ENERGY CONSUMPTION AND ECONOMIC GROWTH: THE CASE OF AFRICAN COUNTRIES

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Introduction

The question of access to energy is a fundamental issue in the challenge of development because energy holds a unique place in the economy due to its distinctive characteristics. Energy can be used for final consumption (lighting, cooking, heating, air-conditioning, etc.), as factor of production, or for intermediate consumption.

In intermediate consumption, energy can be analyzed as both a substitute for or as a complement to the other factors of production (capital and labor). Energy can be considered as both complementary, since it is not feasible to operate machines without it, and as substitutable due to its availability to enable the saving of other factors of production. The availability of energy also facilitates the production of new goods and services.

Energy consumption is an essential component of economic development. According to economic theory, an increase in energy consumption has an effect on economic growth. We notice a double correlation between economic growth and energy consumption: a correlation in time (the consumed energy increases in the same way as production measured by the gross domestic product) and a correlation in space (more developed countries are also those in which the energy consumption is the highest).

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In this work, the intention is to test the relationship between economic growth and energy consumption utilizing non-stationary panel theory in the case of 22 African nations: Algeria, Benin, Botswana, Cameron, Congo, Congo Democratic Republic, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Kenya, Libya, Morocco, Mozambique, Senegal, South Africa, Sudan, Tanzania, Togo, Tunisia, and Zambia.

The paper is divided into three sections: a review of the literature on the relationship between energy consumption and economic growth, a presentation of the model and the methodology of estimations, followed by the results and some brief conclusions.

Literature Review on the Relationship between Energy Consumption and Economic Growth

Although energy is required to initiate a genuine process of development, an increase in production is not a sufficient condition to generate sustained growth. The additional supply should be the result of a consequent demand. It would be interesting to analyze the relationship between energy consumption and economic growth in order to define an optimal energy policy that matches the objectives of development.

J. McVeigh et al. have studied the evolution and determinants of energy intensity and the modeling of energy demand in connection with economic activity.[1] In the early 1970s, the law referred to as "unitary elasticity" led many economists to believe that energy consumption and gross domestic product (GDP) rose at the same pace.

Many empirical studies show the relationship between energy consumption and economic growth. Among them was the pioneering study by J. Kraft and A. Kraft consisting of an analysis of the U.S. economy between 1947 and 1974.[2] J. Kraft and A. Kraft were the first to demonstrate the existence of an uni-directional causality in the United States where gross national product (GNP) causes energy consumption. This research was followed by that of S. Abosedra and H. Baghestani who confirmed the uni-directional causality of GNP to energy consumption (EC) for the United States that originally was highlighted by J. Kraft and A. Kraft.[3] Current research has shown that causality can come from two directions (bi-directional).

D. Nachane, R. Nadkani, and A. Karnik adopted the cointegration approach of Engle and Granger and found a long-term relationship between energy consumption and economic growth for 11 developing countries and five developed countries.[4] The Engle and Granger methodology has been applied by many authors for various countries, sometimes obtaining ambiguous results. The study by H. Yang on Taiwan found bi-directional causality between economic growth and energy consumption over the period 1954–1997.[5] A. Aqueel and M. Butt's paper on Pakistan, including employment as an additional variable and applying a version of the test proposed by Granger and Hsiao, infers that economic growth causes total energy consumption.[6]

U. Soytas and R. Sari analyze how energy consumption can explain the evolution of income over the period 1950 through 1992 in Turkey.[7] In 2004, these authors proposed a generalized technique of decomposition of error variance based on M. Pesaran and Y. Shin to determine the information content of the variance of the growth in Turkish energy consumption.[8]

N. Apergis and J. Payne present an analysis on the relationship between energy consumption and economic growth for a panel of nine South American countries over the period 1980–2005 using a panel error-correction model.[9] They infer a causal relationship between energy consumption and economic growth taking into account the labor force and capital stock. The authors find that the long-run relationship suggests that a 1-percent increase in energy consumption increases real GDP by 0.42 percent.

J. Chontanawat, L. Hunt, and R. Pierse notice that the causal relationship between energy and economic growth is more perceptible in developed than in developing countries.[10]

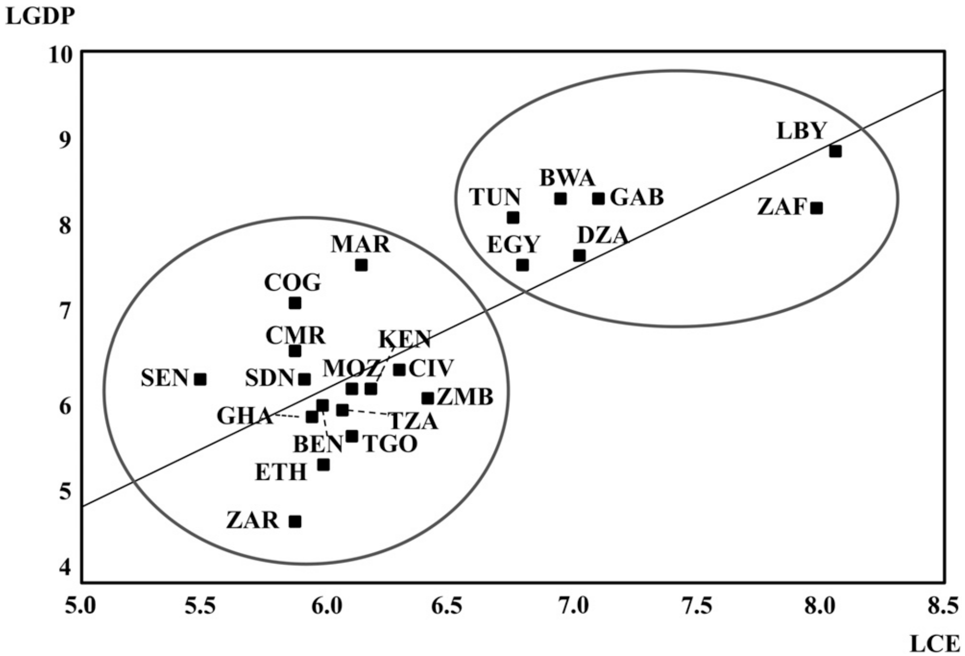
Empirical research on energy demand and economic growth has focused on industrialized countries, but in recent years it has spread to developing nations. Africa suffers from this lack of empirical studies on the relationship between energy intensity and economic growth. To explain the relationship between energy consumption and economic growth, we use a longitudinal estimate of the 22 nations in our study panel (figure 1).

Figure 1 highlights the positive relationship that exists between the two studied variables: the GDP per capita (LGDP) and energy consumption (LEC). In the year of our study (2009), it appears that the obtained results present an interesting analysis of a large sample of nations with different levels of development in the African continent. In figure 1, the countries with results located toward the top and the right are the more developed and have higher levels of energy consumption. On the other hand, the nations located toward the bottom and on the left represent the less developed economies and have the weakest energy consumption. These results attest to a positive relationship between global competitiveness and economic development levels that will become the subject of empirical verification in the following section.

Presentation of the Model and Methodology of Estimations

Presentation of the Model: Our objective in this paragraph is to study the effects of energy consumption on per-capita GDP. The first phase involves the selection of an adequate model. In this case we select the Solow-Swan model, according to N. Mankiw, D. Romer, and D. Weil, which is written as in equation (1).[11]

Figure 1
THE RELATIONSHIP BETWEEN GROSS DOMESTIC PRODUCT PER CAPITA (LGDP) AND ENERGY CONSUMPTION (LEC) FOR 22 AFRICAN NATIONS, 2009[a]



[a] Algeria = DZA, Benin = BEN, Botswana = BWA, Cameron = CMR, Congo = COG, Congo Democratic Republic = ZAR, Côte d'Ivoire = CIV, Egypt = EGY, Ethiopia = ETH, Gabon = GAB, Ghana = GHA, Kenya = KEN, Libya = LBY, Morocco = MAR, Mozambique = MOZ, Senegal = SEN, South Africa = ZAF, Sudan = SDN, Tanzania = TZA, Togo = TGO, Tunisia = TUN, and Zambia = ZMB.

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}, \qquad (1)$$

with $L_t = L_o e^{n_t}$ and $A_t = A_0 e^{g_t + \rho_t \theta}$, and where Y is the real output, K is the stock of physical capital, L is the labor, A is the factor reflecting the level of technology and the efficiency in the economy, n is the rate of the labor force growth, g is the rate of technological progress that is supposed to be constant, ρ is the vector representing the energy consumption and other factors that can affect the level of technology and efficiency in the economy, θ is the vector of coefficients related to these variables, and the subscript t indicates time.

The technological progress (A_t) can explain the relationship existing between energy consumption and economic growth. We take into consideration that energy consumption can encourage a faster reconstruction of capital and this is due to new technologies.

In addition, this relationship between energy consumption and growth can be explained by the Schumpeterian process of "creative destruction." In fact, the negative shocks are catalysts of reinvestment and modernization in equipment. These shocks create, thanks to technological progress, a more elevated growth.

Model Demonstration: The evolution of the economy is represented by the following equation:

$$\dot{K}_t = \frac{dK_t}{d_t} = s_k Y_t - \delta K_t, \tag{2}$$

where s_k is the rate of investment in physical capital.

We suppose that $\dot{K}_t = I_t - \delta K_t$ and $I_t = S_t$, where δ is the rate of the physical capital depreciation. We define the production by a unit of labor and the physical capital stock by a unit of labor as given by the following:

$$y_t = \frac{Y_t}{A_t L_t} \text{ and } k_t = \frac{K_t}{A_t L_t}.$$

We can write the evolution of the physical capital stock by a unit of labor as

$$\dot{k}_t = \frac{d}{d_t}\left[\frac{K_t}{A_t L_t}\right].$$

The Evolution of the Physical Capital by a Unit of Effective Labor: Given as

$$\dot{k}_t = \frac{d}{d_t}\left[\frac{K_t}{A_t L_t}\right],$$

$$\dot{k}_t = \frac{\dot{K}_t(A_t L_t) - (A_t L_t)' K_t}{(A_t L_t)^2},$$

$$\dot{k}_t = \frac{\dot{K}_t}{A_t L_t} - \left[\frac{\dot{A}_t L_t + Lt\dot{A}_t}{A_t L_t}\right]\frac{K_t}{A_t L_t},$$

$$\dot{k}_t = \frac{s_k Y_t - \delta K_t}{A_t L_t} - \left[\frac{\dot{A}_t}{A_t} + \frac{\dot{L}_t}{L_t}\right] k_t,$$

with $\dot{A}_t / A_t = g$, the rate of technical progress supposed exogenous, and $\dot{L}_t / L_t = n$, the rate of demographic growth. Therefore,

$$\dot{k}_t = s_k \frac{Y_t}{A_t L_t} - \delta \frac{K_t}{A_t L_t} - (g+n) k_t$$

$$\dot{k}_t = s_k y_t - (n+g+\delta) k_t. \tag{3}$$

The Evolution of the Production by a Unit of Effective Labor: Given as

$$y_t = \frac{K_t^\alpha (A_t L_t)^{1-\alpha}}{A_t L_t},$$
$$y_t = \frac{K_t^\alpha}{A_t L_t}(A_t L_t)^{1-\alpha},$$
$$y_t = \frac{K_t^\alpha}{A_t L_t}(A_t L_t).\,(A_t L_t)^{-\alpha},$$
$$y_t = \frac{K_t^\alpha}{(A_t L_t)^\alpha},$$
$$y_t = \left(\frac{K_t}{A_t L_t}\right)^\alpha,$$
$$y_t = k_t^\alpha. \tag{4}$$

The substitution of equation (4) into equation (3) produces equation (5):

$$\dot{k}_t = s_k k_t^\alpha - (n+g+\delta)k_t. \tag{5}$$

At the equilibrium, we have $\dot{k}_t = 0$. This result leads us to the following relationship:

$$s_k k^\alpha = (n+g+\delta)k. \tag{6}$$

The Determination of the Steady State of the Economy: While taking into account the relationship in equation (6), we have

$$s_k k^\alpha = (n+g+\delta)\mathrm{k},$$
$$s_k k^{\alpha-1} = (n+g+\delta),$$
$$k^{1-\alpha} = \frac{s_k}{(n+g+\delta)},$$
$$k^* = \left(\frac{s_k}{(n+g+\delta)}\right)^{1/1-\alpha}. \tag{7}$$

The economy converges toward a steady state represented by the relation given in equation (7).

According to the relations outlined in equation (4), we have

$$\left(\frac{Y_i}{A_i L_i}\right)^* = \left(k_i^*\right)^\alpha$$
$$y_i^* = (A_i)^* \left(k_i^*\right)^\alpha. \tag{8}$$

The relationship in equation (8) represents the output by the worker at the equilibrium and for every country.

At the equilibrium, technological progress is represented by

$$A_i^* = A_0 e^{\rho_i \theta_i}, \tag{9}$$

where ρ represents the variables that correspond to the factors that can influence the technological progress. In our study, ρ regroups the variables reflecting energy consumption.

The substitution of equations (7) and (9) into (8) produces

$$(y)^* = A_0 e^{\rho\theta} \left(\frac{s_k}{n+g+\delta}\right)^{\frac{\alpha}{1-\alpha}}. \tag{10}$$

To have a linear relation, we apply the logarithm

$$Ln(y)^* = Ln\left[A_0 e^{\rho^*\theta} \left(\frac{s_k^{1-\beta} s_h^{\beta}}{n+g+\delta}\right)^{\frac{\alpha}{1-\alpha-\beta}} \left(\frac{s_k^{\alpha} s_h^{1-\alpha}}{n+g+\delta}\right)^{\frac{\beta}{1-\alpha-\beta}}\right]. \tag{11}$$

The Production Per Capita through Time and by Country: While adding the indications of time and individual countries, equation (10) can be written

$$Ln\left(y_{i,t}\right)^* = Ln\left(A_{0,i}\right) + \theta_i \rho_{i,t} + \frac{\alpha}{1-\alpha} Ln\left(s_{k_{i,t}}\right) - \frac{\alpha}{1-\alpha} Ln\left(n_{i,t} + g + \delta\right), \tag{12}$$

with $(A_{o,i})$ = the constant of every country, $(s_{ki,t})$ = the physical capital reserves, $n_{i,t}$ = the growth rate of the labor force, g = the growth rate of technological progress, and δ = the rate of investment depreciation. The rates g and δ are supposed to be constant through time and across countries; their sum is equal to 0.05.[12]

As we already have mentioned, the level of energy consumption is considered a key factor in explaining the differences in economic development levels across nations. Energy consumption allows for the building up of physical capital stock, while incorporating some new technologies. (Energy consumption will be represented by the variable ρ in the following equation).

Econometrically, the model can be written

$$gdp_{i,t} = \alpha_i + \beta ec_{it} + \gamma cap_{it} + \delta lab_{it} + \varepsilon_{it}, \tag{13}$$

with $gdp_{i,t}$ denoting GDP per capita; α_i representing individual's effects, with $\alpha_i \in \mathbb{R}$; ec_{it} denoting energy consumption; cap_{it} standing for physical capital stock; and lab_{it} representing the regrouping of the growth rate of the labor force, the growth rates of technological progress, and investment depreciation. Knowing that the growth rate of technological progress and of depreciation are supposedly constant through time and across countries and that their sum $(g+\delta)$ is equal to 0.05, (β, γ, δ) is a vector of the coefficients to estimate and ε_{it} stands for the error term.

Presentation of the Variables and Their Sources: The variables that will be presented are collected for a panel of 22 African nations covering the period from 1980 to 2009. The variables in our study include: the real gross domestic product per capita as an endogenous variable, energy consumption, the physical capital stock per capita, and the labor force. All the variables are extracted from the World Bank's *World Development Indicators*.

Dependent Variable: In our empirical analysis, we use the gross domestic product per capita as the dependent variable.

Physical Capital Stock Per Capita: We calculate the physical capital stock by using the method described by B. Pottelsberghe.[13] In this approach, the stock of physical capital "*K*" of the year "*t*" is equal to its stock at "*t*–1" adjusted by a depreciation rate plus the investment "*I*" at "*t*": $K_t = I_t + (1-\delta)K_{t-1}$, where I_t is the gross fixed capital formation and δ is the capital depreciation rate ($\delta = 6$ percent).

The initial physical capital stock K_0 is equal to the initial investment I_0 divided by the sum of the yearly growth rate of the investment I_t and the physical capital depreciation rate δ: $K_0 = I_0/(\varphi+\delta)$. The physical capital stock per capita is the physical capital stock calculated and divided by the total population.

Labor Force: According to the World Bank, the labor force is estimated as the total active population.

Energy Consumption: The total energy consumption is measured as commercial energy use in kilograms of oil equivalent per capita.

Methodology of Estimations

Panel Unit Root Testing: A series of unit root tests was the next step in the analysis of stationarity in the panel data estimation. We examine our data by performing several unit root tests in a panel framework as outlined by K. Im, M. Pesaran, and Y. Shin (referred to as the IPS test).[14] These are the more frequently used methods when the temporal dimension is limited. The authors propose tests permitting the detection of the presence of unit root in the models using Fisher-augmented Dickey-Fuller (ADF) statistics.

In this paragraph, we study the order of integration of the series and the relations of cointegration among the variables. To study the non-stationarity, we use the IPS test presented by the following equation.

$$\Delta y_{it} = \rho y_{it-1} + \sum_{j=1}^{k_i} \varphi_{ij} \Delta y_{it-j} + \mu_i + \delta_i t + \varepsilon_{it}, \tag{14}$$

where k represents the lag chosen in order to eliminate the auto-correlation of the residual.

The IPS test is calculated as being the t-statistic as an average of the Dickey-Fuller regressions with or without trend. The alternative t-bar statistic allows for the testing of the null hypothesis of the unit root for all individuals ($\beta_i = 0$) and is given as

$$t_{NT}(\rho_i) = \frac{1}{N} \sum_{t=1}^{N} t_{iT}(\rho_i), \tag{15}$$

with $t_{iT}(\rho_i)$ as the estimated ADF tests, N the number of individuals, and T the number of observations.

K. Im, M. Pesaran, and Y. Shin propose the use of the following standardized statistic:

$$Z_\text{i} = (N)^{1/2}(t_{NT} - E(t_{NT}))/(var(t_{NT}))^{1/2}, \tag{16}$$

where $E(t_{NT})$ is the arithmetic average and $var(t_{NT})$ the variances of the individual ADF statistics.

The study of IPS shows that this standardized statistic converges slightly toward the standard normal distribution, which allows comparing the critical values of the distribution N (0, 1). The application of the IPS test is presented in table 1. The verification of the non-stationarity of the properties for all variables of the panel leads us to examine the existence of a long-term relationship among the variables.

Cointegration Testing: To study the existence of a cointegration relationship, we refer to P. Pedroni, whose null hypothesis is to test for the absence of cointegration based on unit roots tests on the estimated residuals.[15] Pedroni developed seven tests for cointegration on panel data.

These tests take into account the heterogeneity in the cointegration relationship, suggesting for each individual there are one or more cointegrating relationships that are not necessarily identical for each individual panel. Each of the seven statistics follows a standard normal distribution for a sufficiently large N and T.

$$\frac{Z_{NT} - \mu\sqrt{N}}{\sqrt{\vartheta}} \rightarrow 0, \tag{17}$$

Table 1
UNIT ROOT TEST RESULTS USING IPS METHOD[a]

Variables	**gdp**	**ec**	**cap**	**lab**
Without trend				
Level	3.88	–0.127	2.642	5.786
First difference	–11.29*	–20.43*	–1.848**	–5.289*
With trend				
Level	–0.267	0.228	2.667	1.229
First difference	–14.51*	–19.83*	–2.119**	–5.569*

[a] Utilizing the IPS methodology from K. Im, M. H. Pesaran, and Y. Shin, "Testing for Unit Roots in Heterogeneous Panels," *Journal of Econometrics*, vol. 115, no. 1 (2003), pp. 53–74; GDP = gross domestic product per capita; ec = energy consumption; cap = physical capital; and lab = labor; * = significance at the 1-percent level; ** = significance at the 5-percent level; and ***significance at 10-percent level.

Source: Calculations by author based on results of the IPS test.

where Z_{NT} is one of the seven statistics while μ and ϑ are other values presented by P. Pedroni. The results of the cointegration test using the Pedroni method is presented with and without trend in table 2. The simulations made by Pedroni show that for values of T higher than 100, the seven statistics give comparable results in terms of potentiality. For smaller sample sizes, the panel-ADF and group-ADF tests have better properties than the other tests. From the results of the Pedroni cointegration tests, we confirm the existence of a cointegration relationship.

Table 2
COINTEGRATION TEST RESULTS USING PEDRONI METHOD[a]

Statistics	**Without Trend**	**With Trend**
Panel v-Statistic	–0.835304	–1.998139
Panel rho-Statistic	3.163270	5.482502
Panel PP-Statistic	–0.668343	0.156309
Panel ADF-Statistic	–1.777187**	–2.295653*
Group rho-Statistic	5.791335	7.108017
Group PP-Statistic	–2.221735**	–6.025668*
Group ADF-Statistic	–1.742755**	–2.317928*

[a] Utilizing the Pedroni methodology from P. Pedroni, "Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis," *Econometric Theory*, vol. 20, no. 3 (2004), pp. 597–625; PP-Statistic = Phillips-Perron test statistic; ADF-Statistic = augmented Dickey-Fuller test statistic; * = significance at the 1-percent level; ** = significance at the 5-percent level; and ***significance at 10-percent level.

Source: Calculations by author based results of the Pedroni test.

Estimation and Interpretation: To estimate systems of cointegrated variables on panel data, it is necessary to apply an efficient estimation method. We identify two different techniques for our study: the fully modified ordinary least squares (FMOLS) method used by P. Pedroni and the dynamic ordinary least squares (DOLS) method. C. Kao, M.-H. Chiang, and B. Chen suggest a fully modified (FM) method and DOLS estimators in a cointegrated regression and show that their limiting distribution is normal.[16] The authors also suggested that the DOLS estimator may be more promising than ordinary least squares (OLS) or FM estimators in estimating the cointegrated panel regressions.

The DOLS approach was recommended initially by P. Saikkonen in the case of temporal series and subsequently was adapted by C. Kao, M.-H. Chiang, and B. Chen for use with panel data.[17] This technique consists of including leads and lags of values of the cointegration relation in order to eliminate the correlation between the explanatory variables and the error term:

$$Y_{it} = \alpha_i + \beta X_{it} + \sum_{j=-r_1}^{r_2} c_{ij} \Delta X_{it-j} + \varepsilon_{it}. \quad (18)$$

The use of the DOLS method implies an arbitrary choice of lags, which represents an interesting question but one that exceeds the scope of this work. We chose to keep the same number of lags for all countries.

In table 3 we summarize the estimation results obtained from the FMOLS and DOLS methods. The results of our estimation confirm that the level of energy consumption has a positive and statistically significant effect on the level of GDP per capita in our sample of 22 African countries. The result can explain and justify the contribution of increasing energy consumption in African nations during recent years and the connection with economic growth. This is an evolution that is

Table 3

REGRESSION RESULTS OF THE FULLY MODIFIED ORDINARY LEAST SQUARES (FMOLS) AND THE DYNAMIC ORDINARY LEAST SQUARES (DOLS) METHOD[a]

(Endogenous variable is gross domestic product per capita–*gdp*)

Variables	***ec***	***cap***	***lab***	**N**
FMOLS	0.439*	0.244*	0.240*	660
DOLS	0.344*	0.035*	0.374*	660

[a] The lags used in the DOLS method are r = –1 and r = –2; ec = energy consumption; cap = physical capital; lab = labor; and N = number of observations; * = significance at the 1-percent level; ** = significance at the 5-percent level; and ***significance at 10-percent level.

Source: Calculations by author based on results from the FMOLS and DOLS methods.

due to a number of economic reforms. Thus, the fruits of these reforms are justified by the positive effect of physical capital accumulation and the increased qualification of the labor force on economic growth.

The effect exercised by energy consumption, confirmed by our econometric study, also can play a role in the transformation of the continent's potential into concrete achievements in the years and decades to come. African countries have achieved high performance levels in terms of economic growth, but the most important issue is continuity, on the one hand, and, on the other hand, the development of the endogenous factors of wealth creation.

Testing for Causality: We follow the approach laid out by C. W. Granger for conducting causality tests on panel data.[18] As the variables are I(1) and are cointegrated, an error-correction model (ECM) such as the following equation can be used to identify the direction of causality.

$$\Delta gdp_{it} = \theta_{1j} + \lambda_{1t} ECT_{it-1} + \sum_{k=1}^{m} \theta_{11ik} \Delta gdp_{it-k} + \sum_{k=1}^{m} \theta_{12ik} \Delta ec_{it-k} + \sum_{k=1}^{m} \theta_{13ik} \Delta cap_{it-k} + \sum_{k=1}^{m} \theta_{14ik} lab_{it-k} + u_{1it} \tag{19.a}$$

$$\Delta ec_{it} = \theta_{2j} + \lambda_{2t} ECT_{it-1} + \sum_{k=1}^{m} \theta_{21ik} \Delta ec_{it-k} + \sum_{k=1}^{m} \theta_{22ik} \Delta gdp_{it-k} + \sum_{k=1}^{m} \theta_{23ik} \Delta cap_{it-k} + \sum_{k=1}^{m} \theta_{24ik} lab_{it-k} + u_{2it} \tag{19.b}$$

$$\Delta cap_{it} = \theta_{3j} + \lambda_{3t} ECT_{it-1} + \sum_{k=1}^{m} \theta_{31ik} \Delta cap_{it-k} + \sum_{k=1}^{m} \theta_{32ik} \Delta gdp_{it-k} + \sum_{k=1}^{m} \theta_{33ik} \Delta ec_{it-k} + \sum_{k=1}^{m} \theta_{34ik} lab_{it-k} + u_{3it} \tag{19.c}$$

$$\Delta lab_{it} = \theta_{4j} + \lambda_{4t} ECT_{it-1} + \sum_{k=1}^{m} \theta_{41ik} \Delta lab_{it-k} + \sum_{k=1}^{m} \theta_{42ik} \Delta gdp_{it-k} + \sum_{k=1}^{m} \theta_{43ik} \Delta ec_{it-k} + \sum_{k=1}^{m} \theta_{44ik} cap_{it-k} + u_{4it} \tag{19.d}$$

where Δ is the difference operator, ECT_{it-1} is the error-correction term derived from the long-run cointegrating relationship, u_{it} represents the white noise error terms, t denotes the years, and i stands for the lag orders of θ.

The vector error-correction model (VECM) results distinguish between short-run and long-run Granger causality. The coefficients of the lagged error-correction term show that there is a long-run causal relationship between economic growth and energy consumption. It also indicates that these variables are adjusting to their long-run equilibrium relationships. The coefficients of the ECM indicate the speed of adjustment to the long-run equilibrium relationship.

Results in table 4 show that there is an uni-directional causality from GDP to energy consumption at the 1-percent significance level, that is, an increase in GDP will bring about an increase in energy use.

Table 4
CAUSALITY RESULTS FROM THE VECTOR ERROR-CORRECTION MODEL (VECM)[a]

Direction of causality →	***Δgdp***	***Δec***	***Δcap***	***Δlab***
Δgdp	-	5.346*	16.663*	0.463
Δec	0.466	-	1.023	0.291
Δcap	4.389**	3.824**	-	2.205
Δlab	2.734***	3.220**	3.549**	-

[a] The optimal lag structure of one year is chosen using the Schwarz-Bayesian criterion and the 2-year lag of the dependent variables is used in the estimation; the significance of the causality results are determined by the Wald F-test; gdp = gross domestic product per capita; ec = energy consumption; cap = physical capital; and lab = labor; * = significance at the 1-percent level; ** = significance at the 5-percent level; and ***significance at 10-percent level.

Source: Calculations by author using the VECM model.

Conclusion

In this work we have addressed the issue of economic growth in a sample of 22 African countries, which has culminated in a set of results. First, we presented the effect of energy consumption on economic growth. Second, through the estimation of a non-stationary panel data model for the sample of African nations during the period 1980 through 2009, we tried to verify the contribution that increasing the energy consumption of these economies would have on their realization of sustained economic growth. Our results show that GDP causes the level of energy consumption.

NOTES

[1]J. McVeigh, D. Burtraw, J. Darmstadter, and K. Palmer, "Winner, Loser, or Innocent Victim? Has Renewable Energy Performed as Expected?," *Solar Energy*, vol. 68, no. 3 (1997), pp. 237–55.

[2]John Kraft and Arthur Kraft, "On the Relationship between Energy and GNP," *The Journal of Energy and Development*, vol. 3, no. 2 (spring 1978), pp. 401–3.

[3]S. Abosedra and H. Baghestani, "New Evidence on the Causal Relationship between United States Energy Consumption and Gross National Product," *The Journal of Energy and Development*, vol. 14, no. 2 (spring 1989), pp. 285–92.

[4]D. M. Nachane, R. M. Nadkani, and A.V. Karnik, "Co-Integration and Causality Testing of the Energy-GDP Relationship: A Cross-Country Study," *Applied Economics*, vol. 20, no. 11 (1988), pp1511–531.

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