Is Energy Consumption Per Capita Stationary? Evidence from First and Second Generation Panel Unit Root Tests

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Abstract: This paper investigates the unit root properties of energy consumption per capita of 103 high, middle and low income countries using first and second generation panel unit root tests. Our results indicate that energy consumption per capita contains stationary process in all groups of countries. This suggests that short run energy policies should be followed to sustain economic growth and to fulfill energy demand.

Keywords: Energy Consumption, Panel Unit Root Test

Introduction

The main objective of this study is to investigate the stationarity properties of energy consumption per capita using the data of 103 high, middle and low income countries. We have applied first and second generation panel unit root tests for this purpose. It is very important for policy makers to know whether fluctuations in the series are transitory or permanent for various reasons. Firstly, if energy consumption is found to be stationary then fluctuations are transitory, which will cause long run energy policies ineffective as the series tends to return to its original symmetric path following a shock in energy markets. In such an environment, governing bodies should not set long term goals. On the other hand, unit root in energy consumption will cause the fluctuations to be permanent. The series will be consistent and stable with path dependency. Path dependency of energy consumption implies that world energy markets innovation will have permanent impacts. Furthermore, the degree to which the energy sector is linked with other sectors of the economy is also important for our analysis as permanent shocks to energy consumption may well be transmitted to other sectors of the economy.

Thirdly, the distinction between temporary and permanent shocks to energy consumption influences the modeling of energy demand and forecasting. Forecasts of energy consumption play a vital role in formulating energy policies. Safe and efficient energy supply for economic growth can only be possible with reliable forecasts in future. If the series is stationary, then the past behavior serves a role in the generation of forecasts. On the other hand, if energy consumption is non-stationary, then the past behavior serves little or no use in forecasting. Fourthly, the distinction between transitory or permanent shocks in energy consumption is very important to model the relationship between energy consumption and economic growth.

In the present work, we extend existing studies in various ways. We used largest possible panel data set in order to increase sample size[1]. We divided our sample group into three groups namely- high income countries, middle income countries and low income countries. We applied both first generation and second generation panel unit root tests. The first generation panel unit root tests ignore the cross-sectional dependence, while the second generation panel unit root tests take this feature into account. Therefore, by using such a battery of panel unit root tests, we are able to demonstrate the problems mentioned above in the unit root analysis. Finally, we also used a panel non-linear unit root test developed by Chang [9] to take into account if any non-linearity is present.

II. Review of Literature

The empirical investigation of the existence of unit root in energy consumption per capita has become field of interest for economists and researchers in recent days. Soytas and Sari, [32] and Lee, [19] reported the unit root problem in energy consumption per capita for the case of Turkey and other developing economies respectively. The evidence of non-stationarity was found due to the abrupt use of low power tests using small sample data (Narayan and Smyth, [26]; Chen and Lee, [10]; Hsu et al. [15]). This has opened a new direction for researchers to find appropriate unit root tests to examine stationarity properties of energy consumption (Hasanov and Telatar, [14]). Due to this weakness in unit root tests, Narayan and Smyth, [26] collected the data of 182 countries to increase number of observations and thus power of the test. They applied ADF unit root test and found stationarity in 56 countries. However, panel unit root test developed by Im et al. [17] rejected the hypothesis of non-stationarity problem. Chen and Lee, [10] applied Carrion-i-Silvestre et al. [8] and found that unit root problem does not exist in the series of energy consumption per capita[2]. In case of 13 Pacific Island countries, Mishra et al. [23] also applied panel unit root test developed by Carrion-i-Silvestre et al. [8]. Their results were biased when they applied traditional panel unit root tests as convectional tests do not consider structural breaks stemming in the series. Mishra et al. [23] found stationarity in 8 out of 13 countries structural break panel unit test. They pointed out that in rest of the five countries, the series contains unit root problem due to high volatility in energy consumption in these countries. The convectional unit root tests are also criticized due to their shortcomings of misinterpretation of null hypothesis in panel unit root tests as further pointed out by (Breuer et al. [7]). Breuer et al. [7] reinvestigated the unit root properties of energy consumption per capita with data of 84 countries. They had separated all countries into five regions. Their results indicated that in most regions, energy consumption contains unit root problem. Hasanov and Telatar, [14] probed the unit root properties of energy consumption and primary energy consumption using the data of 178 countries. They have applied conventional unit root tests, a nonlinear unit root test developed by Kapetanios et al. [18]) and a structural break unit root test developed by Sollis, [31]. They found that nonlinear and structural break unit root tests frequently accept the hypothesis of stationarity process in the series.

Existing literature studies unit root properties of energy consumption by applying first generation panel unit root tests without incorporating structural breaks. These studies are Narayan and Smyth, [26]; Chen and Lee, [10]; Hsu et al. [15]; Narayan et al. [25]; Apergis et al. [2, 3]; Agnolucci and Venn, [1]; Narayan and Pop, [27] etc. These studies applied Im et al. [17]; Levin et al. [20]; Breitung, [6]; Hadri, [13]; Maddala and Wu, [21]. These first generation panel unit root tests are criticized for various reasons. For example, homogeneous unit root tests such as

Levin et al. [20]; Breitung, [6]; Hadri, [13] follow the restrictive hypothesis of stationarity process with AR (1) estimate. Agnolucci and Venn, [1] reported that one finds difficulty in exactly knowing which unit root contains stationary process while applying heterogeneous unit root tests such as Im et al. [17] and Maddala and Wu, [21]. Furthermore, these unit root tests seem to ignore cross-sectional dependence[3].

II. Econometric Methodology

Following Breitung and Pesaran, [5] and Baltagi, [4], we use panel data analysis for the purpose of increasing the power of the unit root test. We divide these tests in two groups, namely, 'first generation panel unit root tests' and 'second generation panel unit root tests. The first generation of panel unit root tests applied in this study included LLC test (Levin et al. [21]), IPS test (Im et al. [17]) and MW test (Maddala and Wu, [21]). The second generation tests are MP test (Moon and Perron, [24]), Pesaran test (Pesaran, [28]) and Choi test (Choi, [12]). The main difference between two generations of tests lies in the cross-sectional independence assumption. First generation tests assume that all cross-sections are independent and second-generation tests relax this assumption. In addition, latter are more useful, when co-movements are observed in the national business cycles in a sample of countries in the same economic area (Hurlin, [16]).

The LLC test employs the following adjusted t-statistic:

$$t_{\partial}^{*} = \frac{t_{\alpha} - (NT)\hat{S}_{N}\sigma_{\tilde{\varepsilon}}^{-2}\sigma_{\hat{\alpha}}\mu_{T}^{*}}{\sigma_{T}^{*}} \qquad (1)$$

where $\hat{S}_N$ is the average of individual ratios in long-run towards short-run variance for country i; $\sigma_{\tilde{\varepsilon}}$ is the standard deviation of the error term in equation (2); $\sigma_{\hat{\alpha}}$ is the standard deviation of the slope coefficients in equation (2); σ_T^* is the standard deviation adjustment; μ_T^* is the mean adjustment.

The IPS test employed a standardized *t*_bar statistic that is based on the movement of the Dickey–Fuller distribution:

$$Z_{t\_bar} = \frac{\sqrt{N}\{t\_bar - N^{-1}\sum_{i=1}^{N} E(t_{iT})\}}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(t_{iT_i})}} \tag{2}$$

where $E(t_{iT})$ is the expected mean of $E(t_{iT})$, and $Var(t_{iT_i})$ is the variance of t_{iT}.

The MW test (Maddala and Wu [21]) is based on the combined significance levels (*p*-values) from the individual unit root tests. According to Maddala and Wu [21], if the test statistics are continuous, the significance levels π_i (i =1, 2, …. N) are independent and uniform (0,1) variables. The MW test uses combined *p*-values, or P_{MW}, which can be expressed as:

$$P_{MW} = -2\sum_{i=1}^{N} \log \pi_i \tag{3}$$

where $-2\sum \log \pi_i$ has a χ^2 distribution with the 2N degree of freedom. Furthermore, Choi [13] suggested the following standardized statistic:

$$Z_{MW} = \frac{\sqrt{N}\{N^{-1}P_{MW} - E[-2\log(\pi_i)]\}}{\sqrt{Var[-2\log(\pi_i)]}} \tag{4}$$

Under the cross-sectional independence assumption, this statistic converges to a standard normal distribution (Hurlin, [16]).

Among the second-generation unit root tests, this paper used: 1) MP test (Moon and Perron, [24]); Pesaran test (Pesaran, [28]) and Choi test, (Choi, [12]). Moon and Perron, [24]) use a factor structure to model cross-sectional dependence. Their model assumes that error terms are generated by r common factors and idiosyncratic shocks.

$$y_{it} = \alpha_i + y_{it}^{0} \tag{5}$$

$$y_{it}^{0} = \rho_i y_{it-1}^{0} + \upsilon_{it} \tag{6}$$

$$\upsilon_{it} = \lambda_i^{'} F_t + e_{it} \tag{7}$$

where F_t is a $r \times 1$ vector of common factors and λ_i is a vector of factor loadings. The idiosyncratic component e_{it} is assumed to be iid: across i and over t. The null hypothesis corresponds to the unit root hypothesis $H_0 : \rho_i = 1$; where i = 1, …, N whereas under the alternative the variable y_{it} is stationary for at least one cross-sectional unit. For testing, under the data are de-factored and then the panel unit root test statistics based on de-factored data are proposed.

Moon and Perron treat the factors as nuisance parameters and suggest pooling de-factored data to construct a unit root test. The intuition is as follows: In order to eliminate the common factors, panel data are projected onto the space orthogonal of the factor loadings. By doing this, the de-factored data and its residual do not retain cross-sectional dependencies. This allows us to define standard pooled t-statistics, as in IPS, and to show their asymptotic normality. Following the above let $\hat{\rho}^{+}_{pool}$ pool be the modified pooled OLS estimator using the de-factored panel data. Then, Moon and Perron, [24] define two modified t-statistics, which have a standard normal distribution under the null hypothesis:

$$t_{\alpha} = \frac{T\sqrt{N}\left(\rho^{+}_{pool} - 1\right)}{\sqrt{2\gamma_e^4 / w_e^4}} \underset{T,N\to\infty}{\overset{d}{\to}} N(0,1) \tag{8}$$

$$t_b = T\sqrt{N}\left(\rho^{+}_{pool} - 1\right)\sqrt{\frac{1}{NT^2} trace(Z_{-1} Q_{\wedge} Z'_{-1}) \frac{w_e^2}{\gamma_e^4}} \underset{T,N\to\infty}{\overset{d}{\to}} N(0,1) \tag{9}$$

where w_e^2 denotes the cross-sectional average of the long-run variances $w_{e_i}^2$ of residuals e_{it} and γ_e^4 denotes the cross-sectional average of $w_{e_i}^4$. Moon and Perron, [24] propose feasible statistics

t_{α}^{*} and t_{b}^{*} based on an estimator of the projection matrix and estimators of long-run variances $w_{e_i}^{2}$.

In Pesaran's test, the augmented Dickey-Fuller (ADF) regressions are augmented with the cross-sectional average of lagged levels and first-differences of the individual time series (Pesaran, [28]). This allows the common factor to be proxied by the cross-section mean of y_{it} and its lagged values. The Pesaran test uses cross-sectional augmented ADF statistics, (denoted as CADF), which are given below:

$$\Delta y_{i,t} = \alpha_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + d_i \Delta \bar{y}_i + e_{i,t} \tag{10}$$

where a_i, b_i, c_i, and d_i are slope coefficients estimated from the ADF test in country *i*; $\bar{y}_{t-1}$ is the mean value of lagged levels, and $\Delta\bar{y}_i$ is the mean value of first-differences; $e_{i,t}$ is the error term.

Pesaran, [28] suggested modified IPS statistics based on the average of individual CADF, which is denoted as a cross-sectional augmented IPS (CIPS). This is estimated from:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i(N,T) \tag{11}$$

where $t\,(N, T\,)$ is the t-statistic of the OLS estimate in equation (11). The next test in this study is the Choi test based on the statistic that combines p-values from ADF tests in which their nonstochastic trend components and cross-sectional correlations are eliminated using the Elliott, Rothenberg and Stock's GLS-based de-trending and the conventional cross-sectional demeaning for the panel data (Choi, [12]). It is called the Dickey-Fuller-GLS statistic. Based on this statistic, Choi, [12] suggested the following Fisher's type statistics:

$$P_m = -\frac{1}{\sqrt{N}} \sum_{i=1}^{N} [\ln(P_i) + 1] \tag{12}$$

$$Z = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \Phi^{-1}(P_i) \tag{13}$$

$$L^* = \frac{1}{\sqrt{\pi^2 N / 3}} \sum_{i=1}^{N} \ln(P_i / 1 - P_i) \tag{14}$$

where P_i is the asymptotic p-values of the Dickey-Fuller-GLS statistic for country *i*; $\Phi(\cdot)$ is the cumulative distribution of a standard normal variable.

III. Data and Definition of Variable

We have used annual data on energy consumption per capita of high income countries: Australia, Austria, Belgium, Brunei Darussalam, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Nicaragua, Norway, Oman, Poland, Portugal, Qatar, Saudi Arabia, Singapore, Slovak Republic, Spain, Sweden, Switzerland, Trinidad and Tobago, UAE, UK, US; middle income countries: Albania, Algeria, Angola, Argentina, Bolivia, Brazil, Bulgaria, Cameroon, Chilli, China, Colombia, Congo Rep. Costa Rica, Cote d'Ivoire, Cuba, Dominican Rep. Ecuador, Egypt, El Salvador, Gabon, Guatemala, Honduras, India, Indonesia, Iran, Iraq, Jamaica, Jordan, Lebanon, Libya, Malaysia, Mexico, Morocco, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Romania, Senegal, South Africa, Sri Lanka, Sudan, Syria, Thailand, Tunisia, Turkey, Uruguay, Venezuela Rep. Vietnam, Yamane Rep. Zambia and low income countries: Bangladesh, Benin, Congo Dem Rep. Ethiopia, Haiti, Kenya, Korea Dem Rep. Malta, Mozambique, Myanmar, Nepal, Tanzania, Togo and Zimbabwe. The present study covers time period of 1971-2010. The data on energy consumption per capita has been sourced from world development indicators (CD-ROM, 2012).

IV. Empirical Results

Primarily, we employed first generation tests for 103 countries, high income countries panel, middle income countries panel, and low-income countries panel. The results are reported in Table-1 below. First we will discuss the results of first generation panel unit root tests. The LLC test provides evidence to reject the null hypothesis which reveals that energy consumption per capita contains unit root for 103 countries panel, high income group countries, middle income countries and low income countries panel at the 1% significance level.

However, LLC unit root test is criticized for its assumption of taking ρ to be homogeneous across i's, i.e. all the cross sections have a unit root property. The IPS unit root test goes a step further and relaxes this assumption by allowing for a heterogeneous ρ. However, it does so by taking the average of the individual unit root test statistic, and tests for the presence of unit root across all the cross sections as its null hypothesis, against the alternative of an absence of unit root.

The results of IPS unit root test provide evidence to reject the null hypothesis of unit root for entire panel of 103 countries at 10% level of significance, high income group countries at 5% level of significance, and middle income countries and low income countries at 10% level of significance. Hence, with the application of IPS unit root test we found that even if IPS unit root test rejects the null hypothesis, level of significance for IPS and LLC test is not same. The MW test (Maddala and Wu, [21]) uses combined significance levels, and rejects the null hypothesis of unit root for entire panel of 103 countries and high income group countries at 1% level of significance and middle income countries at 10% level of significance and for the low income countries the null hypothesis is not rejected. Finally, by using Choi unit root test (Choi, [11]) we find that the null hypothesis of unit root is rejected for entire panel of 103 countries and high income group countries at 1% level of significance (similar to IPS, LLC and MW) and for middle income countries it is not rejected even at 10% level of significance and for low income countries at 5% level of significance.

Table I: First Generation of Panel Unit Root Tests: Full panel				
Types of test statistic	*Test statistic*	*1 % CV*	*5 % CV*	*10 % CV*
LLC test statistic computed in equation (1)	-6.4291	-2.3263	-1.6449	-1.2816
IPS test statistic computed in equation (2)	-1.5869	-2.3263	-1.6449	-1.2816
MW test statistic computed in equation (3)	254.6696	253.9083	238.3220	230.2765
Choi test statistic computed in equation (4)	2.5085	2.3263	1.6449	1.2816
Second-generation panel unit root tests: Full panel				
Moon Perron1 computed in equation (8)	-18.4725	-2.3263	-1.6449	-1.2816

Moon Perron2 computed in equation (9)	-18.4113	-2.3263	-1.6449	-1.2816
Pesaran test, [28] computed in equation (11)	-2.0154	-2.1633	-2.0718	-2.0119
Choi test statistic computed in equation (12)	5.6204	2.3263	1.6449	1.2816
Choi test statistic computed in equation (13)	-3.0707	-2.3263	-1.6449	-1.2816
Choi test statistic computed in equation (14)	-3.5550	-2.3263	-1.6449	-1.2816
Chang, [9] IV (SN2) test	15.4776	-2.3263	-1.6449	-1.2816
First Generation of Panel Unit Root Tests: High income panel				
LLC test statistic computed in equation (1)	-5.4270	-2.3263	-1.6449	-1.2816
IPS test statistic computed in equation (2)	-2.0263	-2.3263	-1.6449	-1.2816
MW test statistic computed in equation (3)	104.8359	100.4252	90.5312	85.5270
Choi test statistic computed in equation (4)	2.9442	2.3263	1.6449	1.2816
Second-generation panel unit root tests: High income panel				
Moon Perron1 computed in equation (8)	-13.9850	-2.3263	-1.6449	-1.2816
Moon Perron2 computed in equation (9)	-14.4221	-2.3263	-1.6449	-1.2816
Pesaran test, [28] computed in equation (11)	-2.5202	-2.2974	-2.1503	-2.0721
Choi test statistic computed in equation (12)	6.7115	2.3263	1.6449	1.2816
Choi test statistic computed in equation (13)	-4.2756	-2.3263	-1.6449	-1.2816
Choi test statistic computed in equation (14)	-4.8388	-2.3263	-1.6449	-1.2816
Chang, [9] IV (SN2) test	8.7152	-2.3263	-1.6449	-1.2816
First Generation of Panel Unit Root Tests: low income panel				
LLC test statistic computed in equation (1)	-3.2224	-2.3263	-1.6449	-1.2816
IPS test statistic computed in equation (2)	-1.3330	-2.3263	-1.6449	-1.2816

MW test statistic computed in equation (3)	21.9104	45.6417	38.8851	35.5632
Choi test statistic computed in equation (4)	-0.5671	2.3263	1.6449	1.2816
Second-generation panel unit root tests: low income panel				
Moon Perron1 computed in equation (8)	-5.6844	-2.3263	-1.6449	-1.2816
Moon Perron2 computed in equation (9)	-5.5871	-2.3263	-1.6449	-1.2816
Pesaran test, [28] computed in equation (11)	-1.4441	-2.4753	-2.2478	-2.1415
Choi test statistic computed in equation (12)	-0.0826	2.3263	1.6449	1.2816
Choi test statistic computed in equation (13)	-0.1697	-2.3263	-1.6449	-1.2816
Choi test statistic computed in equation (14)	-0.1738	-2.3263	-1.6449	-1.2816
Chang, [9] IV (SN2) test	3.0099	-2.3263	-1.6449	-1.2816
First Generation of Panel Unit Root Tests: middle income panel				
LLC test statistic computed in equation (1)	-4.2311	-2.3263	-1.6449	-1.2816
IPS test statistic computed in equation (2)	-1.4569	-2.3263	-1.6449	-1.2816
MW test statistic computed in equation (3)	127.6132	140.4590	128.8039	122.8580
Choi test statistic computed in equation (4)	1.6373	2.3263	1.6449	1.2816
Second-generation panel unit root tests: middle income panel				
Moon Perron1 computed in equation (8)	-19.9559	-2.3263	-1.6449	-1.2816
Moon Perron2 computed in equation (9)	-19.6606	-2.3263	-1.6449	-1.2816
Pesaran test, [28] computed in equation (11)	-1.9453	-2.2372	-2.1135	-2.0405
Choi test statistic computed in equation (12)	2.5761	2.3263	1.6449	1.2816
Choi test statistic computed in equation (13)	-1.0751	-2.3263	-1.6449	-1.2816
Choi test statistic computed in equation (14)	-1.3536	-2.3263	-1.6449	-1.2816

Chang, [9] IV (SN2) test	12.3269	-2.3263	-1.6449	-1.2816
Source: Authors’ calculation				

The first generation panel unit root test is criticized for assuming cross-sectional independence. This assumption is relaxed under second-generation panel unit root tests. The first and second MP tests[4] show stationarity for entire panel of 103 countries, high income group countries, middle income countries and low income countries at 1% level of significance. However, the CIPS test (Pesaran, [30]) rejects the null hypothesis of unit root for high income countries at 1% level of significance and for 103 countries at 10% level of significance; for other group of countries the null of unit root is not rejected. Choi’s first test[5], second test and third test reject the null hypothesis of unit root for entire panel of 103 countries as well as for high income countries; for low income countries none of the Choi’s test rejects the null hypothesis; for middle income countries Choi’s first test rejects the null at 1% level of significance, third test rejects the null hypothesis at 10% level of significance and Choi’s second test does not reject the null hypothesis of unit root. Finally, we find very contrary results from Chang, [9] IV test which provide no evidence to reject the null hypothesis for total group of countries or the sub-group of countries.

V. Conclusion and Policy Implications

The empirical testing of unit root properties of energy consumption per capita is necessary to know the behaviour of business cycles. Furthermore, it would also help to understand the long run and short run impact of macroeconomic policies on energy consumption as well as on energy production. In doing so, we have used battery of panel unit root tests to test stationarity properties of energy consumption per capita for the entire panel of 103; high income group countries, middle income group countries and low income group countries. We applied first generation and second generation panel unit root tests over the period of 1971-2010.

Our analysis indicates that null hypothesis of unit root problem in energy consumption per capita series is rejected by LLC test, IPS unit root test for entire panel of 103 courtiers; high income countries; middle income countries and low income countries. MW unit root test accepts the hypothesis of unit root for low income countries and rejects it for rest panels. Choi unit root test seems to reject the hypothesis of unit root process for entire panel of 103 countries; high income countries and low income countries. Overall first and second generation unit root tests show that energy consumption per capita contains stationary process for entire panel of 103 countries; high income group countries, middle income countries and low income countries. Although, CIPS test (Pesaran, [28]) and Chang, [9] IV unit root tests provide no evidence of stationary process i.e. for high, middle and low income countries and, total group of countries or the sub-group of countries respectively.

Our findings may have some practical implications for econometric modelling as well as for policy makers in formulating energy policy to sustain economic growth in sampled countries. Largely, our analysis shows that energy consumption per capita is stationary around a deterministic trend in all income groups (entire panel of 103 countries; high income group; middle income group and low income group countries). This implies that fluctuations in energy consumption per capita have transitory effect and innovations in energy markets will have a transitory effect on energy consumption per capita. In such an environment, governing bodies should not implement long run redundant goals. Policy makers can use past behaviour to forecast energy demand for future to sustain economic growth.

Footnotes

1. This study to the best of our knowledge has used longer time series than Narayan and Smyth, [26] who used a sample of 182 countries. We have converted all series into logarithm following Shahbaz and Lean, [29, 30].
2. Chen and Lee, [10] also rejected the hypothesis of unit root in energy consumption for 104 countries by applying panel unit root test.
3. Agnolucci and Venn, [1] argued that first generation panel unit root tests may provide biased results because these tests do not contain information about structural breaks in the time series.
4. Note that Moon and Perron, [24] have given two unit root tests. We refer to them as first MP test and second MP test.
5. Note that Choi, [12] has given three test statistics for testing of unit root. We refer to them as the first Choi test, second Choi test and third Choi test.

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