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Energy consumption, prices and economic growth in three SSA countries: A comparative study

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ABSTRACT

In this paper we examine the causal relationship between energy consumption and economic growth in three sub-Saharan African countries, namely South Africa, Kenya and Congo (DRC). We incorporate prices as an intermittent variable in a bivariate setting between energy consumption and economic growth—thereby creating a simple trivariate framework. Using the ARDL-bounds testing procedure, we find that the causality between energy consumption and economic growth varies significantly across the countries under study. The results show that for South Africa and Kenya there is a unidirectional causal flow from energy consumption to economic growth. However, for Congo (DRC) it is economic growth that drives energy consumption. These findings have important policy implications insofar as energy conservation policies are concerned. In the case of Congo (DRC), for example, the implementation of energy conservation policies may not significantly affect economic growth because the country's economy is not entirely energy dependent. However, for South Africa and Kenya there is a need for more energy supply augmentations in order to cope with the long-run energy demand. In the short-run, however, the two countries should explore more efficient and cost-effective sources of energy in order to address the energy dependency problem.

1. Introduction

The debate regarding the relationship between energy consumption and economic growth has attracted vast literature from both theoretical and empirical fronts in recent years. The thrust of this debate largely revolves around the inter-temporal causal relationship between energy consumption and economic growth. Four views currently exist regarding the causal relationship between energy consumption and economic growth. The first view argues that economic growth causes energy consumption, and that as the economy grows the demand for energy from different sections of the economy increases. The second view, however, argues that it is the consumption of energy that causes economic growth. The third view argues that both electricity consumption and economic growth cause each other, i.e. that there is a bi-directional causality between electricity consumption and economic growth. While these three views support the causal relationship between energy consumption and economic growth, the fourth view contends that there is no causal relationship between energy consumption and economic growth. In other words, both energy consumption and economic growth are neutral with respect to each other.

Although a number of studies have been conducted on the causal relationship between energy consumption and economic growth in sub-Saharan African countries, some of these studies have typically relied on the cross-sectional data, which may not satisfactorily address the country-specific issues. The problem of using a cross-sectional method is that by grouping countries that are at different stages of economic development, it fails to address the country-specific effects of energy consumption on economic growth and vice versa. In particular, the method fails to explicitly address the potential biases induced by the existence of cross-country heterogeneity, which may lead to inconsistent and misleading estimates (see Ghirmay, 2004; Quah, 1993; Casselli et al., 1996; Odhiambo, 2008, 2009a). Even where time-series data have been used, the empirical findings on the direction of causality between energy consumption and economic growth have been largely inconclusive (see Odhiambo, 2009a). The current study, therefore, attempts to examine the inter-temporal causal relationship between energy consumption and economic growth in three SSA countries, namely South Africa, Kenya and Congo (DRC). The three countries include two low-income economies, i.e. Kenya and Congo (DRC), and one highly developed economy, i.e. South Africa. The study uses the recently developed ARDL-bounds testing approach in a trivariate setting to examine this linkage. Specifically, the study incorporates prices in the bivariate setting between energy consumption and economic growth—thereby creating a simple trivariate model. The price level has been chosen as an intermittent variable because of its

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effects on both energy consumption and economic growth. On the one hand, an increase in prices (for example) is expected to lead to a decrease in energy demand, thereby leading to a decrease in energy consumption. On the other hand, an increase in prices leads to a decrease in demand, thereby leading to a contraction in aggregate output. The rest of the paper is structured as follows: Section 2 gives an overview of the energy policies in the three study countries. Section 3 presents the literature review, while Section 4 deals with the empirical model specification, the estimation technique and the empirical analysis of the regression results. Section 5 concludes the study.

2. An overview of the energy sector in the three study countries

The energy sector in the three study countries differs significantly from country to country and over time. South Africa, for example, is considered to have the highest energy production and consumption in Africa. Eskom, a parastatal responsible for the supply of electricity in South Africa, is estimated to generate about two-thirds of the total sub-Saharan African electricity output and 80% of the total southern African output (see Estache et al., 2008). With a generating capacity of about 40 000 MW, Eskom is ranked as one of the top five energy utilities in the world. Overall, the energy sector contributes about 15% of the South African GDP, and employs about 250 000 people. The main energy resource in South Africa is coal, which contributes about 88% of the country's total electricity. However, the country recently experienced a decrease in its reserve margin, which forced it to embark on a number of interventions in early 2008. In some instances, load shedding had to be used as the last resort in order to prevent a system-wide blackout. These interventions enabled Eskom to bring the demand for electricity slightly closer to its supply, while at the same time maintaining a reasonable reserve margin. The South African government attributes the unprecedented decline in the electricity reserve margin during the recent years to the robust economic growth and the associated demand for electricity. Currently, the government is working on both medium- and long-term programmes intended to enable the country to cope with the future demand for electricity. At the same time alternative sources of energy are being explored in order to supplement the supply of electricity (see Odhiambo, 2009b). The South African energy policy is based on a number of key objectives. These include: (i) attaining universal access to energy by 2012; (ii) providing accessible, affordable and reliable energy, especially to the poor; (iii) diversifying primary energy sources and reducing dependency on coal; and (iv) proving energy that is environmentally friendly, amongst others. The energy in South Africa is regulated by the National Energy Regulator of South Africa (NERSA), which was launched in 2005. Although South Africa's electricity tariff has been one of the lowest in the world, the recent electricity demand from both the household and business sectors forced Eskom to significantly increase the electricity tariff in order to expand its generating capacity.

Unlike in South Africa, Kenya relies largely on wood fuel. In fact, wood fuel provides about 68% of the total energy requirements in Kenya, while petroleum and electricity provide 20% and 10% of total energy consumption, respectively. Other sources of alternative energy account for the remaining 2%. Just as in other developing countries, a number of policies have been implemented in Kenya since independence in order to address the country's energy needs. One of Kenya's most significant energy policies was the Electric Power Act of 1997, which was legislated to replace the previous electric power Act (CAP 314). The aim of this legislation was to facilitate private sector participation in the provision of electricity. This led to the establishment of an independent electric power producer known as Kenya Electricity Generating Company (KenGen) in 1998. The Electric Power Act of 1997 also provided for rural electrification on a limited scale, using renewable energy technologies. Following the unprecedented power shortages in Kenya in 1999 and 2000, the country decided to formulate a comprehensive energy policy for the entire energy sector. The ultimate goal of this policy is to ensure an adequate, reliable, cost-effective and affordable energy supply for developmental needs, while at the same time paying attention to environmental protection and conservation. The energy sector in Kenya is regulated by the Energy Regulatory Commission (ERC), which replaced the Energy Regulatory Board (ERB) in July 2007. The main functions of the ERC are to: (i) regulate the electrical energy, petroleum and related products, renewable energy and other forms of energy; (ii) protect the interests of consumers, investors and other stakeholders; and (iii) ensure the implementation of the principle of fair competition in the energy sector, amongst others. As in other sub-Saharan African countries, energy prices have risen significantly in Kenya in recent years.

In the Democratic Republic of Congo (DRC), the dynamics are somewhat different. Despite the fact that the country has extensive potential hydro-electric capacity of approximately 100 000 MW, only a fraction of its hydro-electric power has been developed. This has been largely due to the political uncertainties that have ravaged the country and scared potential investors over the years. For example, in 2003 the DRC had a total generating capacity of about 2568 MW, but only produced between 600 and 700 MW because two-thirds of the turbines were dysfunctional. The DRC has massive hydro-electric potential because of its Congo River, which is currently the world's second largest in terms of its flow. Overall, the energy sector in the DRC is largely dominated by the high consumption of wood and bio-mass energy. In fact, it is estimated that only about 6% of the country's population has access to electricity. The current energy focus in the DRC, however, centres mainly on the Grand Inga Scheme, which is expected to produce about 39 000 MW, thereby making it the biggest hydro-electric plant in the world, as well as being the biggest single source of hydro-electric generation. The DRC exports hydro-electricity to the Republic of Congo along a 220 kV connection. It is estimated that this connection supplies nearly one-third of the electricity consumed in Congo-Brazzaville. The country also exports electricity to other African countries such as Zambia, the Central African Republic and Angola, among others. The electricity in the DRC is generated by Societe Nationale d'Electricite (SNEL).

3. Literature review

The causal relationship between energy consumption and economic growth has important implications from the theoretical, empirical and policy standpoints. A unidirectional causality running from energy consumption to economic growth, for example, implies that economic growth is dependent on energy consumption, and a decrease in energy consumption may restrain economic growth (see also Narayan and Singh, 2007, p. 1142; Odhiambo, 2009a). A unidirectional causality running from GDP to energy consumption, on the other hand, implies that a country is not entirely dependent on energy for its economic growth, and that energy conservation policies can be implemented with little or no adverse effects on economic growth. Likewise, the finding of no causality in either direction, i.e. the so-called 'neutrality hypothesis', implies that energy conservation policies have little or no effect on economic growth (see Odhiambo, 2009a; Asafu-Adjaye, 2000; Paul and Bhattacharya, 2004). Table 1 shows the empirical findings of the causality between energy

Table 1
Selected empirical findings on the causality between energy (and electricity) consumption and economic growth.

Author(s)	Region/country	Direction of causality
A: Studies in favour of a unidirectional causality from energy (and electricity) consumption to economic growth		
Yu and Choi (1985)	USA, UK, Poland, Korea, Philippine	Energy consumption → GNP in Korea and Philippine
Masih and Masih (1996)	India, Pakistan, Malaysia, Singapore, Indonesia, Philippine	Energy consumption → Real income in India
Cheng (1997)	Brazil, Mexico and Venezuela	Energy consumption → GDP in Brazil
Yang (2000)	Taiwan	Electricity consumption → Real GDP
Asafu-Adjaye (2000)	Asian developing countries	Energy consumption → Income in India and Indonesia
Chang et al. (2001)	Taiwan	Energy consumption → Output
Soytas and Sari (2003)	G-7 countries and emerging markets	Energy consumption → GDP in Turkey, France, Germany and Japan
Shiu and Lam (2004)	China	Electricity consumption → Real GDP
Wolde-Rufael (2004)	Shanghai	Energy consumption → Real GDP
Lee (2005)	Developing countries	Energy consumption → GDP
Altinay and Karagol (2005)	Turkey	Electricity consumption → Economic growth
Wolde-Rufael (2006)	17 African countries	Electricity consumption → GDP in Benin, Democratic Republic of Congo and Tunisia
Narayan and Singh (2007)	Fiji Island	Electricity consumption → GDP
Narayan and Prasad (2008)	30 OECD countries	Electricity consumption → GDP in Australia, Iceland, Italy, the Slovak Republic, the Czech Republic, Korea, Portugal, and the UK
Odhiambo (2009a)	Tanzania	Energy consumption → GDP
B: Studies in favour of a unidirectional causality from economic growth to energy (and electricity) consumption		
Kraft and Kraft (1978)	USA	GNP → Energy consumption
Abosedra and Baghestani (1989)	USA	GNP → Energy consumption
Cheng and Lai (1997)	Taiwan	GDP → Energy consumption
Masih and Masih (1996)	India, Pakistan, Malaysia, Singapore, Indonesia, Philippine	Real income → Energy consumption in Indonesia
Cheng (1999)	India	GDP → Energy consumption
Ghosh (2002)	India	Economic growth → Electricity consumption
Soytas and Sari (2003)	G-7 countries and emerging markets	GDP → Energy consumption in Italy and Korea
Hatemi-J and Irandoust (2005)	Sweden	Economic growth → Energy consumption
Narayan and Smyth (2005)	Australia	Real income → Electricity consumption
Wolde-Rufael (2006)	17 African countries	Economic growth → Electricity consumption in Cameroon, Ghana, Nigeria, Senegal, Zambia and Zimbabwe
Yoo (2006)	**4 Asean countries**	Economic growth → Electricity consumption in Indonesia and Thailand
Mozumder and Marathe (2007)	Bangladesh	GDO → Electricity consumption
C: Studies in favour of a bi-directional causality between energy (and electricity) consumption and economic growth		
Masih and Masih (1996)	India, Pakistan, Malaysia, Singapore, Indonesia, Philippine	Energy consumption ↔ Real income in Pakistan
Masih and Masih (1997)	2 NICs: Korea and Taiwan	Energy consumption ↔ Real income
Glasure and Lee (1997)	South Korea and Singapore	Energy consumption ↔ GDP
Asafu-Adjaye (2000)	Asian developing countries	Energy consumption ↔ Income in Philippine and Thailand
Glasure (2002)	Korea	Energy consumption ↔ Economic growth
Soytas and Sari (2003)	G-7 countries and emerging markets	Energy consumption ↔ GDP in Argentina
Paul and Bhattacharya (2004)	India	Energy consumption ↔ Economic growth
Wolde-Rufael (2006)	17 African countries	Electricity consumption ↔ Economic growth in Egypt, Gabon and Morocco
Yoo (2006)	**4 Asean countries**	Electricity consumption ↔ Economic growth in Malaysia and Singapore
Odhiambo (2009b)	South Africa	Electricity consumption ↔ Economic growth
D: Studies in favour of neutrality between energy (and electricity) consumption and economic growth		
Akarca and Long (1980)	USA	Energy consumption [0] GNP
Yu and Hwang (1984)	USA	Energy consumption [0] GNP
Yu and Choi (1985)	USA, UK, Poland, Korea, Philippine	Energy consumption [0] GNP in USA, UK and Poland
Cheng (1995)	USA	Energy consumption [0] GNP
Cheng (1997)	Brazil, Mexico and Venezuela	Energy consumption [0] Economic growth in Mexico and Venezuela
Wolde-Rufael (2006)	17 African countries	Electricity consumption [0] Economic growth in Algeria, Congo (Rep), Kenya, South Africa and Sudan

Notes: →, ↔ and [0] denote unidirectional causality, bi-directional causality and neutrality (no causality), respectively.

(and electricity) consumption and economic growth drawn from some previous studies.

4. Estimation techniques and empirical analysis

4.1. Cointegration—ARDL-bounds testing procedure

In this study the recently developed Autoregressive Distributed Lag (ARDL)-bounds testing approach is used to examine the long-run cointegration relationship between energy consumption, prices and economic growth in the three study countries. The ARDL modelling approach was originally introduced by Pesaran and Shin (1999) and later extended by Pesaran et al. (2001).[1]

[1] The ARDL cointegration approach has numerous advantages in comparison with other cointegration methods (see Odhiambo (2009a) and Harris and Sollis (2003) for more details).

The ARDL model used in this study can be expressed as follows (see Odhiambo, 2009a):

$$\begin{aligned}\Delta \mathrm{In}\, y/N_t = a_0 + \sum_{i=1}^{n} a_{1i}\Delta \mathrm{In}\, y/N_{t-i} + \sum_{i=0}^{n} a_{2i}\Delta \mathrm{In}\, ENC_{t-i} \\ + \sum_{i=0}^{n} a_{3i}\Delta \mathrm{In}\, PRICE_{t-i} + a_4 \mathrm{In}\, y/N_{t-1} + a_5 \mathrm{In}\, ENC_{t-1} \\ + a_5 \mathrm{In}\, PRICE_{t-1} + \mu_t \end{aligned} \tag{1}$$

$$\begin{aligned}\Delta \mathrm{In}\, ENC_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i}\Delta \mathrm{In}\, ENC_{t-i} + \sum_{i=0}^{n} \beta_{2i}\Delta \mathrm{In}\, y/N_{t-i} \\ + \sum_{i=0}^{n} \beta_{3i}\Delta \mathrm{In}\, PRICE_{t-i} + \beta_4 \mathrm{In}\, y/N_{t-1} + \beta_5 \mathrm{In}\, ENC_{t-1} \\ + \beta_6 \mathrm{In}\, PRICE_{t-1} + \mu_t \end{aligned} \tag{2}$$

$$\begin{aligned}\Delta \mathrm{In}\, PRICE_t = \Delta_0 + \sum_{i=1}^{n} \Delta_{1i}\Delta \mathrm{In}\, PRICE_{t-i} + \sum_{i=0}^{n} \Delta_{2i}\Delta \mathrm{In}\, y/N_{t-i} \\ + \sum_{i=0}^{n} \Delta_{3i}\Delta \mathrm{In}\, ENC_{t-i} + \Delta_4 \mathrm{In}\, y/N_{t-1} + \Delta_5 \mathrm{In}\, ENC_{t-1} \\ + \Delta_6 \mathrm{In}\, PRICE_{t-1} + \mu_t \end{aligned} \tag{3}$$

where In y/N is the log of per capita real GDP; In *ENC*, the log of total energy consumption per capita; In *PRICE*, the log of price; μ_t, the white-noise error term; Δ, the first difference operator.

Annual time-series data, which cover the period 1972–2006, are utilised in this study. The energy per capita data is measured as kg of oil equivalent per capita, while consumer price index was used to measure changes in prices.[2] All data used in this study were obtained from the International Financial Statistics Yearbook (various issues) and World Development Indicators CD-ROM (2007).

The bounds testing procedure is based on the joint *F*-statistic (or Wald statistic) for cointegration analysis. The asymptotic distribution of the *F*-statistics is non-standard under the null hypothesis of no cointegration between examined variables. The null hypothesis of no cointegration among the variables in Eq. (1) is (H_0: $a_4=a_5=a_6=0$) against the alternative hypothesis (H_1: $a_4 \neq a_5 \neq a_5 \neq 0$). In Eq. (2) the null hypothesis of no cointegration is (H_0: $\beta_4=\beta_5=\beta_6=0$) against the alternative hypothesis (H_1: $\beta_4 \neq \beta_5 \neq \beta_6 \neq 0$). In Eq. (3) the null hypothesis of no cointegration is (H_0: $\delta_4=\delta_5=\beta_6=0$) against the alternative hypothesis (H_1: $\delta_4 \neq \delta_5 \neq \delta_6 \neq 0$).

Pesaran and Pesaran (1997) and Pesaran et al. (2001) report two sets of critical values for a given significance level. One set of critical values assumes that all variables included in the ARDL model are $I(0)$, while the other is calculated on the assumption that the variables are $I(1)$. If the computed test statistic exceeds the upper critical bounds value, then the H_0 hypothesis is rejected. If the *F*-statistic falls into the bounds then the cointegration test becomes inconclusive. If the *F*-statistic is lower than the lower bounds value, then the null hypothesis of no cointegration cannot be rejected.

4.2. Empirical model specification

According to Granger's definition of causality, a time series, X_t, causes another time series, Y_t, if Y_t can be predicted better (in a mean-squared-error sense) using past values of X_t than by not doing so. That is if past values of X_t significantly contribute to forecasting Y_t, then X_t is said to Granger-cause Y_t. Causality from Y to X can also be defined in the same way. The Granger causality model used in the current study is based on the following model (see Narayan and Smyth, 2008; Odhiambo, 2009c):

$$\begin{aligned}\Delta \mathrm{In}\, y_t = a_0 + \sum_{i=1}^{n} a_{1i}\Delta \mathrm{In}\, y_{t-i} + \sum_{i=0}^{n} a_{2i}\Delta \mathrm{In}\, ENC_{t-i} \\ + \sum_{i=0}^{n} a_{3i}\Delta \mathrm{In}\, PRICE_{t-i} + ECM_{t-1} + \mu_t \end{aligned} \tag{4}$$

$$\begin{aligned}\Delta \mathrm{In}\, ENC_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i}\Delta \mathrm{In}\, ENC_{t-i} + \sum_{i=0}^{n} \beta_{2i}\Delta \mathrm{In}\, y_{t-i} \\ + \sum_{i=0}^{n} \beta_{3i}\Delta PRICE_{t-i} + ECM_{t-1} + \mu_t \end{aligned} \tag{5}$$

$$\begin{aligned}\Delta \mathrm{In}\, PRICE_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i}\Delta \mathrm{In}\, ENC_{t-i} + \sum_{i=0}^{n} \beta_{2i}\Delta \mathrm{In}\, y_{t-i} \\ + \sum_{i=0}^{n} \beta_{3i}\Delta \mathrm{In}\, PRICE_{t-i} + ECM_{t-1} + \mu_t \end{aligned} \tag{6}$$

where ECM_{t-1} is the lagged error-correction term obtained from the long-run equilibrium relationship.

Although the existence of a long-run relationship between energy consumption, prices and economic growth suggests that there must be Granger causality in at least one direction, it does not indicate the direction of temporal causality between the variables. The direction of the causality in this case can only be determined by the *F*-statistic and the lagged error-correction term. While the *t*-statistic on the coefficient of the lagged error-correction term represents the long-run causal relationship, the *F*-statistic on the explanatory variables represents the short-run causal effect (see also Odhiambo, 2009c; Narayan and Smyth, 2006; Oh and Lee, 2004). It should, however, be noted that even though the error-correction term has been incorporated in all equations, only the cointegrating vector in each of the study countries will be estimated with an error-correction term (see Odhiambo, 2009a; Narayan and Smyth, 2006; Morley, 2006).

Table 2
Stationarity tests of variables on first difference—Philips–Perron (PP) test.

Variable	No trend	Trend	Stationarity status
South Africa			
D In y/N	−4.089458***	−4.047437**	Stationary
D In *ENC*	−5.119393***	−5.131764***	Stationary
D In *PRICE*	−9.537277***	−6.504101***	Stationary
Kenya			
D In y/N	−5.254371***	−4.915619***	Stationary
D In *ENC*	−6.936936***	−7.114824***	Stationary
D In *PRICE*	−6.241716***	−6.196010***	Stationary
Congo (DRC)			
D In y/N	−4.195266***	−5.736807***	Stationary
D In *ENC*	−7.253373***	−7.521101***	Stationary
D In *PRICE*	−7.070361***	−9.922922***	Stationary

Note: (1) The truncation lag is based on Newey and West (1987) bandwidth. (2) ** and *** denote statistical significance at the 5% and 1% levels, respectively.

4.3. Empirical analysis

4.3.1. Stationarity test

The results of the stationarity tests in levels (not presented here) show that all variables are non-stationary in levels. Having

[2] The CPI was used as a proxy for energy prices because energy prices for all the study countries were not available (see also Asafu-Adjaye, 2000).

found that the variables are not stationary in levels, the next step is to difference the variables once in order to perform stationarity tests on differenced variables. The results of the stationarity tests on differenced variables are presented in Tables 2 and 3.

The results reported in Tables 2 and 3 show that after differencing the variables once, all the variables were confirmed to be stationary. The Phillips–Perron and Ng–Perron tests applied to the first difference of the data series reject the null hypothesis of non-stationarity for all the variables used in this study. It is, therefore, worth concluding that all the variables used in this study are integrated of order one.

4.3.2. Cointegration test

In this section the long-run relationship between energy consumption, prices and economic growth is examined in the three study countries using the ARDL-bounds testing procedure (see Odhiambo, 2009a). The ARDL-bounds test involves two steps. In the first step, the order of lags on the first differenced variables in Eqs. (1)–(3) is obtained from the unrestricted models by using the Akaike Information Criterion (AIC) and the Schwartz Bayesian Criterion (SBC). In the second step, the bounds *F*-test is applied to Eqs. (1)–(3) in order to establish a long-run relationship between energy consumption, prices and economic growth in the three study countries. The results of the bounds test are reported in Table 4.

The results reported in Table 4 show that for South Africa the calculated *F*-statistic is higher than the critical value at the 1% in the economic growth equation, but lower than the critical value in the energy consumption and price equations. In Kenya the calculated *F*-statistic is higher than the critical value at the 1% in the economic growth equation and at the 5% in the energy consumption equation, but lower than the critical value in the price equation. Finally, in Congo (DRC) the calculated *F*-statistic is higher than the critical value at the 1% and 10% in the price and energy consumption equations, respectively, but it is lower than the critical value in the economic growth equation. This, therefore, shows that there is a unique cointegrating vector in the case of South Africa (i.e. y/N equation); two cointegrating vectors in the case of Kenya (i.e. y/N and *ENC* equations) and two cointegrating vectors in the case of Congo (DRC) (i.e. *ENC* and *PRICE* equations).

4.3.3. Analysis of causality test

Having found that there is a long-run relationship between energy consumption, prices and economic growth in South Africa, Kenya and Congo (DRC), the next step is to test for the direction of causality between the three variables in each country by incorporating the lagged error-correction term into the relevant cointegrating vectors. The causality in this case is examined through the significance of the coefficient of the lagged error-correction term and joint significance of the lagged differences of the explanatory variables using the Wald test. The results of the causality tests are reported in Table 5.

The empirical results reported in Table 5 show that there is a distinct unidirectional causal flow from energy consumption to economic growth in the case of South Africa and Kenya, but a unidirectional causality from economic growth to energy consumption in the case of Congo (DRC). The results apply irrespective of whether the causality is estimated in the short-run or in the long-run. The short-run causality is supported by the

Table 3
Stationarity tests of variables on first difference—Ng–Perron test.

Variable	Ng–Perron test			
	MZa	*MZt*	*MSB*	*MPT*
South Africa				
D In *y/N*	−15.4597	−2.68227	0.17350	1.94550
D In *ENC*	−19.2294	−2.99761	0.15589	1.63481
D In *PRICE*	−31.7741	−3.98166	0.12531	0.78371
Kenya				
D In *y/N*	−37.3449	−4.32046	0.11569	0.65803
D In *ENC*	−17.1810	−2.84485	0.16558	1.73639
D In *PRICE*	−35.7584	−4.22599	0.11818	0.69207
Congo (DRC)				
D In *y/N*	−19.8018	−3.06233	0.15465	1.52935
D In *ENC*	−21.4187	−3.26873	0.15261	1.15691
D In *PRICE*	−16.3537	−2.79587	0.17096	1.72934
Critical values				
1%	−13.8000	−2.58000	0.17400	1.78000
5%	−8.10000	−1.98000	0.23300	3.17000
10%	−5.70000	−1.62000	0.27500	4.45000

Where *MPT*, *MZa*, *MZt* and *MSB* are Ng–Perron test statistics—calculated using generalised least-squares (GLS) de-trended data.

Table 4
Bounds *F*-test for cointegration.

Dependent variable	Function		*F*-test statistic			
South Africa						
In *y/N*	In *y/N* (In *ENC*, In *PRICE*)		8.2531***			
In *ENC*	In *ENC* (In *y/N*, In *PRICE*)		1.2632			
In *PRICE*	In *PRICE* (In *ENC*, In *y/N*)		1.43913			
Kenya						
In *y/N*	In *y/N* (In *ENC*, In *PRICE*)		8.4554***			
In *ENC*	In *ENC* (In *y*/N, In *PRICE*)		5.6397**			
In *PRICE*	In *PRICE* (In *ENC*, In *y/N*)		1.4507			
Congo (DRC)						
In *y/N*	In *y/N* (In *ENC*, In *PRICE*)		0.7519			
In *ENC*	In *ENC* (In *y/N*, In *PRICE*)		4.6019*			
In *PRICE*	In *PRICE* (In *ENC*, In *y/N*)		7.652***			
Asymptotic critical values						
	1%		**5%**		**10%**	
	***I*(0)**	***I*(1)**	***I*(0)**	***I*(1)**	***I*(0)**	***I*(1)**
Pesaran et al. (2001), p. 301, Table CI(iv) Case IV	4.99	5.85	3.88	4.61	3.38	4.02
Narayan (2005), p. 1989, Appendix: Case IV	6.428	7.505	4.535	5.415	3.770	4.535

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 5
Granger non-causality tests.

***F*-statistics [*P*-value]**				***t*-statistics**
Dependent variable	Δ In y/N_t	Δ In ENC_t	Δ In $PRICE_t$	ECM_{t-1}
South Africa				
Δ In y/N_t	–	4.8521[0.0042]***	1.4213 [0.2924]	-0.5035 [-3.290]***
Δ In ENC_t	0.4633 [0.8993]	–	0.4807 [0.8884]	–
Δ In $PRICE_t$	1.6636 [0.2242]	1.8983[0.1591]	–	–
Kenya				
Δ In y/N_t	–	3.4691[0.02031]**	3.2835 [0.02721]**	-0.6582 [-2.411]**
Δ In ENC_t	1.3836 [0.2904]	–	0.6243 [0.7945]	-0.0434 [-0.801]
Δ In $PRICE_t$	1.9388 [0.1305]	6.6966 [0.0005]***	–	–
Congo (DRC)				
Δ In y/N_t	–	1.3404 [0.3777]	4.7051[0.0079]***	–
Δ In ENC_t	5.884 [0.0029]***	–	3.2385 [0.0351]**	-0.7804[-3.786]***
Δ In $PRICE_t$	1.041 [0.4551]	4.1471[0.0140]***	–	-0.7928[-3.287]***

** and *** denote statistical significance at the 5% and 1% levels, respectively.

F-statistics, which are statistically significant in the economic growth function in the case of South Africa and Kenya, and in the energy consumption function in the case of Congo (DRC). The long-run causality, on the other hand, is supported by the coefficient of the lagged error-correction term, which is negative and statistically significant in the economic growth function in the case of South Africa and Kenya, and in the energy consumption in the case of Congo (DRC). Other results show that: (i) for Kenya, there is a unidirectional causal flow from prices to economic growth and a *prima-facie* (short-run) causal flow from energy consumption to prices; (2) for Congo (DRC) there is a distinct unidirectional causal flow from energy consumption to prices and a *prima-facie* (short-run) causal flow from prices to economic growth. The remaining causal flows, however, proved to be insignificant.

5. Conclusion and policy implications

This study examines the causal relationship between energy consumption and economic growth in three sub-Saharan countries, namely South Africa, Kenya and the DRC. The study incorporates prices as an intermittent variable in the energy-growth nexus in order to avoid the common biases associated with the bivariate causality analysis —thereby creating a simple trivariate framework. The results show that the causality between energy consumption and economic growth varies significantly across the study countries. In the main, the results show that there is a distinct unidirectional causal flow from energy consumption to economic growth in the case of South Africa and Kenya, but a unidirectional causality from economic growth to energy consumption in the case of Congo (DRC). The results apply irrespective of whether the causality is estimated in the short-run or in the long-run. Other results show that: (i) for Kenya, there is a unidirectional causal flow from prices to economic growth and *prima-facie* (short-run) causal flow from energy consumption to prices; (2) for Congo (DRC) there is a distinct unidirectional causal flow from energy consumption to prices and a *prima-facie* (short-run) causal flow from prices to economic growth. The findings of this study have important policy implications insofar as energy conservation and efficiency policies are concerned. For example, for Congo (DRC) the implementation of energy conservation policies may not significantly affect economic growth because Congo's economy is not energy dependent. However, for South Africa and Kenya there is a need for more energy supply augmentations in order to cope with the growing energy demand. In the short-run, however, the two countries should explore more efficient and cost-effective sources of energy in order to address the energy dependency problem.

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