The energy consumption-GDP nexus: Panel data evidence from 88 countries

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Abstract:

This paper uses panel data from 88 countries to examine the relationship between per capita GDP and per capita energy consumption. The results show that per capita GDP and per capita energy consumption are cointegrated. Also, there is a two-way short-run, long-run and strong causality between the growth of GDP and growth of energy consumption. These results are in contrast to almost all other existing studies.

JEL Codes: C23, O10

I. Introduction

There have been numerous studies on the relationship between energy consumption and GDP. This paper uses panel data from the following 88 countries to examine the relationship: Algeria, Argentina, Australia, Austria, Bangladesh, Belgium, Benin, Bolivia, Brazil, Cameroon, Canada, Chile, China, Colombia, Democratic Republic of the Congo, , Republic of the Congo, Costa Rica, Cote d'Ivoire, Cyprus, Denmark, Dominican, Ecuador, Egypt, El Salvador, Finland, France, Gabon, Georgia, Germany, Ghana, Greece, Guatemala, Haiti, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Latvia, Luxembourg, Malaysia, Malta, Mexico, Morocco, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Portugal, Saudi Arabia, Senegal, Singapore, South Africa, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Syrian Arab Republic, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, UAE, UK, USA, Uruguay, Venezuela, Zambia and Zimbabwe. This paper differs from the previous panel study in two important ways. First, we use the largest dataset by including a panel of 88 countries. Second, for per capita income, we use purchasing power adjusted data. Previous studies such as Lee (2005) and Mahadevan and Asafu-Adjaye (2007) use per capita income in constant US dollars. But, purchasing power parity adjusted data on per capita income are preferable for panel data.

There is a large body of literature that examines the relationship between GDP and energy. One of the first studies was by Kraft and Kraft (1978). They use data for the USA for 1947-1974 to study the causal relationship between gross energy consumption and GNP. They find uni-directional causality flowing from GNP to energy. Their conclusion is that energy conservation would not adversely affect GNP. This study was followed by many other studies such as Akarca and and Long II (1980), Abosedra and Baghestani (1991), Masih and Masih (1997) and Soytas and Sari (2003). These studies employ data for a single country or countries and find varied results. More recent studies use panel data. Al-Iriani (2006) uses panel data for member countries of the Gulf Cooperation Council (GCC). He finds uni-directional causality from GDP to energy consumption. This result suggests that energy conservation policies may be adopted by the GCC without any adverse effects on the growth rate of GDP. Chien-Chiang (2005) uses panel data for 18 developing countries. He finds short-run and long-run uni-directional causality flowing from energy to GDP. His result suggests that energy conservation may harm economic growth in the short-run and the long run. Mahadevan and Asafu-Adjaye (2007) find that for the energy exporting developed countries, there is both short-run and long-run bi-directional causality between economic growth and energy consumption while for the energy exporting developing countries, energy consumption causes economic growth only in the short-run.

II. Data, Methodology and Results

This paper uses panel data for 88 countries for natural logarithms of per capita GDP in constant purchasing power parity terms (denoted by *gdp*) and per capita energy consumption in terms of kilograms of oil equivalent (denoted by *energy*). The first differences of these two variables (which give us the growth rates) are denoted by Δgdp and $\Delta energy$. Annual data are for 1975-2003 for all countries. Thus, we have a balanced panel. All data are from the *World Development Indicators* On-line (August 2008). We use the following panel unit root tests: Im, Pesaran and Shin (2003) test, and Levin, Lin and Chu (2002) test and Fisher type ADF and PP tests proposed by Maddala and Wu (1999). The results of the panel unit root tests for *gdp* and *energy* are in Tables 1 and 2, respectively. We find that both *gdp* and *energy* have unit roots according to LLC, IPS, Fisher ADF and Fisher PP unit root tests. The unit root tests for Δgdp and $\Delta energy$ are in Tables 3 and 4 respectively. Both variables are stationary in their first differences. Since both variables are I(1), we proceed with Pedroni's (1999, 2004) panel cointegration tests. We consider the following bivariate relationships:

$$gdp_{it} = \alpha_i + \delta_t + \beta energy_{it} + \varepsilon_{it} \qquad (1)$$

where α is the country effect, δ is the fixed effect and ε is the residual.

[Tables 1-5, about here]

The results of the panel ADF and panel PP cointegration tests are in Table 5. It shows that *gdp* and *energy* are cointegrated at the 5% level of significance. Since the two variables are cointegrated, we proceed with the dynamic panel VECM causality tests. Like Mahadevan and Asafu-Adjaye (2007), we use Granger causality model with a dynamic error term as proposed by Holz-Eakin, Newey and Rosen (1988). For the VECM tests, we use the error correction model as follows:

$$\Delta gdp_{it} = \Delta\theta_{1j} + \sum_{k}^{m} \theta_{11ik}\,\Delta gdp_{it-k} + \sum_{k}^{m} \theta_{12ik}\,\Delta energy_{it-k} + \lambda_1\,\varepsilon_{it-1} + u_{1it} \qquad (2)$$

$$\Delta energy_{it} = \Delta\theta_{2j} + \sum_{k}^{m} \theta_{21ik}\,\Delta energy_{it-k} + \sum_{k}^{m} \theta_{22ik}\,\Delta gdp_{it-k} + + \lambda_2\,\varepsilon_{it-1} + u_{2it} \qquad (3)$$

Here, k is the lag length, Δ stands for first difference and ε_{it-1} is the lagged residual from the cointegrating equation (1) . To test for short run causality running from the growth of energy consumption to economic growth, we have to whether the coefficients θ_{12ik} are equal to zero. Similarly, the reverse short run causality can be tested by testing the restriction that the coefficients θ_{22ik} are equal to zero. To test for long run causality flowing from the growth of per capita energy consumption to the growth rate of per capita GDP, we test the restriction $\lambda_1 = 0$ in (2). The reverse long run causality is examined by testing the restriction $\lambda_2 = 0$ in (3). For the joint short run/long run causality (also known as the strong Granger causality) running from the growth of per capita energy consumption to growth of per capita GDP, we test the restrictions that θ_{12ik} and λ_1 are equal to zero. The reverse causality is similarly defined.

The results for short run causality, long run causality and strong causality for lags of 1, 2 and 3 are given in tables 6, 7 and 8, respectively. Tests with higher order lags up to 10 were also carried out. The results were the same. The Schwarz Bayesian criterion did not select lags higher than 3.

[Tables 6-8, about here]

The results are clear-cut. We find that there is evidence of short run, long run and strong two-way Granger causality between the growth rates of per capita GDP and energy consumption. These results are in contrast to many other studies which find causality in one direction or the other. Our sample of countries consists of 58 developing and 30 developed countries. Although not reported here, we also performed cointegration and causality tests separately for developing and developed countries. The results are quite similar for those of the panel of 88 countries.

III. Conclusions

We use panel data for 88 countries to test for cointegration between per capita real GDP and per capita energy consumption. We find that these two variables are cointegrated.

Thus, we conduct tests for short-run, long run and strong Granger causality between the growth rates of per capita GDP and energy consumption. We find evidence for two-way short-run, long-run and strong causality between the two variables. These results contradict the results of a number of other studies using panel data.

References:

Abosedra, S. and Baghestani, H. (1991), “New Evidence on the Causal Relationship United States Energy Consumption and Gross National Product,” *Journal of Energy and Development*, vol. 14, pp. 285-292.

Akarca, A.T. and Long II, T.V. (1980), “On the Relationship between Energy and GNP: A reexamination,” *Journal of Energy and Development*, vol.5, pp. 326-331.

Al-Iriani, M.A. (2006), “Energy-GDP Relationship Revisited: An Example from GCC Countries using Panel Causality,” vol. 34, pp. 3342-3350.

Holz-Eakin, D., Newey, W. and Rosen, H. (1988), “Estimating Vector Autoregressions with Panel Data,” *Econometrica*, vol. 56, pp. 1731-1395.

Im, K. S., Pesaran, M. H., and Y. Shin (2003), “Testing for Unit Roots in Heterogeneous Panels,” *Journal of Econometrics*, vol. 115, pp. 53–74.

Kraft, J. and A. Kraft (1978), “On the Relationship between Energy and GNP,” *Journal of Energy and Development*, vol. 3, pp. 401-403.

Lee, C-C (2005), “Energy consumption and GDP in developing countries: A cointegrated panel analysis,” *Energy Economics*, vol. 27, pp. 415-427.

Masih, M. M and R. Masih (1997), “On the Temporal Causal Relationship between Energy Consumption, Real Income and Prices: Some New Evidence from Asian-energy Dependent NICs based on Multivariate Cointegration/Vector Error Correction Approach,” *Journal of Policy Modeling*, vol. 19, pp. 417-440.

Levin, A., Lin, C. F., and C. Chu (2002), “Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties,” *Journal of Econometrics*, vol. 108, pp. 1–24.

Maddala, G. S. and S. Wu (1999), “A Comparative Study of Unit Root Tests with Panel Data and A New Simple Test,” *Oxford Bulletin of Economics and Statistics*, vol. 61, pp. 631–52.

Mahadevan, R. and Asafu-Adjaye, J. (2007), “Energy consumption, economic growth and prices: A reassessment using panel VECM for developed and developing countries,” *Energy Policy*, vol. 35, pp. 2481-2490.

Pedroni, P. (1999) “Critical Values for Cointegration Tests for Heterogeneous Panel with Multiple Regressors” *Oxford Bulletin of Economics and Statistics*, vol. 61, pp. 653-70.

Pedroni, P (2004) “Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis” *Econometric Theory*, vol. 3, pp. 579-25.

Soytas, U. and Sari, R. (2003), "Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets," *Energy Economics*, vol. 25, pp. 33-37.

Table 1. Panel unit root tests for *gdp*

Test type	Test statistic	Probability
LLC	2.5598	0.9948
IPS	3.5493	0.9948
Fisher ADF	133.526	0.9927
Fisher PP	158.062	0.8302

Note: *gdp* stands for the natural logarithm of real per capita GDP in purchasing power parity terms. LLC and IPS stand for Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003), respectively.

Table 2. Panel unit root tests for *energy*

Test statistic	Test statistic	Probability
LLC	-1.1316	0.1289
IPS	1.1362	0.8721
Fisher ADF	153.894	0.8841
Fisher PP	177.885	0.4461

Note: *energy* stands for the natural logarithm of per capita energy consumption. LLC and IPS stand for Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003), respectively.

Table 3. Panel unit root tests for Δgdp

Test type	Test statistic	Probability
LLC	-18.9967	0.0000
IPS	-19.5765	0.0000
Fisher ADF	766.630	0.0000
Fisher PP	1060.00	0.0000

Note: Δgdp stands for the first difference of natural logarithm of real per capita GDP in purchasing power parity terms. LLC and IPS stand for Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003), respectively.

Table 4. Panel unit root tests for Δ*energy*

Test type	Test statistic	Probability
LLC	-21.6111	0.0000
IPS	-20.5191	0.0000
Fisher ADF	800.926	0.0000
Fisher PP	2120.16	0.0000

Note: Δ*energy* stands for the first difference of natural logarithm of per capita energy consumption. LLC and IPS stand for Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003), respectively.

Table 5. Pedroni's panel cointegration tests for *gdp* and *energy*

Test type	Test statistic	Probability
Panel PP	-2.7793	0.0084
Panel ADF	2.8356	0.0072

Note: *gdp* and *energy* stand for the per capita constant GDP in purchasing power terms and per capita energy consumption

Table 6. Short run causality tests between the growth rates of real per capita GDP and per capita energy consumption

Lag	Cause	Effect	F test statistic	Probability
1	$\Delta energy$	Δgdp	630.44	0.0000
1	Δgdp	$\Delta energy$	1949.92	0.0000
2	$\Delta energy$	Δgdp	244.77	0.0000
2	Δgdp	$\Delta energy$	1114.25	0.0000
3	$\Delta energy$	Δgdp	45.10	0.0000
3	Δgdp	$\Delta energy$	594.10	0.0000

Note: Δgdp and $\Delta energy$ stand for the growth rates of real per capita purchasing power parity GDP and per capita energy consumption, respectively.

Table 7. Long run causality tests between the growth rates of real per capita GDP and per capita energy consumption

Lag	Cause	Effect	F test statistic	Probability
1	$\Delta energy$	Δgdp	2432.28	0.0000
1	Δgdp	$\Delta energy$	1664.60	0.0000
2	$\Delta energy$	Δgdp	2025.75	0.0000
2	Δgdp	$\Delta energy$	1309.00	0.0000
3	$\Delta energy$	Δgdp	628.21	0.0000
3	Δgdp	$\Delta energy$	1357.32	0.0000

Note: Δgdp and $\Delta energy$ stand for the growth rates of real per capita purchasing power parity GDP and per capita energy consumption, respectively.

Table 8. Joint short/long (strong Granger) causality tests between the growth rates of real per capita GDP and per capita energy consumption

Lag	Cause	Effect	F test statistic	Probability
1	$\Delta energy$	Δgdp	2145.75	0.0000
1	Δgdp	$\Delta energy$	49450.68	0.0000
2	$\Delta energy$	Δgdp	1263.59	0.0000
2	Δgdp	$\Delta energy$	1258.60	0.0000
3	$\Delta energy$	Δgdp	492.53	0.0000
3	Δgdp	$\Delta energy$	2178.50	0.0000

Note: Δgdp and $\Delta energy$ stand for the growth rates of real per capita purchasing power parity GDP and per capita energy consumption, respectively.