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Convergence in energy consumption per capita among ASEAN countries

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Abstract

We test for convergence in energy consumption per capita among the ASEAN-5 over the period 1971 to 2011 using the univariate and panel KPSS stationarity test with, and without, structural breaks and the univariate and panel lagrange multiplier (LM) unit root test with, and without, structural breaks. There is mixed evidence of convergence with the univariate tests with breaks, depending on whether the null is specified as stationarity or a unit root. The results for the panel stationarity and unit root tests with structural breaks find support for energy convergence in the ASEAN-5.

Keywords

Energy consumption per capita; Convergence; Unit root

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1. Introduction

A series of papers have examined convergence of energy consumption per capita or energy intensity using different methods (see eg. Jakob et al., 2012; Liddle, 2009; Markandya et al., 2006; Maza & Villaverde, 2008; Miketa & Mulder, 2005; Mohammadi & Ram, 2012; Mulder & de Groot, 2012). At the same time, a series of studies have examined conditional convergence in other variables using unit root tests, including carbon dioxide emissions (see eg. Barassi et al., 2008; Lee & Chang, 2008; List, 1999; Strazicich & List, 2003); Gross Domestic Product (GDP) (see eg. Carlino & Mills, 1993; Guetat & Serranito, 2007) and tourist arrivals (see eg. Narayan, 2006, 2007; Lean & Smyth, 2008). Testing for conditional convergence, employing unit root testing, has advantages over conditional tests for convergence based on so-called β convergence, given the original Solow-Swan growth model (Solow, 1956; Swan, 1956), suggests conditional, rather than absolute, convergence.

Beginning with Narayan and Smyth (2007) a large literature has emerged which examines the unit root properties of (disaggregated) energy consumption (see Smyth, 2013 for a review). Recently, Meng et al (2013) extended this literature to apply unit root tests to test for conditional convergence in energy consumption per capita in Organization for Economic Cooperation and Development (OECD) countries.

The purpose of this paper is to build on Meng et al's (2013) contribution, to apply unit root tests to examine conditional convergence in energy consumption per capita in Association of Southeast Asian Nations (ASEAN) countries. Our particular focus is on the ASEAN-5 (Indonesia, Malaysia, Philippines, Singapore, Thailand), which were the original, and remain the most important, members of the ASEAN community. Our contribution differs from Meng et al. (2013) in two respects. First, we examine energy convergence within a group of countries explicitly committed to greater economic (and energy) integration. Second, in addition to univariate tests, we apply panel tests to examine conditional energy convergence. Specifically, we employ univariate and panel versions of the lagrange (LM) unit root test and KPSS (Kwiatkowski et al, 1992) stationary test, with and without structural breaks.

The issue of energy convergence is important because it has implications for sustainable energy consumption and efforts to curtail carbon dioxide emissions. It is important to know how energy consumption changes in relation to growth in GDP. Many countries have adopted policies to decrease energy intensity and promote energy efficiency. At the same time, there has been a concerted effort to reduce carbon dioxide emissions. If there is evidence of rapid energy convergence and growth rates are relatively modest, this suggests that targets to contain growth in energy consumption are feasible. Reductions in disparities in energy consumption per capita between countries is, thus, evidence such policies have been successful.

A high proportion of the world's population is concentrated in the developing countries of Southeast Asia. There are 600 million people in ASEAN alone. These countries have experienced high growth rates in GDP and energy use. Average economic growth in the so-called ASEAN – 6 (the ASEAN-5 plus Vietnam) in the lead up to the global financial crisis (GFC) (2003-07) was 6 per cent. Projected growth rates for the same set of countries after recovery from the GFC (2011-15) is 6 per cent (OECD, 2014). The growth rate in primary energy consumption in the Asia Pacific region, as a whole, is almost double the world average (Aguilera et al, 2014). At the same time, there is a high level of energy poverty, with relatively low rates of access to electricity across many of the ASEAN countries (Navarro et al 2013). Fast growth in GDP and energy use in ASEAN has put the need for sustainable energy solutions front and centre in the ASEAN countries. This is reinforced by the finding that the ASEAN-5 are energy dependent countries (Lean & Smyth, 2010).

ASEAN has placed much emphasis on energy integration as part of more general economic integration. The target is for ASEAN to establish the ASEAN Economic Community (AEC) by December 31, 2015.[1] The ASEAN Plan of Action for Energy Cooperation (APAEC) 2010-15 covers the energy component of the AEC blueprint. The centrepiece of APAEC is an ASEAN Power Grid (APG) and Trans-ASEAN Gas Pipeline (TAGP), which are designed to facilitate energy integration within ASEAN. The APG aims to link ASEAN members who are in power surplus with those in power deficit by 2020. The objective of the TAPG is to link suppliers and purchasers of gas within ASEAN. As of the end of 2013, there were 11 gas pipelines connecting ASEAN countries with a twelfth due to be completed in mid-2014 (Desker, 2013).

Energy market integration within ASEAN is seen as an important vehicle to promote energy efficiency and reduce carbon dioxide emissions. One study suggests that if 50 per cent of energy demand in ASEAN was met through trade as a result of APAEC, that the total cost of meeting energy demand would fall by 3.9 per cent, equivalent to $US 29 billion (Chang & Li, 2013). The Asian Development Bank (ADB) estimates

[1] Officially ASEAN remains committed to establishing the AEC by 2015, but increasingly regard 31 December 2015 as a target and not as a deadline. ASEAN releases scorecards as to the progress of implementing the AEC Blueprint – the document outlining the targets, sectors and proposed measures covered under the AEC initiative. The scorecards produce a statistic referred to as the ‘implementation rate’, which is the ratio of measures that are fully implemented to total number of measures targeted. A news article published in February 2014 (Kyodo News, 2014) quotes ASEAN officials that place this figure at 72 per cent and notes that the overall progress has declined since 2013.

that the closely related Greater Mekong Subregion energy agreement will result in a 3 per cent reduction in carbon dioxide emissions (ADB, 2009).

The issue of energy convergence speaks directly to whether energy market integration promotes more equitable energy access across countries. An objective of energy market integration is more equitable access to energy in the region; however, the evidence on whether economic integration reduces the gap between countries is mixed (Sheng & Shi, 2013). Evidence of convergence in energy consumption per capita would be consistent with energy market integration in ASEAN promoting not only more efficient, but also more equitable access to energy within the region.

2. Method

2.1. Data

The data for per capita energy consumption for the five ASEAN countries for the period 1971 – 2011 were collected from the World Development Indicators (WDI) database. Per capita consumption use is expressed in kg of oil equivalent and is defined as the use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport. Descriptive statistics for the energy series for each of the ASEAN-5 is in Table 1.

[**INSERT TABLE 1**]

For each country i, we transformed the energy consumption series to a measure of relative energy consumption, using the following formula:

$$Relative\ Energy\ Consumption_{it} = \ln\left(\frac{Per\ Capita\ Energy\ Consumption_{it}}{Average\ Per\ Capita\ Energy\ Consumption_{t}}\right)$$

All the analysis is conducted on this transformed series. The transformed series is used to measure the convergence properties of energy consumption. The transformation also removes the cross-sectional shocks that affect all the countries in the panel. For instance, any positive shock to energy consumption across all the countries will increase the average by the same proportion and hence leave the relative energy consumption series unchanged (Meng et al., 2013). This implies that any structural breaks identified in the transformed series would be country specific.

In order to test efficacy of this approach in removing cross-sectional dependence, we conducted the Pesaran (2004) cross-sectional dependence (CD) test on the energy consumption series, before and after transforming it into relative energy consumption. The results are reported in Table 2.

[**INSERT TABLE 2**]

The top panel reports the results for the untransformed energy use series. We note that the Pesaran CD statistic is highly significant at all the 4 lags, implying a strong rejection of the null of cross-sectional independence. The bottom panel reports CD statistics for the transformed series, where we fail to reject the null of cross-sectional independence, even at the 10 per cent level of significance.

These results suggest that cross-sectional dependence is not present in the data.

2.2. Unit root tests

Our testing strategy is to employ univariate and panel versions of two families of unit root tests, with and without structural breaks. The first is the LM unit root test. We employ the univariate LM unit root with no breaks (Schmidt & Phillips, 1992) and with two endogenous breaks (Lee & Strazicich, 2003). We also employ the panel LM unit root test with no breaks and two endogenous breaks (Im et al 2005).

The second is the KPSS stationarity test. We employ the KPSS stationarity test with no breaks (Kwiatkowski et al, 1992) and KPSS stationarity test with two endogenous breaks (Carrion-i-Silvestre & Sanso, 2007). We also employ the panel KPSS stationarity test with no breaks (Hadri, 2000) and with multiple breaks (Carrion-i-Silvestre et al., 2005). We do not reproduce the details of these tests because both families of tests have been used in the literature before and are well known.

Both families of tests have advantages for our purposes. The LM unit root test with breaks has better size and power properties than the Augmented Dickey-Fuller (ADF) alternative (Lumsdaine & Papell, 1997), which assumes there are no breaks under the null (Lee & Strazicich, 2001, 2003). Because the KPSS test assumes stationarity as the null, it is a natural robust check for the LM test. Moreover, several studies have noted that for many applications, stationarity is a more natural null (Bai & Ng, 2004). This is arguably the case when testing for energy convergence in a set of countries which are committed to integration of their energy markets. The panel KPSS test has several advantages. It allows for *n* structural breaks; it allows the number of structural breaks to differ between countries and it reports the results for individual countries.

3. Results

The results for the KPSS stationarity test and the Schmidt and Phillips (1992) LM unit root test without structural breaks are reported in Table 3. The unit root null is unable to be rejected for any of the ASEAN-5 at the 5 per cent level using the Schmidt and Phillips (1992) test. The null of stationarity is rejected at the 5 per cent level for

Singapore and Thailand (and, at the 10 per cent level for Indonesia). Overall, the results for the tests without breaks suggest that the series are non-stationary.

[**INSERT TABLE 3**]

The problem with the tests in Table 3 is that they do not accommodate structural breaks. Ignoring structural breaks lowers the power of the LM unit root test to reject the null (Perron, 1989) and biases the KPSS test in favour of rejecting the null of stationarity (Lee et al., 1997). In Table 4 we report the results for the LM root test with two breaks in the intercept (Model AA) and two breaks in the intercept and trend (Model CC). The unit root null is rejected in Model AA for Indonesia and in Model CC for the Philippines and Thailand, but there is not much evidence of convergence.[2] In Table 5 we present the results for the Carrion-i-Silvestre and Sanso (2007) KPSS stationarity test with two breaks. The null of stationarity is rejected for the Philippines, but generally the KPSS test with two breaks suggest stationarity.

[**INSERT TABLES 4-5**]

Overall, the univariate stationarity and unit root tests suggest different conclusions. The KPSS test with two breaks indicates a high level of convergence, while the LM test with two breaks indicates much less evidence of convergence.

Table 6 reports the results for individual countries in the KPSS panel test with multiple structural breaks with maximum breaks set at five. The null of stationarity is rejected for the Philippines and Singapore at the 5 per cent level or better in the intercept only model. In the model with intercept and trend, the null of stationarity is only rejected for the Philippines at the 5 per cent level.

[**INSERT TABLE 6**]

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[2] Narayan and Popp (2013) show that the Narayan and Popp (2010) test has better power and size properties than the Lee and Strazicich (2003) test. As a robust check, we also used the Narayan and Popp (2010) test and the results were similar to the Lee and Strazicich (2003) results.

Table 7 reports the results of the Hadri (2000) panel KPSS test with no breaks and the Carrion-i-Silvestre et al. (2005) KPSS test with two breaks. In the intercept only model, the null of stationarity is rejected in the no-break case; however, in the intercept only and intercept and trend models, the null of stationarity fails to be rejected when we allow for multiple structural breaks. The findings in Table 7 are supported by the results for the Im *et al.* (2005) panel LM unit root test in Table 8. In the test with no breaks, one break and two breaks, the unit root null is rejected.

[**INSERT TABLES 7-8**]

A potential issue with the results in Table 8 is that they may be biased toward rejecting the unit root null by the presence of the Philippines and Thailand, which the Lee and Strazicich (2003) Model CC suggest are stationary. As a robust test, we apply the panel LM test to an ASEAN-3 (ASEAN-5 less the Philippines and Thailand). The results, reported in Table 9, are consistent with the findings reported in Table 8.

[**INSERT TABLE 9**]

4. Discussion

Overall, our results for the univariate tests with structural breaks differ from Meng et al's (2013) results. Meng et al (2013) found evidence of convergence in energy per capita in the OECD, while we find mixed evidence of convergence with univariate tests for the ASEAN-5. Our conclusions depend on whether the null is specified as stationarity or a unit root. We do, however, find evidence of convergence in energy consumption per capita when we employ panel tests that accommodate structural breaks. This finding holds irrespective of how the null is specified.

One important reason we do find convergence is that the ASEAN-5 have similar economic and social structures. The ASEAN countries, moreover, are pursuing economic and energy integration via the AEC and APAEC. In this setting, one expects to find evidence of convergence (Liddle, 2009). Beyond this, other characteristics of the ASEAN-5 have contributed to energy convergence (Maza & Villaverde, 2008). One is the significant economic development experienced by the lower-income ASEAN countries over the time period considered. The second is increased awareness of energy conservation measures in the more developed ASEAN countries. The third, which is related to the second, is increasing international pressure to curtail CO_2 emissions and implement policies to promote renewable energy in high energy users, as reflected in the main objectives of the APAEC.

The objective of APAEC is to facilitate trade in energy across ASEAN to ensure a more equitable allocation of energy consumption across the region and reduce pollution emissions. The finding of energy convergence across the ASEAN-5 is consistent with this objective. Our results are consistent with the findings in Sheng and Shi (2013) who, using energy trade and energy market competition indices, found that energy market integration improves growth equality across nations.

Consistent with the findings in Meng et al. (2013), most of the breaks can be linked to global events that have affected world energy markets. The main events are the oil price shock in 1979, associated with the Iranian Revolution; the oil price shock in 1990, associated with the first Gulf War; the Asian financial crisis (1997-99); the 2000 energy crisis; the 9/11 terrorist attacks in 2001 and the oil price shock in the second gulf war in 2003. Beyond these global events, many of the break dates can be linked to the commencement date of cross-border natural gas pipelines under the TAPG in 1998, 2000, 2001, 2003 and 2005 (see Sovacool, 2009, Table 2).

To visualise our empirical findings, we take the break dates identified using the univariate KPSS test with two structural break (the most parsimonious model that finds all but one series stationary) and superimpose them on the actual plot of relative energy consumption for each country. A linear OLS regression is used to estimate trends connecting break dates. The results, presented in Figure 1, show that the break dates identified by the test concur with the visual examination of the series.

[**INSERT FIGURE 1 HERE**]

5. Conclusions and policy implications

The results provide impetus for policies to promote energy integration in ASEAN. The findings suggest that the objectives of energy integration in ASEAN are realizable. In particular, the results suggest that countries with low energy consumption are catching up with countries with higher energy consumption. This is being facilitated by initiatives such as the APG and TAPG, which are at the core of the objectives in the APAEC to promote more equitable energy access.

The finding of energy convergence in the ASEAN-5 can be attributed to policies under the APAEC designed to decrease energy intensity, promote energy efficiency and generate more equitable distribution. Policies to promote further efficiency savings and reduce carbon dioxide emissions, such as the promotion of renewable energy, can be expected to result in further energy convergence (Maza & Villaverde, 2008; Meng et al., 2013). Such policies are very much consistent with the intent of the APAEC. Examples are the ASEAN Energy Manager Accreditation Scheme, established in 2010, which aims to reduce energy consumption and curtail CO_2 emissions in manufacturing; the renewable energy program under APAEC, which aims to increase the share of renewable energy in regional power generation; and the civilian nuclear energy program, which is designed to promote nuclear energy as a long-term alternative to fossil fuel consumption in ASEAN (Shi & Malik, 2013).

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Tables and Figures

Table 1: Descriptive statistics of energy consumption (kg of oil equivalent per capita) for the sample period (1971 – 2011) for ASEAN-5 Nations

Country	Observations	Mean	Std. Dev.	Min.	Max.	Skewness
Indonesia	41	563.49	193.06	299.61	877.93	0.09
Malaysia	41	1474.9	708.19	523.77	2673.99	0.28
Philippines	41	455.81	26.25	406.13	513.47	0.37
Singapore	41	3874.9	1790.12	1292.18	7402.84	0.14
Thailand	41	890.05	468.99	360.63	1789.64	0.47

Notes: Sample consisted of annual data for the period 1971 - 2011. Energy consumption is expressed as kg of oil equivalent per capita. Energy consumption refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.

Table 2. Cross-section correlation of the errors in the ADF(*p*) regression for energy consumption per capita across ASEAN - 5 countries.

	P=1	P=2	P=3	P=4
Panel A = Actual energy consumption per capita (kg of oil equivalent)				
$\bar{\hat{\rho}}$	0.170	0.162	0.164	0.149
CD	3.269***	3.124***	3.149***	2.871***
Panel B = Relative energy consumption per capita [ln(Energy consumption per capita in country i/Average energy consumption per capita)]				
$\bar{\hat{\rho}}$	0.062	0.061	0.058	0.059
CD	1.195	1.177	1.124	1.140

Notes: The cross-sectional dependence (CD) test statistic is proposed in Pesaran (2004) for testing for cross sectional dependence in panels. All statistics are based on univariate AR(*p*) specifications in the level of the variables with $p \leq 4$. The null hypothesis is that output innovations are cross-sectionally independent. The 10%, 5% and 1% critical values for the CD statistic are 1.64, 1.96 and 2.57 respectively.

Table 3: Results of KPSS and LM tests without structural breaks

Country	KPSS Test	Schmidt and Philips LM Unit root test
Indonesia	0.131	-2.846
Malaysia	0.087	-2.649
Philippines	0.095	-2.397
Singapore	0.170**	-2.046
Thailand	0.189**	-1.885

The unit root tests were performed with the assumption of an intercept and trend in the series. The lag lengths were selected using the Bayesian Information criteria (BIC). The null hypothesis for the LM test is a unit root, whereas the null hypothesis for the KPSS test is stationarity. The 1% and 5% critical values for the LM unit root test are -3.73 and -3.11 respectively.

Table 4: Results for Lee and Strazicich (2003) LM unit root test with two structural breaks

	Break in Intercept			Break in Intercept and Trend		
Series	**Test statistic**	**TB1**	**TB2**	**Test statistic**	**TB1**	**TB2**
Indonesia	-3.865**	1990	1998	-4.885	1990	1997
Malaysia	-3.243	1989	1999	-4.095	1982	1995
Philippines	-3.702	1989	1998	-5.717**	1988	1997
Singapore	-2.861	1998	2006	-4.723	1989	1996
Thailand	-2.715	1994	2004	-5.944**	1981	1997

Critical values for S_{t-1}									
Model AA (Break in Intercept only)									
1%	5%	10%							
-4.54	-3.84	-3.50							
Model CC (Break in Intercept and Trend)									
λ_2		0.4			0.6			0.8	
λ_1	1%	5%	10%	1%	5%	10%	1%	5%	10%
0.2	-6.16	-5.59	-5.27	-6.41	-5.74	-5.32	-6.33	-5.71	-5.33
0.4	-	-	-	-6.45	-5.67	-5.31	-6.42	-5.65	-5.32
0.6	-	-	-	-	-	-	-6.32	-5.73	-5.32

Notes: TB_1 and TB_2 are the dates of the structural breaks. λ_j denotes the location of the breaks. The LM unit root test for model AA is invariant to the location of the breaks; however, this invariance does not hold for model CC, for which the null distribution of the LM test depends on the relative location of the breaks. ** denotes statistical significance at the 5% level.

Table 5: KPSS Test with two breaks

Country	KPSS test statistic (Bartlett kernel)	Break Dates		KPSS test statistic (Bartlett kernel)	Break Dates	
		TB_1	TB_2		TB_1	TB_2
	Intercept Only			Intercept and Trend		
Indonesia	0.040	1991	1997	0.040	1992	2002
Malaysia	0.072	1989	2009	0.029	1982	1995
Philippines	0.070	1990	1997	0.142***	1989	1997
Singapore	0.081	1997	2004	0.045	1998	2004
Thailand	0.029	1977	1982	0.035	1987	1994

Notes: Critical values for KPSS test with two structural break are based on Carrion-i-Silvestre and Sansó (2007). *** denote significance at the 1% level.

Table 6: Results for the individual countries of the Panel KPSS test with multiple structural breaks

Country	KPSS test statistic (using Bartlett kernel)	TB_1	TB_2	TB_3	TB_4	TB_5
	Intercept Only Model					
Indonesia	0.050	1982	1990	-	-	-
Malaysia	0.045	1978	1989	1996	2004	-
Philippines	0.184***	1977	1983	1989	2002	-
Singapore	0.080**	1983	1989	1997	2004	-
Thailand	0.024	1977	1994	2004	-	-
	Intercept and Trend Model					
Indonesia	0.032	1990	1994	1998	2004	-
Malaysia	0.021	1974	1983	1993	2000	2004
Philippines	0.041**	1977	1983	1989	1994	2000
Singapore	0.029	1974	1988	1994	2000	2004
Thailand	0.035	1982	1988	1994	2004	-

Notes: ** and *** denote significance at the 5% and 1% levels, respectively. Bootstrap critical values are based on a Monte Carlo simulation with 2000 replications.

Table 7: Results of Panel KPSS test with no breaks and multiple breaks.

Panel of 5 ASEAN countries	KPSS test statistic (using Bartlett kernel)	Bootstrap critical values		
		10%	5%	1%
	Intercept Only Model			
No Breaks (Homogenous)	14.889**	2.817	4.112	6.692
No Breaks (Heterogeneous)	7.635***	2.409	3.298	4.765
Breaks (Homogenous)	4.005	5.079	6.672	8.029
Breaks (Heterogeneous)	5.216	6.322	7.516	10.859
	Intercept and Trend Model			
No Breaks (Homogenous)	0.818	3.111	4.075	6.433
No Breaks (Heterogeneous)	0.942	3.860	5.148	7.371
Breaks (Homogenous)	0.168	6.504	8.208	12.783
Breaks (Heterogeneous)	1.193	11.030	14.001	21.045

Notes: (1.) ** and *** denotes significance at the 5% and 1% levels, respectively. Bootstrap critical values are based on a Monte Carlo simulation with 2000 replications.

Table 8: Results of the Im et al (2005) panel LM unit root test

Panel of 5 ASEAN countries	Panel LM test statistic
No Breaks	-2.522***
One Break	-5.023***
Two Breaks	-5.478***

Notes: (1.) The 1, 5 and 10% critical values for the panel LM unit root tests are -2.236, -1.645 and -1.282 respectively. (2.) *** denotes statistical significance at the 1% level.

Table 9: Results of the Im et al (2005) panel LM unit root test for ASEAN-3

Panel of 3 ASEAN countries (Indonesia, Malaysia, Singapore)	Panel LM test statistic
No Breaks	-2.267***
One Break	-3.865***
Two Breaks	-3.988***

Notes: (1.) The 1, 5 and 10% critical values for the panel LM unit root tests are -2.236, -1.645 and -1.282 respectively. (2.) *** denotes statistical significance at the 1% level.

Figure 1: Time series plot of the Log of per capita energy use relative to the mean energy use. Break dates based on Model CC of Univariate KPSS test with 2 breaks.