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Electricity consumption and economic growth: a time series experience for 17 African countries

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Abstract

While the availability of electricity by itself is not a panacea for the economic and social problems facing Africa, the supply of electricity is nevertheless believed to be a necessary requirement for Africa's economic and social development. This paper tests the long-run and causal relationship between electricity consumption per capita and real gross domestic product (GDP) per capita for 17 African countries for the period 1971–2001 using a newly developed cointegration test proposed by Pesaran et al. (2001) and using a modified version of the Granger causality test due to Toda and Yamamoto (1995). The advantage of using these two approaches is that they both avoid the pre-testing bias associated with conventional unit root and cointegration tests. The empirical evidence shows that there was a long-run relationship between electricity consumption per capita and real GDP per capita for only 9 countries and Granger causality for only 12 countries. For 6 countries there was a positive uni-directional causality running from real GDP per capita to electricity consumption per capita; an opposite causality for 3 countries and bi-directional causality for the remaining 3 countries. The result should, however, be interpreted with care as electricity consumption accounts for less than 4% of total energy consumption in Africa and only grid-supplied electricity is taken into account.

Keywords: Africa; Electricity consumption; Causality

1. Introduction

Despite the immense energy potential Africa possesses, energy consumption in general and electricity consumption in particular is very low (Karekezi and Kimani, 2002; Economic Commission for Africa (ECA), 2004).[1] The average African is still using less energy than the average person used energy in England more than a century ago (Davidson and Sokona, 2002). The disparity in electricity consumption, let alone between Africa and the rest of the world even among African countries themselves, is glaring. Even more glaring is the wide disparity within African countries themselves. For instance, in Ghana 62% of the urban population has access to electricity while only 4% of the rural population has access to electricity (Saghir, 2002). Electrification rates range from as low as 3.7% in Uganda, 4.7% in Ethiopia and 5.0% in Malawi to as high as 45% in Ghana, 50% in the Ivory Coast and 66% in South Africa (International Energy Agency (International Energy Agency (IEA), 2002). Similarly, electricity power consumption per capita ranged from as high as 556 kWh in Zambia, 698 kWh in Gabon and 845 kWh in Zimbabwe to low as 22 kWh in Ethiopia, 47 kWh in the Democratic Republic of the Congo and 58 kWh in Tanzania (World Bank, 2003). The average per capita electricity consumption for Sub-Saharan Africa (excluding South Africa) was 112.8 kWh in 2000, representing a

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[1] The problem with Africa's electricity sector is not that of scarcity but the lack of "... institutions, rules, financing mechanisms, and regulations needed to make markets work in support of energy for sustainable development" (UNDP, 2004).

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mere 5% of the world average.[2] With only 23% of its population electrified compared to the world average of 73%, Africa has the lowest electrification rate of any major world region (IEA, 2002). More than 500 million Africans are still without access to electricity. To make matters still worse, while the world electricity per capita consumption has been rising steadily over the past three decades, Sub-Saharan Africa's per capital electricity consumption has been stagnant. In fact, the electricity per capital consumption of Sub-Saharan African countries (excluding South Africa) declined from 132.6 kWh in 1980 to 112.8 kWh in 2000 (World Bank, 2003). To aggravate the problem further, less than 10% of the Sub-Saharan Africa population has access to electricity, with electricity largely confined to the energy-intensive sub-sector of the commercial and industrial enterprises and to the high-income households, while the electrification of the rural and urban poor is 'woefully inadequate' or non-existent (Karekezi, 2002). The number of people without electricity in Africa has doubled in rural areas and tripled in urban areas in the last 30 years. Most of the people without access to electricity in 2030 will still be in Sub-Saharan Africa (650 million) and South Asia (680 million) (IEA, 2002), with the population of Sub-Saharan Africa without electricity increasing steadily until 2025. It is estimated that at the rate of connections of the past decade, it would take more than 40 years to electrify South Asia and almost twice as long for Sub-Saharan Africa (IEA, 2002). If the transition to modern fuels is usually complete by the time per capita income reaches US$1000–1500 (Toman and Jemelkova, 2003), Sub-Saharan Africa has a long way to go: "… access to electricity for the poor is a dream that is unlikely to be realised in the near future" (Karekezi and Kimani, 2002).

The purpose of this paper is to investigate the long-run and causal relationship between electricity consumption and economic growth for 17 African countries using a newly developed cointegration test due to Pesaran et al. (2001) and using a modified version of the Granger causality test proposed by Toda and Yamamoto (1995). Cointegration is preferred over conventional methodology for two main reasons. In the first place, the relationship found using ordinary regression analysis of time series data could be spurious as the time series properties of the data are not taken into consideration. Granger and Newbold (1974) have shown that when using non-stationary data, standard statistical *t*- and *F*-tests are misleading. In a spurious regression, there is no relationship between the series under consideration. Tests of ordinary regression to time series data may often suggest a statistically significant relationship between variables, where none in fact exists. Cointegration provides a way of avoiding the misleading inference associated with a spurious regression (see Enders, 2004). Moreover, while the use of ordinary regression is useful in detecting correlation between two or more variables, it cannot detect whether there is a long-run or a casual relationship between or among the time series data under consideration; correlation does not imply causation. From a policy perspective, it is important to know the direction of causality, say, between energy consumption and economic development, so that energy conservation measures may or may not be taken depending on the direction of causality between energy consumption and economic growth.

Despite the burgeoning literature on the study of causality between electricity consumption and economic growth, there are not many time series studies concerning African countries (see Jumbe, 2004). Apart from filling this gap, we focus on electricity for two other reasons. While 89% of Sub-Saharan people rely for their energy consumption on biomass, long-term time series data for biomass are only available since 1994 (IEA, 2002). Electricity seems to be the only sub-sector where long-term time series data are available from the World Bank, World Development Indicators (2004), and this is one of the factors that motivated this paper. More importantly however, we focus on electricity because of the pivotal role it plays in economic development and technological progress. While the availability of electricity is not by itself a panacea for the economic and social problems facing Africa, the supply of electricity is nevertheless believed to be a necessary requirement for Africa's economic and social development (IEA, 2002). Even at the individual level, research shows that electricity service appears to be one of the most important services for improving the welfare of the poor individual (IEA, 2002). At the national level, in this era of the digital economy, it is really difficult to envisage development without the use of electricity. Electricity and other modern energy sources are necessary requirements for economic and social development (IEA, 2002). "No country in the world has succeeded in shaking loose from subsistence economy without access to the services of modern energy provides" (World Bank, n.d.). Apart from the physical availability of energy, change in the quality of energy service is one of the most important drivers of economic productivity (see Toman and Jemelkova, 2003). The process of economic development necessarily involves a transition from low levels of energy consumption to higher levels where the linkages among energy, other factor inputs and economic activity change significantly

[2] This contrasts with 40.8% for South Asia, 86.6% for Latin America and 89.6% for East Asia/China (International Energy Agency (IEA), 2002). The electricity power consumption kWh per capita was 456 for South Asia, 1493 for Latin America and 2159 for the world (see World Development Indicators (2004); African Development Indicators, 2004).

as an economy moves through different stages of development (see Burney, 1995; Toman and Jemelkova, 2003). Furthermore, as the economy progresses, commercial fossil fuels and ultimately electricity becomes predominant (see Toman and Jemelkova, 2003). Thus, although currently Sub-Saharan African countries consume a mere fraction of the electricity consumed by industrial countries, rapid urbanization combined with economic growth is likely to accelerate the energy transition from traditional to commercial energy use (IEA, 2002).

Statistical evidence also suggests that electricity consumption is strongly correlated with wealth and lack of electricity is strongly correlated to the number of people living below $2 per day (IEA, 2002). The elasticity of power system capacity to GDP in developing countries is about 1.4 (Munasinghe and Meir, 1993). Ferguson et al. (2000) also found that for developed countries, there is a strong correlation between increases in wealth over time and increases in energy consumption. Moreover, there is a stronger correlation between electricity use and wealth creation than there is between total energy use and wealth (Ferguson et al., 2000). The experience of developed countries also shows that the electricity supply sector played a crucial role in their economic development not only as a key input in their industrial development but also as a key factor in improving the quality of life of their people (Rosenberg, 1998). Further, increasing electricity use has been identified as an important source of productivity improvement in developed countries and it is the sector that is currently fuelling the "new digital economy" (Ebohon, 1996; Rosenberg, 1998). For developing countries it has also been found out that there is a significant correlation between export diversification and per capita electricity consumption and electricity production per worker in Africa (ECA, 2004). Countries with high per capita electricity consumption are expected to have lower energy costs and vice versa. Export diversification is positively associated with per capita electricity consumption and electricity production per worker, implying that countries that have more access to electricity tend to have a relatively lower cost of energy and are more diversified (ECA, 2004). The evidence suggests that good and reliable energy infrastructure is a prerequisite for export diversification and sustained growth, but the inability of many African countries to provide good and adequate energy services has been a major constraint for their export diversification and growth (ECA, 2004).

It is now widely accepted that if Sub-Saharan African countries are to pursue sustained economic growth which is vital to their efforts of eradicating poverty and social development, the availability of financially feasible, reliable and efficient supply of electricity is crucial (Turkson and Wohlgemuth, 2001). Further, the expansion of electricity supply is important for Sub-Saharan Africa in order to minimize the consumption of traditional fuel (biomass) that has been responsible for the massive deforestation, desertification and the health problems associated with wood fuel and charcoal consumption (IEA, 2002). The ubiquitous electricity restructuring that is currently taking place in many African countries is part of the process of the recognition that electricity can play a pivotal role in Africa's social and economic development.[3] Implicit in this restructuring process is the assumption that investment in electricity and the drive towards making the electricity sector more efficient can promote economic growth. Therefore, knowledge of the direction of causality between electricity consumption and economic growth is of prime importance if appropriate energy policies and energy conservation measures are to be devised. Central to the debate is whether electricity consumption stimulates, retards or is neutral to economic growth. Some argue that modern energy use is a prerequisite for economic, social and technological progress where it complements labour and capital in the production process (see, Ebohon, 1996; Templet, 1999). For the proponents of the above hypothesis, lack of energy is a limiting factor to economic growth and technological progress. They believe that electricity has been a major source of betterment of the standard of living of advanced countries and it has played a crucial role in the technological and scientific advancement of these countries (see, Rosenberg, 1998). Even in poor countries, it has been found out that the use of electricity is associated with improving the health and educational standards of the poor (IEA, 2002). Others however contend that the role of energy is minimal or is neutral to economic growth. This is because the cost of energy is very small as a proportion of GDP and thus energy consumption is not likely to have a significant impact on output growth. Moreover, they argue that as the economy grows, its production structure is likely to shift to the service sector that is less energy intensive relative to the industrial sector (see Ghali and El-Saka, 2004). This, however, may not be true for the electricity sector as the evidence from the US experience suggests that the US economy is becoming simultaneously less energy intensive but more electricity intensive (Rosenberg, 1998).

The above contrasting hypotheses have motivated many researchers to seek the direction of causality between electricity consumption and economic development. The empirical evidence is mixed, reflecting the divergent hypotheses with causality ranging from bi- to uni-directional (see Fatai et al. 2004; Jumbe, 2004;

[3]For an excellent summary of the power restructuring in African countries, see Karekezi and Kimani (2001); Turkson and Wohlgemuth (2001) and Turkson (2000).

Wolde-Rufael, 2004; Ghali and El-Saka, 2004). For instance, Yang (2000) found bi-directional causality between electricity consumption and economic growth for Taiwan as did Morimoto and Hope (2004) for Sri Lanka; Yoo (in press) for South Korea; Glauser and Lia (1997) for South Korea and Singapore and Jumbe (2004) for Malawi. Causality running from economic growth to electricity consumption was found for India by Ghosh (2002); for Australia by Narayan and Smyth (2005) and by Fatai et al. (2004) and for the USA by Thoma (2004). In contrast, uni-directional causality running from electricity consumption to economic growth was found by Shiu and Lam (2004) for China and by Wolde-Rufael (2004) for Shanghai. These conflicting evidences have major implications for energy policy. If there is a unidirectional causality running from electricity consumption to economic growth, reducing electricity consumption could lead to a fall in economic growth (see Asafu-Adjaye, 2000). In contrast, if there is a uni-directional causality running from economic growth to electricity consumption, it could imply that policies for reducing electricity consumption may be implemented with little or no adverse effect on economic growth. On the other hand, if there is no causality running in any direction between electricity consumption and income, reducing electricity consumption may not affect income and energy conservation policies may not affect economic growth (see Asafu-Adjaye, 2000; Jumbe, 2004; Yoo (in press)). In contrast, if there is a bi-directional causality, economic growth may demand more electricity while more electricity use may induce economic growth; electricity consumption and economic growth complement each other and energy conservation measures may negatively affect economic growth.

The diversity of the empirical findings, together with the important role electricity consumption plays in economic development, not only necessitates further research but also new methodologies for testing the relationship between electricity consumption and economic growth. With this objective in mind, the rest of the paper is organized as follows. An outline of the methodology is presented in Section 2 followed by the empirical evidence presented in Section 3. Some concluding remarks are outlined in Section 4.

2. Methodology

The paper argues that many of the time series studies cited above, which that have attempted to conduct cointegration and causality tests between energy consumption and economic growth, have two basic limitations. In the first place, the methodology used for testing a long-run cointegration relationship requires that both series to be integrated are of order one or I(1) and any inference that can be made about the energy-economic growth nexus is conditional on the assumption that both series are I(1). If the series are not I(1), or are integrated of different orders, no test for a long-run relationship is usually carried out. However, given that unit root and cointegration tests have low power against the alternative, these tests can be misplaced and can suffer from pre-testing bias (see Pesaran et al., 2001; Toda and Yamamoto, 1995). Moreover, as demonstrated by Toda and Yamamoto (1995), the conventional F-statistic used to test for Granger causality may not be valid as the test does not have a standard distribution when the time series data are integrated or cointegrated (see Toda and Yamamoto, 1995; Giles and Mizra, 1998; Giles Williams, 1999).[4]

2.1. The bounds test approach to cointegration

This paper attempts to extend the electricity–economic growth nexus by using the cointegration test suggested by Pesaran et al. (2001) that does not require knowledge of the order of integration or cointegration ranks of the variables and thus avoids the inherent limitations in testing for unit roots prior to testing for cointegration. The approach is particularly attractive when we are not sure whether the series is I(0) or I(1). It can be applied irrespective of whether the regressors are I(0) or I(1) or mutually cointegrated. The approach proposed by Pesaran et al. (2001) can be applied to studies that have small sample sizes, such as this study with 31 observations for each county. The approach is based on the estimation of a dynamic error correction representation for the variables involved and tests whether or not the lagged levels of the variables are statistically significant. The test consists of estimating the following unrestricted error correction model (UECM) considering each variable in turn as a dependent variable:

$$\Delta LY_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i}\,\Delta LY_{t-i} + \sum_{i=1}^{m} \delta_{1i}\,\Delta LE_{t-i} + \eta_1 LY_{t-1} + \eta_2 LE_{t-1} + \mu_{1t}, \tag{1}$$

where LY_t is the log of real GDP per capita and LE_t is the log electricity consumption measured in kWh per capita. All data are from World Development Indicators CD-Rom version 2004. The number of countries was determined by the availability of data for 1971–2001.

We test for the joint significance of the lagged levels in Eq. (1) using the F-test, where the null hypothesis of no cointegration is defined as H_0: $\eta_1 = \eta_2 = 0$ against the alternative that H_1: $\eta_1 \neq 0$, $\eta_2 \neq 0$. The asymptotic distribution of the F-test is non-standard under the null

[4]The Toda and Yamamoto (1995) approach has also some limitations including small sample bias (see Kuzozumi and Yamamoto, 2000).

and is derived and tabulated in Pesaran et al. (2001). Two sets of critical values are provided: one which is appropriate when all the series is I(0) and the other is for all the series that is I(1), thus covering all the possible classifications of the series into I(0), I(1) or mutually cointegrated (Pesaran et al., 2001). If the computed F-statistic falls above the critical bounds, a conclusive inference can be made regarding cointegration without the need to know the order of integration of the series. In this case, the null of no cointegration is rejected regardless of whether the series is I(0) or I(1). Alternatively, when the test statistic falls below the lower critical value, the null hypothesis is accepted, again regardless of whether the series is I(0) or I(1). In contrast, if the computed F-statistic falls inside the lower and upper bounds, a conclusive inference cannot be made unless we know the order of integration of the series under consideration.

2.2. *The Toda–Yamamoto approach to Granger causality test*

For the causality test, a modified Wald test (MWALD) is used as proposed by Toda and Yamamoto (1995) that avoids the problems associated with the ordinary Granger causality test outlined above by ignoring any possible non-stationary or cointegration between series when testing for causality. The Toda and Yamamoto (1995) approach fits a standard vector autoregressive model in the levels of the variables (rather than the first differences, as the case with Granger causality tests), thereby minimizing the risks associated with the possibility of wrongly identifying the order of integration of the series (Mavrotas and Kelly, 2001). The basic idea of this approach is to artificially augment the correct VAR order, k, by the maximal order of integration, say $d_{\max}$. Once this is done, a $(k + d_{\max})$th order of VAR is estimated and the coefficients of the last lagged $d_{\max}$ vector are ignored (see Caporale and Pittis, 1999; Rambaldi and Doran, 1996; Rambaldi, 1997; Zapata and Rambaldi, 1997). The application of the Toda and Yamamoto (1995) procedure ensures that the usual test statistic for Granger causality has the standard asymptotic distribution where valid inference can be made.

To undertake Toda and Yamamoto (1995) version of the Granger non-causality test, we represent the electricity-GDP model in the following VAR system:

$$LY_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} LY_{t-i} + \sum_{j=k+1}^{d\max} \alpha_{2j} LY_{t-j} + \sum_{i=1}^{k} \phi_{1i} LE_{t-i} + \sum_{j=k+1}^{d\max} \phi_{2j} LE_{t-j} + \lambda_{1t}, \quad (2)$$

$$LE_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} LE_{t-i} + \sum_{j=k+1}^{d\max} \beta_{2j} LE_{t-j} + \sum_{i=1}^{k} \delta_{1i} LY_{t-i} + \sum_{j=k+1}^{d\max} \delta_{2j} LY_{t-j} + \lambda_{2t}, \quad (3)$$

where the series are defined in Eq. (1) above. From (2), Granger causality from LE_t to LY_t implies $\phi_{1i} \neq 0 \forall_i$; similarly in (3), LY_t Granger causes LE_t, if $\delta_{1i} \neq 0 \forall_i$. The model is estimated using Seemingly Unrelated Regression (SUR) (see Rambaldi and Doran, 1996).

3. Empirical results

Results of the Pesaran et al. (2001) tests for the 9 countries for which the null hypothesis of no long-run relationship between real GDP per capita and electricity consumption per capita is rejected are presented in Table 1. For 5 countries (Congo Republic, Gabon, Nigeria, South Africa and Zimbabwe),there was a long-run relationship when real GDP per capita was used as the dependent variable, while there was a long-run relationship for 4 countries (Benin, Cameroon, Morocco and Zambia) when electricity consumption per capita was used as the dependent variable.[5] For the remaining 6 countries, LY_t and LE_t did not have any long-run relationship, i.e. they were not cointegrated. Except for Benin, Gabon and Zambia, the error-correction term was negatively and statistically significant, showing a speed of adjustment of any disequilibrium towards a long-run equilibrium state ranging from 24% to 65% within 1 year.

To complement the above results, causality tests were also carried out using the Toda and Yamamoto (1995) procedure. In order to undertake causality, the optimal lag, k has to be determined.[6] The optimum lag was selected according to Lütkepohl's (1993, p. 306) procedure, where he suggests linking the lag length (*mlag*) and number of endogenous variables in the system (m) to a sample size (T) according to the $m * mlag = T^{1/3}$ formula (see Kónya, 2000). With $T = 31$, we initially set $k = 3$, and we used the Akaike Information Criteria (AIC) and the SBIC to select the optimal lag (see Enders, 2004).

Results of the causality tests are presented in Table 2. As can be learned from the significance of the p-values of the modified Wald (MWALD) statistic, there was causality for 12 countries and no causality for the remaining 5 countries. For 6 countries (Cameroon,

[5] The fact that there is a long-run relationship when LY_t and LE_t were used as dependent variables alternatively is an indication of a bi-directional causality (see Fatai et al., 2004). As can be seen from Table 2, this was only true for the case of Gabon.

[6] The order of integration of the series was found out to be I(1).

Ghana, Nigeria, Senegal, Zambia and Zimbabwe) there was a positive uni-directional causality running from LY_t to LE_t, implying that economic development seems to have taken precedence over electricity consumption and that economic growth caused greater demand for electricity consumption. The unidirectional causality running from economic development to energy consumption may statistically suggest that electricity conservation measures may be taken without jeopardizing economic development. In practice, however, to suggest measures that can lead to the reduction of electricity consumption to the end-user in order to stall any conservation problem arising out of electricity consumption may not be a viable option for these countries, particularly given the magnitude of their energy problems and the fact that the current energy infrastructure of these countries is still inadequate to support their quest for rapid economic growth that is required to eradicate poverty and to raise the living standards of their people. Reducing electricity consumption while the overwhelmingly majority of their population is still denied access to the use of electricity may not be a viable option. These countries have not yet reached the energy ladder that may warrant such a suggestion but they can still improve the detrimental consequences of electricity consumption without reducing electricity consumption. By making their electricity sector more efficient and by making it available to a larger part of their population, electricity used per unit of output can be raised. Although the average African currently uses far less energy than the world average, producing a dollar's worth of GDP uses more energy in Africa on the average than the rest of the world (ECA, 2004). For instance, for Nigeria and Senegal, electricity conservation can be achieved by reducing electric power transmission and distribution losses that stood at

Table 1
Tests for cointegration using the ARDL approach

Country	Dependent variable	*F*-statistic	Long-run coefficient	Error correction term, *ecm*(−1)
Benin	ΔLE	6.915*a	0.081	None
Cameron	ΔLE	7.286***	0.547	−0.653***
Congo Republic	ΔLY	5.861**	2.375***	−0.531***
Gabon	ΔLY	6.334*	−0.264***	−0.621***
Morocco	ΔLE	11.947***	2.154	−0.374***
Nigeria	ΔLY	6.941*	−0.442**	−0.286**
South Africa	ΔLY	5.403*	−0.129	−0.243**
Zambia	ΔLE	7.647**a	−0.465	−0.458***
Zimbabwe	ΔLY	7.896***	0.052	None

Notes: ***, ** and * denote significant at 1%, 5% and 10% respectively. The *F*-statistic is non-standard and is tabulated in Pesaran et al. (2001). 'a' denotes with trend. Due to the small size, a maximum lag structure of three ($m = 3$) was considered for the UECM in Eq. (1). The appropriate lag structures were selected according to the Akaike and Schwartz criteria (see Pesaran and Pesaran, 1997; Enders, 2004). Several misspecification tests showed no major deviation from normal regression assumptions (see Pesaran and Pesaran, 1997). For Gabon and South Africa, there was also a long-run relationship when ΔLE was used as a dependent variable.

Table 2
Granger no causality test

	From LE to LY		From LY to LE		Direction of causality
	p-value	Sum of lagged coefficients	*p*-value	Sum of lagged coefficients	
Algeria	0.774	0.032	0.392	0.124	NO
Benin	0.008***	0.068	0.693	0.418	$LE \rightarrow LY$
Cameroon	0.486	0.015	0.000***	0.086	$LY \rightarrow LE$
Congo, DR.	0.000***	0.161	0.164	0.627	$LE \rightarrow LY$
Congo, Rep.	0.893	−0.015	0.744	0.587	NO
Egypt	0.052**	0.239	0.002***	0.197	$LE \leftrightarrow LY$
Gabon	0.000***	−0.225	0.000***	1.201	$LE \leftrightarrow LY$
Ghana	0.796	0.023	0.000***	1.705	$LY \rightarrow LE$
Kenya	0.260	0.104	0.556	−0.192	NO
Morocco	0.000***	1.408	0.000***	1.367	$LE \leftrightarrow LY$
Nigeria	0.158	0.074	0.076*	0.387	$LY \rightarrow LE$
Senegal	0.933	−0.017	0.040**	0.442	$LY \rightarrow LE$
South Africa	0.713	−0.096	0.707	−0.051	NO
Sudan	0.484	0.110	0.928	0.093	NO
Tunisia	0.017**	−0.150	0.378	0.369	$LE \rightarrow LY$
Zambia	0.672	−0.077	0.059**	0.392	$LY \rightarrow LE$
Zimbabwe	0.647	−0.511	0.097*	0.512	$LY \rightarrow LE$

Notes: ***, ** and * denote 1%, 5% and 10% significant levels. The Lagrange multipliers test is also used to test whether the error terms are serially uncorrelated. In addition, the residuals were also checked for serial correlation using the Box-Pierce *Q*-statistic test (see Enders, 2004). Finally, the Jarque–Bera test for normality of the disturbance term was used (Pesaran and Pesaran 1997).

31.8% and 16.9% of output, respectively (ECA, 2004). Nigeria had the lowest level of energy efficiency in Africa, with $1.2 for one unit of energy use in 2000. By contrast, Namibia and Morocco recorded one of the highest levels of energy efficiency in the world, with respectively $12 and $9.5 for one unit of energy use (ECA, 2004). Increasing the efficiency of current supply and utilization should be the top-most priority of strategies for power sector development. Increasing energy efficiency and reducing the adverse effects of electricity generation can be achieved without reducing electricity supply to the end-user. Increasing energy efficiency can cut down growth of electricity demand that can mitigate conservation and health problems. Finding ways of expanding the quality and quantity of energy services while simultaneously addressing the environmental impacts associated with energy use represents one of the critical challenges Africa is facing (IEA, 2002).

For 3 countries (Benin, the Democratic Republic of the Congo and Tunisia) there was an opposite causality running from electricity consumption to economic growth. For Benin and the Democratic Republic of the Congo there was a positive causality, implying that electricity consumption acted as a stimulus to economic growth. In these countries, electricity consumption infrastructure shortages and the problems of blackout and constant interruptions so rampant in African countries can jeopardize their social and economic progress. In order to increase the supply of electricity, adequate investment provisions should be made by involving private capital, which is conspicuously lacking in many African countries. By investing more and reducing inefficacy in the supply and use of electricity, the sector can further stimulate economic growth. Benin and the Democratic Republic of the Congo had among the lowest levels of energy efficiency in Africa, with $2.3 and $3.2, respectively, for one unit of energy use (ECA, 2004). Generating adequate electricity supply for sustained development may be crucial especially for Benin and the Democratic Republic of Congo, where the electrification rate is 22% and 7%, respectively. In contrast to these two countries, in the case of Tunisia electricity consumption and economic growth were negatively related; as the economy progresses it requires less energy.

Bi-directional causality was detected for 3 other countries, Egypt, Gabon and Morocco. In the case of Egypt and Morocco, there was a positive bi-directional causality (feedback) implying that economic growth demands more electricity use and more electricity consumption induces economic growth. Since electricity consumption stimulates economic growth and in turn electricity consumption is stimulated by economic growth, investment and other efficient measures that increase electricity supply can be implemented, but such measures should not be at the expense of the environment. Morocco recorded one of the highest levels of energy efficiency in the world, $9.5 for one unit of energy use (ECA, 2004), while Egypt's was almost half of that of Morocco's level, but slightly above the average for less developed countries. Energy conservation measures to increase efficiency per unit of output are more pressing in Egypt than in Morocco. Unlike these two countries, in the case of Gabon, while there was a positive causality from economic growth to electricity consumption, there was a negative causality from electricity consumption to economic growth. Since electrification rate is only 30% in Gabon, it may not be feasible to reduce electricity consumption; what is needed is to make the electricity sector more efficient to produce more output per unit of electricity used. Even though the energy used per unit of output is above the average for less developed countries, Gabon can still increase its energy efficiency rate by increasing the output per unit of energy used.

For the remaining 5 countries where there was no causality in any direction between LE_t and LY_t, electricity consumption seems neither to promote nor to retard economic growth. Theoretically, for these countries energy conservation policies may be pursued without adversely affecting economic growth. Kenya, Congo Republic and the Sudan had the lowest levels of energy efficiency in Africa with, respectively, $1.3, $1.2 and $1.1 output for one unit of energy use. Low energy-efficiency levels in many African countries are due in large part to the virtual absence of energy conservation measures in their industrial sectors (ECA, 2004). For these countries, measures to increase efficiency should be one of the primary measures in energy conservation. Again, electricity conservation measures undertaken should not be at the expense of economic growth and poverty reduction measures such as expansion of electrification to the rural poor. These countries have to find ways of expanding the quality and quantity of energy services while simultaneously addressing the environmental impacts associated with energy use (IEA, 2002).

In summary, causality and long-run relationship were simultaneously detected for 7 out of the 17 countries. While long-run relationship could be found between LY_t and LE_t for the Congo Republic and South Africa, there was no evidence of causality between the two series in these two countries. In contrast, while causality could be detected between LY_t and LE_t for the Democratic Republic of the Congo, Egypt, Ghana, Senegal and Tunisia, there was no long-run relationship between these series in these countries. The lack of significant relationship between LY_t and LE_t for many countries could be attributed to some omitted variables that can affect both economic development and electricity consumption (Lütkepohl, 1982). While the study may help us to understand the causal relationship between electricity consumption and economic growth, the research is limited in that it did not take into consideration other factors that are important in determining economic growth and influencing electricity demand. For some of these countries where there was no causality, electricity may not be an important factor in complementing other factors of production and may not be used extensively in the production of goods and services. Electricity consumption still accounts for a small share of energy consumption in Africa, hardly more than 4% of total energy consumption.[7] The bulk of African countries do not depend on electricity as a source of their energy supply. Moreover, many businesses and individuals in these countries do not depend on grid-supplied electricity and the electricity used for this study may have understated the total electricity used in these countries. In these countries, there is a huge electricity demand by households and business that is not satisfied through grid supply but with electricity generators.[8] Access to a central power grid is a major challenge for Africa. It is therefore important that these weaknesses should be taken into account when interpreting these results.

4. Concluding remarks

In this paper, a recently developed cointegration and a modified version of the Granger causality tests were applied to investigate the long-run and causal relationship between real GDP per capita and electricity per capita consumption for 17 African countries for the period 1971–2001. Long run cointegrating relationship between the two series could be detected only for 9 countries, while causality for only 12 countries. This paper did not provide a definite stand on the existence or non-existence of the causal relationship between electricity consumption and economic growth, but our results show the following: (1) past values of economic growth have a predictive ability in determining present values of electricity consumption in some countries, (2) past values of electricity consumption have a predictive ability in determining the present values of economic growth; (3) there was feedback in some countries and (4) there was a lack of causal relationship for some countries. What the evidence may suggest is that there may be a number of factors at work that differ significantly across countries that account for the different directions of causality detected in this paper. Finding some of these factors that can help to explain this disparity may be another line of inquiry that can help us understand the relationship between electricity consumption and economic development. It is also important to note that the results of this study should be interpreted with care as electricity consumption not only accounts for a very small share of total energy consumed but is also confined to the urban and commercial and industrial but denied to the substantial majority of people in Africa. In addition, non–grid electricity consumption, which plays a significant role especially in small businesses and medium–sized enterprises development, is not taken here into consideration.

The challenge of providing adequate and reliable energy cannot be divorced from the other challenges Sub–Saharan African is facing. Poverty and poor access to modern energy are intractably linked and cannot be divorced from the many challenges Africa must tackle. Africa's energy problem is partly a result of the continent's macroeconomic mismanagement. Without improving the management of the economy and reducing the role of the state that has been blamed for Africa's economic ills, it is difficult to envisage how the energy challenges facing African countries can be addressed. The twin problems of low accessibility and lack of financial resources cannot be solved without drastic and fundamental changes to Africa's energy policy. Scarcity of energy supply is not the fundamental problem Sub–Saharan Africa is facing but its management is. It is encouraging to see that Africa is trying to make strides in restructuring its power sector industry with the view to making this sector efficient and accessible. However, without making the environment conducive to attracting the huge financial requirement needed to address the energy problem, African will remain without modern electricity for many years to come. It was beyond the scope of the paper to investigate the impact of the current wave of electricity restructuring that is sweeping Africa, but it would be interesting to see if these policy changes have made any impact on the accessibility and efficiency of the electricity sector in Africa. Unless the infrastructure necessary for modern supply of electricity and other forms of modern energy is firmly laid down, the talk about making electricity a driving force in Africa's economic development and an instrument for alleviating poverty and deprivation is naïve at best and a deliberate deception at worst.

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[7] However, even for South Africa, the largest consumer of electricity both in absolute and in per capita terms, there is no causality in any direction between electricity consumption per capita and per capita real GDP.

[8] I am grateful to the anonymous referee for pointing out this to me.

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