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ARE SHOCKS TO ENERGY CONSUMPTION PERMANENT OR TEMPORARY? EVIDENCE FROM 182 COUNTRIES

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ABSTRACT

This paper applies univariate and panel data unit root tests to annual panel data for 182 countries over the period 1979-2000 to examine the stationarity properties of per capita energy consumption. The univariate unit root test can only reject the unit root null for 29 per cent of the countries at the 10 per cent level or better without a trend and 37 per cent of the countries at the 10 per cent level or better with a trend. However, it is often argued that unit root tests have low power with short spans of data and therefore failure to reject the unit root null should be treated with caution. When we apply the panel data unit root test we find overwhelming evidence that energy consumption is stationary. We discuss the implications of these findings for econometric modeling and policy formulation.

Keywords: Energy consumption, Unit roots, Panel data

ARE SHOCKS TO ENERGY CONSUMPTION PERMANENT OR TEMPORARY? EVIDENCE FROM 182 COUNTRIES

1. INTRODUCTION

A standard approach in the energy demand literature is to first test for the stationarity of energy consumption and conditional on the finding for the order of integration proceed to examine whether energy consumption is cointegrated with other variables of interest. The stationarity properties of energy consumption have important implications for economic policies given the presumed impact of oil price shocks on macroeconomic variables. Hamilton (1983) showed that oil price shocks, via their effect on energy consumption, are responsible for almost every recession in the United States since World War II. Several studies have linked oil price shocks to output and inflation (Hamilton, 1996, Cunado and Perez de Gracia, 2003), the natural rate of unemployment (Caruth *et al.* 1998), movements in stock market indices (Huang *et al.* 1996, Sardosky 1999, Papapetrou 2001) and fluctuations in business cycles (Kim and Loungani, 1992).

Failure to reject the null hypothesis implies a non-stationary series where shocks to energy consumption have permanent effects. This would be consistent with path dependency or hysteresis in energy consumption (see Agnolucci et al. 2004).[i] Meanwhile rejection of the null supports the alternative hypothesis of a stationary series where shocks to a country's energy consumption have temporary effects. If energy consumption is non-stationary and is characterized by hysteresis or path dependency, structural change in the world oil market, such as the first or second oil price shock, will have permanent effects on energy consumed. If this is the case, other variables linked to energy demand such as income and expenditure will 'inherit' that non-stationarity and transmit it to employment and wages and so on (Hendry and Juselius, 2000).

The stationarity properties of energy consumption also have important implications for time series modeling of energy demand. If energy demand contains a unit root close to unity in its autoregressive representation meaning that it is integrated of order one (I(1)) this has profound ramifications for estimation, statistical testing and forecasting (see Engsted and Bentzen 1997, p. 262). In terms of forecasting, if energy consumption is stationary, forecasts of the level of the variable will have a constant variance, while if energy consumption is an I(1) process forecasts will entail uncertainty which increase with the forecast horizon. Moreover, if energy consumption is I(1), the usual practice in economics of treating 'trends' and 'cycles' as different concepts in modeling is invalid. Because a shock to the series will have permanent effects on the level of the series, regressions involving I(1) variables will be spurious unless the variables are cointegrated.

Most studies employing univariate unit root tests have concluded that energy consumption is an I(1) process.[ii] But univariate unit root tests have low power. There have been few attempts to apply panel unit root tests to energy consumption. Joyuex and Ripple (2004) apply the Levin et al. (2002) and Im et al (2003) panel unit root tests to a panel of eight Asian countries, but their findings are not robust because they do not address the problem of cross-sectional dependence. Other related literature include Perman and Stern (1999) and Strazichich and List (2003) who apply panel data unit root tests to examine the stationarity properties of carbon emissions as part of broader studies.

This paper applies the t-bar test developed by Im et al (2003) to annual panel data for 182 countries over the period 1979-2000 to examine the stationarity properties of per capita energy consumption. In order to provide a benchmark we begin with the Augmented Dickey-Fuller (ADF) unit root tests. The ADF unit root tests can only reject the unit root null for 29 per cent of the countries at the 10 per cent level without a trend and 37 per cent of the countries at the 10 per cent level or better with a trend. However, it is often argued that unit root tests have low power with short spans of data and therefore failure to reject the unit root null should be treated with caution (see eg De Jong et al 1992).

Several panel data unit root tests have been developed to exploit the extra power in the panel properties of the data (see Baltagi and Kao, 2000 for a review). These include the Levin et al (2002) test, Feasible Generalized Least Squares (FGLS) (O'Connell, 1998) and the t-bar test proposed by Im et al (2003). In this paper we employ the t-bar test developed by Im et al (2003) in preference to these alternatives. This is because the t-bar test does not assume that all cross-sectional units converge towards the equilibrium value at the same speed under the alternative hypothesis and thus is less restrictive than either the Levin et al (2002) or FGLS tests. Maddala and Wu (1999) and Karlsson and Lothgren (2000) perform Monte Carlo simulations, which show that in most cases the Im et al (2003) test outperforms the Levin et al (2002) and FGLS tests. With the t-bar test we find overwhelming evidence that energy consumption is stationary.

2. DATA AND UNIVARIATE UNIT ROOT TEST

The data used in this study is for per capita primary energy consumption for 182 countries for the period 1980-2000. We converted data into natural logs before undertaking the empirical analysis. All data are obtained from the Energy Information Administration and are available from their webpage: http://www.eia.doe.gov.

We started through testing for the presence of a unit root in energy consumption per capita using the Augmented Dickey and Fuller (ADF) unit root test:

$$\Delta y_t = \kappa + \alpha y_{t-1} + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \qquad (1)$$

$$\Delta y_t = \kappa + \alpha y_{t-1} + \beta t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \qquad (2)$$

The ADF auxiliary regression tests for a unit root in y_t, where y refers to energy consumption per capita in each country, $t = 1,...T$ is an index of time, Δy_{t-j} is the lagged first differences to accommodate serial correlation in the errors, μ_t. Equation (1) tests for the null of a unit root against a mean stationary alternative in y_t. Equation (2) tests the null of a unit root against a trend stationary alternative. In Equations (1) and (2) the null and the alternate hypotheses for a unit root in y_t are: $H_0 \;\; \alpha = 0$ and $H_1 \;\; \alpha < 0$.

To select the lag length (k) we use the ‘t-sig’ approach proposed by Hall (1994). This involves starting with a predetermined upper bound k_{max}. If the last included lag is significant, k_{max} is chosen. However, if k is insignificant, it is reduced by one lag until the last lag becomes significant. If no lags are significant k is set equal to zero. The ‘t-sig’ approach has been shown to produce test statistics which have better properties in terms of size and power than information-based methods such as the Akaike Information Criterion or Schwartz Bayesian Criterion (see eg Hall 1994, Ng and Perron, 1995). We set k_{max}=8 and use the approximate 10 per cent asymptotic critical value of 1.60 to determine the significance of the t-statistic on the last lag. The results of the ADF unit root test with and without a trend are reported in Table 1. The ADF unit root tests can only reject the unit root null for 46 countries at the 5 per cent level or better and a further seven countries at the 10 per cent level without a trend and 57 countries at the 5 per cent level or better and a further 10 countries at the 10 per cent level with a trend.

Insert Table 1

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3. PANEL DATA UNIT ROOT TEST

A possible reason for the failure of the ADF test to reject the unit root null for about two-thirds of countries is the time span of the data. We address this issue by employing the t-bar test proposed by Im et al (2003) in order to exploit the extra power in the panel properties of the data. As discussed in the introduction, it is less restrictive under the alternative hypothesis than either the Levin et al (2002) or FGLS panel unit root tests

There are two stages in constructing the t-bar test statistic. The first is to calculate the average of the individual ADF t-statistics for each of the countries in the panel. The second is to calculate the standardized t-bar statistic according to the following formula:

$$\text{t-bar} = \sqrt{N}\left(t_\alpha - \kappa_t\right) \Big/ \sqrt{\nu_t} \qquad (3)$$

where N is the size of the panel, t_α is the average of the individual ADF t-statistics for each of the countries and κ_t and ν_t are respectively estimates of the mean and variance of each $t_{\alpha i}$. Im et al (2003) provide Monte Carlo estimates of κ_t and ν_t and tabulate exact critical values for the t-bar statistic for various combinations of N and T.

A potential problem with the t-bar test, involves cross-sectional dependence. When there is cross-sectional dependence in the disturbances the t-bar test is no longer applicable. However, Im et al (2003) suggest that in the presence of cross-sectional dependence, the data can be adjusted by subtracting the cross-sectional means and then applying the t-bar statistic to the transformed data. The standardized de-meaned t-bar statistic converges to a standard normal in the limit.[iii] The existing evidence suggests that the de-meaning procedure does dramatically reduce cross-sectional dependence even in instances where the observed data are highly correlated (see eg. Luntiel, 2001, and Smyth, 2003).

Insert Table 2

Table 2 reports the results of the Im et al (2003) t-bar test with and without a trend applied to both the raw data and demeaned series as well as the critical values for the t-bar test from Im et al. (2003). We report results for seven regional panels (North America, Eastern Europe and the former Soviet Union, Africa, Far East and Oceania, Middle East, Central South America and Western Europe). With a trend we are able to reject the null hypothesis that the series for each panel is non-stationary at the 1 per cent level. Without a trend we are able to reject the null hypothesis of a non-stationary series at the 1 per cent level for all panels except North America and East Europe and the former Soviet Union. The null hypothesis of non-stationarity can be rejected for North America at the 10 per cent level to two decimal places with the de-meaned data.

Taylor and Sarno (1998), Karlsson and Lothgren (2000) and others suggest that rejection of the null hypothesis of joint non-stationarity using panel data tests might be due to as few as one of the series being stationary. Thus in Table 3 we present the results of the Im et al (2003) t-bar test excluding those countries on each regional panel for which the ADF test reveals energy consumption per capita to be stationary. This makes no difference to the results. We are able to reject the null hypothesis of non-stationarity in energy consumption per capita at the 1 per cent level for each of the regional panels.[iv]

Insert Table 3

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4. CONCLUDING REMARKS

Unit root testing of macroeconomic variables has taken centre stage in the applied time series econometrics literature since the work of Nelson and Plosser (1982). Over the last couple of decades, several techniques have been developed to test for unit roots. This innovation is important and draws motivation from the policy and modelling relevance of unit root testing. A finding that energy consumption per capita is nonstationary means that shocks to energy consumption have a permanent effect, implying unit root hysteresis or path dependency in energy demand. On the other hand, a finding of stationarity implies that shocks will have a transitory effect on energy consumption. This is important given the potential effect of oil price shocks on energy consumption and flow through effects to other macroeconomic variables such as inflation and output.

In this paper we have examined the unit root properties of per capita energy consumption for 182 countries. The contribution of this paper is that we apply both univariate and panel unit root techniques to investigate the unit root properties of energy. Panel unit root techniques are important if one wants to improve the power of the unit root test, particularly in small sample sizes such as in the present study. When we apply the univariate test, we find a unit root in per capita consumption for 67 per cent of the countries. However, when we apply the panel version of the ADF test, we find overwhelming evidence that there is no unit root in per capita energy consumption.

Taken together, our results suggest three important messages. The first is related to econometric modeling: In order to examine long-run relationships, say between per capita energy consumption and per capita GDP, most cointegration tests require variables to be characterized by a unit root. Similarly, in testing for causality, say between per capita energy consumption and per capita GDP, one needs to know the order of integration of the variables in order to correctly specify the model and avoid spurious results.

The second implication of our results relates to policy. Our findings suggest that shocks to per capita energy consumption are transitory. This provides important insights for policy makers, as it contributes to their understanding of the behavior of energy consumption. In the event of a major structural change in the world oil market, such as the first or second oil price shock, per capita energy consumption will return to its original equilibrium over a short period of time. Other variables linked to energy demand via flow-on effects such as income and expenditure will not inherit that non-stationarity and transmit it to major economic variables such as employment and wages.

The third implication relates to the advent of an important area of research from our study. We believe that future research should consider extending our work by examining the relationship between per capita energy consumption and per capita GDP. A related direction of research would be to examine whether per capita GDP causes per capita energy consumption, or whether per capita energy consumption causes per capita GDP within panel cointegration and/or panel vector autoregression frameworks.

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Table 1: Augmented Dickey Fuller unit root test

Country	**Without trend**		**With trend**	
	α	$t - statistic$	α	$t - statistic$
Bermuda	0.5482	0.7504 [8]	-7.5330	-3.4463 [8]*
Canada	-0.1989	-1.1452 [0]	-7.0919	-2.0716 [8]
Mexico	-0.0386	-2.023 [7]	-10.1281	-3.1942 [8]
Saint Pierre	-0.1761	-1.4007 [2]	-1.4423	-3.5397 [6]*
USA	-0.1121	-2.9119 [8]*	-3.4794	-1.1364 [8]
Albania	-0.0473	-0.8419 [4]	-4.5544	-2.6034 [8]
Bulgaria	-0.0611	-0.7525 [0]	-5.7176	-3.6952 [8]**
Hungary	-1.6878	-2.9278 [7]*	-0.0919	-1.4322 [1]
Poland	-0.1309	-1.2592 [0]	-0.3974	-2.0338 [0]
Romania	0.0137	0.1689 [0]	-2.5635	-4.3759 [8]***
Algeria	-0.1469	-0.6657 [2]	-1.1807	-1.9795 [8]
Angola	-0.0500	-0.2413 [1]	-0.4304	-2.1472 [0]
Benin	-1.8029	-3.0147 [8]**	-1.2833	-0.5195 [8]
Botswana	-0.3058	-1.7113 [8]	5.1195	1.0547 [8]
Burkina Faso	1.1752	1.5851 [6]	-0.9342	-2.2259 [2]
Burundi	-1.6400	-7.1259 [8]***	-1.8093	-5.5662 [8]***
Cameroon	-0.3090	-1.8136 [0]	-0.6332	-0.9070 [6]
Cape Verde	-0.4160	-2.9770 [0]**	-0.4496	-2.5543 [0]
Central Africa	-2.7494	-4.1969 [8]***	-7.2240	-19.0648 [8]***
Chad	-0.4436	-2.2474 [0]	-1.0849	-2.5459 [2]
Comoros	-0.4258	-1.5747 [4]	-0.8976	-2.0418 [4]
Congo B	-0.3067	-1.4204 [0]	-6.7244	-1.3829 [8]
Congo K	1.6009	1.6251 [8]	6.5968	1.3534 [8]
Cote Ivoire	-0.2348	-1.7418 [0]	-9.5214	-3.1155 [8]
Djibouti	-1.4742	-12.2295 [8]***	-0.8011	-31.1899 [8]***
Egypt	-0.1239	-1.2310 [2]	-1.2769	-2.1598 [8]
Equatorial Guinea	-1.6077	-7.9974 [8]***	-2.6109	-5.8854 [8]***
Ethiopia	-0.4769	-0.3216 [8]	0.2219	0.3349 [7]
Gabon	-1.3086	-2.2819 [8]	-3.7760	-0.1975 [8]
Gambia	-0.0779	-0.5636 [0]	-1.2769	-0.2902 [7]
Ghana	-0.3477	-2.1018 [0]	-0.3612	-2.1358 [0]
Guinea	-0.4850	-1.9078 [4]	-1.0402	-2.8157 [5]
Guinea Bissau	-0.6704	-2.2675 [8]	0.0259	0.1567 [2]
Kenya	-0.4525	-3.0844 [3]**	-0.7560	-2.1214 [2]
Lesotho	-0.6573	-1.3618 [7]	-2.2650	-1.6473 [8]
Liberia	-0.3524	-11.9112 [8]***	-1.5511	-2.9186 [8]
Libya	-0.4765	-3.2473 [0]**	-8.5450	-2.5033 [8]

Madagascar	-1.0322	-3.7649 [5]***	-3.0448	-12.3480 [8]***
Malawi	-0.1846	-1.3783 [0]	-8.1833	-5.1251 [8]***
Mauritania	-0.1191	-1.0900 [0]	-0.4514	-2.1956 [0]
Mauritius	-0.4899	-9.2552 [7]***	-0.6843	-2.4447 [7]
Morocco	-1.3127	-3.7848 [8]***	-1.1697	-1.1255 [8]
Mozambique	-0.3824	-4.3473 [0]***	-1.1575	-2.2276 [8]
Niger	-0.8432	-4.1244 [8]***	-0.8505	-3.1890 [8]
Nigeria	-1.1033	-5.5317 [8]***	-0.7589	-0.6005 [8]
Reunion	-0.1423	-1.2609 [5]	-14.1177	-2.9290 [8]
Rwanda	-0.3028	-1.0219 [5]	0.0433	0.0507 [5]
Saint Helen	-0.3416	-2.1954 [4]	-1.5068	-1.3629 [8]
Sao Tome	-0.1514	-1.2118 [0]	-0.3850	-2.0192 [0]
Senegal	-0.3565	-1.9170 [0]	-0.3297	-1.7467 [0]
Seychelles	-0.1904	-1.5832 [0]	-2.2817	-3.4553 [0]*
Sierra Leone	-0.2501	-1.5566 [0]	1.5209	0.6276 [8]
Somalia	-0.0517	0.8795 [0]	-0.3795	-1.7642 [0]
South Africa	-1.0373	-4.4910 [0]***	-1.0659	-4.4591 [0]***
Sudan	-0.2811	-1.6327 [0]	-17.7636	-7.6614 [8]***
Swaziland	-0.2091	-1.3140 [0]	-5.6531	-14.1029 [8]***
Tanzania	0.4888	1.1377 [7]	-4.4981	1.7513 [8]
Togo	-0.9635	-4.0560 [0]***	-1.0388	-3.9802 [0]**
Tunisia	1.1678	2.3061 [7]	-3.6126	-7.3043 [8]***
Uganda	-0.0911	-0.9412 [1]	-4.9444	-3.2606 [8]*
Western Sahara	-0.7747	-5.0496 [8]***	-0.8472	-0.7782 [8]
Zambia	-0.0296	-0.5395 [0]	-6.4106	-3.3269 [8]*
Zimbabwe	-0.6557	-0.7139 [8]	-5.3523	-1.4654 [8]
Afghanistan	-0.0629	-0.5341 [0]	-1.1980	-0.8215 [8]
American Samoa	-0.2264	-1.3794 [0]	-4.5397	-3.5156 [8]*
Australia	0.2065	1.4874 [8]	-10.8751	-4.1424 [8]**
Bangladesh	-0.1312	-3.1026 [7]**	-1.4607	-0.9846 [7]
Bhutan	-0.0791	-1.1761 [1]	1.9719	1.5089 [8]
Brunei	-0.3246	-2.0780 [0]	-0.7886	-3.1538 [0]
Burma	1.0300	0.2881 [8]	1.0600	0.2881 [8]
China	-0.2101	-2.6695 [7]*	3.5876	4.7101 [8]***
Cook Islands	-0.9560	-3.9716 [7]***	1.5909	-3.9547 [7]**
Fiji	-1.4079	-1.9695 [7]	-3.4055	-2.9317 [8]
Tahiti	-0.3437	-4.3925 [0]***	-0.2817	-4.5396 [0]***
Guam	-0.1337	0.4119 [6]	-1.2799	-6.1541 [5]***
Hong Kong	-3.0443	-3.4343 [8]**	-3.4647	-7.9517 [8]***
India	-0.0438	-1.3759 [0]	-10.2451	-3.4419 [8]*
Indonesia	-0.0894	-1.6538 [4]	-4.8131	-5.9270 [8]***

Japan	-0.3453	-3.3659 [8]**	-0.4022	-0.2728 [8]
Kiribati	-0.1586	-1.2437 [0]	-19.4104	-2.3501 [8]
North Korea	-0.1537	-2.6131 [1]	-0.1373	-1.6198 [1]
South Korea	-0.0135	-0.5313 [0]	-3.6987	-10.9697 [8]***
Laos	-0.3399	-2.0159 [0]	-4.1783	-26.9430 [8]***
Macau	-0.1964	-2.0394 [0]	-0.6418	-2.2154 [3]
Malaysia	-0.0461	-1.4470 [0]	-0.1822	-1.0189 [0]
Maldives	-0.1583	-1.7391 [1]	-6.8253	-1.7923 [8]
Mongolia	0.0456	0.6243 [0]	-1.7915	-1.9701 [8]
Nauru	-0.5252	-1.9684 [3]	-15.8811	-4.4986 [8]***
Nepal	0.0616	0.8389 [2]	-1.0187	-4.3165 [0]***
New Caledonia	-1.1744	-2.2152 [8]	-0.3097	-0.4591 [7]
New Zealand	-0.1084	-1.6521 [0]	-0.1938	-1.8023 [1]
Niue	-1.2076	-2.7183 [6]*	-6.9840	-11.1137 [8]***
Pakistan	-0.2930	-2.3785 [8]	-59.3415	-5.1832 [8]***
PNG	-0.6744	-1.5306 [8]	-2.5235	-1.7099 [8]
Philippines	0.0122	0.1255 [4]	-4.0606	-2.8277 [8]
Samoa	-0.3502	-2.4099 [0]	-5.1603	-2.8540 [8]
Singapore	-0.0067	-0.1689 [0]	-3.4112	-8.2899 [8]***
Solomon Islands	1.1855	7.1975 [8]***	2.1095	8.4339 [8]***
Sri Lanka	-0.0187	-0.1733 [0]	-0.3146	-1.8318 [0]
Taiwan	0.0549	1.0036 [8]	-3.3543	-3.9936 [6]**
Thailand	-0.4367	-2.1375 [8]	-3.3978	-1.3839 [8]
Tonga	-1.1140	-3.7167 [8]***	-1.1185	-1.4481 [8]
Vanuatu	-0.0149	-0.2086 [0]	-0.3880	-2.3327 [1]
Vietnam	0.0193	0.2323 [0]	-1.2346	-5.9705 [8]***
Bahrain	-0.6345	-3.4376 [0]**	-2.1954	-1.0114 [8]
Cyprus	-0.0876	-1.2176 [4]	-4.7034	-14.6000 [8]***
Iran	-0.0482	-0.7930 [0]	-12.6024	-6.6586 [8]***
Iraq	-0.3119	-1.8298 [0]	-0.7631	-3.2170 [0]
Israel	-1.2474	-7.7048 [8]***	-1.2703	-1.8388 [8]
Jordon	-0.6520	-4.0444 [0]***	-0.8075	-1.7950 [4]
Kuwait	-0.3994	-1.9936 [0]	-0.7341	-2.9028 [1]
Lebanon	-0.0555	-0.4858 [0]	-0.5045	-1.3402 [4]
Oman	-1.4117	-3.0881 [8]**	-1.7117	-0.9427 [8]
Qatar	-0.1256	-1.0521 [1]	-5.9089	-85.2693 [8]***
Saudi Arabia	-0.2870	-0.3693 [8]	-3.3837	-2.9350 [6]
Syria	-0.0881	-1.2963 [0]	-0.4369	-1.9737 [0]
United Arab Emirates	0.4345	0.6326 [8]	-0.6654	-3.6167 [5]**
Yemen	-2.4252	-13.6792 [8]***	-2.6017	-16.0931 [8]***
Antigua and Bermuda	-0.8182	-3.5515 [5]**	-0.9271	-3.8899 [5]**

Argentina	0.8786	5.6041[1]***	-0.4528	-0.1998 [0]
Bahamas	-0.2467	-2.4006 [3]	-0.9029	-0.9183 [0]
Barbados	-6.4023	-2.1766 [4]	-8.0106	-3.1689 [4]
Belize	-0.9089	-3.3241 [1]**	0.1108	0.0289 [1]
Bolivia	0.0582	0.2660 [0]	-0.3122	-1.8811 [0]
Brazil	0.0217	0.5264 [0]	-6.0974	-26.9652 [5]***
Cayman Islands	-0.2129	-1.5266 [1]	-0.4155	-2.0625 [4]
Chile	0.0490	0.8476[1]	-7.0879	-3.9475 [6]**
Colombia	-1.7046	-3.1220 [1]**	-4.3992	-26.1003 [7]***
Costa Rica	-0.5317	-3.0778 [1]**	-0.5400	-2.9721 [5]
Cuba	-0.3916	-0.8298 [3]	-1.1409	-1.9942 [4]
Dominica	-0.0807	-0.8368 [0]	-5.7016	-5.8453 [3]***
Dominican	0.3579	7.9590 [6]***	-1.3210	-3.2421 [3]*
Ecuador	-0.1844	-0.8346 [0]	-7.6470	-5.9685[4]***
El Salvador	2.6326	2.6594 [0]*	0.3659	0.7391 [0]
Falkan islands	-0.0873	-1.0620 [1]	-0.2836	-1.4684 [0]
French Guiana	-0.4066	-2.1385 [2]	-0.6310	-2.8629 [2]
Grenada	-0.1417	-1.9090 [2]	-0.3961	-1.2438 [0]
Guadeloupe	-0.3333	-4.9574 [4]***	2.2269	11.7253 [4]***
Guatemala	-0.4084	-1.6537 [0]	-0.4413	-3.8481 [1]**
Guyana	-2.2908	-5.4217 [4]***	-2.1898	-2.0234 [0]
Haiti	-0.9050	-2.3946 [3]	-0.4230	-2.1417 [0]
Honduras	-0.0699	-0.5694 [0]	-4.5688	-1.4368 [1]
Jamaica	-0.0834	-0.9220 [1]	3.3943	45.0511 [8]***
Martinique	-0.0818	-0.9995 [1]	-0.0936	-0.1349 [0]
Montserrat	-0.0408	-0.2351 [0]	-11.8343	-10.8362 [8]***
Netherlands Antilles	-0.1385	-2.0468 [1]	-0.1678	-1.3330 [1]
Nicaragua	13.1578	1.3867 [1]	-5.1131	-3.8998 [4]**
Panama	-0.2165	-0.9124 [1]	-3.3518	-26.5152 [5]***
Paraguay	-0.7088	-3.0922 [0]**	-4.2933	-16.5353 [6]***
Peru	-0.9746	-3.3668 [2]**	-1.8916	-3.1531 [3]*
Puerto Rico	-0.4901	3.1221 [3]**	-4.5721	-1.6977 [2]
Saint Kitts	0.2870	-1.9052 [4]	0.6899	0.4095 [0]
Saint Lucia	-0.0965	-0.9347 [3]	-0.5420	-2.6073 [2]
Saint Vincent/Grenadines	-0.2011	-3.5714 [2]**	-2.8582	-1.4907 [1]
Suriname	-0.9516	-1.8855 [0]	1.4739	0.6742 [0]
Trinidad and Tobago	-0.2437	-1.1781 [3]	-1.0923	-1.8534 [0]
Uruguay	-0.0072	-0.0610 [2]	-0.3928	-2.6682 [1]
Venezuela	-0.2415	-1.5924 [1]	-1.8349	-1.5563 [1]
Virgin Islands	1.8607	2.3157 [1]	-0.2233	-0.4688 [0]
Austria	0.0375	0.2955 [2]	-0.8331	-4.0274 [4]**

Belgium	0.4067	3.2591 [3]**	6.3583	5.9910 [4]***
Denmark	-0.2728	-1.7065 [2]	-8.8585	-2.6077 [2]
Faroe Islands	-0.0613	-0.6864 [0]	-0.3272	-1.9256 [1]
Finland	-0.1118	-0.9036 [1]	-0.8552	-3.4117 [3]*
France	-0.4625	-4.9083 [5]***	-1.5258	-0.6394 [1]
Gibraltar	0.2235	0.4113 [2]	0.7222	1.8050 [1]
Greece	-0.1779	-1.3230 [1]	-1.7237	-4.0270 [3]**
Iceland	0.0917	1.2348 [1]	-0.0635	-0.3537 [0]
Ireland	0.0823	1.3137 [0]	-2.6278	-2.2130 [1]
Italy	-0.0171	-0.2189 [3]	-0.6690	-2.8205 [2]
Luxemburg	-0.4258	-2.6826 [1]*	-0.4400	-2.0761 [0]
Malta	-0.2317	-1.0143 [2]	-11.1502	-2.5219 [0]
Netherlands	-0.2196	-2.4230 [3]	2.6080	6.3001 [3]***
Norway	-0.1315	-1.3662 [1]	-0.8402	-2.5951 [2]
Portugal	-0.0451	-0.6789 [1]	-1.7831	-3.1461 [2]
Spain	0.0184	0.2422 [0]	-0.5102	-2.1903 [0]
Sweden	-10.0211	-18.7389 [5]***	-10.3814	-19.9976 [8]***
Switzerland	-2.1814	-3.7569 [4]***	-1.9325	-2.5606 [5]
Turkey	-0.4179	-2.6363 [4]*	-4.4140	-2.0793 [4]
UK	-0.1366	-1.1002 [0]	-1.8312	-1.5429 [0]

Critical values	No Trend	Trend
1%	-3.6793	-4.3098
5%	-2.9678	-3.5742
10%	-2.6229	-3.2217

Notes: ***(**)(*) denotes statistical significance at 1%, (5%), (10%). Lag length is reported in parenthesis. Critical values are from MacKinnon (1991).

Table 2: Im *et al* (2003) t-bar panel unit root test

Regions $[N \times T]$	**No trend**		**Trend**	
	Raw data	**Demeaned data**	**Raw data**	**Demeaned data**
North America $[5 \times 21]$	1.6575	2.037	-53.472***	-18.186***
East Europe and the former USSR $[5 \times 21]$	0.399	1.420	-8.898***	-30.572***
Africa $[54 \times 21]$	-20.821***	-20.740***	-17.081***	-17.510***
Far East and Oceania $[42 \times 21]$	-22.832***	-21.261***	-18.555***	-17.513***
Middle East $[14 \times 21]$	-18.856***	-73.851***	-16.482***	-67.797***
Central South America $[42 \times 21]$	-17.956***	-21.378***	-17.370***	-20.503***
Western Europe $[21 \times 21]$	-16.964***	-14.647***	-9.426***	-12.177***

CRITICAL VALUES

	No trend			Trend		
$[N \times T]$	1%	5%	10%	1%	5%	10%
$[5 \times 21]$	-2.50	-2.19	-2.04	-3.13	-2.82	-2.67
$[54 \times 21]$	-1.82	-1.73	-1.69	-2.46	-2.38	-2.33
$[42 \times 21]$	-1.82	-1.73	-1.69	-2.46	-2.38	-2.33
$[14 \times 21]$	-2.08	-1.91	-1.82	-2.71	-2.55	-2.46
$[21 \times 21]$	-2.00	-1.86	-1.78	-2.63	-2.49	-2.42

Note: *** denotes statistical significance at the 1% level. We do not include a 'world panel' because the statistical program used for the t-bar test cannot function for a panel 182x21.

Table 3: Im *et al* (2003) t-bar panel unit root test (excluding those countries for which the ADF test reveals energy consumption to be stationary)

Regions $[N \times T]$	**No trend**		**Trend**	
	Raw data	**Demeaned data**	**Raw data**	**Demeaned data**
East Europe and the former USSR $[3 \times 21]$	-	-	-37.711***	-11.049***
Africa $[38 \times 21]$	-22.700***	-22.182***	-17.072***	-17.596***
Far East and Oceania $[36 \times 21]$	-22.538***	-20.883***	-18.670***	-17.395***
Middle East $[9 \times 21]$	-13.572***	-12.435***	-12.558***	-12.500***
Central South America $[32 \times 21]$	-142.656***	-26.726***	-96.934***	-4.854***
Western Europe $[18 \times 21]$	-14.667***	-6.011***	-11.349***	-2.958***

CRITICAL VALUES

	No trend			Trend		
$[N \times T]$	1%	5%	10%	1%	5%	10%
$[3 \times 21]$	-2.50	-2.19	-2.04	-3.13	-2.82	-2.67
$[38 \times 21]$	-1.82	-1.73	-1.69	-2.46	-2.38	-2.33
$[36 \times 21]$	-1.82	-1.73	-1.69	-2.46	-2.38	-2.33
$[9 \times 21]$	-2.08	-1.91	-1.82	-2.71	-2.55	-2.46
$[32 \times 21]$	-1.83	-1.82	-1.75	-2.46	-2.38	-2.33
$[18 \times 21]$	-2.00	-1.86	-1.78	-2.63	-2.49	-2.42

Note: *** denotes statistical significance at the 1% level. There is no North American panel in this table because at the 5% level the ADF test suggests that per capita energy consumption for each of the countries in North America is nonstationary.

ENDNOTES

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[i] Strictly speaking this would be consistent with unit root hysteresis. See, by way of analogy, the literature on unemployment hysteresis reviewed in Roed (1997).

[ii] See the literature review in Engsted and Bentzen (1997). Some of the more recent studies which have concluded that energy consumption is I(1) include Glasure and Lee (1997), Beenstock et al (1999), McAvinchey and Yannopoulos (2003)

[iii] Im *et al* (2003) assume that $\varepsilon_{it} = \theta_t + \nu_{it}$ where θ_t is a time-specific common effect which indicates the degree of dependence across countries and ν_{it} are i.i.d. idiosyncratic random effects. While cross sectional de-meaning will introduce dependence across the de-meaned error terms, the tests will remain asymptotically valid provided that the ν_{it} are rendered uncorrelated.

[iv] Lee and Strazicich (2003) (2003a) develop panel unit root tests with one and two structural breaks. We do not implement these here given our finding of joint stationarity using the panel data test without a structural break. Given the panels are stationary without structural breaks, introducing one or two structural breaks will reduce the power of the panel data unit root tests.