Energy Consumption and Economic Growth: Evidence from COMESA Countries

Chali Nondo[a], Mulugeta S. Kahsai[b], Peter V. Schaeffer[c]

RESEARCH PAPER 2010-1

Abstract

This study applies panel data techniques to investigate the long-run relationship between energy consumption and GDP for a panel of 19 African countries (COMESA) based on annual data for the period 1980-2005. In the first step, we examine the degree of integration between GDP and energy consumption and find that the variables are integrated of order one. In the second step, we investigate the long-run relationship between energy consumption and GDP; our results provide strong evidence that GDP and energy consumption move together in the long-run. In the third step, we estimate the long-run relationship and test for causality using panel-based error correction models and find a long-run bidirectional relationship between GDP and energy consumption. Further, our analyses reveal that causation runs from energy consumption to GDP for low income COMESA countries.

Key Words: Energy consumption, GDP, Panel causality tests, COMESA

JEL Codes: O13, O55

a Ph.D. in Natural Resource Economics, West Virginia University, Corresponding author. Tel: (412)203-1934, Email: chalinondo@yahoo.com

b Post-doctoral Fellow, Regional Research Institute, West Virginia University, Email: Mulugeta.Kahsai@mail.wvu.edu

c Professor, Division of Resource Management, West Virginia University, Email: Peter.Schaeffer@mail.wvu.edu

1. Introduction

Despite being endowed with an array of natural energy resources, such as coal, water, oil, natural gas, and uranium, Sub-Saharan Africa (SSA) has the lowest per capita energy consumption levels in the world (United Nations Economic Commission of Africa, 2004). More than 80 percent of the SSA population relies on traditional energy sources, such as biomass, agricultural residues, and other primitive energy sources, which exacerbate environmental degradation and air pollution related health impacts (Legros et al. 2009). The inadequate provision of modern energy services in SSA has been cited by the United Nations Economic Commission for Africa (UNECA, 2004) as a limiting factor in economic growth and poverty alleviation efforts.

Following the independence of most African countries by the early 1970's, African leaders embraced regional integration as a central element of their development strategies (World Energy Council, 2005). The period marked the beginning of the formation of regional economic communities (RECs) in Africa. The regional economic communities were primarily aimed at promoting unity, enhancing sustainable development, increasing competitiveness, and integrating African countries into the global economy through mutual cooperation among member countries. Our study region, the Common Market for Eastern and Southern Africa (COMESA), which is composed of 19 countries, was formed with the objective of promoting regional integration through trade development.

Within COMESA, there are marked differences in the levels of development, natural energy resource endowment, and energy demand. Cognizant of the competitive advantages that some member states have, COMESA has developed protocols that provide for cooperation in energy development through the pooling of energy resources. In principle, these protocols are aimed at increasing energy accessibility and promoting economic growth. The direction of causation between energy consumption and economic growth has important policy implications for COMESA countries, which pursue the common goal of increasing energy supply through regional energy cooperation and trade.

Understanding the causal relationship between energy consumption and economic growth will help policymakers formulate energy policies for COMESA and its member countries. Given that no attempt has been made in the empirical literature to quantify the causal relationship between energy consumption and economic growth for any regional economic community in Africa, this study aims to fill that gap by employing panel unit root tests, panel cointegration tests, and the dynamic panel error correction model on a panel of the 19 COMESA countries. To date, the few causality studies that have been conducted are based on individual countries and use time series data (Akinlo, 2008; Jumbe, 2004; Odhiambo, 2009; Wolde-Rufael, 2006).

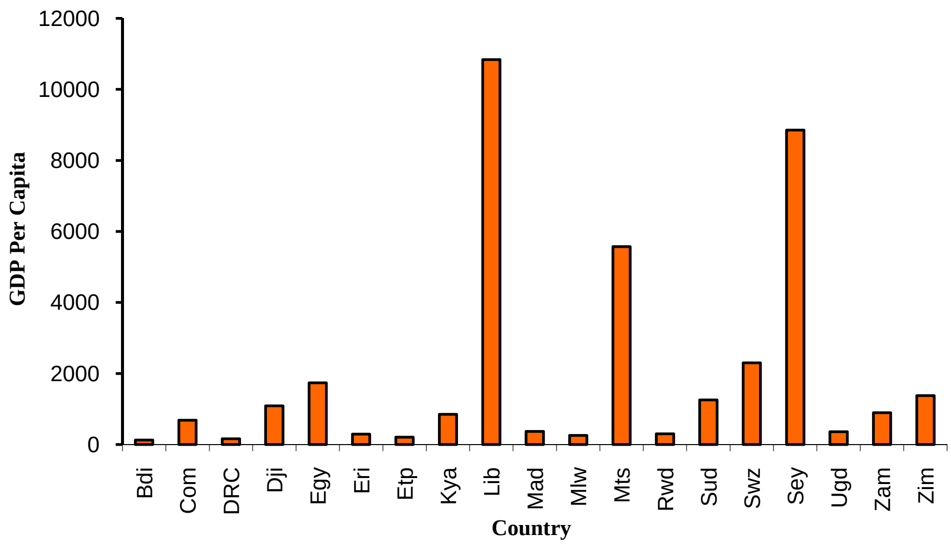
The rest of the paper is organized as follows. Section 2 provides a summary of the economic and energy profile of COMESA countries; section 3 presents the literature review, while section 4 deals with the methodology and data sources. Section 5 provides a discussion of the empirical results, and section 6 contains conclusions and policy recommendations.

2. Economic and Energy Profile

Formed in 1993, COMESA is composed of 19 African countries: Burundi, Comoros, Democratic Republic of Congo, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Swaziland, Sudan, Seychelles, Uganda, Zambia, and Zimbabwe. COMESA is Africa's largest regional economic community, with a combined population of 400 million people and an aggregate GDP of US$361 billion in 2007 (World Bank, 2008). Figure 1 shows that there are very large variations in GDP per capita among member countries, with

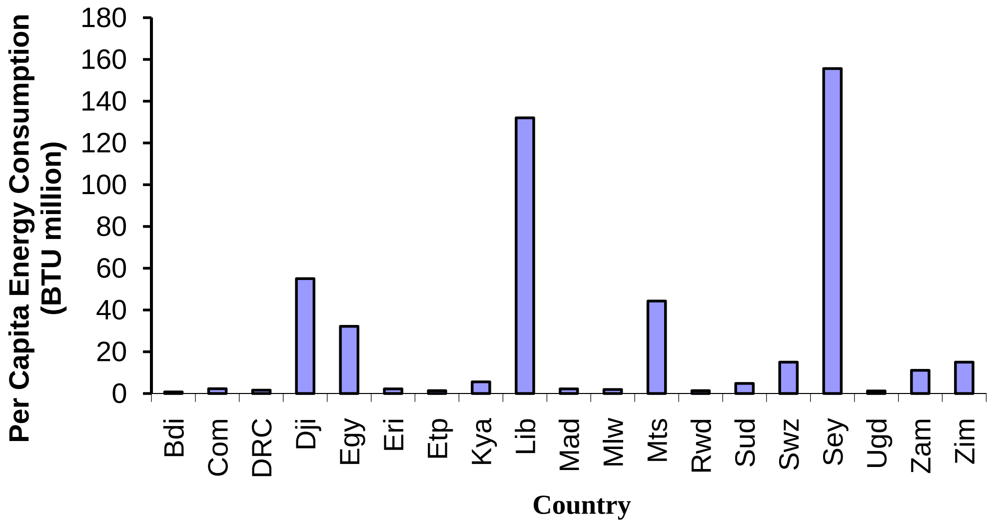
Burundi having the lowest GDP per capita of US $ 127 and Libya having the highest GDP per capita of US $ 10,840 (2007 dollars).

Figure 1: COMESA Countries' GDP Per Capita



Similarly, there are marked differences in per capita energy consumption between COMESA countries (figure 2). Seychelles has the highest per capita energy consumption (155.6 million BTU), followed by Libya (132 million BTU); Burundi has the lowest per capita energy consumption (0.8 million BTU). Most COMESA countries are considered to be among the Least Developed Countries (LDCs) and are also listed as Highly Indebted Poor Countries (HIPC)[i]. Therefore, energy provision will play an important role in poverty alleviation and sustainable development efforts, including achievement of the United Nations' Millennium Development Goals (MDG), which are to eliminate poverty by 2015 (Global Network on Energy for Sustainable Development, 2007). Appendix 1 provides 2007 economic and energy profiles of COMESA member states.

Figure 2: COMESA Countries' Per Capita Energy Consumption (BTU million)



3. Literature Review

Interest in the causal relationship between energy consumption and economic growth was spawned by Kraft and Kraft's (1978) seminal work. Empirical approaches to test the causal relationships between energy consumption and economic growth have been synthesized into four testable hypotheses (Apergis and Payne, 2009). The first hypothesis is that energy consumption is a prerequisite for economic growth given that energy is a direct input in the production process and an indirect input that complements labor and capital inputs (Ebohon, 1996; Toman and Jemelkova, 2003). In this case a unidirectional Granger causality running from energy consumption to GDP means that the country's economy is energy dependent, and that policies promoting energy consumption should be adopted in to stimulate economic growth because inadequate provision of energy may limit economic growth.

The second hypothesis asserts that when causality runs from economic growth to energy consumption, an economy is less energy dependent, and thus energy conservation policies, such as phasing out energy subsidies may not adversely affect economic growth (Mehra, 2006).

Ferguson et al. (2000) find strong evidence that an increase in wealth is positively related to energy consumption. Rosenberg (1998) provides anecdotal evidence that increased energy provision played an important role in the development process of industrialized countries.

The third hypothesis assumes that there is no causality between energy consumption and economic growth (also known as the neutral hypothesis). Thus, policies aimed at conserving energy will not retard economic growth (Asafu-Adaye, 2000; Jumbe, 2004). Finally, the fourth hypothesis assumes a bidirectional relationship between energy consumption and economic growth. The implication of the bidirectional relationship is that energy consumption and economic growth are complementary, and that an increase in energy consumption stimulates economic growth, and vice-versa.

Empirical research on the energy consumption-economic growth nexus has yielded mixed results, mainly because of estimation techniques, choice of study period, and level of development of the country being studied. Panel estimation techniques have recently become popular because of their ability to capture country-specific effects (Pesaran, 2003). In addition, panel estimations have the advantage of improving the degrees of freedom as well as allowing for heterogeneity in the direction and magnitude of the parameters.

Lee (2005) applies panel estimation techniques to 18 developing countries, including sub-Saharan African Kenya and Ghana, and finds evidence of causality running from energy consumption to GDP. Lee et al. (2008) use a panel error correction model to examine the short-run and long-run causality between energy consumption and economic growth for a panel of 22 OECD countries. Their results show a bidirectional relationship between energy consumption, capital stock, and GDP. Similarly, Mehra (2007) applies panel estimation techniques to 11 oil exporting countries and finds evidence of a strong unidirectional causality running from energy consumption to per capita GDP. In a recent effort, Ciarreta and Zarraga (2008) apply the heterogeneous panel cointegration tests and panel system GMM to estimate the causal relationship between economic growth and electricity consumption for 12 European countries. They find no evidence of a short-run causal relationship, but establish a long-run relationship running from electricity consumption to GDP.

Chen et al. (2007) also employ a dynamic panel error correction model on a panel of 10 Asian developing countries. Results from Chen et al. indicate a bidirectional relationship between electricity consumption and economic growth in the long-run, while causality runs from electricity consumption to economic growth only in the short-run. Apergis and Payne (2009, 2010) examine the causal relationship between energy consumption and economic growth for a panel of 11 countries of the Commonwealth of Independent States[ii]. They find unidirectional causation from energy consumption to economic growth in the short-run, and a bi-directional relationship between energy consumption and growth of real output in the long-run. In general the empirical literature shows that energy consumption stimulates economic growth, and vice versa.

4. Methodology and Data

Previous studies have examined the relationship between energy consumption (electricity consumption) and economic growth in Sub-Saharan Africa using country-level data and time-series techniques. In this study, we employ panel estimation techniques to determine the dynamic relationship between energy consumption and economic growth. The methodology adopted in this study uses a three-step procedure. First, panel unit root tests are applied to test the degree of integration between economic growth and energy consumption. Second, panel cointegration techniques (Pedroni, 1999) are applied to determine the long-run relationship between energy consumption and GDP. Finally, a dynamic panel error correction model is applied to determine the direction of causation in the short-run and long-run.

4.1 Panel Unit Root Tests

Panel unit root tests are used to examine the degree of integration between GDP and energy consumption. Such tests have been suggested as an alternative for examining the causal relationship between energy consumption and economic growth in a panel framework. This estimation method is becoming more popular because the asymptotic distribution is standard normal, instead of non-normal asymptotic distributions (Baltagi, 2004).

We test for unit roots using three panel-based methods proposed by Levin, Lin and Chu (2002), hereafter referred to as LLC, Im, Pesaran, and Shin (2003), hereafter referred to as IPS, and Hadri (2000). For each estimation technique, we test for unit roots in the panel using two types of models.[iii] The first model involves estimating the variables in level form with and without a deterministic trend, while the second model involves estimating the first difference of the variables with and without a deterministic trend. The LLC test is the most widely used panel unit root test and can be specified as follows:

$$\Delta y_{it} = \alpha_i + \delta_i y_{it-1} + \sum_{j=1}^{p_i} p_i \Delta y_{it-j} + e_{it} \quad (1)$$

Δ is the first difference operator, y_{it} is the series of observations for country i for $t = 1,.....,T$ time periods. The test has the null hypothesis $H_0 : \delta_i = \delta = 0$ for all i against the alternative of $H_1 : \delta_i = \delta < 0$ for all i, which presumes that all series are stationary. LLC assumes that δ is homogenous across regions and the test is based on the t-bar statistic. The IPS test is an extension of the LLC test and is based on the mean of the individual unit root statistic in the same model used in the LLC test. Unlike the LLC test, the IPS test allows for heterogeneity in the value of δ under the alternative hypothesis. The Hadri test is an LM-based test with the null hypothesis that all series in the panel are stationary.

4.2 Panel Cointegration

The second step of our empirical work involves investigating the long-run relationship between energy consumption and GDP, using the panel cointegration technique due to Pedroni (1999). This technique allows for heterogeneity among individual members of the panel and is an improvement over conventional cointegration tests. Following Pedroni's methodology, the cointegration relationship we estimate is specified as follows:

$$LGDP_{it} = \alpha_i + \delta_t + \beta_i LEC_{it} + \varepsilon_{it} \qquad (2)$$

LEC and $LGDP$ are the natural logarithms of the observable variables, $t = 1,.....T$ are time periods; $i = 1,.....N$ are panel members; α_i denotes country-specific effects, δ_t is the deterministic time trends, and ε_{it} is the estimated residual.

The estimated residual indicates the deviation from the long-run relationship. With the null of no cointegration, the panel cointegration is essentially a test of unit roots in the estimated residuals of the panel. Pedroni (1999) shows that there are seven different statistics for the cointegration test. They are the panel v-statistic, panel ρ-statistic, Pedroni Panel (PP)-statistic, panel Augmented Dickey-Fuller (ADF)-statistic, group rho-statistic, group PP-statistic, and group ADF-statistic. The first four statistics are known as panel cointegration statistics and are based on the within approach. The last three statistics are group panel cointegration statistics and are based on the between approach. In the presence of a cointegrating relationship, the residuals are expected to be stationary. The panel v-test is a one-sided test, with the null of no cointegration being rejected when the test has a large positive value. The other tests reject the null hypothesis of no cointegration when they have large negative statistics.

4.3 Panel Granger Causality Tests

If the variables LGDP and LEC are cointegrated, then causality exists between the two series, but this does not indicate the direction of causality. To test for Granger causality in the long-run relationship, we employ a two-step process. The first step involves the estimation of the residuals from the long-run model (equation 2), while the second step involves fitting the estimated residuals as a right-hand variable in a dynamic error correction model. The dynamic error correction model used is specified as follows:

$$\Delta LGDP_{it} = \alpha_{\gamma i} + \beta_{\gamma i} ECT_{it-1} + \gamma_{y1i} \Delta LEC_{it-1} + \gamma_{y2i} \Delta LEC_{it-2} + \delta_{y1i} \Delta LGDP_{it-1} + \delta_{y2i} \Delta LGD_{it-2} + \varepsilon_{yit} \quad (3)$$

$$\Delta LEC_{it} = \alpha_{ei} + \beta_{ei} ECT_{it-1} + \gamma_{e1i} \Delta LEC_{it-1} + \gamma_{e2i} \Delta LEC_{it-2} + \delta_{e1i} \Delta LGDP_{it-1} + \delta_{e2i} \Delta LGDP_{it-2} + \varepsilon_{eit} \quad (4)$$

Δ denotes the difference operator; ECT is the lagged error correction term derived from the long-run cointegrating relationship; β_y and β_e are adjustment coefficients; and ε_y and ε_e are disturbance terms.

We can identify the sources of causation by testing for the significance of the coefficients on the lagged dependent variables in equations (3) and (4). To evaluate weak Granger causality (short-run), we first test $H_0 : \gamma_{e1i} = \gamma_{e2i} = 0$ for all i in equation (3), or $H_0 : \delta_{e1i} = \delta_{e2i} = 0$ for all i in equation (4). Masih and Masih (1996) interpret weak Granger causality as the short-run causality in the sense that the dependent variable responds only to the short-term shocks to the stochastic environment. On the other hand, long-run causality can be tested by examining the significance of the coefficient of the error correction term in equations (3) and (4). In each equation, change in the endogenous variable is caused not only by their lags, but also by the previous period's disequilibrium in level.

The coefficients on ECT show how quickly deviations from the long-run equilibrium are eliminated following changes in each variable. The significance of β_{yi} indicates the long-run relationship of the cointegrated process; hence movements along this path are considered permanent. To examine the long-run causality relationship, we test $H_0 : \beta_{yi} = 0$ for all i in equation (3) or $H_0 : \beta_{ei} = 0$ for all i in equation (4). For example, if β_{yi} is zero, then $LGDP$ does not respond to deviations from the long-run equilibrium in the previous period.

When $\beta_{yi} = 0$ and $\beta_{ei} = 0$ for all i there is no Granger causality both in GDP and energy consumption in the long-run. The sources of causation will be determined by testing the joint hypothesis of $H_0 : \beta_{yi} = \gamma_{e1i} = \gamma_{e2i} = 0 \quad \forall i$ in equation (3) or $H_0 : \beta_{ei} = \delta_{e1i} = \delta_{e2i} = 0 \quad \forall i$ in equation (4). This is referred to as a strong Granger causality test. The joint test indicates which variables are most responsible for short-run adjustment to re-establish long-run equilibrium, following a shock to the system (Asafu-Adjaye, 2000). If there is no causality in either direction, the neutrality hypothesis holds.

4.4 Data

Data used in this analysis are pooled annual time series for nominal GDP (hereafter referred to as GDP) and energy consumption (EC hereafter) for 19 COMESA countries for the period 1980 to 2005. BTU of energy is used as a proxy for energy consumption (EC), and this data is obtained from United States Energy Information Administration (EIA). GDP data come from the International Monetary Fund' (IMF) *World Economic Outlook 2008*. All variables used in the estimation are in natural logarithm form.

5. Results

5.1 Panel Unit Root Results

The results of the IPS, LLC and Hadri panel unit root tests for the series LGDP and LEC are shown in table 1. The unit root statistics reported are for the level and first differenced series of LGDP and LEC. At the 1% significance level the statistics show that the two series have a panel unit root. As can be seen from table 1, with the exception of the LLC and Hadri tests, the IMS fail to reject the null hypothesis in level form. Overall, all three panel unit test techniques reject the null hypothesis for the differenced series and thus show that LGDP and LEC are integrated of order one.

Table 1: Panel Unit Root Results for LGDP and LEC, 1980-2005

Variable	IPS Test		LLC Test		Hadri Test	
	No Trend	Trend	No Trend	Trend	No Trend	Trend
LGDP	0.7621	0.7461	-3.017^{**}	-0.9799	15.078^{***}	8.362^{***}
LEC	0.531	-1.115	-1.935^{*}	-1.685^{*}	11.821^{***}	8.768^{***}
ΔLGDP	-12.016^{***}	-10.819^{***}	-10.355^{***}	-8.463^{***}	3.489^{***}	6.720^{***}
ΔLEC	-16.296^{***}	-15.782^{***}	-18.0830^{***}	-16.1108^{***}	3.983^{***}	7.0623^{***}

Note: ***, **, and * indicate rejection of the null hypothesis at the 1%, 5%, and 10% significance levels, respectively.

5.2 Panel Cointegration Results

Table 2 reports the results of the panel cointegration. The tests reject the null of no cointegration, and thus we can conclude that GDP and energy consumption move together in the long-run. The implication is that there is a long-run relationship between energy consumption and GDP for a cross section of the countries after allowing for a country-specific effect.

Table 2: Panel Cointegration Results, 1980-2005

Statistic	Intercept and no time trend	Intercept and time trend
Panel v-stat	−0.9450	5.5994***
Panel Rho-stat	−1.2997	0.8346
Panel PP-stat	−3.2081**	0.1221
Panel ADF-stat	0.4158	1.4750
Group Rho-stat	0.3434	1.8277*
Group PP-stat	−2.0133*	0.3005
Group ADF-stat	0.9422	0.6103

Note: ***, **, and * indicate rejection of the null hypothesis at the 1%, 5%, and 10% significance levels, respectively.

5.3 Granger Causality Results

Table 3 summarizes the causality estimates for the three tests specified in section 3.3. In neither the GDP nor the energy consumption equations are the coefficients for energy consumption and GDP significant. This implies that there is no short-run transitory relationship running from energy consumption to GDP or from GDP to energy consumption in the COMESA countries during the study period. Furthermore, the finding that there is no short-run transitory relationship between GDP and energy consumption in either direction supports the neutrality hypothesis that GDP has a neutral effect on energy consumption and vice versa.

However, in both cases the coefficient of the error correction term (*EC*) is significant, which is evidence of a long-run permanent relationship between energy consumption and GDP. In addition, in both the GDP and the energy consumption equation, the joint test for the short-run and long-run relationship is significant. From these findings we conclude that even though both GDP and energy consumption do not respond to short-term shocks, they are strongly interdependent in the long-term.

Table 3: Results of Panel Causality Tests (All COMESA Countries)

Dependent Variable	Sources of Causation				
	Short Run		Long-run	Joint (short run/ long run)	
	ΔLGDP	*ΔLEGC*	*ECT(-1)*	*ΔLGDP, ECT(-1)*	*ΔLEGC, ECT(-1)*
ΔLGDP	-	F=2.08	9.31***	-	F= 4.9**
ΔLEGC	F = 0.59	-	F= 17.76***	F = 6.06***	-

*Significant at 10%, **Significant at 5%, and ***Significant at 1%,

Additional estimations are performed to test the short and long-run relationship between GDP and energy consumption for low income COMESA countries. As can be seen from table 4, the coefficient of energy consumption in the GDP equation is highly significant in the short-run as well as the long-run. This finding implies that energy consumption stimulates GDP growth, in the short and long-run for low income countries in COMESA. Turning to the energy consumption equation, estimation results indicate that causation runs from GDP to energy consumption only in the long-run. This means that for low income COMESA countries energy consumption is vital for their economic development.

Table 4: Results of Panel Causality Tests (Low Income COMESA Countries)

Dependent Variable	Sources of Causation				
	Short Run		Long-run	Joint (short run/ long run)	
	ΔLGDP	*ΔLEGC*	*ECT(-1)*	*ΔLGDP, ECT(-1)*	*ΔLEGC, ECT(-1)*
ΔLGDP	-	F=2.4*	3.96**	-	F= 2.9**
ΔLEGC	F = 0.469	-	F12.66***	F = 4.51***	-

*Significant at 10%, **Significant at 5%, and ***Significant at 1%,

These findings suggest that reducing energy consumption for COMESA countries could lead to a decline in economic growth. In particular, low income COMESA countries which have low energy thresholds will need more energy to develop their economies and engage in regional trade. In the last five years, the world has witnessed volatility of energy prices. In light of the fact that many COMESA member countries are highly indebted poor countries and have energyintensive economies, volatile energy prices may negatively affect their long-term development goals. A study by the International Energy Agency (IEA) shows that a $10 increase in oil price would result in more than 3% loss in GDP for oil-importing Sub-Saharan countries (IEA, 2004). These findings suggest that COMESA countries need to formulate policies that guarantee a continuous flow of affordable energy in order to develop their economies and catch-up with the rest of the world.

6. Conclusions and Policy Recommendations

The purpose of this study was to test for Granger causality between energy consumption and GDP in COMESA countries using panel causality tests. From the test results, we conclude that in the short-run the neutral hypothesis holds, but in the long-run, there is strong causation running in both directions for the 19 countries in our study. In low income COMESA countries, there is a short-run causation that runs from energy consumption to GDP. From the foregoing, it can be inferred that policies that stimulate both energy consumption and GDP growth should be formulated and implemented.

It is reasonable to conclude that one factor explaining COMESA countries' poor economic growth is the lack of investments in energy infrastructure and services. Thus, the current low investment in energy infrastructure may be an obstacle that may prevent some COMESA member states from reaching the Millennium Development Goals. As a consequence, energy related problems are and will be crucial policy issues for COMESA countries. Against this background, relying on volatile energy markets will not guarantee sustainable development and greater regional energy self-sufficiency should be one of the major objectives of COMESA countries. The significant hydro-electric and geothermal potentials, and the proven oil and gas reserves in COMESA countries can be tapped to reliably supply low-cost energy to the region and then improve energy supply, in general.

Acknowledgments

We acknowledge partial support for this research from the West Virginia Agricultural and Forestry Experiment Station and from the Regional Research Institute. Dale Colyer reviewed an earlier version of this article. His questions and suggestions have significantly improved this article. The usual caveat applies.

References

Akinlo, A. E. “Energy consumption and Economic Growth: Evidence from 11 Sub-Sahara African Countries.” *Journal of Energy Economics* 30(2): 2391-2000.

Apergis, N., and J. E. Payne (2010). “The Emissions, Energy Consumption, and Growth Nexus: Evidence from the Commonwealth of Independent States.” *Energy Policy* 38(1): 650-655.

_____, (2009). “Energy Consumption and Economic Growth: Evidence from the Commonwealth of Independent States.” *Journal of Energy Economics* 31(5): 641-647.

Asafu-Adjaye, J. (2000) “The Relationship between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries.” *Journal of Energy Economics* 22 (6): 615-625.

Baltagi, B.H. (2004). *Panel Data: Theory and Applications.* Physica-Verlag Heidelberg, Germany.

Chen, S-T., H-I, Kuo, and C-C, Chen. (2007). “The Relationship between GDP and Electricity Consumption in 10 Asian countries.” *Journal of Energy Policy* 35 (4): 2611-2621.

Ciarreta, A., and A. Zarraga. (2008) “Economic Growth and Electricity Consumption in 12 European Countries: A Causality Analysis Using Panel Data.” Working Paper, Dept. of Applied Economics III (Econometrics and Statistics), University of the Basque Country.

Ebohon, O.J. (1996). “Energy, Economic growth and Causality in Developing Countries: A Case Study of Tanzania and Nigeria.” *Journal of Energy Policy* 24(5): 447–453.

Ferguson, R., W. Wilkinson, and R. Hill (2000). “Electricity Use and Economic Development.” *Journal of Energy Policy* 28(13): 923–934.

Global Network on Energy for Sustainable Development. (2007). *Reaching the Millennium Development Goals and Beyond: Access to Modern Forms of Energy as a Prerequisite*. http://www.gnesd.org/Downloadables/MDG_energy.pdf (accessed December 10, 2008).

Hadri, K. (2000). "Testing for Stationarity in Heterogeneous Panel Data." *Journal of Econometrics* 3(2): 148-161.

IEA. (2004). "The Impact of High Oil Prices on the Global Economy", Economic Analysis Division Working Paper, OECD/IEA, Paris.

Jumbe, C.B.L. (2004). "Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi." *Journal of Energy Economics* 26(1): 61-68.

Kraft, J. and A. Kraft. (1978). "On the Relationship between Energy and GNP. *Journal of Energy Development* 3, 401–403.

Im, K.S., M.H. Pesaran, and Y. Shin. (2003). "Testing for Unit Roots in Heterogeneous Panels." *Journal of Econometrics* 115 (1): 53-74.

Lee, C.C. (2005). "Energy Consumption and GDP in Developing Countries: A Cointegrated Analysis." *Journal of Energy Economics* 27 (3): 415-427.

Lee, C.C., P. C. Chang, and P. F. Chen. (2008). "Energy-Income Causality in OECD Countries Revisited: The Key Role of Capital Stock." *Journal of Energy Economics* 30(5): 2359-2373.

Legros, G., I. Havet, N. Bruce, and S. Bonjour. (2009). "The Energy Access Situation in Developing Countries: A Review Focusing on The Least Developed Countries and Sub-Saharan Africa." United Nations Development Programme, New York.

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

Masih, A.M.M., R. Masih. (1996). "Energy Consumption, Real Income and Temporal Causality: Results from A Multi-Country Study Based on Cointegration and Error-Correction Modeling Techniques." *Journal of Energy Economics* 18(3), 165–183.

Mehra, M. (2006). "Energy Consumption and Economic Growth: The Case of Oil Exporting Countries." *Journal of Energy Policy* 35 (5): 2939-45.

Odhiambo, N. M. (2009). "Electricity Consumption and Economic Growth in South Africa: A Trivariate Causality Test." *Journal of Energy Economics* 31(5): 635-640

Pedroni, P. (1999). "Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors." *Oxford Bulletin of Economics and Statistics* 61: 653-670.

Rosenberg, N. (1998). "The Role of Electricity in Industrial Development." *The Energy Journal* 19(2): 7–24.

Toman, T., B. Jemelkova. (2003). "Energy and Economic Development: An Assessment of the State of Knowledge." Discussion Paper 03-13, Resources For The Future.

Wolde-Rufael, Y. (2005). "Energy Demand and Economic Growth: The African Experience." *Journal of Policy Modeling* 27 (8): 891-903.

United Nations Economic Commission for Africa (UNECA). 2004. *Economic Report on Africa 2004: Unlocking Africa's Trade Potential*. http://www.uneca.org/cfm/2004/overview.htm (accessed December 3, 2008).

World Energy Council (WEC). (2005). "Regional Energy Integration in Africa." WEC Report, London, UK.

Appendix 1: 2007 Economic and Energy Profile of COMESA Countries

Name	GDP Current Prices (Billion $)	GDP Per Capita ($)	Population 2006 (million)	Energy Intensity (BTU/$ GDP)	Per Capita Consumption (BTU Million)	Income Category	Other
Burundi	1.0	127	.08	1,385	0.8	Lower income	HIPC
Comoros	0.4	682	0.69	3,342	2.3	Lower income	HIPC
DR Congo	9.9	161	62.38	6,124	1.6	Lower income	HIPC
Djibouti	0.8	1090	0.49	15,456	55.0	Lower Middle income	
Egypt	127.9	1739	78.95	6,551	32.2	Lower Middle income	
Eritrea	1.4	293	4.79	3,152	2.2	Lower income	HIPC
Ethiopia	15.9	206	74.78	1,517	1.4	Lower income	HIPC
Kenya	29.5	851	35.89	3,393	5.6	Lower income	
Libya	66.0	10840	5.9	13,048	132	Upper middle income	
Madagascar	7.3	371	18.87	2,362	2.2	Lower income	HIPC
Malawi	3.4	257	13.28	1,834	1.9	Lower income	HIPC
Mauritius	7.0	5572	1.25	2,779	44.3	Upper middle income	
Rwanda	2.8	303	9.64	1,231	1.4	Lower income	HIPC
Sudan	46.7	1257	38.57	3,148	4.8	Lower middle income	HIPC
Swaziland	2.7	2299	1.14	3,722	15.0	Lower middle income	
Seychelles	0.7	8852	0.08	13,833	155.6	Upper middle income	
Uganda	11.1	360	29.21	1,130	1.2	Lower income	HIPC
Zambia	10.9	895	11.29	9,961	11.1	Lower income	HIPC
Zimbabwe	16.2	1378	12.24	7,295	15.0	Lower income	
Total	361.6	896.6					

Source: Energy Information Administration (EIA) of U.S. Dept. of Energy except for GDP and GDP per capita. Both are from the official COMESA website (http://www.comesa.int/).

[i] Information about HIPC countries and standards are available from the International Monetary Fund at http://www.imf.org/external/np/hipc/index.asp .

[ii] The Commonwealth of Independent States was founded in 1991 and includes eleven now independent former Soviet Republics.

[iii] For a detailed discussion of panel unit root tests, see Levin, Lin and Chu; Hadri (2000); and Im, Pesaran, and Shin (1997; 2003).