THE EVALUATION OF STANDARD OF LIVING AND THE ROLE OF HOUSEHOLD ELECTRICITY CONSUMPTION: A PANEL COINTEGRATION ANALYSIS

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Abstract

This research takes the analysis of the relationship between energy and income in a different direction than prior research, and it introduces a new set of analytical tools to the area. The results of our research are important because they raise additional questions about the effectiveness of income as a proxy indicator for standard of living, and these conclusions are supported by the use of more powerful analytical techniques.

Our paper employs state-of-the-art econometric time series panel techniques to evaluate the nature of the relationship between income measures and energy consumption measures for seven East Indian Ocean countries. The fundamental premise of our research is that energy consumption at the household/residential level is a key indicator of the standard of living for the residents of a country.

The general finding of the paper is that income and household electricity consumption measures are not cointegrated. Given this finding we conclude that standard of living measures/indexes that rely on income measures and do not directly include household-level energy consumption information will necessarily miss important indications of both levels and changes of standard of living.

JEL Classifications: I31, C33, Q43.

Key words: Standard of living, energy consumption, panel cointegration.

1. Introduction

This research takes the analysis of the relationship between energy and income in a different direction than prior research, and it introduces a new set of analytical tools to the area. The results of our research are important because they raise additional questions about the effectiveness of income as a proxy indicator for standard of living, and these conclusions are supported by the use of more powerful analytical techniques.

The fundamental premise of our research is that energy consumption at the household/residential level is a key indicator of the standard of living for the residents of a country. We have chosen household electricity consumption as our observable measure of residential energy consumption.

Our selection of household electricity consumption is not an arbitrary or random decision. Household electricity consumption is widely viewed and accepted as providing substantial standard of living (quality of life) gains. These gains come in many areas and suggest that observable household electricity consumption may provide useful insights into the nature of standard of living across countries and its changes over time.

Evaluating the effectiveness of a proxy indicator is made even more difficult when the variable of interest is unobservable, as with the concept of standard of living. The approach we have taken is to identify an observable variable at the household level that carries with it strong theoretical bases for linkage to standard of living. Other observable variables may be sought out and chosen, however, the consumption of energy (perhaps especially electricity) in the household can be linked to improvements in standard of living on many levels and in many areas. For example, the availability of electricity allows for the refrigeration of food. This will positively improve standard of living by improving the quality of food available, and therefore also improve health. Both of these can be expected to increase longevity, which is one of the measures incorporated into the UN’s human development index (HDI).

Another area of improvement is in education. The availability of electricity will provide lighting, which will facilitate reading and study after sunset. It will also make possible the use of computers, and potentially the internet (obviously, depending upon the availability of internet service providers). This captures another component of the HDI composite indicator; literacy.

Further, productivity will increase, because workers will not be required to cease work prior to sunset to facilitate food preparation while there is still ambient light. Productivity will also be enhanced by the ability to redirect labor from gathering traditional fuels to directly productive activities. This should increase income; the third component of the HDI.

In addition, there are positive environmental outcomes that also should improve standard of living/quality of life. Heavy reliance on traditional fuels has led to deforestation and worsening air quality, due to elevated particulate matter from burning these fuels. Commercial fuels, like electricity, will tend to reduce both of these negative effects.

These characteristics suggest that household electricity consumption will be a robust indicator of standard of living at the household level where it matters.

Based on these characteristics and their theoretical linkage to standard of living, household level consumption of electricity is believed to convey important information regarding the standard of living. Such information may be viewed from both an absolute and relative perspective. From the absolute perspective, we may establish an electricity consumption benchmark akin to a poverty line. From the relative perspective, we may examine the relative living standard across countries and across time, according to the consumption of electricity at the residential level. Ripple (2000) provides a rudimentary standard of living benchmark based on household electricity consumption. Before investing in the further development of an index based on household electricity consumption (which is beyond the scope of this paper), we must first determine whether or not currently employed indexes capture the information content associated with electricity consumption.

Given the premise that electricity consumption at the residential level provides valuable insights into the standard of living of a country's residents, any index that purports to measure standard of living must capture the information contained in observed residential electricity consumption. A standard of living index that does not capture the information content of residential electricity consumption should be viewed with deep suspicion. In line with this premise, we examine whether or not the role of electricity consumption at the household level is adequately captured by traditional income-based measures of standard of living.

The purpose of this research is to examine the information relationship between a measure of aggregate income and residential electricity consumption as they relate to measuring relative levels of standard of living. The relationship between energy and income has been studied in the literature and among policy analysts for quite some time. The focus of this paper, however, differs from these earlier works, as it focuses on whether or not measures of income are adequate to capturing standard of living changes that are the direct, and indirect, result of changes in the level of residential energy usage.

Several papers have argued that income measures are inadequate for effective measurement of relative changes of standard of living among countries of the world. These articles typically have in mind replacing the income measure with some composite index, which will typically retain a role for some income measure. There is then additional research that tells us why these composites fail, with some of the emphasis on how they fail to tell us anything significant beyond what a stand-alone income measure revealed.

Given the questions raised regarding composite indexes, we selected purchasing-power-parity (PPP) adjusted GDP as our measure of aggregate income. Our results lend support, via a completely new avenue of research, to the conclusion that income is an inadequate proxy for standard of living. We may also conclude that income measures will be meaningless for the evaluation of the success or failure of targeted household energy development programs.

Our alternative approach also introduces state-of-the-art econometric time series panel techniques to the evaluation of the nature of the relationship between income measures and energy consumption measures. While our focus is on the information content relationship between the PPP-GDP and residential electricity consumption series, we will also have a little bit to say about some of the older questions addressed in earlier research regarding the relationships between income and broader definitions of energy consumption.

The paper will proceed with a discussion of the literature relating energy and income in section two. Section three will introduce the hypothesis of this paper related to the information content of energy versus income series. Section four will introduce the data, while section five will present the panel data time series techniques employed to test our hypothesis. Section six will summarize the results, and section seven will conclude with some suggestions for useful research extensions of the methods employed herein.

2. Energy and income – economic growth

The seminal paper inquiring into the relationship between energy consumption and aggregate income was Kraft and Kraft (1978). The focus of their paper, and much of the energy-income research that followed, was to attempt to determine a causal relationship between these two economic variables. The theoretical arguments ran in both directions.

The analyses were conducted at an aggregated, national level. Kraft and Kraft (1978) tested the causal relationship between gross energy consumption and gross national product (GNP) for the United States, with data covering the 1947-1974 period. Their motivation is captured in the following: "According to a current view, there is a constant and unchanging relationship between gross energy consumption and gross national product (GNP). A logical corollary is that energy conservation is an unacceptable policy option since it would adversely influence economic activity. This implies that the direction of causality runs from energy to GNP as well as the other way around." (Kraft and Kraft, 1978, p. 401) Their primary finding was that causality was unidirectional running from GNP to energy, suggesting that energy conservation programs would not adversely affect economic growth.

An extensive literature has followed on from Kraft and Kraft (1978). These include Akarca and Long (1980), Yu and Choi (1985), Erol and Yu (1988), Abosedra and Baghestani (1991), Hwang and Gum (1992), Yu and Jin (1992), Masih and Masih (1996, 1997), and Soytas and Sari (2003). The findings of these papers, and others, provide anything but consensus. Indeed, Akarca and Long (1980) declare that the Kraft and Kraft (1978) results are spurious, based on a finding of no causal relationship, in either direction, by changing the time period by just two years; a reduction, eliminating 1973 and 1974 data, which may introduce a structural shift into the series. This result suggested neutrality between GNP and energy consumption. These two papers examined United States data.

Yu and Choi (1985), while also examining the U.S., broadened the research to include both developed and developing countries[1]. They also extended the analysis by examining causal relationships between GNP and various disaggregations of energy by energy types, e.g., solid fuels, liquid fuels, natural gas, etc. Yu and Choi (1985) also find no causal relationships for the U.S., U.K., or Poland, and mixed results for the remaining countries, both in terms of total energy consumption and the disaggregated fuel consumption.

Erol and Yu (1988) examine the energy income relationships for six major industrialized countries and find disparate results across the sample. Abosedra and Baghestani (1991) find results consistent with Kraft and Kraft (1978). This is the reverse of many of the intervening studies. Abosedra and Baghestani (1991) employ the direct-Granger test for causality, and further, they take into consideration the magnitude and significance of individual estimated coefficients on the lagged independent variables. This differs from

[1] The set of countries examined were the United States, United Kingdom, Poland, the Philippines, and South Korea.

the Sims test for Granger causality, which relies upon joint influence of the lagged variables as measured by the F statistic.

The initial work in this area involved primarily basic Granger causality testing. Yu and Jin (1992) introduced cointegration tests into the literature on the relationships between energy and income. They find a lack of cointegration between energy consumption and real output or employment. They conclude, harkening back to the initial motivation for Kraft and Kraft (1978), that an energy conservation policy should therefore "not be instrumental in affecting economic activity." (Yu and Jin (1992, p. 265))

Masih and Masih (1996) extend the cointegration analyses into dynamic vector error correction and variance decomposition modeling. The latter two methodologies provide a basis for examining causality from within a cointegration framework. Their paper also covers four of the countries included in the current paper. They also arrive at mixed results for both cointegration and direction of causality across their six countries. The four countries in common between Masih and Masih (1996) and our paper are India, Indonesia, Malaysia, and Singapore. They find cointegration for the first two, but no cointegration for the other two. Moreover, they find the direction of causality for India to run from energy consumption to income, but the reverse held for Indonesia.

Soytas and Sari (2003) investigate the causal relationships for 16 countries, made up of both developed and emerging countries, using cointegration and vector error correction (VEC) and variance decompositions (VDC) methodologies. They find seven countries with cointegrating relationships, but again the direction of causality, within this group was mixed.

In one sense the work in the present paper may be seen as extending this line of research by analyzing the cointegrating relationships based on panel data. An advantage of employing a panel is the increased power of the tests relative to that for individual country analyses. In addition to the introduction of new methodology, our focus shifts from the question of direction of causality between the energy and income variables to information content as they impinge on revealing answers to questions of standard of living.

3. Energy versus income – information content

Numerous United Nations and World Bank documents[2], as well as other literature, identify a relationship between energy consumption and standard of living. Indeed, these organizations, along with regional and national agencies, have significant programs targeting the development of facilities to deliver commercial energy to households. We take this to imply an economically significant relationship between residential energy consumption and standard of living. Thus, it is important that indicators of relative and changing standard of living capture the influence of residential energy consumption. To that end, it is relevant to ask whether or not the typically employed indicators of standard of living adequately capture the influence of residential energy consumption.

[2] See, for example, Sanghvi and Barnes (2001), Dzioubinski and Chipman (1999), Barnes (1995), and Goldemberg and Johansson (1995).

In 1990, the UN introduced Human Development Index (HDI), which is a composite index, including income, education, and life expectancy measures. The HDI meant to enhance the typical income measure by capturing information related to additional factors deemed to be closely related to standard of living. McGillivray (1991) concludes that the HDI may be viewed as a (another) redundant measure of standard of living because the composite index reveals (captures) little more than an income measure alone. This issue is relevant to the question being addressed in this paper.

We are not directly concerned with the question of whether income leads energy consumption or vice versa, as most of the work in this area has been. We are instead concerned with whether or not an indicator of standard of living based on income is capable of capturing the effects of energy consumption on standard of living. We test this question employing panel cointegration methodologies.

The existence of cointegration between two non-stationary series implies that such series move together through time, tracing a long-run path from which they are disturbed by temporary shocks but to which they continually readjust. In the short run, they may move away from their equilibrium relationship, but in the long run, economic forces bring about changes in those series which will in turn bring them back to equilibrium. In the absence of a cointegrating relationship there is no such adjustment mechanism. Hence, if we find no cointegration between income and residential electricity consumption, we may conclude that income and residential electricity do not have a common trend.

Consequently, income cannot be assumed to capture all the information contained in residential electricity.

The question of whether or not increased per capita income is expected theoretically to cause an increase in residential energy consumption, or vice versa, is not central to this current research. Indeed, our primary hypothesis is that there is no cointegrating relationship between these two.

Theoretical arguments may suggest long-run causality in either direction. For example, we may posit that increases in per capita income will lead to higher levels of household energy consumption through an income effect. Alternatively, it may be argued that as a result of increased educational and health benefits associated with increased household energy consumption, the residents will be more productive, which will lead to increased per capita income. However, it is our contention that the very nature of the residential energy (electricity) sector tends to break these potential long-run links.

The link is likely broken in developing[3] countries as a result of the domestic and international programs that are specifically designed to increase the usage of commercial energy sources at the residential level. The existence of these programs may be viewed as a revealed belief, on the part of the agencies and governments involved, that there are significant gains to be had in terms of standard of living improvements through increased residential energy consumption that cannot efficiently be accomplished via per capita

[3] If there is no cointegration between income and residential electricity consumption in developed economies, it may be due to regulated prices within this industry, which may break the link.

income-increasing policy avenues. It may still be the case that increased income at the residential/household level will lead to increased residential energy consumption, and through that consumption to higher standards of living. However, the typical per capita income measures available do not reflect directly on the residential level income, but rather are simply the result of the division of the national income aggregate by the national population. If the national income is not percolating down to the residential level on a proportionate basis, which it typically does not, the per capita income measure tells us very little about the effective change in income at the residential/household level.

It is usually the case that the desired or expected outcome of cointegration analysis is that the studied economic time series are found to be cointegrated. Alternatively, the *lack* of cointegration has been employed to signify the existence of explosive speculative bubbles in equity markets (Morin, 2003). In our analyses, we may conclude that the lack of cointegration between the income measures and the residential electricity consumption measures implies significant differential growth for residential electricity consumption relative to income.

Such observed deviation carries several implications. First, it implies that significant information may be being lost, or ignored, when standard of living is evaluated on the basis of income (or income driven) measures alone. If there is no cointegration found between these two series, one cannot adequately capture the long-run information content of residential electricity consumption with respect to standard of living by employing income measures as a proxy indicator. Second, the deviation implied by the lack of observed cointegration may be interpreted as evidence that national and international programs aimed explicitly at increasing access to electricity (due to perceived standard-of-living benefits) are in fact working. And third, it may be seen as evidence that national income measures are too imprecise in their information content to adequately reveal meaningful indications of changes in standard of living at the household level, where it really counts.

Ripple (2000) took a preliminary look at the relationship between residential electricity consumption and income. The finding was a lack of close relationship between these variables, however the analysis was based on simple graphical and ranking methodologies. The current paper examines the same countries contained in Ripple (2000), but makes use of an expanded, updated, data set, as well as taking advantage of the state-of-the-art panel time series analysis techniques. Figures 1 and 2, reprise some of the analysis found therein. Two points are worth making here. First, the initial and ending rankings of countries differ depending on whether we use PPP-GDP or residential electricity consumption per capita. And second, the range for PPP-GDP appears to expand over the period, while the range for per capita residential electricity consumption appears relatively stable to slightly shrinking. Table 1 reports the average annual compound growth rates for each country. With the exception of the USA, there is very little relationship between the growth rates over the period for income and residential electricity consumption.

4. Data

The data employed in our analyses are from the International Energy Agency (IEA), and drawn from the IEA's internet data service. The data available through the data service are more complete than found in the hardcopy volumes of IEA Energy Statistics and Balances, for both OECD and Non-OECD countries. The IEA data series provide for consistency across time and countries and hence provide a very suitable basis for analyzing multi-country relationships via panel techniques.

The variables employed for the central questions addressed in this paper are residential electricity consumption, PPP-adjusted GDP, and population. We also employ measures of total energy consumption and total electricity consumption, to gain some insights into relationships examined in the earlier literature mentioned above.

The electricity consumption series are measured in gigawatt hours (GWh), while the total energy consumption series are measured in thousands of tonnes of oil equivalents (ktoe). The GDP series are PPP adjusted and in 1995 U.S. dollars.

The countries included are India, Indonesia, Burma[4], Bangladesh, Malaysia, Thailand, Singapore, Australia, the United States, and the European Union. Our analysis extends that initiated in Ripple (2000) addressing the countries of the East Indian Ocean area. The

[4] The PPP-GDP data for Burma have been questioned by our colleague Wylie Bradford. We ran all the panel analyses with and without the inclusion of Burma, and our overall results and conclusions are unchanged. Thus, for continuity and completeness we report the Burma-inclusive results.

time period covered is1971 through 2001, with the exception of Malaysia where residential electricity consumption is not available for 1971 and 1972.

5. Methodology

In this paper we pool cross-section and time series data to study relationships between income and different measures of energy consumption. Before we conduct tests of cointegration between those variables, it is necessary to perform unit root tests. Unit root and cointegration tests in the time series dimension suffer of low power and/or size distortion. The addition of the cross-section dimension, however, brings an improvement to the power of unit root and cointegration tests by acting as repeated draws from the same distribution.

5.1 Panel Unit Root Tests

We consider three panel unit root tests: the Levi-Lin-Chu (2002) (LLC), Im, Pesaran and Shin (2003) (IPS) and Choi (2004) tests. The first two tests assume cross-sectional independence. This is a restrictive assumption since it implies that there is no cointegration between groups of countries in the cross sections. This assumption is likely to be violated for the income variable. It has also been found by Banerjee, Cockerill and

Russell (2001) and O'Connell (1998) that these tests have poor size properties and have a tendency to over-reject the null of a unit root if the cross-sectional independence assumption does not hold. Choi (2004) relaxes this assumption.

The Levin-Lin-Chu (2002) tests are conducted using the following model:

$$\Delta y_{i,t} = a_i + d_i t + q_t + r_i y_{i,t-1} + \sum_{L=1}^{p_i} g_{iL} \Delta y_{it-L} + V_{i,t} \qquad (1)$$

where i = 1,…,N denotes countries, t =1,…,T denotes time. $\zeta_{i,t}$ are assumed to be IID(0, σ^2) and to be independent across the units of the sample.

This model allows for fixed effects, unit specific time trends and common time effects. The coefficient of the lagged dependent variable is restricted to be homogenous across all units of the panel. Therefore the null hypothesis of non-stationarity

H_0: $\rho_i = 0$

is tested against the alternative

H_1 : $\rho_i = \rho < 0$ for all i.

Levin-Lin-Chu (2002) tabulate the statistics for three specifications of the deterministic terms in (1), and generalize to the case where $\zeta_{i,t}$ is autocorrelated:

model 1: $\Delta y_{i,t} = r_i y_{i,t-1} + \sum_{L=1}^{p_i} g_{iL} \Delta y_{it-L} + V_{i,t}$

model 2: $\Delta y_{i,t} = a_i + r_i y_{i,t-1} + \sum_{L=1}^{p_i} g_{iL} \Delta y_{it-L} + V_{i,t}$

model 3: $\Delta y_{i,t} = a_i + d_i t + q_t + r_i y_{i,t-1} + \sum_{L=1}^{p_i} g_{iL} \Delta y_{it-L} + V_{i,t}$

Separate ADF regressions are carried out for each cross-section unit and pooled t-statistics are computed. Those t-statistics have asymptotic standard normal distribution.

Im, Pesaran and Shin (2003) relax the assumption of homogeneity of the coefficient of the lagged dependent variable. They test the null that each series in the panel has a unit root for all cross-section units against the alternative that at least one of the series is stationary.

H_0: $\rho_i = 0$ for all i; H_1 : $\rho_i < 0$ for i = 1, 2, ..., N_1, $\rho_i = 0$ i = N_1+1, N_1+2,..., N

The ζ_{it} errors are also assumed to be autocorrelated with different serial correlation and variance properties across the cross-section units.

The Im, Pesaran and Shin (2003) test used in this study is the average of the ADF individual unit root tests statistics. They tabulate the statistics for three specifications of the deterministic terms in (1). The IPS statistic is asymptotically N(0,1), as T and N go to infinity, when N/T go to k, a positive finite constant, and the lim(N_1/N)= λ_1, 0< $\lambda_1 \leq 1$. Breitung (2000) shows that the power of both the LLC and IPS tests is sensitive to the specification of the deterministic terms.

Karlson and Lothgren (2000) note that for large T, and if a few cross-section units are stationary, there is a risk that the whole panel will be modeled as stationary because of the high power of both panel unit root tests. For small T, on the other hand, there is a risk that the whole panel may be modeled as non stationary. This is due to the relatively low power of the tests if the proportion of stationary series in the panel is large. For small T they show that the LLC test exhibits size distortions. They conclude that "…a careful joint analysis of both the individual and the panel unit root tests results are called for to fully assess the stationary properties of the panel data."

Choi (2004) develops unit root tests for cross-sectionally correlated panels. These tests are obtained by combining p-values from the ADF tests applied to the individual series after elimination of the deterministic trend components and cross-sectional correlations. Those tests have a standard normal asymptotic distribution.

5.2 Panel Cointegration Tests

As is the case for unit root tests cointegration panel tests can be expected to have higher power than the corresponding time series tests. The tests applied in this analysis are single equation tests which have been developed by Pedroni (1997, 2003).

Pedroni (1997, 2003) develop tests for the null of no cointegration in the bivariate case.

Pedroni (1999) generalizes these tests to the multivariate case.

Pedroni (1999) uses the following model:

$$y_{it} = a_i + d_i t + b_{1i} x_{1it} + ... + b_{Ki} x_{Kit} + e_{it} \qquad (2)$$

where there are K regressors, which are allowed to be endogenous.

The tests for the null of no cointegration are based on testing whether the error process e_{it} is stationary. This is achieved by testing whether r_i = 1 in:

$$\hat{e}_{it} = r_i \hat{e}_{it-1} + v_{it} \qquad (3)$$

Pedroni (2003) presents seven tests which can be divided into two groups. Tests statistics in the first group, the panel cointegration statistics, are averages of the cointegration time series test statistics across cross-sections. The alternative hypothesis for those tests is that $r_i = r < 1$. Tests statistics in the second group, the group mean cointegration statistics, are based on averaging the individual estimated values of r_i for each cross-section unit i. The alternative hypothesis for those tests is that $r_i < 1$ for all i. Those tests are less restrictive since they allow for heterogeneity across countries.

For both groups Pedroni constructs two non parametric and one parametric test statistics that take autocorrelation into consideration:

i. A Phillips-Perron (1988) (PP) type *rho* statistic;

ii. A Phillips-Perron (1988) (PP) type t-statistic;

iii. A Dickey-Fuller (1979) (ADF) type t-statistic (those tests are analogous to the LLC and IPS tests in the unit root case).

He also develops a non parametric panel variance ratio test statistic. Those seven test statistics can be rescaled so that they are distributed as standard normal. Under the alternative of cointegration the panel variance statistic diverges to plus infinity whereas the other six test statistics diverge to minus infinity. Consequently for the panel variance test the right tail of the standard normal distribution is used to reject the null of no cointegration and for the other six tests the left tail is used.

In practice it is possible for different tests to give contradicting conclusions. Choosing which test is more appropriate is not easy. The group mean tests particular strength is that they are less restrictive. Regarding the best way to correct for autocorrelation, non parametric tests are likely to be more robust to outliers but have poor size properties and tend to over-reject the null when it is true. The ADF-type tests have better power if the errors follow an autoregressive process (Harris and Sollis (2003)).

Pedroni (2003) examines the small sample power properties of his seven tests statistics. He finds that the size distortion is small and the power is high for T>100. For smaller T he shows that the group ADF test has the best power properties followed by the panel ADF test, the panel variance and group *rho* perform poorly.

6. Results

The methodology described in the previous section is applied to study the relationship between per capita PPP adjusted GDP and each of per capita residential electricity consumption, per capita total electricity consumption, and per capita total energy as described in section 4. All the variables are in logs. Results for the log of the gross variables are also presented.

6.1 Unit Root Tests

Before we can test for cointegration between per capita PPP adjusted GDP and each of the electricity and energy variables we first need to ensure that the variables are integrated of order 1, (I(1)). We initially conduct unit root tests individually for each country. The tests chosen are the ADF and PP tests. Summary of the results are presented in Table 2. The unit root tests, on individual countries, reveal that income and total energy contain unit roots, just as found by earlier studies of the causal relationships between these variables. There is one exception, that being Bangladesh, where income is found to have no unit root by either the ADF or PP tests, and total energy is found to have a unit root by the ADF test but not according to the PP test. The unit root results for total electricity and residential electricity are somewhat more mixed. For total electricity, India, Burma, Thailand, Malaysia, Singapore, Indonesia, and USA exhibit unit roots according to both tests. The EU exhibits no unit root by either test and Australia exhibits a unit root according to the PP test but not the ADF test, while Bangladesh reveals just the opposite.

For residential electricity consumption, unit roots exist according to both tests for India, Bangladesh, Burma, Malaysia, and Indonesia. Residential electricity consumption is stationary (no unit root) according to both tests for Thailand and the USA. Singapore's and the EU's residential electricity exhibit a unit root by ADF, but not PP. Australia's residential electricity shows the reverse.

Since we have only a small number of time series observations panel unit root tests should have better power and less size distortion than their time series counterpart. The panel unit root tests are displayed in Table 3. Four test statistics were calculated for each variable, with and without a trend: the Levin-Lin *rho* statistic, Levin-Lin t-statistic, Levin-Lin ADF statistic, and the IPS ADF statistic. The panel does not include Australia, the USA, or the EU; they were included for preliminary benchmarking only, in line with Ripple (2000). Since our focus is on the developing economies of the region, we restricted the panel. The results provide strong evidence of panel unit roots for the residential electricity, total electricity and total energy variables (per capita or gross), both with and without trends included. The evidence is more mixed for the income variable. For the per capita and gross data the Levin-Lin *rho* test rejects the null for GDP only when a trend is included.

The cross-sectional error terms were checked for the presence of contemporaneous correlations between countries. For the GDP variable some of the correlations were large: around 0.8 between Indonesia and Thailand, around 0.5 between Indonesia and Singapore. The contemporaneous correlations for the total electricity variable were also of some concern: around 0.5 between Malaysia and Thailand both with and without trend. The results of the Choi tests are thus particularly relevant for the GDP and total electricity variables. The results from the Levin-Lin *rho* tests for the GDP unit root tests can be explained by the fact that these tests have poor size properties and have a tendency to over-reject the null of a unit root if the cross-sectional independence assumption does not hold. The null of a unit root is not rejected by any of the Choi tests (see Table 4).

It is thus possible to conclude from the previous tests that there is no strong evidence in favor of the rejection of the null of a unit root for our four variables.

6.2 Cointegration Tests

The next step in our analysis is the panel cointegration testing. In order to deal with possible cross-sectional dependence a common time dummy is included to capture the Asian financial crisis in 1997. The estimates of Pedroni (1999, 2003) panel cointegration test statistics are displayed in Table 5. Of the seven test statistics the null of no cointegration is rejected only by the panel variance ratio test for total electricity and GDP (both per capita and gross data) and for total energy and GDP (gross data only). As mentioned earlier, for smaller T the group ADF test has the best power properties followed by the panel ADF test; the panel variance and group *rho* tend to perform poorly. Since we have a small number of observations we can conclude that cointegration is not present for all three pairings; residential electricity and GDP, total electricity and GDP, and total energy and GDP.

Engle-Granger (1987) and Johansen (1991) cointegration tests were also performed for the individual countries. The results are summarized in Tables 6 and 7. While the panel cointegration tests provide better power than the individual country tests, it is worth noting that with few exceptions cointegration is not found when employing either the Engle-Granger or the Johansen tests. For the Johansen test, cointegration is found to exist between residential electricity and income for Indonesia and Thailand and between total energy and income for Bangladesh and Malaysia. There was no cointegration between total electricity and income for any of the seven countries, which were included in the panel. For the Engle-Granger tests there is some sensitivity to the inclusion of a trend, but again a finding of cointegration is the exception.

It is also worth noting that the Johansen tests are regularly attacked for too easily finding the existence of cointegration. For our purposes, this seeming weakness is an added strength. That is, even when employing a test that is notorious for finding (questionable) cointegration, we find virtually none. As with the panel results, the relative lack of support for cointegration extends over all three series pairings.

The focus of our analyses, however, is on the relationship between residential electricity consumption and income (as measured herein by PPP adjusted GDP). Moreover, we introduced the panel data techniques to the study of the relationship to increase the power of the tests. And these results are unambiguous, and support our initial hypothesis. Returning to the results presented in Table 5, we find that with the more powerful panel techniques, the null hypothesis of no cointegration cannot be rejected by any of the seven test statistics.

The implication of these results is that income-based measures will not be capable of capturing the information contained in residential electricity consumption data. So, if one accepts our premise (and that of the World Bank and others) that residential energy consumption enhances standard of living, the typical, income-based measures of standard of living will necessarily miss important information about levels and changes in standard of living.

7. Summary and future research

The overall conclusion from this research is that there is no cointegrating relationship between residential electricity consumption and GDP. As such, income-based measures of standard of living will be incapable of capturing the long-run information content of residential energy consumption as it affects standard of living. Given this finding we conclude that standard of living measures/indexes that rely on income measures and do not directly include household-level energy consumption information will necessarily miss important indications of changes of standard of living; likely for both absolute and relative measures. Moreover, composites that are themselves indistinguishable from income measures will also fail.

The observed lack of a cointegrating relationship between income measures and residential electricity consumption may be viewed as providing evidence of the success of intervention programs by both domestic and international organizations and as evidence that there is information value in residential electricity consumption measures that cannot be proxied by reference to income measures.

One obvious extension of this research is to evaluate developing and developed economies beyond our selected seven. While there is no obvious reason to suggest our results are limited to our selected countries, confirmation would be useful. Moreover, these results suggest two lines of additional research. First, it suggests that there may be value in developing a standard of living index that combines income with residential energy consumption measures. And second, there should also be value in testing existing composite indexes, like the HDI, employing the panel data techniques introduced herein, to determine whether or not the composites are providing meaningful information beyond that observable from anyone of the individual measures.

Figure 1: Per Capita PPP-GDP Comparisons

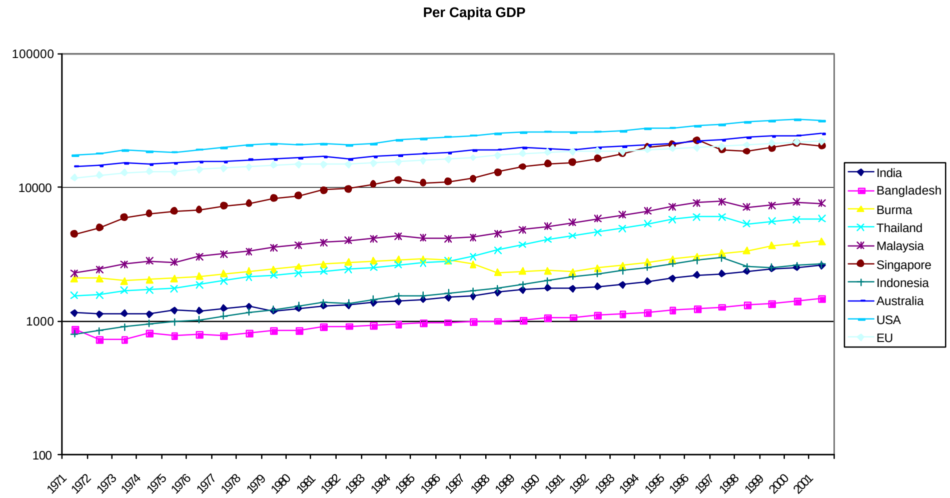

Figure 2: Per Capita Residential Electricity Consumption

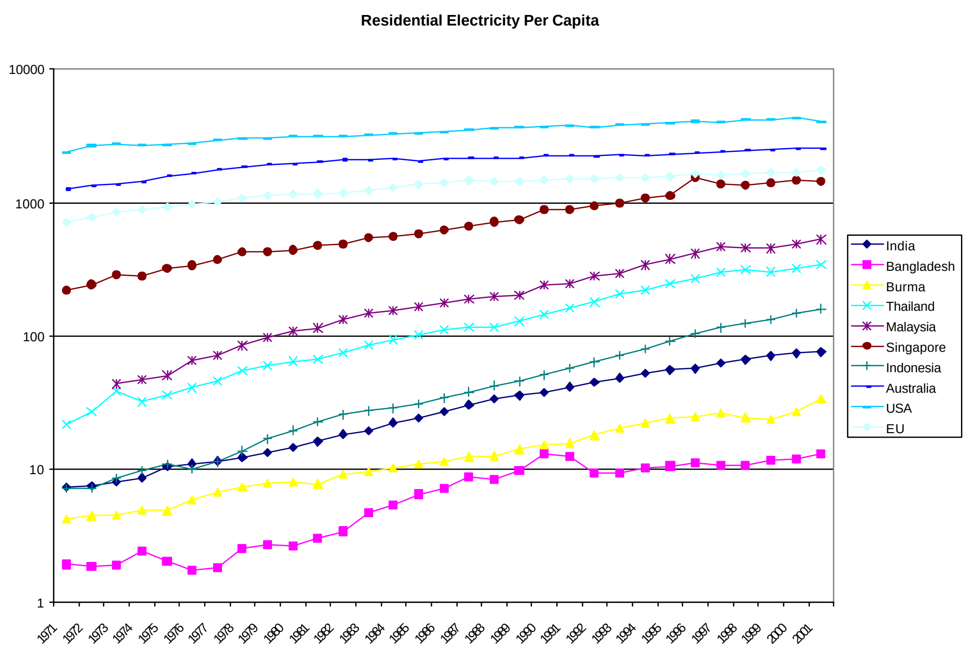

Table 1

Average annual compound growth rates for PPP-GDP and Residential Electricity Consumption 1971-2001										
	India	**Bangladesh**	**Burma**	**Thailand**	**Malaysia**	**Singapore**	**Indonesia**	**Australia**	**USA**	**EU**
PPP-GDP	2.71	1.74	2.13	4.39	3.76	5.04	4.01	1.85	2.00	2.11
Res.Elec.	7.77	6.36	6.90	9.23	8.93	6.30	10.35	2.35	1.77	3.04
RE/GDP	2.87	3.65	3.24	2.10	2.37	1.25	2.58	1.26	0.88	1.44

Table 2

ADF Tests for Unit Roots (per capita)[a]

Country	PPP GDP			Residential Electricity			Total Electricity			Energy		
	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ
India	0	-2.555	(-1.628)	0	-0.133	-1.385	0	-0.503	-0.860	0	-2.412	-0.144
Bangladesh	0	-6.992*	(0.856)	0	-1.309	-0.792	2	-2.365	-0.084	4	-2.253	-0.052
Burma	1	-1.596	-0.428	0	-2.795	-0.060	0	-1.651	0.474	0	-1.451	-1.794
Thailand	1	-1.6743	-1.092	0	-3.849*	(-1.788)	1	-.878	-0.817	1	-2.124	0.193
Malaysia	0	-1.692	-1.499	0	-1.723	-2.223	0	-1.281	-0.565	0	-3.028	0.605
Singapore	0	-1.764	-2.418	1	-2.591	-1.601	0	-2.469	(-2.870*)	0	-1.550	(-3.745*)
Indonesia	0	-0.669	-1.875	0	-2.368	-0.276	0	-1.139	-0.866	1	-2.323	-1.783
Australia	0	-1.703	0.866	2	-3.451*	(-3.319*)	1	-3.498*	(-3.150*)	0	-2.307	-0.900
USA	0	-2.889	-0.814	0	-4.515*	(-2.482)	0	-2.984	(-2.203)	0	-1.934	-1.576
EU	0	-2.871	-0.962	1	-2.832	(-3.181*)	0	-3.327*	(-2.667*)	4	-1.403	-0.343

[a] τ_τ is the t-statistic with constant and trend, τ_μ is the t-statistic with constant.

10% MacKinnon (1991) critical values for τ_τ is -3.224 and for τ_μ is -2.624.

* Rejects at 10% significance level the null of a unit root.

A number in parenthesis for τ_μ indicates that for that variable the null hypothesis of a trend and a unit root was rejected, and therefore the relevant statistic is the one with th constant and trend included.

Phillips-Perron Tests for Unit Roots (per capita)[a]

Country	PPP GDP			Residential Electricity			Total Electricity			Energy		
	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ
India	1	-2.557	(-1.912)	1	-0.257	-1.342	1	-0.832	-0.807	1	-2.445	-0.144
Bangladesh	1	-6.560*	(0.986)	1	-1.471	-0.810	1	-3.572*	(-0.722)	1	-3.332*	(-0.531)
Burma	1	-0.916	0.314	1	-2.962	-0.074	1	-1.810	0.483	1	-1.538	-1.862
Thailand	1	-1.229	-0.747	1	-3.849*	(-1.925)	1	-1.148	-1.489	1	-1.507	0.218
Malaysia	1	-1.910	-1.429	1	-1.640	-2.468	1	-1.523	-0.529	1	-3.064	0.537
Singapore	1	-1.905	-2.334	1	-3.535*	(-1.661)	1	-2.438	(-3.771*)	1	-1.584	(-3.667*)
Indonesia	1	-0.942	-1.771	1	-2.610	-0.279	1	-1.336	-0.849	1	-1.897	-2.162
Australia	1	-1.717	0.951	1	-2.730	(-4.685*)	1	-2.444	-3.150*	1	-2.329	-0.883
USA	1	-3.107	-0.809	1	-4.537*	(-2.610)	1	-3.043	(-2.207)	1	-2.121	-1.648
EU	1	-3.026	-0.911	1	-3.577*	(-5.378*)	1	-3.261*	(-2.483)	1	-2.604	-1.430

[a] τ_τ is the t-statistic with constant and trend, τ_μ is the t-statistic with constant.

10% MacKinnon (1991) critical values for τ_τ is -3.224 and for τ_μ is -2.624.

* Rejects at 10% significance level the null of a unit root.

A number in parenthesis for τ_μ indicates that for that variable the null hypothesis of a trend and a unit root was rejected, and therefore the relevant statistic is the one with th constant and trend included.

ADF Tests for Unit Roots (gross)[a]

Country	PPP GDP			Residential Electricity			Total Electricity			Energy		
	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ
India	0	-2.921	(1.501)	0	0.186.	-1.667	0	-0.033	-1.172	0	-1.932	-0.324
Bangladesh	0	-9.478*	(0.960)	0	-1.174	-0.832	2	-2.150	-0.415	4	-3.610*	(-0.574)
Burma	1	-1.783	-0.154	0	-2.526	-0.330	0	-2.078	0.223	0	-1.531	-1.014
Thailand	1	-1.480	-1.482	0	-3.091	(-2.259)	1	-1.558	-1.135	1	-2.166	-0.066
Malaysia	0	-1.756	-1.290	0	-1.766	-2.043	0	-1.327	-0.387	0	-3.069	(0.850)
Singapore	0	-2.048	-1.391	0	-2.671	-0.315	4	-3.394*	(-1.579)	0	-1.925	(-2.875*)
Indonesia	0	-0.353	-2.313	0	-1.987	-0.612	0	-0.721	-1.163	1	-2.262	-1.933
Australia	0	-1.977	0.777	2	-3.421*	(-2.909*)	1	-3.085	(-2.886*)	0	-2.606	-0.717
USA	0	-2.822	-0.398	0	-5.199*	(-2.167)	0	-3.357*	(-1.991)	0	-1.630	-0.706
EU	0	-3.038	-1.041	1	-3.017	(-3.118*)	0	-3.608*	(-2.712*)	4	-1.394	-0.134

[a] τ_τ is the t-statistic with constant and trend, τ_μ is the t-statistic with constant.

10% MacKinnon (1991) critical values for τ_τ is -3.224 and for τ_μ is -2.624.

* Rejects at 10% significance level the null of a unit root.

A number in parenthesis for τ_μ indicates that for that variable the null hypothesis of a trend and a unit root was rejected, and therefore the relevant statistic is the one with th constant and trend included.

Phillips-Perron Tests for Unit Roots (gross)[a]

Country	PPP GDP			Residential Electricity			Total Electricity			Energy		
	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ	lags	τ_τ	τ_μ
India	1	-2.922	(1.752)	1	0.096.	-1.610	1	-0.377	-1.074	1	-2.010	-0.324
Bangladesh	1	-8.847*	(1.071)	1	-1.340	-0.833	1	-3.469*	(0.898)	1	-3.418*	(-0.758)
Burma	1	-1.123	0.305	1	-2.694	-0.334	1	-2.068	0.225	1	-1.621	-1.150
Thailand	1	-0.597	-1.390	1	-3.077	(-2.459)	1	-0.863	-2.182	1	-1.491	-0.240
Malaysia	1	-1.948	-1.236	1	-1.657	-2.325	1	-1.536	-0.369	1	-3.084	(0.783)
Singapore	1	-2.314	-1.311	1	-2.710	-0.305	1	-3.740*	(-1.647)	1	-1.998	-2.819*
Indonesia	1	-0.628	-2.135	1	-2.229	-0.590	1	-0.891	-1.133	1	-1.867	-2.513
Australia	1	-2.006	0.839	1	-2.800	(-4.758*)	1	-2.235	(-3.684*)	1	-2.630	-0.725
USA	1	-3.057	-0.403	1	-5.163*	(-2.326)	1	-3.415*	(-1.989)	1	-1.861	-0.903
EU	1	-3.160	-0.974	1	-3.853*	(-5.393*)	1	-3.516*	(-2.519*)	1	-2.610	-1.060

[a] τ_τ is the t-statistic with constant and trend, τ_μ is the t-statistic with constant.

10% MacKinnon (1991) critical values for τ_τ is -3.224 and for τ_μ is -2.624.

* Rejects at 10% significance level the null of a unit root.

A number in parenthesis for τ_μ indicates that for that variable the null hypothesis of a trend and a unit root was rejected, and therefore the relevant statistic is the one with th constant and trend included.

Table 3

Panel Unit Root Tests (per capita)[a]

	Trend				**No Trend**			
Tests **Variables**	Levin-Lin rho	Levin-Lin t	Levin-Lin ADF	IPS ADF	Levin-Lin rho	Levin-Lin t	Levin-Lin ADF	IPS ADF
PPP GDP	-1.870*	-0.707	-0.817	-0.646	1.763	2.047	1.766	2.395
Residential Electricity	-1.623	-0.525	-1.099	-2.619	1.512	1.388	2.094	2.267
Electricity	-1.155	-0.093	-0.830	-1.070	1.586	1.538	3.093	3.117
Total energy	0.720	-0.199	-0.407	-1.134	1.297	1.116	1.638	1.905

Panel Unit Root Tests (gross data)[a]

	Trend				**No Trend**			
Tests **Variables**	Levin-Lin rho	Levin-Lin t	Levin-Lin ADF	IPS ADF	Levin-Lin rho	Levin-Lin t	Levin-Lin ADF	IPS ADF
PPP GDP	-3.439*	-1.187	-1.489	-1.546	1.758	1.881	1.871	2.796
Residential Electricity	0.328	0.143	-0.294	-1.035	1.594	1.531	2.071	2.244
Electricity	-1.631	-0.198	-0.963	-1.725	1.651	1.656	2.977	2.699
Total energy	0.361	-0.226	-0.513	-1.383	1.339	1.356	2.126	1.952

[a] All tests statistics are asymptotically distributed as N(0,1). * Rejects at 5% level. All tests are one-sided tests, thus values of the test statistic in the left tail of the standard normal distribution are evidence for rejection of the null of a unit root. Exact 5% critical values for the IPS tests are -2.07 without trend and -2.69 with trend (obtained from IPS (2003) Table 2 with N = 7 and T = 30).

Table 4

Choi (2004) Panel Unit Root Tests (per capita)[a]

Tests **Variables**	Inverse normal: Z	Modified inverse chi-squared: P_m	Modified logit: L*
PPP GDP	1.304	-1.404	1.218
Residential Electricity	-0.847	0.867	-0.951
Electricity	0.018	-0.101	-0.021
Total energy	0.436	0.356	0.400

Choi (2004) Panel Unit Root Tests (gross data)[a]

Tests **Variables**	Inverse normal: Z	Modified inverse chi-squared: P_m	Modified logit: L*
PPP GDP	0.345	-0.427	0.272
Residential Electricity	-1.061	1.410	-1.088
Electricity	-0.596	0.564	-0.619
Total energy	0.210	0.121	0.099

[a] All test statistics are asymptotically distributed as N(0,1). All tests are one-sided tests, thus values of the test statistic in the left tail of the standard normal distribution are evidence for rejection of the null of a unit root.

Table 5

Panel Cointegration Tests

Cointegration Tests: per capita[a]						
	GDP and Residential Electricity		GDP and Total Electricity		GDP and Total Energy	
	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend
panel v-stat	-1.295	1.6111	-0.332	3.39033*	0.02087	-0.3823
panel rho-stat	1.328	1.0966	0.43671	0.82179	0.55364	1.99295
panel pp-stat	0.8671	-0.16	-0.3055	-0.1551	-0.3323	1.88888
panel adf-stat	0.4992	-0.021	-0.1309	-0.1181	-1.2213	0.99212
group rho-stat	1.9815	1.1177	1.13745	1.49593	1.4503	2.28026
group pp-stat	1.1965	-0.547	-0.3925	-0.0248	-0.2279	1.74398
group adf-stat	0.7728	-0.851	0.08368	0.45972	-1.1281	0.62464
Cointegration Tests: gross[a]						
	GDP and Residential Electricity		GDP and Total Electricity		GDP and Total Energy	
	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend
panel v-stat	-0.42545	0.32643	0.80451	2.64890*	3.73650*	3.36304*
panel rho-stat	1.16521	1.69416	0.44302	0.59637	0.18525	0.27292
panel pp-stat	0.97243	0.99833	0.24372	-0.37839	-1.02612	-1.04036
panel adf-stat	0.58698	1.07858	0.61011	-0.34460	-1.30389	-0.90106
group rho-stat	1.86212	1.92810	1.02161	1.05224	0.97046	1.10267
group pp-stat	1.33653	0.78723	0.21276	-0.69608	-0.90742	-0.84911
group adf-stat	0.94869	0.74611	0.53334	-0.16572	-0.91102	-0.44114

[a] All tests statistics are asymptotically distributed as N(0,1). * Rejects at 5% level. All tests are one-sided tests: for the panel variance test the right tail of the standard normal distribution is used to reject the null of no cointegration and for the other six tests the left tail is used.

Table 6
Engle-Granger Cointegration Tests (per capita)[a]

Country	Electricity and Income		Residential Electricity and Income		Energy and Income	
	Trend	No Trend	Trend	No Trend	Trend	No Trend
Bangladesh	-2.516	-5.652*	-2.018	-1.795	-2.029	-6.343*
Burma	-2.955	-1.891	-2.951	-1.914	-2.612	-1.955
India	-0.540	-1.197	-1.809	-1.818	-1.823	-0.998
Indonesia	-2.619	-1.856	-2.665	-1.153	-1.830	-1.409
Malaysia	-2.088	-2.317	-2.078	-2.112	-2.640	-2.435
Singapore	-2.990	-2.516	-3.256	-2.508	-2.271	-1.962
Thailand	-4.146*	-2.726	-4.322*	-2.912	-0.631	-0.673

[a] 5% Mackinnon (1991) critical values are -4.10 if a trend is included in the cointegrating regression and -3.54 when there is no trend included.
* Rejects the null of no cointegration at the 5% level.

Table 7
Johansen (1991) Tests for the Cointegration Rank
Total Electricity and Income (per capita)[a]

Country	H_0: r =	n-r	λ_{trace}	Corrected λ_{trace}	$\lambda_{trace}(0.95)$	λ_{max}	Corrected λ_{max}	$\lambda_{max}(0.95)$
Bangladesh	0	2	22.40	19.51	25.32	12.22	10.64	18.96
	1	1	10.18	8.87	12.25	10.18	8.87	12.25
Burma	0	2	14.04	12.23	25.32	9.70	8.45	18.96
	1	1	4.34	3.78	12.25	4.34	3.78	12.25
India	0	2	23.49	20.46	25.32	14.34	12.49	18.96
	1	1	9.15	7.97	12.25	9.15	7.97	12.25
Indonesia	0	2	17.24	15.08	25.32	13.78	12.00	18.96
	1	1	3.46	3.01	12.25	3.46	3.01	12.25
Malaysia	0	2	9.08	7.91	25.32	6.06	5.28	18.96
	1	1	3.01	2.62	12.25	3.01	2.62	12.25
Singapore	0	2	19.20	16.72	25.32	11.26	9.81	18.96
	1	1	7.94	6.92	12.25	7.94	6.92	12.25
Thailand	0	2	16.03	13.96	25.32	13.09	11.40	18.96
	1	1	2.94	2.56	12.25	2.94	2.56	12.25

[a] In all cases aVAR model with 2 lags, with an unrestricted constant and a trend restricted to the cointegrating relationship, was used in the tests. Structural breaks intervention dummy variables were included when needed.

Critical values from Osterwald-Lenum (1992) are denoted by $\lambda_{trace}(0.95)$and $\lambda_{max}(0.95)$

For small samples adjusting for degrees of freedom has been suggested (Ahn and Reinsel (1988), Reimers (1992)) by dividing the maximum eigenvalue and trace statistics by *T/(T-nk)* (where *T* is the number of observations, *n* is the number of variables and *k* is the number of lags.

Johansen (1991) Tests for the Cointegration Rank
Residential Electricity and Income (per capita)[a]

Country	H_0: r =	n-r	λ_{trace}	Corrected λ_{trace}	$\lambda_{trace}(0.95)$	λ_{max}	Corrected λ_{max}	$\lambda_{max}(0.95)$
Bangladesh	0	2	21.62	17.44	25.32	19.45	15.69	18.96
	1	1	2.17	1.75	12.25	2.17	1.75	12.25
Burma	0	2	17.71	15.42	25.32	13.41	11.68	18.96
	1	1	4.30	3.75	12.25	4.30	3.75	12.25
India	0	2	18.68	16.27	25.32	12.05	10.50	18.96
	1	1	6.63	5.77	12.25	6.63	5.77	12.25
Indonesia	0	2	51.61	38.29*	25.32	43.07	31.96*	18.96
	1	1	8.54	6.34	12.25	8.54	6.34	12.25
Malaysia	0	2	9.31	8.11	25.32	6.69	5.83	18.96
	1	1	2.62	2.28	12.25	2.62	2.28	12.25
Singapore	0	2	15.40	13.41	15.41	10.76	9.37	14.07
	1	1	4.63	4.03	3.76	4.63	4.03	3.76
Thailand	0	2	33.21	28.92*	25.32	31.73	27.64*	18.96
	1	1	1.47	1.28	12.25	1.47	1.28	12.25

[a] A VAR model with 2 lags with an unrestricted constant and a trend restricted to the cointegrating relationship was used in the tests except for Bangladesh 3 lags were used, for Indonesia 4 lags were used, for Singapore 2 lags were used but the constant was unrestricted and there was no trend. Structural breaks intervention dummy variables were included when needed.

* Indicates cointegration at 5% level.

Critical values from Osterwald-Lenum (1992) are denoted by $\lambda_{trace}(0.95)$and $\lambda_{max}(0.95)$

For small samples adjusting for degrees of freedom has been suggested (Ahn and Reinsel (1988), Reimers (1992)) by dividing the maximum eigenvalue and trace statistics by $T/(T\text{-}nk)$ (where T is the number of observations, n is the number of variables and k is the number of lags.

Johansen (1991) Tests for the Cointegration Rank
Energy and Income (per capita)[a]

Country	H_0: r =	n-r	λ_{trace}	Corrected λ_{trace}	$\lambda_{trace}(0.95)$	λ_{max}	Corrected λ_{max}	$\lambda_{max}(0.95)$
Bangladesh	0	2	34.22	29.80*	25.32	25.53	22.24*	18.96
	1	1	8.70	7.58	12.25	8.70	7.58	12.25
Burma	0	2	12.50	10.89	25.32	12.50	10.89	18.96
	1	1	3.70	3.22	12.25	3.70	3.22	12.25
India	0	2	17.56	16.43	25.32	14.25	13.33	18.96
	1	1	3.31	3.10	12.25	3.31	3.10	12.25
Indonesia	0	2	10.97	9.55	15.41	10.67	9.29	14.07
	1	1	0.30	0.26	3.76	0.30	0.26	3.76
Malaysia	0	2	44.46	35.85*	25.32	35.09	28.30*	18.96
	1	1	9.37	7.56	12.25	9.37	7.56	12.25
Singapore	0	2	17.48	15.22	25.32	10.04	8.74	18.96
	1	1	7.45	6.49	12.25	7.45	6.49	12.25
Thailand	0	2	13.56	11.81	25.32	9.83	8.56	18.96
	1	1	3.73	3.25	12.25	3.73	3.25	12.25

[a] A VAR model with 2 lags with an unrestricted constant and a trend restricted to the cointegrating relationship was used in the tests except for India 1 lag was used, for Malaysia 3 lags were used, for Indonesia 2 lags were used but the constant was unrestricted and there was no trend. Structural breaks intervention dummy variables were included when needed.

* Indicates cointegration at 5% level.

Critical values from Osterwald-Lenum (1992) are denoted by $\lambda_{trace}(0.95)$and $\lambda_{max}(0.95)$

For small samples adjusting for degrees of freedom has been suggested (Ahn and Reinsel (1988), Reimers (1992)) by dividing the maximum eigenvalue and trace statistics by *T/(T-nk)* (where *T* is the number of observations, *n* is the number of variables and *k* is the number of lags.

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