Examining the convergence of energy consumption: comparison between oil importing versus oil exporting countries

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Abstract. Convergence analysis is one way to check for the sustainability. In this study, examination of convergence is performed to check on the sustainability of energy consumption in the main oil importing versus oil exporting groups. In particular, we examined for stochastic versus beta conditional convergence. In addition, the speed of convergence is compared among countries using time series and panel data analyses. For the purpose of analysis, the generalized method of moments (GMM) and seemingly unrelated regression augmented Dicky-Fuller (SURADF) techniques are applied. The results revealed the evidences of convergence in energy consumption in two groups of countries, indicating the sustainable of energy consumption. The speed of convergence is very similar for both groups of countries. However, the speed of convergence is varying across individual countries. The main determinant contributes to energy consumption is oil price.

1. Introduction
Energy is one of the main resources used in production and the use of energy may boost to economic growth especially for the highly oil dependence countries. However, at the same time, the use of energy may lead to unpleasant impact on the environmental quality. Hence, it is important to investigate if the energy consumption of a country exhibiting a divergence or convergence trend.

The concept of convergence is related to “whether non-developed or developing countries have caught up with developed countries in terms of per capita income” in the literature of growth. Borrowing the same concept to the energy literature, the concept is comparing “whether per capita electricity consumption is converging between countries or regions” [1]. And in this study, the convergence refers to whether per capita energy usage is converging between countries.

The study of convergence of energy consumption is important for several reasons. First, it is important for the policymaker to understand the level or path of energy consumption in accordance with its green environment policy to maintain the environmental quality and health. The reveal of convergence in energy consumption implies the sustainable path of energy usage which is the crucial condition should be achieved. The convergence implies that the impact of shocks to energy consumption would lead to temporary effect while the divergence implies to the shocks to energy consumption is permanent in nature [2]. Second, the convergence of energy relative to the group or cluster of countries may reveal some useful information. Countries that share the similar characteristics tend to achieve convergence. Such convergence may imply to the energy integration or possibility for economic integration. Energy market integration is a way to promote energy efficiency, reduce carbon dioxide
emissions and to improve trades which may benefit each other. As indicated by Solarin and Lean, 2018 [3] and Narayan and Smyth, 2007 [4] took the first initiative to test the energy integration properties based on energy consumption. This work was expanded by other researchers such as Wang et al., 2016 [5] and Shahbaz et al., 2015 [6]. The reveal of convergence of single country to its group’s energy consumption level indicate to the potential of individual economy to catch up to the more rapid growth level. This leads to the better understanding on how the demand on energy will change over time when an individual economy is moving to the higher income level. Third, the speed of catch up/convergence is also crucial to reveal how rapidly the energy consumption change over time and what are the main factors determine such convergence rate, if the convergence rate appropriate with prudential macroeconomic policies. Comparative of speed of convergence among groups of economies may reveal variety economic structure and characteristics.

In this study, we seek to examine the stability of energy consumption, i.e. if the consumption of energy for a group of countries converges to the equilibrium level or share the same equilibrium level in the long-run. We also seek to reveal the convergence club and the factors may determine to the energy consumption and its speed of convergence. The form of convergence club reveals that the countries in the group share the same characteristics in terms of energy consumption. The study is focused on the top oil importing versus top oil importing countries. The seemingly unrelated regression augmented Dicky-Fuller (SURADF) is used to study the relative versus absolute convergence club while the generalized method of moments (GMM) is applied to study the static versus dynamic conditional convergence effect of energy consumption ($\beta$-convergence).

1.1. Review of global energy consumption
According to the Independent Statistic & Analysis, U.S. Energy Information Administration, energy consumption is usually defined as the amount of energy consumed in a process or system, or by an organization or society as a source of power or heat or as a raw material input into a manufacturing process. On the other hand, primary energy consumption is the consumption of primary energy that produced from other energy sources. For instance, coal coke is produced from coal. The energy source is included in primary energy only if their energy content is not already been included as part of the original energy sources.

According to the BP Statistical Review of World Energy [7], the world primary energy consumption growth showed an average 2.2% in 2017 which is higher than the 10-year average of 1.7% per year between 2006-2017. China was the largest energy consumption country for the 17th consecutive year with the growth rate of consumption 3.1% in 2017. On the other hand, India showed the much higher growth rate of 4.6% for year 2017 (Table 1). In terms of oil consumption, US and China were the single largest country that highly consume oil. Comparing the growth of gross domestic products (GDP) with the energy consumption (Figure 1), the world GDP and the demand on primary energy showed the increment in 2017 relative to the 2006-17 while energy productivity was declined. Global energy demand increased 2.2% in 2017, such growth was driven by the increase in the energy consumption in Organisation of Economic Cooperation and Development (OECD) countries. Apart from OECD, developing countries, in particular China also contributed to the high energy consumption.

Since energy is used more intensively over time especially in countries highly dependent on energy, it is crucial to examine if the energy consumption exhibits its sustainable nature with converging trend.
Table 1. World primary energy consumption

| Country       | Million tonnes oil equivalent | Growth rate per annum |
|---------------|-------------------------------|-----------------------|
|               | 2007  | 2010  | 2015  | 2017  | 2017  | 2006-17 |
| US            | 2320.8 | 2235.6 | 2227.0 | 2234.9 | 0.6   | -0.3    |
| China         | 2150.3 | 2491.3 | 3009.8 | 3132.2 | 3.1   | 4.4     |
| India         | 450.4  | 538.0  | 686.9  | 753.7  | 4.6   | 5.7     |
| Japan         | 524.4  | 503.8  | 453.0  | 451.2  | 1.4   | -1.6    |
| Russian       | 673.1  | 668.2  | 678.6  | 698.3  | 1.5   | 0.3     |
| Germany       | 331.9  | 328.7  | 323.3  | 335.1  | 2.4   | -0.5    |
| North America | 2809.5 | 2720.7 | 2739.7 | 2772.8 | 0.7   | -       |
| South & Cent. America | 587.0  | 632.5  | 701.1  | 700.6  | 0.8   | 2.1     |
| Europe        | 2041.7 | 2001.1 | 1908.7 | 1969.5 | 2.1   | -0.6    |
| CIS           | 989.8  | 967.8  | 960.7  | 978.0  | 0.9   | -0.1    |
| Middle East   | 618.2  | 714.3  | 848.3  | 897.2  | 3.4   | 4.1     |
| Africa        | 346.9  | 386.9  | 429.4  | 449.5  | 2.9   | 2.8     |
| Asia Pacific  | 4195.2 | 4696.1 | 5472.4 | 5743.6 | 3.1   | 3.5     |
| World         | 11588.4 | 12119.4 | 13060.2 | 13511.2 | 2.2  | 1.7     |

Source: summary from BP Statistical Review of World Energy (June 2018)

2. Literature review – convergence of energy consumption

The concept of convergence is used to describe things that are in the process of coming together. In terms of energy consumption, it is when new things that towards new evolution or converged that occurred in the energy consumption as individually. This concept is borrowed from the growth literature, which refers to the tendency of less developed economies or poor countries to grow faster than more mature economies or rich countries. Convergence also known as catch-up effect when the less developed countries catch up to the level of the mature countries. Studies showed that poor countries tend to grow faster compared to the rich countries [8]. The speed of convergence tells us how fast an economy is approaching its steady state. If an economy is far from its steady state, it might converge faster than the coconut that already or nearly to the steady state. This leads to the view that poor countries tends to grow faster than the rich one and [9] provided evidence based on the 48 contiguous U.S. states data.

Convergence can be classified into different types: unconditional/ absolute β-convergence, conditional β-convergence and σ-convergence. Absolute β-convergence exists when all countries converge to the same level of income per worker at steady state [10]. On the other hand, the conditional convergence states that a country’s income per worker (or per capita) converges to a country-specific long-run growth path which is given by the basic structural characteristics of the country [10]. In other words, convergence happens conditionally on a number of factors [11]. σ-convergence, on the other hand may exist when the dispersion of levels of income across economies shows a reduction over time. Apart from these, one more convergence is called a stochastic convergence which does not require each country to converge to the same steady state. Stochastic convergence occurs in per capita income disparities between economies follow a mean-stationary process [12]. Hence, the relative per capita income shocks may lead to transitory deviations from any tendency toward convergence and the existence of stochastic convergence means that all economies have reached their own steady state. The theory of convergence leads to the formation of convergence clubs. Convergence clubs hypothesis claim that the convergence can only happen across groups of countries that share some common characteristics. Therefore, homogeneous country group with adjacent to each other and have similar initial conditions and features might converge to the same steady state in the economic development [13].

Empirical studies applied different approaches to examine the convergence and its clubs and reached different results. Baumol, 1996 [14] formed a convergence club by grouping countries with respect to political systems as OECD membership, middle income countries and command economies.
Durlauf and Johnson, 1995 [15] allowed for clustering by using a regression tree method to define the country clubs with the common initial conditions and literacy characteristics such as initial income levels and literacy rates. While Chatterji, 1992 [16] grouped countries based on initial income per capita levels and tested convergence cross-sectionally. On the other hand, Apergis and Christou, 2015 [17] reported the rejection of full convergence and the presence of a certain number of clubs. Applying the transitional curves, they found that over the long-run energy productivity tends to converge, indicating the strong attempts of the countries under investigation to adopt energy policies that eventually contribute to a convergence pattern.

Pan and Maslyuk, 2017 [2] discussed the methodologies applied in testing for energy consumption. They classified the unit-root tests into four main sets in testing for stochastic convergence into. The first group applied the univariate unit-root tests. Since the univariate tests are subject to biases in the presence of structural breaks and are in linear form which might have no power to reject the null if the process is non-linear. For these reasons, the studies have extended to structural breaks unit-root (second set), panel unit-root tests (third set) and the fourth set is non-linear tests. Applying the second set approach, many studies found evidences of convergence in energy consumption per capita around a trend. Among them include Mishra and Smyth, 2014 [18] and Mishra and Smyth, 2017 [19]. The studies that employed the panel data unit-root tests with no breaks showed mixed results [20] while studies using panel unit-root tests with breaks revealed evidence of convergence (for instance, Mishra and Smyth, 2014 [18] and Shahbaz et al., 2016 [21]. Some studies applied non-linear unit-root tests to overcome the limitations in linear unit-root tests. Among them include Hasanov and Telatar, 2011 [22] and Solarin and Lean, 2018 [3]. The later found evidence of convergence using the data of OPEC countries.

Previous studies also found a strong impact of crude oil price on energy consumption. Changes of oil price may impact the production cost at production level and affects the income level at consumer level. Many studies found that rising in energy prices may lead to the reduction of energy consumption ([23], [24] and [25]).

3. Data and methodology
The study is focused on the top oil importing versus exporting countries. Eight countries are selected for each group by referring to The World Factbook, 2017 [26] on the rank of the top 10 oil importing and exporting countries. The selected countries are as follows:
Oil importing: United States, India, Japan, South Korea, Nepal, Germany, Spain and Italy
Oil exporting: Saudi Arabia, Russia, Iraq, Canada, Nigeria, Nepal, Angola and Kuwait
The data for per capita energy consumption were retrieved from the World Development Indicators published by the World Bank. Energy consumption is expressed in kg oil equivalent per capita refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus stock changes and imports, minus exports and fuels supplied to ships and aircraft engaged in international transport. The control variables for convergence club include GDP in terms of constant U.S. Dollar, CPI and oil price. The period is ranging from 1971 to 2014 based on the data availability. In particular, we define the relative (REC) and actual energy consumption per capital (LEC) as natural log of the ratio of energy consumption for country i over its group’s average value and the natural log of energy consumption respectively. The variables used are as summarized in Table 2.
Table 2. Description of variables

| Variables | Descriptions |
|-----------|--------------|
| EC        | Energy consumption per capita (Kg) |
| GDP       | Gross domestic product (US Dollar) |
| CPI       | Consumer price index (2010=100) |
| OIL       | World oil price (US Dollar) |
| LEC       | Natural logarithm of energy consumption per capita |
| LGDP      | Natural logarithm of gross domestic product |
| LCPI      | Natural logarithm of consumer price index |
| LOIL      | Natural logarithm of world crude oil price |
| REC       | In (EC / Average of EC) |

Our study applied the seemingly unrelated regression augmented Dicky-Fuller (SURADF) to examine the relative versus absolute convergence club and the generalized method of moments (GMM) to study the static versus dynamic conditional convergence effect of energy consumption (β-convergence).

3.1. SURADF – stochastic convergence
SURADF technique is the combination of seemingly unrelated regression (SUR) and Augmented Dickey-Fuller (ADF) test. SURADF is a method proposed by [27], which is derived from Augmented Dickey-Fuller test to test unit root based on the system of ADF equations which can be written as [28]:

\[
\Delta y_{1,t} = \alpha_1 + \beta_1, y_{1,t-1} + \sum_{j=1}^{\varphi_j} \varphi_j \Delta y_{1,t-j} + u_{1,t}
\]

\[
\Delta y_{2,t} = \alpha_2 + \beta_2, y_{2,t-1} + \sum_{j=1}^{\varphi_j} \varphi_j \Delta y_{2,t-j} + u_{2,t}
\]

\[\vdots\]

\[
\Delta y_{N,t} = \alpha_N + \beta_N, y_{N,t-1} + \sum_{j=1}^{\varphi_j} \varphi_j \Delta y_{N,t-j} + u_{N,t}
\]

where \(\varphi_j\) is the autoregressive coefficient for series \(j\) and \(\beta_j = (\varphi_j - 1)\). The dependent variable \(y\) in this study is represented by per capita energy consumption of each country LEC and REC for the absolute versus relative convergence equation respectively. Each system equation contains 8 equations representing 8 countries of oil importing and oil exporting countries respectively. We estimate this system by using SUR procedure and the \(n=8\) different null and alternative hypotheses can be tested individually with the test statistics as [29]:

\[H_0^A: \beta_1 = 0 \quad H_A^A: \beta_1 < 0\]

\[H_0^B: \beta_2 = 0 \quad H_A^B: \beta_1 = 0\]

\[\vdots\]

\[H_0^N: \beta_N = 0 \quad H_A^N: \beta_N = 0\]

The test power of ADF unit root test procedure is enhanced by SURADF test [30]. [31] showed that the power of the SURADF test is much higher than that of a simple ADF test if cross-correlations are present. The rejection of the null hypothesis implies the detection of stochastic convergence in that particular country.
3.2. GMM – β-convergence

For testing the present of β-convergence, we apply regression analysis. Conditional β-convergence presents if the convergence is dependent on other explanatory variables. In this study, our response variable is energy consumption and the regressors are gross domestic product (GDP), consumer price index (CPI) and world oil price.

GMM is a generic method for estimating parameters in statistical models; it uses predetermined variables and some endogenous variables as instrumental variables which can eliminate endogeneity to improve accuracy of regressions [32]. The GMM estimator belongs to a class of estimators known as M-estimators that are defined by minimizing some criterion function. To describe the GMM estimator, let \( \beta \) denote a \( p \times 1 \) parameter vector, \( w_i \) a data observation with \( i = 1, \ldots, n \), where \( n \) is the sample size. Let \( g_i(\beta) = g(w_i, \beta) \) be a \( m \times 1 \) vector of functions of the data and parameters. The GMM estimator is based on a model where, for the true parameter value \( \beta_0 \) the moment conditions

\[
E[g_i(\beta_0)] = 0
\]

are satisfied. The estimator is formed by choosing \( \beta \) so that the sample average of \( g_i(\beta) \) is close to its zero population value. Let

\[
\hat{g}(\beta) \equiv \frac{1}{n} \sum_{i=1}^{n} g_i(\beta)
\]

Denote the sample average of \( g_i(\beta) \). Let \( \hat{A} \) denote an \( m \times m \) positive semi-definite matrix. The GMM estimator is given by

\[
\hat{\beta} = \arg \min_{\beta} \hat{g}(\beta)' \hat{A} \hat{g}(\beta)
\]

That is \( \hat{\beta} \) is the parameter vector that minimizes the quadratic form \( \hat{g}(\beta)' \hat{A} \hat{g}(\beta) \). The GMM estimator chooses \( \hat{\beta} \) so the sample average \( \hat{g}(\beta) \) is close to zero. We perform both static and dynamic models:

**Static model:**

\[
\ln \left( \frac{EC_i}{EC_{i-1}} \right) = \beta_0 + \beta_1 \ln EC_{i-1} + \beta_2 Z_t + \mu + \tau_t + \epsilon_t
\]

**Dynamic model:**

\[
\ln EC_{i,t} = \beta_0 + \gamma \ln EC_{i,t-1} + \beta_2 Z_{i,t} + \mu_t + \tau_t + \epsilon_{i,t}
\]

where \( EC_{i,t} \) is the energy consumption of province \( i \) in year \( t \), thus the \( \frac{EC_{i,t}}{EC_{i,t-1}} \) means annual growth rate of energy consumption between year \( t-1 \) and year \( t \). \( Z_{i,t} \) is column vectors of control variables. \( \mu_t \) denotes individual effect, \( \tau_t \) stands for time effect and \( \epsilon_{i,t} \) is random error. \( \beta_3 \) is a parameter testing null hypothesis of absolute convergence while \( \beta_2 \) is to test the null hypothesis of conditional convergence and lastly \( \beta_0 \) is the intercept.

The logarithmic equation in the static model is the model that ignoring dynamic factors. However, the inertia of energy consumption determines that current data are affected by preliminary data. Therefore, we need to put this factor into regressions, otherwise it may cause errors. We add \( \ln e_{i,t-1} \) to both sides of equation of static model and get the modified equation [32]:

\[
\ln e_{i,t-1} = \beta_0 + \gamma \ln e_{i,t-2} + \beta_2 Z_{i,t} + \mu + \tau_t + \epsilon_{i,t}
\]

where \( \gamma = \beta_1 + 1 \), which is the dynamic effect of energy consumption which implies the convergence rate of \( \beta_1 = \gamma - 1 \). This equation belongs to standard dynamic model with first lagged terms on its right side. Thus, we use GMM instead of traditional regression methods such as OLS which are not adequate due to the significant serial correlation among residuals.

3.3. J-statistic

J-statistic is used as a test of over-identifying moment conditions. The test statistics is given by

\[
T = n \hat{g}(\beta)' \hat{A}^{-1} \hat{g}(\beta)
\]

When the moment conditions \( E[g_i(\beta_0)] = 0 \) are satisfied then as the sample size grows we will have
\[ T \rightarrow \chi^2(m - p) \]

Under the conditions for asymptotic normality, \( \Omega \) nonsingular and \( \hat{\Omega} \rightarrow \Omega \) for an efficient GMM estimator, it follows that \( T \rightarrow \chi^2(m - p) \).

The \( J \)-statistic, introduced in [33], refers to the value of the GMM objective function evaluated using an efficient GMM estimator. It acts as an omnibus test statistic for model misspecification. A large \( J \)-statistic indicates a mis-specified model. Unfortunately, the \( J \)-statistic does not give any information about how the model is mis-specified. The null and alternative hypotheses are as follow:

\[ H_0: \text{the instrument is sufficient} \]
\[ H_a: \text{the instrument is not sufficient} \]

The test statistic has a \( \chi^2 \) distribution under the null hypothesis that the instruments are valid. The significant statistic indicates that one or more of our instruments are not valid (assuming that the model is otherwise correctly specified).

### 4. Results

The results are indicated by the significance levels: * for 10%; ** for 5% and *** for 1% significance. Table 3 and 4 summarize the result of SURADF for testing actual versus relative stochastic convergence respectively. The rejection of the null hypothesis indicates to the stationary of shocks, hence evident to the convergence of energy consumption. It is observed that majority countries are converging to their group’s average level based on actual stochastic convergence analysis. Hence there are two convergence clubs of oil importing and oil exporting countries with the exception of non-convergence of Japan, Italy and Kuwait (Table 3). On the other hand, the relative convergence reveals that only Japan, South Korea and Spain are able to form the oil importing convergence club and all countries are in the oil exporting convergence club except Canada and Kuwait. The members of convergence clubs share the similar level of energy consumption by exhibiting stochastic stationary property in shock over time.

#### Table 3. SURADF - Actual stochastic convergence

| Oil importing   | Lag 1       | Lag 2       | Oil exporting | Lag 1       | Lag 2       |
|----------------|-------------|-------------|---------------|-------------|-------------|
| United States  | -0.2055***  | -0.1528**   | Saudi Arabia  | -0.0826***  | -0.0870***  |
| India          | 0.0269***   | 0.0206*     | Russia        | -0.1656**   | -0.1622**   |
| Japan          | -0.039221   | -0.0193     | Iraq          | -0.1286**   | -0.1234**   |
| South Korea    | -0.0275***  | -0.0258**   | Canada        | -0.1413***  | -0.1523***  |
| Nepal          | 0.0908**    | 0.1239***   | Nigeria       | -0.1016***  | -0.0933***  |
| Germany        | -0.1750***  | -0.2053***  | Nepal         | 0.1315***   | 0.1379***   |
| Spain          | -0.0612***  | -0.039081** | Angola        | -0.1250**   | -0.1420**   |
| Italy          | -0.0232     | -0.0056     | Kuwait        | -0.1982     | -0.0752     |

#### Table 4. SURADF - Relative stochastic convergence

| Oil importing   | Lag 1       | Lag 2       | Oil exporting | Lag 1       | Lag 2       |
|----------------|-------------|-------------|---------------|-------------|-------------|
| United States  | -0.0116     | -0.0086     | Saudi Arabia  | -0.0844**   | -0.0984**   |
| India          | 0.0415      | 0.0457      | Russia        | -0.2496***  | -0.2874***  |
| Japan          | -0.1328***  | -0.0804     | Iraq          | -0.1371**   | -0.1286*    |
| South Korea    | -0.0351***  | -0.0337***  | Canada        | -0.0521     | -0.0481     |
| Nepal          | -0.0959*    | -0.0772     | Nigeria       | -0.0838**   | -0.0728*    |
| Germany        | -0.0143     | -0.0133     | Nepal         | -0.1254***  | -0.1277***  |
| Spain          | -0.1072***  | -0.0929***  | Angola        | -0.0969***  | -0.0954***  |
| Italy          | -0.0226     | -0.0746     | Kuwait        | -0.1942     | -0.2149     |

Table 5a-8b show the results of GMM on \( \beta \) convergence using cross-section and time series specifications. In all cases, \( J \)-statistic is not significant and hence passes the instrumental test of proper identification. The coefficient of \( \ln(EC) \) captures the convergence, it should be negative and significant.
Positive or non-significance imply to non-convergence. By focusing the results on static model (Table 5a, b), we observe that all oil importing countries achieve convergence except Italy and Nepal. The results hold for both times series and cross section specifications. The convergence is conditional to some factors. Oil price is influential in which higher oil price leads to lower energy consumption in most countries. On the other hand, GDP also an important factor where higher GDP leads to higher energy consumption. Table 6a, b show the results for oil exporting countries (static model). As observed, convergence is evident in all countries except Nepal and Kuwait. To be concerned, Nepal appears in the list of top oil importing and exporting groups. It is ranked number 6 and 7 as top oil importing and consumption level. Oil price has limited impact to determine the energy consumption in oil exporting group. The dynamic models, results are consistent, showing oil exporting countries with higher convergence rate through dynamic model captures the dynamic effect of energy consumption. Higher dynamic effect signifies to lower convergence effect. Comparing the results between static and dynamic model, we found that the convergence rate is much higher in oil exporting countries. Among them, Iraq, Russia and Angola show very high convergence rate while those with no evidence of convergence like Nepal and Italy exhibit very low convergence rate.

For robustness checking, we compare the results of static model with the dynamic model. The results hold for both times series and cross-section specifications. The convergence is conditional to some factors. Oil price is influential in which higher oil price leads to lower energy consumption in most countries. On the other hand, GDP also an important factor where higher GDP leads to higher energy consumption. Table 5a, b show the results for oil importing countries (static model). As observed, all oil importing countries achieve convergence except Italy and Nepal. The convergence is conditional to some factors. Oil price is influential in which higher oil price leads to lower energy consumption in most countries. On the other hand, GDP also an important factor where higher GDP leads to higher energy consumption. Table 6a, b show the results for oil exporting countries (static model). As observed, convergence is evident in all countries except Nepal and Kuwait. To be concerned, Nepal appears in the list of top oil importing and exporting groups. It is ranked number 6 and 7 as top oil importing and consumption level. Oil price has limited impact to determine the energy consumption in oil exporting group. The results hold for both times series and cross section specifications. Comparing the results between static and dynamic model, we found that the convergence rate is much higher in oil exporting countries. Among them, Iraq, Russia and Angola show very high convergence rate while those with no evidence of convergence like Nepal and Italy exhibit very low convergence rate.

For robustness checking, we compare the results of static model with the dynamic model. The results hold for both times series and cross-section specifications. Comparing the results between static and dynamic models, results are consistent, showing oil exporting countries with higher convergence rate and oil price has limited impact to determine the energy consumption in oil exporting group. The results also reveal that Nepal does not converge to any group in terms of energy consumption level. Oil price has no significant impact in Nepal’s energy consumption.

| Variable | GMM (Static model) - Cross section β convergence for oil importing countries |
|----------|--------------------------------------------------------------------------------------------------|
| ln(EC)   | 0.5022                                             | -0.5026                                             | 0.2201                                             | -1.6037***                                             |
| ln(GDP)  | -0.2930***                                         | -0.1212**                                           | -0.2257***                                         | -0.1973***                                             |
| ln(CPI)  | 0.0942***                                          | 0.0476**                                            | 0.0845***                                          | 0.1326***                                             |
| ln(Oil Price) | -0.1389**                                         | -0.0036                                            | -0.1530***                                         | -0.0511                                               |
| J statistic | 0.1168                                        | 0.2010                                             | 0.1725                                             | 0.1595                                                 |
| Wald test | 27.6712***                                        | 16.5601***                                         | 44.5595***                                         | 22.1771***                                             |

| Variable | GMM (Static model) – Time series β convergence for oil importing countries |
|----------|------------------------------------------------------------------------------|
| ln(EC)   | -0.1960                                                        | 2.6862***                                          | -0.1705                                           | 0.1901                                                 |
| ln(GDP)  | -0.0562                                                        | -0.2725***                                         | -0.841*                                           | 0.0220                                                 |
| ln(CPI)  | 0.0252                                                         | -0.0234***                                         | 0.0387                                            | -0.0113                                                |
| ln(Oil Price) | -0.0071                                                        | 0.0659*                                            | -0.0024                                           | 0.0231                                                 |
| J statistic | 0.2257                                        | 0.1715                                             | 0.1859                                            | 0.2485                                                 |
| Wald test | 5.4603                                                         | 24.1333***                                         | 35.1400***                                         | 59.9185***                                              |

| Variable | GMM (Static model) – Time series β convergence for oil importing countries |
|----------|------------------------------------------------------------------------------|
| ln(EC)   | -0.2132                                                        | -0.6819***                                         | 0.3005                                            | -1.4733***                                              |
| ln(GDP)  | -0.2866***                                                        | -0.1021***                                         | -0.2495***                                         | -0.1914***                                              |
| ln(CPI)  | 0.1230***                                                        | 0.0510***                                          | 0.0847***                                          | 0.1248***                                               |
| ln(Oil Price) | -0.1861**                                                        | -0.0086                                           | -0.1282***                                         | -0.0459                                                 |
| J statistic | 0.1645                                        | 0.1715                                             | 0.1776                                            | 0.1331                                                 |
| Wald test | 63.0893***                                                      | 24.9539***                                         | 75.6396***                                         | 34.4351***                                               |
\begin{table}[h]
\centering
\begin{tabular}{lllll}
\hline
Variable & S. Arab & Russia & Iraq & Canada \\
\hline
Constant & 0.6995 & 5.5837 & -3.0960 & 1.8136** \\
In(EC) & -0.1561** & -0.6616 & -0.7794 & -0.2360*** \\
In(GDP) & 0.0018 & 0.0525 & 0.0513 & 0.1488 \\
ln(Oil Price) & 0.0249 & 0.0929** & -0.0812 & -0.0216** \\
\hline
J statistic & 0.2329 & 0.1597 & 0.3172 & 0.1543 \\
Wald test & 4.3881 & 287.6719*** & 14.8988*** & \\
\hline
\end{tabular}
\caption{GMM Static model – Cross-section β convergence for oil exporting countries}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{lllll}
\hline
Variable & S. Arab & Russia & Iraq & Canada \\
\hline
Constant & 1.5698* & -0.1960 & 1.7163 & -3.7739 \\
In(energy) & -0.2489* & -0.0562 & -0.4709 & 0.1426 \\
In(GDP) & 0.0018 & 0.0525 & 0.0513 & 0.1488 \\
ln(Oil Price) & 0.0249 & 0.0929** & -0.0812 & -0.0216** \\
\hline
J statistic & 0.1039 & 0.1451 & 0.1903 & 0.1256 \\
Wald test & 14.1944*** & 347.0314*** & 125.7064*** & 40.9428*** \\
\hline
\end{tabular}
\caption{GMM Static model – Time-series β convergence for oil exporting countries}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{lllll}
\hline
Variable & U.S. & India & Japan & S. Korea \\
\hline
Constant & 0.5023 & -0.5026 & 0.2201 & -1.6037** \\
In(EC(-1)) & 0.7070*** & 0.8788*** & 0.7743*** & 0.8027*** \\
In(GDP) & 0.0942*** & 0.0476*** & 0.0845*** & 0.1326*** \\
ln(CPI) & -0.1389** & -0.0036 & -0.1530*** & -0.0511 \\
ln(Oil Price) & -0.0285*** & -0.0057 & -0.0318*** & -0.0349*** \\
\hline
J statistic & 0.1168 & 0.2010 & 0.1725 & 0.1595 \\
Wald test & 27.671*** & 16.560*** & 44.559*** & 22.177*** \\
\hline
\end{tabular}
\caption{GMM Dynamic model – cross-section β convergence for oil importing countries}
\end{table}
Table 7b. GMM (Dynamic model) – Time series β convergence for oil importing countries

| Variable | U.S. | India | Japan | S. Korea |
|----------|------|-------|-------|----------|
| Constant | -0.2130 | -0.6819*** | 0.3005 | -1.4733*** |
| ln(EC(-1)) | 0.7134*** | 0.8979*** | 0.7505*** | 0.8086*** |
| ln(GDP) | 0.1230*** | 0.0510*** | 0.0847*** | 0.1248*** |
| ln(CPI) | -0.1861*** | -0.0086 | -0.1282*** | -0.0459 |
| ln(Oil Price) | -0.0275*** | -0.0077 | -0.0340*** | -0.0322*** |

| J statistic | 0.1645 | 0.1715 | 0.1776 | 0.1331 |
| Wald test | 63.1042*** | 5.4603 | 24.133*** | 35.140*** |

Table 8a. GMM (Dynamic model) – Cross-section β convergence for oil exporting countries

| Variable | S. Arab | Russia | Iraq | Canada |
|----------|--------|--------|------|--------|
| Constant | 0.6995 | 5.5837 *** | -3.0960 *** | 1.8136 ** |
| ln(EC(-1)) | 0.8439*** | 0.3384 *** | 0.2206 * | 0.7640 *** |
| ln(GDP) | 6.99E-05 | -0.012 | 0.3311 *** | 1.0219*** |
| ln(CPI) | 0.1276 | -0.0075 | 0.1007 | 0.0222 |
| ln(Oil Price) | -0.0040 | -0.0171 | -0.0668*** | -0.0410*** |

| J statistic | 0.1446 | 0.1288 | 0.1545 | 0.1232 |
| Wald test | 9.1212** | 44.2592 *** | 83.1322*** | 126.0311*** |

Table 8b. GMM (Dynamic model) – Time series β convergence for oil exporting countries

| Variable | S. Arab | Russia | Iraq | Canada |
|----------|--------|--------|------|--------|
| Constant | 1.5698 * | -0.196 | 1.7163 *** | -3.7739 |
| ln(EC(-1)) | 0.7511 *** | 0.9438 | 0.5291 *** | 1.1426 * |
| ln(GDP) | 0.0018 | 0.0252 | 0.0513 *** | 0.1488 |
| ln(CPI) | 0.004 | -0.0071 | -0.0045 | -0.1405 |
| ln(Oil Price) | 0.0048 | -0.0025 | -0.0077 | -0.1665 |

| J statistic | 0.1284 | 0.2257 | 0.4469 | 0.1925 |
| Wald test | 5.1089 | 5.4603 | 113.6708 *** | 2.0679 |

| Variable | S. Arab | Russia | Iraq | Canada |
|----------|--------|--------|------|--------|
| Constant | 0.7055 | 5.2098 *** | -2.9012 *** | 1.7990 *** |
| ln(EC(-1)) | 0.7988 *** | 0.3850 *** | 0.2937 *** | 0.7424 *** |
| ln(GDP) | 0.0104 | -0.0117 | 0.2962 *** | 0.0197 |
| ln(CPI) | 0.148 | -0.0011 | 0.1360 * | 0.0131 |
| ln(Oil Price) | 0.0284 | 0.0795 ** | -0.0774 * | -0.0233 *** |

| J statistic | 0.1039 | 0.1451 | 0.1903 | 0.1256 |
| Wald test | 14.1494 *** | 347.0314 *** | 125.7064 *** | 40.9428 *** |

| Variable | S. Arab | Russia | Iraq | Canada |
|----------|--------|--------|------|--------|
| Constant | 1.7668 *** | -0.1138 | 1.6756 *** | -5.448 |
| ln(EC(-1)) | 0.7210 *** | 0.9088 *** | 0.5525 *** | 1.2133 *** |
| ln(GDP) | 0.0018 | 0.0311 | 0.0465 *** | 0.2027 |
| ln(CPI) | 0.0049 *** | -0.0091 | -0.0034 | -0.1842 |
| ln(Oil Price) | 0.0043 | -0.004 | -0.0056 | -0.2013 |
## 5. Conclusion

In this study, the main focus is to examine the convergence of energy consumption in the top oil importing versus exporting countries. Two approaches namely the generalized method of moments (GMM) and seemingly unrelated regression augmented Dicky-Fuller (SURADF) are applied in examining the stochastic (actual versus relative convergence) and conditional β-convergence. This study seeks to reveal the possibility to form two convergence clubs, to compare the convergence rates and to identify the determinants of energy consumption in these two groups of countries. The results of SURADF found evidences of energy consumption to form oil importing versus oil exporting groups with different countries subject to the types of convergence. The results of GMM also found evidences of convergence in both groups of countries. Based on the results of conditional convergence, India and Nepal are excluded from the convergence club for oil importing group while Nepal and Kuwait did not achieve convergence among the oil exporting countries. Nepal appears as the top oil importing and exporting country did not converge to any group. The results also revealed that oil price has significant impact in the group of oil importing where higher oil price causes to lower energy consumption. The impact of oil price is limited in the oil exporting group. Comparing the convergence rates, our results found that oil exporting countries such as Iraq, Russia and Angola exhibit very high convergence rate while countries like Nepal and Italy with non-convergence evidence exhibit very low rate. These two countries might experience more persistency of energy consumption with lower possibility to achieve convergence to the stability or steady state in the long-run. While majority countries that show evidences of convergence tend to achieve stability in the energy consumption and are in the sustainable path of energy consumption.

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