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Alinsato, Alastaire Sèna

Centre de Formation et de Recherche en Développement (University of Abomey-Calavi), University of Cocody (Abidjan)

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Electricity consumption and GDP in an electricity community:

Evidence from bound testing cointegration and Granger-causality tests

Alastaire Sèna Alinsato[1]

Centre de Formation et de Recherche en Développement, 02 BP 2163 Gbégamey-Cotonou, Université d'Abomey-Calavi (Bénin)

e-mail : alastaires@yahoo.fr Cel : (+229) 97 871 700

ABSTRACT

This study probes nexus between electricity consumption and GDP for the electricity community of Togo and Benin using ARDL bounds testing approach of cointegration. Long-run equilibrium has been established among these variables for Benin. The study further establishes long- and short-run Granger causality running from GDP to electricity consumption for Benin and short-run Granger causality running from GDP to electricity consumption for Togo. The results of the cointegration test and the causality reflect better the Benin and Togo economies that are less dependent on electricity. The absence of causality running from electricity consumption to GDP implies that electricity demand side management measures can be adopted to reduce the wastage of electricity, which would not affect future economic growth in the community.

Key words: ARDL, cointegration, causality, growth, electricity

JEL classification: C22, C32, O19

[1] Is also in the University of Cocody Abidjan

1. Introduction

Benin and Togo stand in Subsaharan Africa as a successful example of electricity energy cooperation. Indeed, since 1973, Benin and Togo cooperate with regard to the production of the electric energy through the electric Community of Benin (CEB). The Electric Community of Benin (CEB) is an international public establishment for electric energy development in Benin and Togo. It has been created by the international agreement of July 1968 instituting the electricity code between the Republic of Benin and the Republic of Togo. From this agreement, the CEB has the monopole of the production, the transport and the importations/exportations of the electric energy within the two State territories. The regulation of the electricity sector is managed by the CEB as well as the planning and the development of the sector.

Despite this example of integration, the electricity sector of both countries is characterized by outages and shortage. The total capacity installed by the CEB in 2006 is 1309 Gwh of which 664 Gwh and 645 Gwh respectively for Benin and Togo.

The total electrical energy has risen at a rate of around 200% from 1990 to 2006 for both countries. However, historically it has been found that capacity addition always falls short of target. On consumption side, per capita electricity consumption is about 47.82 Kwh per year for Benin and about 89.37 Kwh for Togo during this last two decades, which are among the lowest in subsaharian Africa countries.[2] Despite this low level of electricity consumption in average Benin experiment 44 shortage days in a year [WB, 2005].

Studies on the causal relationship between electricity consumption and economic growth occupy a substantial portion of economic literature. These studies have undergone extensively after the oil embargos in 1970s, and recently in developing countries since access to modern energy as electricity is found to be important for poverty reduction. The central issue has been whether economic growth stimulates consumption of energy or the energy consumption itself is a stimulus for economic growth via the indirect channel of effective aggregate demand, improved overall efficiency and technological progress. Blanchard and Gali (2007) and Brown and Yücel (2002) among others provide a survey of the theory and evidence on the macroeconomic impact of energy prices. Apart from price effects, the relationship between energy consumption and economic growth was also explored. As the level of electricity consumption can be taken to signal, in addition to economic growth, the level of socioeconomic development of a country, more recent studies have focused on examining the causality relationship between electricity consumption and economic growth (Belloumi, 2009; Ghosh, 2009; Akinlo, 2009; Narayan and Singh, 2007; Wolde-Rufael, 2006; Ferguson et al. 2000) . However, the debate on the nature of the relationship is far from being settled. The role of electricity consumption in economic growth has produced varying results across time and countries. Some empirical studies have identified a causal relation running from electricity consumption to economic growth (Akinlo, 2009; Wolde-Rufael, 2006), while few others reported the opposite (Wolde-Rufael, 2006; Jumbe, 2004). Few others have provided evidence of bidirectional causality between the electricity consumption and economic growth (Mozumder and

[2] 162,58 Kwh percapita for Côte d'Ivoire, 92,48 Kwh for Nigeria and 123 Kwh for Senegal.

Marathe, 2007; Wolde-Rufael, 2006). Yet, a handful of studies have reported neutral causal relation between electricity consumption and economic growth (Mozumber and Marathe, 2007; Jumbe, 2004; Asafu-Adjaye, 2000). The findings from the studies vary not only across countries, but depend also on methodologies within the same country (Akinlo, 2009; Wolde-Rufael, 2006; Soytas and Sari, 2003). Despite this numerous studies, none have focused on the causal relationship between energy consumption and GDP for Togo. Wolde-Rufael (2006) examined the cointegration and Granger causality using Pesaran et al (2001) procedure. His study failed to establish a cointegration relationship between GDP and electricity consumption for Benin.

But the study of Wolde-Rufael (2006) has some shortcoming due to the data it used. In fact, the author uses data from the WDI 2004 with data length below 30 year. Other weakness of his paper is that the author uses despite of the small size of his sample, the original critical values of Pesaran and al. (2001). Narayan (2005) argued that the existing critical values, because they are based on large sample sizes, cannot be used for small sample sizes. The present study tempts to account for this fact and examines with a reasonable data set the causal relation between the consumption of electricity and the growth.

This study is determinant since it tries to examine the relation between electricity and GDP in two energy integrated countries. The study will allow specifying whether it is of interest for both countries to have the same electricity policy. The previous studies don't try to look at that. Our concern here is then to check the existence of long-run relation between GDP and electricity consumption in Benin and Togo. In other world does cointegration exist between electricity consumption and GDP in Benin and in Togo?

How do electricity consumption and growth influence each other in the short term in the two integrated countries? Answers to these questions are necessary to define and implement the appropriate electricity development policies in the CEB. This type of study becomes necessary seen the importance of the regional initiative in order to assure energy security.

To meet it goal, this study employed recently developed autoregressive distributed lag (ARDL) bounds testing approach of cointegration developed by Pesaran et al. (2001). ARDL approach of cointegration has become popular in energy market analysis (Narayan and Smyth, 2005; Ghosh, 2009; Odhiambo, 2009) and is intensively used in other disciplines like macroeconomics, applied finance, education economics, tourism, etc. Some of the articles in these areas include Katircioglu (2009), Muchapondwa and Pimhidzai (2009), Narayan (2005).

2. Data and econometric methodology

2.1. Data description

Annual data on real GDP (in local currency) and electricity consumption have been collected from the World Development Indicator (2007) produced by the World Bank and the Electricity Community of Benin (CEB), for the time span 1973-1974 to 2005-2006. Table 1 gives the summary statistics of each of the variables used in the analysis. All the variables are in logarithm transformation.

2.2. Cointegration

ARDL bounds testing approach has been employed to examine both short run and long run elasticities among the variables. An ARDL model is a general dynamic specification, which uses the lags of the dependent variable and the lagged and contemporaneous values of the independent variables, through which the short-run effects can be directly estimated, and the long-run equilibrium relationship can be indirectly estimated. Unlike other single-equation estimation frameworks, it offers explicit tests for identifying a unique cointegration vector rather than assuming it. However, the ARDL approach is only valid when there is a unique cointegration vector. ARDL technique involves estimating the following unrestricted error-correction model:

$$\Delta ELEC_t = a_{0ELEC} + \sigma_{1ELEC} ELEC_{t-1} + \sigma_{2ELEC} GDP_{t-1} + \sum_{i=1}^{p} b_{iELEC} \Delta ELEC_{t-i} + \sum_{i=0}^{p} c_{iELEC} \Delta GDP_{t-i} + \varepsilon_{1t} \qquad (1)$$

$$\Delta GDP_t = a_{0GDP} + \theta_{1GDP} ELEC_{t-1} + \theta_{2GDP} GDP_{t-1} + \sum_{i=1}^{p} b_{iGDP} \Delta ELEC_{t-i} + \sum_{i=0}^{p} c_{iGDP} \Delta GDP_{t-i} + \varepsilon_{2t} \qquad (2)$$

Where, Δ is the first difference operator.

The existence of a long run relationship is independent of the variables order of integration provided that none of the variables are integrated of order 2.

The null hypothesis of no cointegration among the variable in equation (1) is $H_0 : \sigma_{1ELEC} = \sigma_{2ELEC} = 0$ is tested against the alternative that at least $\sigma_{iELEC} \neq 0$.

Similarly for equation (2), $H_0: \theta_{1GDP} = \theta_{2GDP} = 0$, against the alternative that at least $\theta_{iPIB} \neq 0$.

Table 1: Summary of the variables

Benin	GDP (local currency)	Elect (KWh)
Mean	27.41	19.18
Maximum	28.44	20.11
Minimum	25.44	17.80
Median	26.90	18.95
Standard deviation	27.21	18.74

Togo	GDP (local currency)	Elect (KWh)
Mean	30.53	19.64
Maximum	27.81	20.2
Minimum	25.22	18.66
Median	26.76	19.58
Standard deviation	26.58	18.73

The test statistics is the standard F-Statistic ($\hat{F}$). However, the F-test has a non-standard distribution which depends upon (i) whether variables included in the ARDL model are I(0) or I(1); (ii) the number of regressors; (iii) whether the ARDL model contains an intercept end/or a trend; and (iv) the sample size. Two sets of critical F values have been provided by Pesaran and Shin(1999) and Pesaran et al. (2001) for large samples and by

Narayan (2005) for sample size ranging from 30 to 80, where one set assuming that all variables in ARDL model are I(1) and another assuming that all variables are I(0) in nature. It is important to note that the critical values based on large sample size deviates significantly from that of small sample size. Narayan (2004a, 2004b) compares the critical values (CV) generated with 31 observations and the critical values reported in Pesaran et al. (2001) and finds that the upper bound CV at the 5% significance level for 31 observations with 4 regressors is 4.13 while the corresponding CV for 1000 observations is 3.49, which is 15,5% lower than the CV for 31 observations. We then extract appropriate CVs from Narayan (2005).

The critical value has lower bound (F_L) and upper bound (F_U). If $\hat{F} < F_L$ no cointegration relation exists and when $\hat{F} > F_U$ a cointegration relation exists. However, when $F_L < \hat{F} < F_U$, inference remains inconclusive under such circumstance, a knowledge of the order of integration of the underlying variables is needed to proceed further.

2.3. Granger causality

If we do not find evidence for cointegration among the variables, then the specification of the Granger causality test will be a vector autoregression (VAR) in first difference form. However, if we find evidence for cointegration then we need to augment the Granger-type causality test model with a one period lagged error correction term. This is an important step because Engel and Granger (1987) caution that if the series are integrated of order one, in the presence of cointegration VAR estimation in first differences will be misleading. Granger-causality test is a convenient approach for detecting causal relationship between two or more variables.

In our case, test for Granger causality can be done through following equations:

$$\Delta ELEC_t = \beta_{10} + \sum_{i=1}^{p} \beta_{11i} \Delta ELEC_{t-i} + \sum_{i=0}^{p} \beta_{12i} \Delta GDP_{t-i} + \beta_{13} ECT_{t-1} + u_{1t} \quad (3)$$

$$\Delta GDP_t = \beta_{20} + \sum_{i=0}^{p} \beta_{21i} \Delta ELEC_{t-i} + \sum_{i=1}^{p} \beta_{22i} \Delta GDP_{t-i} + \beta_{23} ECT_{t-1} + u_{2t} \quad (4)$$

Where β's are parameters to be estimated, u_t's are the serially uncorrelated error terms, and ECT_{t-1} is the error-correction term (ECT). The F-statistics on the lagged explanatory variables of the ECM indicates the significance of the short-run causal effects. The *t*-statistics on the coefficients of the lagged error correction term indicates the significance of the long-run causal effect. The lag length *p* is based on Schwarz-Bayessian (SBS) and/or Akaike Information Criteria (AIC). Letting $M_1 = (\beta_{121=\cdots=}\beta_{12p}),$ and $M_2 = (\beta_{211=\cdots=}\beta_{21p})$ the causality test is carried out by generating F statistics to establish whether the null hypotheses can be accepted or rejected. For equation (3) this amounts to $H_0: M_1 = 0$ and for equation (4) it is $H_0: M_2 = 0$.

3. Empirical results

3.1. Cointegration tests

The cointegration test under the bonds framework involves the comparison of the F-statistics against the critical values, which are generated for specific sample sizes. Using equation (1) and (2), the calculated F-statistics are reported in table 1.

When electricity consumption is the dependent variable for Benin, the calculated F-statsitics $F_{ELEC}(ELEC|GDP)$=5,34 is higher than the upper bound critical value of 4,957 at the 10% level. However if Benin's GDP is the dependent variable over the same periode (1973-2006), the calculated F-statistics $F_{GDP}(GDP|ELEC)$=3,88 is lower than the lower bound critical value at 10% level (4,427). This suggests that the null hypothesis of no cointegration cannot be supported for Benin when electricity is the dependent variable.

When electricity consumption is the dependent variable for Togo, the calculated F-statsitics $F_{ELEC}(ELEC|GDP)$=4,05 is lower than the upper bound critical value of 4,290 at the 10% level. Likewise if Togo's GDP is the dependent variable over the same period (1973-2006), the calculated F-statistics $F_{GDP}(GDP|ELEC)$=0,94 is lower than the lower bound critical value at 10% level (4,427). This suggests that the null hypothesis of no cointegration between growth and electricity consumption can be accepted for Togo.

Once a long-term relationship has been established for Benin, in the next stage, a further two-step procedure is carried out. In the first step, the optimal order of lags in the model are selected based on Schwarz-Bayessian information criteria; we ensured that residuals do not suffer from serial correlation, the LM test for serial correlation is used in this regard and in the second step, the selected model (equation 3) is estimated through ordinary least-square technique.

The existence of a long-run relationship among electricity consumption and GDP suggests that there must be Granger causality at least in one direction. Table 2 reveals results of the short and long run Granger causality within ECM framework. In the short-run there is no significant variable, which imply that GDP doesn't cause electricity consumption in the short-run. Turning to the long-run causality result, the coefficient of the lagged error-correction term is statistically significant at 1% level with correct sign implying that the series is non-explosive and long-run equilibrium is attainable. The speed of adjustment is 88,05%. The long-run elasticity of GDP is 1,80; in other words, an increase in GDP of 1 percentage point in the long-run increases electricity consumption by 1.80%.

Table 2: Bounds tests for cointegration

Critical value bounds of the F-statistics: intercept and no trend						
	10%		5%		1%	
T	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
30	4.290	5.080	5.395	6.350	8.170	9.285
35	4.225	5.050	5.290	6.175	7.870	8.960

Calculated F statistics		
	$F_{ELEC}(ELEC\|GDP)$	$F_{GDP}(GDP\|ELEC)$
Benin	5.34	3.88
Togo	4.05	0.94

Note: Critical values are extracted from Narayan (2005, p. 1988)

3.2. Granger causality

To complete the above results, Granger causality test were also carried out. While the bounds test for cointegration does not depend on pre-testing the order of integration, all variables need to be integrated of order one in order to apply the Granger causality test. To determine the order of integration, the work applies the Augmented Dickey-Fuller (ADF) unit root tests. All the series are I(1) we can then proceed to the Granger causality test. For Benin since there is a long-run relation between the variable we use equation (3), for Togo, we do not find any evidence for cointegration among the variables then the specification of the Granger causality test will be a vector autoregression (VAR) in first difference form (Narayan and Singh, 2007; Engel and Granger, 1987); i.e equations (3) and (4) without the error-correction term.

Beginning on Benin, the existence of a cointegration relationship between electricity consumption and GDP suggest that there must be Granger causality in at least one direction, but it does not indicate the direction of temporal causality between the variables. We examine both short-run and long-run Granger causality in this section. The short-run causal effect is obtained by the F-test of the lagged GDP variable, while the t-statistics on the coefficient of the lagged error-correction term in equation (3) indicates the significance of the long-run causal effect. In the short-run, GDP is significant at 10%, this implies that GDP Granger cause electricity consumption in the short-run. In the long-run, the coefficient on the lagged error correction term (- 0,86) is significant with the correct sign at 1%, which confirms the results from the bounds test for cointegration. When we use equation (4), we don't find any causality relation in the short-run neither in the long-run. Thus, GDP causes electricity consumption both in the long-run and in the short-run. However our results are different to the result obtained by Wolde-Rufael (2006) who did not obtain a cointegration relation between electricity consumption and GDP but found causality runs from electricity consumption to GDP. The difference in the result is two folds: Wolde-Rufael used data from WDI (2004) that naturally does not contains enough series (28 years of data) and the author used Pesaran et al. (2001) critical values that are not appropriate for small size data. Rather, this study uses WDI (2007) and data from CEB (2008) and Narayan (2005) critical values which are more suitable for small size data.[3]

Table 3: Results of Granger causality tests

Benin			
Dependent Variable	$\Delta LELEC$	$\Delta LGDP$	ECT_{t-1}
$\Delta LELEC$	-	2.05 (-1.7865)	-0.86 (-3.3200)
$\Delta LGDP$	0.012161 (0.4050)	-	-0.14 (-1.7922)
Togo			
Dependent Variable	$\Delta LELEC$	$\Delta LGDP$	ECT_{t-1}
$\Delta LELEC$	-	0.67 (2.4022)	-
$\Delta LGDP$	-0.17 (-1.7544)	-	-

Figures in parenthesis are t-statistics

Turning to Togo, we estimated Eq(3) and Eq(4) without the error-correction term. We use the LR test to determine the appropriate lag. In Eq(3) the lagged GDP variable is significant at 5%, this imply that in the short-run, GDP Granger causes electricity consumption in Togo.

[3] We can also mention the fact that Wolde-Rufael (2006) found a different result to the one obtained by Akinlo (2009) on the direction of the causality between electricity consumption and GDP for Nigeria. For Wolde-Rufael, the causality runs from GDP to electricity consumption while for Akinlo the causality runs from electricity consumption to GDP. Other controversial results can be found in the literature (Tang, 2008).

4. Concluding remarks and policy suggestion

In this paper, we use Pesaran et al. (2001) cointegration technique and Granger causality tests to investigate the long-run and causal relationship between real GDP and electricity consumption for an electricity community: CEB (Benin and Togo). The study detected long run cointegration relationship between electricity consumption and GDP for Benin, and causality for both countries. The results of the cointegration test and the causality reflect better the Benin and Togo economy that are less dependent on electricity. The economy of these two countries are heavily dominated by the agriculture sector contributing more than 33% to the total GDP. The result suggests that a permanent rise in GDP may cause a permanent growth in electricity consumption. This shows that growth in this line is more beneficial to people in urban area since, so far, electrification is a matter of urban area in both countries (in both countries about 52% of the urban population are electrified when less than 2% are in rural area; where the majority of the agricultural production in undertaken). These results suggest clearly that Benin and Togo to engage in pro-poor growth strategies so that the fruit of growth can be reoriented to electrify rural zone that contribute to more than 33% to the GDP. Likewise, they must make more efficient their electricity sector, by reducing the detrimental consequences of electricity consumption without reducing electricity consumption and reducing electricity power transmission and distribution losses that stood between 2 and 10% in the CEB network (CEB, 2008). The absence of causality running from electricity consumption to GDP implies that electricity demand side management measures can be adopted to reduce the wastage of electricity, which would not affect future economic growth of the community. These measures will develop energy conservation strategies in these countries. It'll be however interesting to investigate on the differences between Togo and

Benin economies that make Benin to have long-run relation between electricity and GDP and not for Togo. This can help us understand the relationship between electricity consumption and economic development and the appropriate energy policy for each country.

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