resemblance to the LED model is none other than solid fuels demand i.e. the LSolid model notwithstanding the referred basis of significance level. By having the coefficients of LRGDP, LURBAN and LEA, which are statistically significant at the 5% significance level, these variables would affect the variations of solid fuels demand in both favourable and detrimental manners. Correspondingly, the linkages go with a percent advancement in economic growth would stimulate about 3.41% hikes in the demand prospect of solid fuels whereas increases in a percent of urbanization and energy access would trim the demand growth of solid fuels by −4.66% and −4.91%, respectively. While the economic senses suggested by Pachauri and Jiang (2008) and Poumanyvong and Kaneko (2010) behind the negative coefficients of LURBAN and LEA remain true for most cases in the developing nations, past studies such as Leach (1992) and Ibitoye (2013) showed the evidences of such long run relationships, accordingly.

5. CONCLUDING REMARKS

The long run relationship among ED (e.g. aggregated, coal, natural gas, oil, renewables and solid fuels) and its determinants; WOP, economic growth, population, urbanization and energy access over the 2000–2016 period would have important policy implications especially on the necessities of implementing and strengthening energy conservation policy such as energy saving and energy efficiency initiatives in the ASEAN-5. Collectively, the long run results indicate the evidences of "conservation hypothesis" that advocates for the energy conservation policy based on the cases of four energy determinants excluding WOP. Irrespective to energy levels, the positive and negative signs of economic growth, population, urbanization and energy access are found statistically significant. Therefore, it implies that these variables serve as the initial receptors of exogenous shocks and the long run steady positions are equilibrated in both ED levels eventually.

Due to dwindling domestic oil and natural gas production and inadequate domestic energy resources, combined with higher energy intensity regionally, these have caused the ASEAN-5 in particular to undertake the energy conservation efforts at varying momentums domestically (Asian Development Bank [ADB], 2013). As such, there is little adverse or negligible impact being expected on economic growth, population, urbanization and energy access across the ASEAN-5. Rather the one-size-fits-all policy, fuel specific energy policies are favourably recommended as a common reference among the policy makers to closely monitor the continued developments of fuels in a country's primary energy mix so that the demand profiles of these fuels will remain at the manageable level going forward. By having sound energy policy frameworks in place accordingly, policy makers, businesses and consumers will continue to improve the effectiveness of current systems and possibly curb the rising energy requirements in realizing the fact that the efficient use of energy at present constitutes as one of the greatest potential sources of energy supply in the future.

In the light of increasing calls for health and environmental concerns from now onwards, fuel switching activities, whenever possible, will duly take place i.e. shifting fuels from the former carbon-intensive to the least-to-zero carbon intensive ones and similarly, from traditional solid fuels to modern energy services. As part of the concerted efforts to maintain a country's long term energy security, affordability and sustainability, the policy makers are suggested to secure for reliable and affordable energy supplies with minimal environmental impact, promote a sustainable development and socio-economic growth and enhance the quality of life. Amid the main goal of phasing out the unsustainable use of coal and oil on a staggered basis, this will be further altered by greater utilization of natural gas domestically and rapid commercialization of indigenous renewable energy sources that are well suited to realize the country's desirable plan in strategically paving into the sustainable energy future or the so-called the future of a low carbon economy (IGU, 2012; ADB, 2013).

Although WOP is proven to be statistically insignificant in the long run in all models, this does not mean that its potential effect can be taken for granted. Thus, future studies, which are suggested to focus at the sectoral level and determine various causal directions via capturing the short run effects among the variables, would probably support for the notion of WOP fluctuations to significantly affect the variations in both ED levels, respectively.

REFERENCES

Abubakar, A.M., Agayev, F., Ilkan, M. (2013), Energy demand interplay with real GDP and oil prices. Advances in Management and Applied Economics, 3(4), 95-103.

Alshehry, A.S., Belloumi, M. (2014), Investigating the causal relationship between fossil fuels consumption and economic growth at aggregate and disaggregate levels in Saudi Arabia. International Journal of Energy Economics and Policy, 4(4), 531-545.

Al-Azzam, A., Hawdon, D. (1999), Estimating the Demand for Energy in Jordan: A Stock-Watson Dynamic OLS (DOLS) Approach. Energy Discussion Papers. University of Surrey, United Kingdom.

Asian Development Bank. (2013), Energy outlook for Asia and the Pacific. Available from: http://www.adb.org/publications.

Aziz, A.A., Nik Mustapha, N.H., Ismail, R. (2013), Factors affecting energy demand in developing countries: A dynamic panel analysis. International Journal of Energy Economics and Policy, 3, 1-6.

Bhattacharyya, S.C. (2006), Energy access problem of the poor in India: Is rural electrification a remedy? Energy Policy, 34(18), 3387-3397.

Bayramoglu, A.T., Sukruoglu, D (2016), Non-Energy import demand function in Turkey: New evidence. Asian Economic and Financial Review, 6(12), 750-761.

Dickey, D.A., Fuller, W.A. (1979), Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366), 427-431.

Engle, R.F., Granger, C.W.J. (1987), Cointegration and error correction: Representation, estimation and testing. Econometrica, 55(2), 251-276.

Farhani, S., Ben, R.J. (2015), Link between Economic Growth and Energy Consumption in Over 90 Countries. IPAG Working Paper Series.

Available from: http://www.ipag.fr/wp-content.

Gately, D., Huntington, H.G. (2002), The asymmetric effects of changes in price and income on energy and oil demand. Energy Economics, 23, 19-55.

Gohlke, J.M., Thomas, R., Woodward, A., Lendrum, D.C., Ǜstun, A.P., Hales, S., Portier, C.J. (2011), Estimating the global public health implications of electricity and coal consumption. Environmental Health Perspectives, 119(6), 821-826.

Hamilton, J. (1983), Oil and the macroeconomy since World War II. Journal of Political Economy, 91(2), 228-248.

Hong, Z. (2010), Energy security concerns of China and ASEAN: Trigger for conflicts or cooperation in the South China Sea? Asia Europe Journal, 8(3), 413-426.

Houthakker, H.S. (1951), Some calculations on electricity consumption in Great Britain. Journal of Royal Statistical Society, 3, 359-371.

Ibitoye, F.I. (2013), The millennium development goals (MDGs) and household energy requirements in Nigeria. SpringerPlus, 2(1), 529-537.

Im, K., Pesaran, M.H., Shin, Y. (2003), Testing for unit roots in heterogeneous panels. Journal of Econometrics, 115(1), 53-74.

International Energy Agency. (2013), World Energy Outlook Special Report: Southeast Asia Energy Outlook. Available from: http://www.iea.org/publications.

International Energy Agency. (2016), Country Statistics. Available from: http://www.iea.org/statistics.

International Gas Union. (2012), Global Vision for Natural Gas: The Pathway Towards a Sustainable Energy Future. Available from: http://www.igu.org/publications.

Jain, V. (2011), Challenges of economic growth and the concern for energy security: A comparative analysis of South and South-East Asia. Millennial Asia, 2(2), 207-227.

Kanchana, K., Unesaki, H. (2014), ASEAN energy security: An indicator-based assessment. Energy Procedia, 56, 163-171.

Karanfil, F. (2009), How many times again will we examine the energy–income nexus using a limited range of traditional econometric tools? Energy Policy, 36, 1191-1194.

Kilian, L. (2014), Oil Price Shocks: Causes and Consequences. Available from: http://www.personal.umich.edu.

Leach, G. (1992), The energy transition. Energy Policy, 20(2), 116-123.

Lei, Y., Li, L., Pan, D. (2014), Relationships between coal consumption and economic growth of the six biggest coal consumption countries. Energy Procedia, 61, 624-634.

Levin, A., Lin, C.F., Chu, C.S. (2002), Unit root tests in panel data: Asymptotic and finite sample properties. Journal of Econometrics, 108(1), 1-24.

Madlener, R., Bernstein, R., Gonzalez, M.A.A (2011), Econometric estimation of energy demand elasticities. Available from: http://www.eonerc.rwth-aachen.de/global.

Magazzino, C. (2014), A panel VAR approach of the relationship among economic growth, CO_2 emissions and energy use in the ASEAN-6 countries. International Journal of Energy Economics and Policy, 4(4), 546-553.

Mehra, Y.P., Peterson, J.D. (2005), Oil prices and consumer spending. FRB Richmond Economic Quarterly, 91(3), 53-72.

Michieka, N.M., Fletcher, J.J. (2014), Population Dynamics, Economic Growth and Energy Consumption in Kenya. Available from: http://www.ageconsearch.umn.edu.

Narayan, P.K., Smyth, R. (2007), A panel cointegration analysis of the demand for oil in the Middle East. Energy Policy, 35(12), 6258-6265.

Nkomo, J.C. (2007), Energy use, poverty and development in the SADC. Journal of Energy in Southern Africa, 18(3), 10-17.

Olsen, O., Roland, K. (1988), Modelling Demand for Natural Gas: A Review of Various Approaches. Available from: https://www.ssb.no/a/histstat/sos/sos_067.pdf.

Pachauri, S. (2012), Demography, urbanization and energy demand. Environment and Policy, 54, 81-94.

Pachauri, S., Jiang, L. (2008), The household energy transition in India and China. Energy Policy, 36, 4022-4035.

Pachauri, S., Spreng, D. (2004), Energy use and energy access in relation to poverty. Economic and Political Weekly, 39(3), 271-278.

Pedroni, P. (2000), Fully modified OLS for heterogeneous cointegrated panels. Advances in Econometrics, 15, 93-132.

Pedroni, P. (2004), Panel cointegration: Asymptotic and finite sample properties of pooled time series with an application to the PPP hypothesis. Econometric Theory, 20(3), 597-625.

Poumanyvong, P., Kaneko, S. (2010), Does urbanization lead to less energy use and lower CO_2 emissions? A cross-country analysis. Ecological Economics, 70(2), 434-444.

Saibu, O.M. (2013), Causal implication of oil price shock, energy demand on sustainable economic growth in Africa: The case of Nigeria. Journal of Sustainable Development in Africa, 15(5), 30-48.

Zhu, Q., Lu, Q.Y., Zhou, X.Y., Lai, K.K. (2014), A driving force and forecast for gas consumption demand in China. Mathematical Problems in Engineering, 2014, 1-11.