Energy Consumption and Economic Growth:
Evidence from COMESA Countries

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia, January 31-February 3, 2009

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 by employing three panel unit root tests 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. Results overwhelming show 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. The results indicate that long-run and short-run causality is unidirectional, running from energy consumption to GDP.

Key Words: energy consumption, GDP, panel unit root, panel cointegration, panel causality tests

JEL Codes: O13, O55

1. Introduction

Although nature has endowed sub-Saharan Africa with an array of natural energy resources such as wind, coal, water, oil, wood and solar, a large number of these resources have remained unexploited for decades. Consequently, many African countries face serious energy deficits due to poor investment in energy infrastructure. The inadequate provision of energy services in Sub-Saharan Africa has been cited by the United Nations Economic Commission for Africa (UNECA, 2004) as a limiting factor to economic growth and poverty alleviation efforts. Predominantly, the rural population and the urban poor are the ones who do not have access to modern energy services; a situation which has resulted in majority of the population to live on less than $1 a day (GNESD, 2007). In order to meet daily energy needs, majority of the population relies on traditional biomass sources such as wood, agricultural residues, and other primitive energy sources and thus exacerbating the problems of environmental and land degradation.

The post-independence period in the African continent started in the late 1960's and led many African leaders to embrace regional integration as a central element of their development strategies (UNECA, 2004). This period marked the beginning of the formation of regional economic communities (RECs) in Africa. The formation of RECs was aimed at, among other things, to promote unity, enhance sustainable development, increase competitiveness and integrate African countries into the global economy through mutual cooperation among member countries. With regard to energy provision, many African countries have recognized the importance of regional energy cooperation and integration to address the energy deficit. For example, the Common Market for Eastern and Southern Africa (COMESA) composed of 20 countries was formed with the objective of promoting regional integration through trade development. Majority of COMESA member countries are considered to be the Least Developed Countries (LDCs) and are also listed as Highly Indebted Poor Countries (HIPC).

Within the COMESA region, there is insufficient investment in the energy sector to the extent that majority of commercial energy infrastructure is still underdeveloped. In line with the Millennium Development Goals (MDGs), many COMESA member countries have recognized that accessibility to affordable energy services is a prerequisite to poverty alleviation, as well as a necessary condition for sustainable economic growth. Thus, COMESA is promoting regional energy integration with the view to enhancing provision of energy services to millions of people within the region. Implicit in this policy goal is that increased energy consumption per capita can help achieve social development and enhance economic growth.

Therefore, if appropriate energy policies are to be formulated, it is important to determine the causal relationship between energy consumption and economic growth for COMESA. The direction of causation between energy consumption and economic growth has important implications for COMESA countries which share the common goal of increasing energy supply through regional energy integration development. This is cognizant of the fact that some of the member countries have a comparative advantage in terms of energy resources.

The causality relationship between energy consumption and economic growth has spawned a lot of interest among economists. In principal, this interest stems from the inherent policy implications. Overall, the findings indicate that there is a strong relationship between energy consumption and economic growth. For example, a unidirectional Granger causality running from energy consumption to GDP entails that the country's economy is energy dependent and therefore, energy consumption is a prerequisite for economic growth (Jumbe, 2004). In other words, inadequate provision of energy may limit economic growth or may result in poor economic performance. However, when causality runs from economic growth to energy consumption, this indicates that an economy is less energy dependent and thus energy conservation policies, such as phasing out energy subsidies may not adversely affect economic growth (Mehara, 2006). On the other hand, if there is no causality between energy consumption and economic growth (also known as the neutral hypothesis), this implies that policies to enhance energy consumption will not increase economic growth.

Despite the burgeoning volume of literature on the causal relationship between energy consumption and economic growth, no attempt has being made to quantify the direction of causality between energy consumption and economic growth for any regional economic community in Africa. The few causality studies that have been conducted are based on individual countries and use time series data. Results from these studies have been mixed, mainly because of the different econometric methods used. Jumbe (2004) examined the causality relationship between GDP and per capita consumption of electricity for Malawi and found a bidirectional relationship. Wolde-Rufael (2006) investigated the long-run relationship between energy use per capita and per capita real GDP for 19 African countries and found mixed results, ranging from negative causality to bidirectional causality.

As already indicated, previous causality studies have been done at country level and use time series data. Panel estimation techniques are less applied in the study for the causal relationship between energy consumption and GDP (Ciarreta and Zarraga, 2008). Lee (2005) applies panel estimation techniques on 18 developing countries, which includes two sub-Saharan African countries (Kenya and Ghana) and finds evidence of causality running from energy consumption to GDP. Mehra (2007) applies a similar technique for 11 oil exporting countries and finds evidence of a unidirectional strong causality running from energy consumption to per capita GDP. Recently, 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.

The purpose of this study is to examine the dynamic relationship between energy consumption (BTU of energy) and Purchasing Power Parity (PPP) of GDP (as a proxy for economic growth) using a panel for 19 COMESA countries.[1] These include Burundi, Comoros, Democratic Republic of Congo, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Swaziland, Sudan, Seychelles, Uganda, Zambia, and Zimbabwe. This will be accomplished by employing panel unit root tests, panel cointegration tests, and finally the dynamic error correction model. The rest of the paper is organized in the following manner: section 2 gives a summary of the economic and energy profile of COMESA countries; section 3 presents the methodology and data sources; section 4 presents the results and the discussion; and section 5 gives the conclusions and policy recommendations.

2. Economic and Energy Profile

COMESA has a population of over 380 million people with gross domestic product (GDP) of US $361 billion. GDP per capita varies significantly among the nineteen 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 summarizes the 2007 GDP per capita for the nineteen countries and figure 2 shows the per capita consumption of energy for COMESA countries. Seychelles has the highest per capita consumption (155.6 BTU of energy), followed by Libya (132 BTU of energy) and Burundi having the lowest per capita consumption.

[1] Due to data problems, our analysis does not include Eritrea; hence the panel is reduced to 18 countries.

Overall, COMESA countries can be classified under three income groups: lower income; lower middle income; and upper middle income.[2] Given the fact that many COMESA countries are pursuing MDGs, achievement of these goals will also entail addressing the energy deficit the region faces.

Figure 1: COMESA Countries' GDP Per Capita

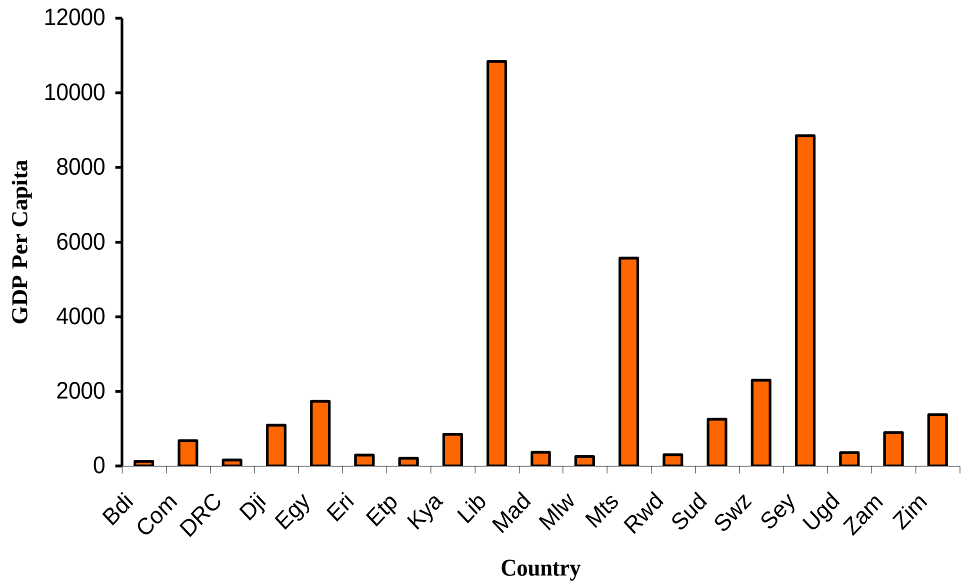
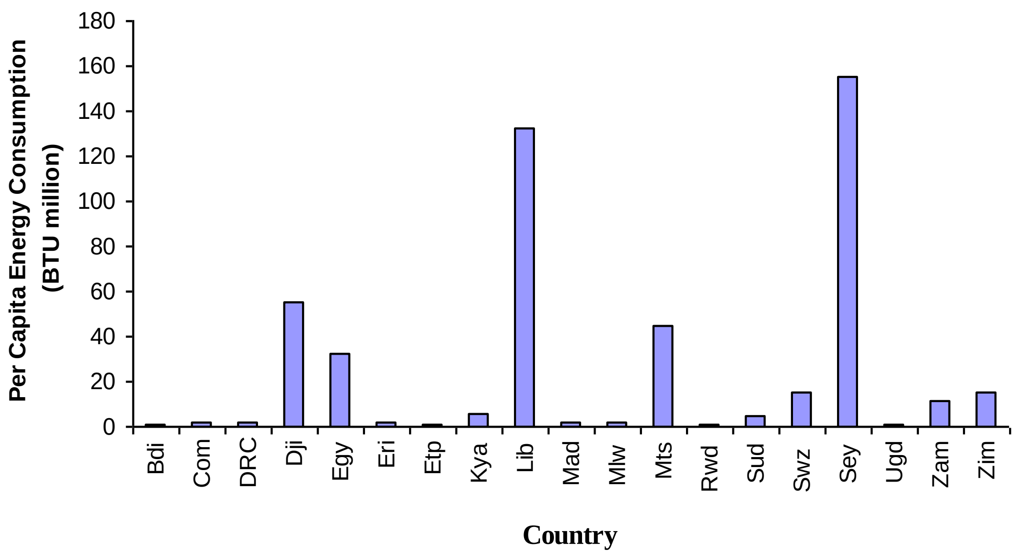


Figure 2: COMESA Countries' Per Capita Energy Consumption (BTU million)



[2] Appendix 1 gives a snapshot of the 2007 economic and energy profile for COMESA countries.

3. Methodology and Data Sources

3.1 Panel Unit Root Tests

The panel unit root test will be used to examine the degree of integration between GDP and energy consumption. Panel unit root tests have been suggested as an alternative test for examining the causal relationship between energy consumption and economic growth in a panel framework (Baltagi, 2004). This estimation method is becoming more popular because their asymptotic distribution is standard normal instead of non-normal asymptotic distributions. Pesaran (2003) point out that the power of the unit root test can be augmented by using cross-sectional information. This is because panel unit root tests are able to capture the country-specific effects and allows for heterogeneity in the direction and magnitude of the parameters.

We test for unit roots using the 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.[3] The first model has a constant and a deterministic trend stationarity and the second model has only a constant and no trend. The LLC test is the most widely used panel unit root test and can be specified as follows:

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

Where Δ is the first difference operator, y_{it} is the series of observations for country i, $t = 1,.....,T$ time periods. The test has the null hypothesis of $\delta_i = \delta = 0$ for all i against the alternative of $H_1 = \delta_i = \delta < 0 \;\; i$, which presumes that all series are stationary. LLC assumes that

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

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 and is based on 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. Hadri test is an LM-based test assumes under the null hypothesis that all the series in the panel are stationary.

3.2 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 thus an improvement over conventional cointegration tests. Following the methodology employed by Pedroni (1999), the cointegration relationship we estimate is specified as follows:

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

Where EC and GDP are the observable variables and are in natural logarithm form, $t = 1,.....T$ time periods; $i = 1,.....N$ members of the panel; α_i is the 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) has shown that there are seven different statistics for this test. They are panel v-statistic, panel ρ-statistic, panel PP-statistic, Panel ADF-statistic, group rho-statistic, group PP-statistic, and group ADF-statistic. The first four statistics are known as panel cointegration statistics 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 statistics reject the null hypothesis of no cointegration when they have large negative.

3.3 Panel Granger causality tests

If the two variables (LGDP and LEC) are cointegrated this implies that causality exists between the two series; however 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) and 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:

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

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

Where 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 the weak Granger weak causality, we first test $H_A : \gamma_{e1i} = \gamma_{e2i} = 0$ for all i in equation (3), or $H_A : \delta_{e1i} = \delta_{e2i} = 0$ for all i in equation (4). Masih and Masih (1996) interpreted the 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. The long-run causality can be tested by looking at the significance of the coefficient of the error correction term in eqns (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 the ECT represent how fast 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 for the long-run causality relationship, we test $H_A : \beta_{yi} = 0$ for all i in eqn (3) or $H_A : \beta_{ei} = 0$ for all i in eqn (4). For example, if β_{yi} is zero, then $LGDP$ does not respond to deviations from the long-run equilibrium in the previous period. $\beta_{yi} = 0$ and $\beta_{ei} = 0$ for all i is equivalent to both Granger non-causality in the long-run and the weak exogeneity (Mehra, 2007).

The sources of causation will be done by testing the joint hypothesis of $H_A : \beta_{yi} = \gamma_{e1i} = \gamma_{e2i} = 0 \ \ \forall i$ in equation (3) or $H_A : \beta_{ei} = \delta_{e1i} = \delta_{e2i} = 0 \ \ \forall i$ in equation (4). This is referred to as a strong Granger causality test. The joint test indicates which variables bear the burden of 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.

3.4 Data

Data used in this analysis are annual time series on PPP GDP (hereafter referred to as GDP) and energy consumption (referred to as EC hereafter) for 19 COMESA countries for the years 1980 to 2005. GDP data is obtained from the IMF, World Economic Outlook 2008. Energy consumption (EC) is measured as a BTU of energy. Energy data is obtained from U.S., Energy Information Administration (EIA). All variables used are in natural logarithm.

4. Results

4.1 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 a 1% significance level the statistics confirm that the two series have a panel unit root. Overall, all the 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 or

Table 1: Panel unit root results for LGDP and LEC

Variables	IPS		LLC		Hadri	
	No Trend	Trend	No Trend	Trend	No Trend	Trend
LGDP	3.1105	2.3825	-2.6682***	1.9016	15.5183	10.3946***
LEC	2.3595	-0.5003	-0.43-70	-0.3028	14.1182***	8.2972***
ΔLGDP	-6.7406***	-5.7859***	-4.2159	-3.9347***	6.9080***	5.3095***
ΔLEC	-11.3957***	-10.1234***	-9.4216***	-7.5754***	4.0992***	8.7409***

*** Indicate rejection of the null hypothesis at the 1% significance levels.

4.2 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

Statistic	No time effects	Time effects
Panel v-stat	-0.583343	-3.061821**
Panel Rho-stat	-1.069962	0.844190
Panel PP-stat	-3.896978***	-1.839384
Panel ADF-stat	-0.991902	1.349837
Group Rho-stat	0.142056	3.695465***
Group PP-stat	-3.588435***	-0.404647
Group ADF-stat	-1.033349	2.645910**

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

4.3 Granger Causality results

Table 3 summarizes results for the causality tests specified in section 3.3. It is clear from the results that the coefficients of GDP and ECT are not significant individually or jointly in the energy consumption equation. This indicates that there is no short-run or long-run causation running from GDP to energy consumption in the COMESA countries during the study period. GDP has a neutral effect on energy consumption. Table 3 also shows that the coefficients for energy consumption and ECT in the GDP equation are significant at the 10% and 5% level, respectively, and the two variables are jointly statistically significant at the 1% level. This clearly shows that there is a unidirectional Granger Causality running from energy consumption to GDP in the short and long-run.

Table 3: Results of Panel Causality Tests

Dependent	Sources of Causation				
	Short Run		Long-run	Joint (short run/ long run)	
Variable	*ΔLGDP*	*ΔLEC*	*ECT(-1)*	*ΔLGDP, ECT(-1)*	*ΔLEC, ECT(-1)*
ΔLGDP	-	F=2.36 *	2.40 **	-	F= 3.38 ***
ΔLEC	F = 1.89	-	F= -1.10	F = 1.387	-

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

These results partially confirm past findings of Wolde-Rufael (2005) in his study of the causality between energy consumption and GDP for 19 African countries. Wolde-Rufael found causality running from energy use to economic growth in three countries, causality running in the opposite direction in five countries, bi-directional in two countries, and no causality in the rest nine countries.

5. Conclusions and policy implications

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 unidirectional Granger causality runs from energy consumption to GDP for the 18 countries in our study. This implies that reducing energy consumption could lead to a decline in economic growth. This is not surprising given the fact that majority of the countries in COMESA and other parts of sub-Saharan Africa have very low per capita energy consumption. As it is already known, low energy consumption can result to limitation of economic opportunities. Thus, we infer that the slow economic growth and high poverty levels that has been witnessed in many of these African countries is attributable to low per capita energy consumption. The findings of this study further suggest that long term development goals, such as achievement of MDGs may be hampered due to the sub-optimal investment in energy infrastructure.

From the foregoing discussion, it is clear that energy related problems within the COMESA region will require practical policy actions. In order to stimulate economic growth and address the poverty issues, COMESA countries need to look for alternative sources of energy that would guarantee a sustainable flow of energy. Considering the fact that the region is endowed with renewable energy resources, COMESA should focus on formulating policies that would promote development and expanded supply of clean energy based on renewable resources. In addition, COMESA should formulate appropriate policies and legislation that would attract investors who can invest in Clean Development Mechanism (CDM) projects. This will have an added advantage of minimizing carbon emissions and climate change.

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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 Official COMESA website.