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To cite this version:

Eléazar Zerbo. CO2 emissions, growth, energy consumption and foreign trade in Sub-Sahara African countries. 2015. hal-01110769

HAL Id: hal-01110769
https://hal.archives-ouvertes.fr/hal-01110769

Submitted on 28 Jan 2015

Lemna

EA 4272

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Eléazar Zerbo*

2015/02

(*) LEMNA, Université de Nantes

Laboratoire d'Economie et de Management Nantes-Atlantique
Université de Nantes
Chemin de la Censive du Tertre – BP 52231
44322 Nantes cedex 3 – France
www.univ-nantes.fr/iemn-iae/recherche
Tél. +33 (0)2 40 14 17 17 – Fax +33 (0)2 40 14 17 49

CO2 EMISSIONS, GROWTH, ENERGY CONSUMPTION AND FOREIGN TRADE IN SUB-SAHARA AFRICAN COUNTRIES ☆

Eléazar ZERBO*
LEMNA, University of Nantes

Abstract

This paper analyzes the effect of economic growth, energy consumption and foreign trade on CO_2 emissions on eight Sub-Sahara African countries, namely Botswana, Cameroon, Gabon, Ivory Coast, Kenya, Senegal, South Africa and Togo. The ARDL bound testing approach to cointegration developed by Pesaran, Shin and Smith (2001) is used to test the long run relationship among the variables. Our findings show the existence of a long run relationship only in South Africa and Togo. The results show that energy consumption has an effect in increasing CO_2 emissions in Botswana, Kenya, South Africa and Togo in the short term. Trade openness is not sufficient to improve environment quality in Kenya while it does in South Africa. Furthermore, we apply the Toda and Yamamoto (1995) Granger causality test, and find that Kenya is dependent on energy while economic growth and energy consumption have a neutral relationship in Cameroon, Senegal, South Africa and Togo, suggesting that an energy efficiency policy may be implemented. However, the econometric results should be interpreted with care, as the variables are found to be weakly stable over the study period.

Keywords: CO_2 emissions; Economic growth; Energy consumption; Foreign trade; Sub-Sahara Africa.

JEL classification: Q43; Q56; O13; C32

☆ I am very grateful to Olivier Darné for his attention, insight and useful comments. The usual disclaimer applies and all errors are the sole responsibility of the author.

* IEMN-IAE, Chemin de la Censive du Tertre, BP 52231, 44322 Nantes Cedex 3, France. E-mail address: eleazar.zerbo@univ-nantes.fr

1. Introduction

In economic literature, there are several studies that link economic activity and environmental degradation, including empirical studies that have used either panel data or time series. Most of these studies have focused on the Environmental Kuznets Curve (EKC).[1] EKC is a hypothesis which postulates that the relationship between economic growth and pollution can be represented in an inverted-U curve. During the first stage of economic growth, the evolution of the pollution would have an upward trend, but only up to a certain income level and then this trend declines. This hypothesis has been the subject of several empirical studies and there is many of them critical concerning the logic and methodology used to test this hypothesis. The use of new and more appropriate econometric methods on time series has given a significant advance in the estimation of the relationship between economic growth and pollution.

However, few studies have focused on developing countries, especially Sub-Sahara African (SSA) countries; most of them have been concerned with the developed and emerging countries. This can be explained by the low level of pollution in SSA in absolute terms and its level of development compared to the rest of the world. Indeed in 2010, the SSA countries recorded 0.71 billion tons of carbon dioxide compared to 5.43 billion tons for the United States of America (USA), 3.71 for the European Union and 8.29 billion tons for China (WDI, 2013).

Studies on the countries of the SSA countries are more focused on the causality between energy consumption and economic growth (Akinlo, 2008; Wolde-Rufael, 2009) in order to study the dependence or not of different countries on energy. Those which have studied the effect of economic growth and other economic factors on pollution relate mainly to South Africa, which is considered as an emerging country (Kohler, 2013; Menyah and Wolde-Rufael, 2010; Shahbaz et al., 2013).

This paper examines the dynamic early in the development process, because the SSA has an economy highly dependent on natural and environmental resources and is the region which suffers most from natural disasters and the phenomenon of climate change due to its financial difficulties in adapting to these changes. In addition, in order to control the current poverty level, it is necessary to improve the dynamics of economic growth. In fact, during the last decade SSA has experienced dynamic economic growth at around 5.6% (AfDB, 2013), which

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[1] See Grossman and Krueger (1991) for a survey.

was mainly driven by the exploitation of natural and environmental resources. This also raises the issue of the sustainability of the growth path. Despite the good economic performance recorded over the period, poverty has not declined significantly due to an average decrease in poverty of 0.84 % per annum (AfDB, 2013). Economic growth is one of the main way to improve the well-being of the population in developing countries (Fagnart and Hamaide, 2012; Hugon, 2006). And yet production involves polluting nature. Moreover, Liousse et al. (2014) forecast the level of organic emissions in Africa by 2030 compared to the 2005 level and find that it could be 50% of the global level. This then summarizes some reasons to study the factors affecting pollution and economic growth in SSA.

This study aims to fill this gap by studying the effect of economic growth, energy consumption and international trade on carbon dioxide in different SSA countries, namely Botswana, Cameroon, Gabon, Ivory Coast, Kenya, Senegal, South Africa and Togo. The results will be particularly important in policy decisions in order to act on the level of emissions while pursuing economic growth objectives.

The rest of the paper will focus on the following points: Section 2 presents briefly the literature review on the inter-relationship between environment pollution, output, energy consumption, trade openness and financial development. Section 3 describes the econometric methodology used in this study. Section 4 presents the results. Section 5 discusses empirical results and concludes.

2. Literature review

In the economic literature, there are a variety of empirical studies that focus on the link between environmental degradation and economic activity. The main study in this area concerns the EKC that connects economic growth and pollution. The pioneers of this study were Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992) and Panayotou (1993). The EKC is a hypothesis which postulates that the relationship between the growth of per capita income and the level of pollution could be represented as an inverted-U shape. Pollution increases in the early stages of economic growth, and after a certain level of development, it will present a downward trend.

Few studies on EKC have focused on SSA countries. Studies which consider the Africa continent have used mainly deforestation as an environmental pressure measure. For example, Bhattarai and Hammig (2001) examined the relationship between income and deforestation in 66 countries of Latin America, Asia and Africa. In the case of African countries, their results support the EKC hypothesis. In the same way, Culas (2007) studied the dynamic between income and deforestation in a panel of 15 countries including four SSA countries, namely the Congo Democratic Republic, Ivory Coast, Kenya and Nigeria. He failed to support the EKC hypothesis in these countries. Recently, Onafowora and Owoye (2014) use carbon dioxide to check for EKC in Brazil, China, Egypt, Japan, Korea, Mexico, Nigeria and South Africa. They employ the ARDL bound testing approach to cointegration and find that the long-run relationship between CO2 emissions and economic growth follows an N-shaped trajectory in Nigeria and South Africa. This mean that carbon dioxide rises with economic growth, declines from a first turning point to increase again from a second turning point. However, the estimated turning points are outside the sample.

While the EKC hypothesis has been the subject of several empirical studies, it has not been verified for all indicators of pollution, such as carbon dioxide (CO_2). It has mainly been verified for sulfur dioxide (SO_2) though (Nourry, 2007).[2]

Moreover, some studies focus on the causality between energy consumption and economic growth. The objective of these studies is to verify whether the relationship between energy consumption and income growth may be unidirectional, bidirectional, or neutral. A unidirectional relationship of energy consumption to income growth (or vice versa) will involve an expansion economic policy (or energy conservation policy). This allows economic governors to pursue an effective policy in reducing emissions which does not have a significant impact on income growth, assuming that the consumption of energy, especially fossil fuel, has an important share in pollutant emissions. The seminal article in this field was published by Kraft and Kraft (1978), who studied causality between gross national product (GNP) and energy consumption in the United States and found that the relation runs from GNP to energy consumption.

Some authors have focused on SSA countries by investigating the hypothesis that prevailed in these countries. Ebohon (1996) examined the causal relationship between economic growth and energy consumption in Tanzania and Nigeria. His results suggest a complementarity between energy consumption and income growth. This result requires massive investments in the energy sector to stimulate economic activity. In the same way, other authors have examined the nature of this relationship in various SSA countries (Akinlo, 2008; Fondja

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[2] For a fairly detailed review on EKC, refer to Dinda (2004).

Wandji, 2013; Odhiambo, 2010; Ouédraogo, 2010; Tamba et al., 2012; Wolde-Rufael, 2005), and the results of these studies reveal that the direction of causality vary from one country to another according to its specificity.

Recent econometric methods on time series have allowed several authors to analyze the relationship between pollution, economic growth and energy consumption in the same multidimensional framework. For emerging and developing countries, Saboori and Sulaiman (2013a) and Saboori and Sulaiman (2013b) considered CO_2 emissions, energy consumption and economic growth in Southeast Asia countries and Malaysia in the same framework by using the cointegration approach. This approach allows one to check the effects of energy consumption and economic growth on the level of CO_2 emissions. In the same way, Halicioglu (2009) adds international trade to these variables in order to estimate the effect of trade openness on pollution. For the author, the sign of international trade depends on the level of economic development of the country. In the case of Turkey, he finds that this effect has certainly less impact but it increases pollution. Contrary to this result, Kohler (2013) found that international trade contributes to reducing CO_2 emissions in South Africa.

It is clear that previous studies did not concern the effect of these variables (economic growth, energy consumption and international trade) on the variation of CO_2 emissions in SSA countries. The objective of this study is to fill this gap, by proposing to study the impact of economic growth, energy consumption and international trade on the variation of CO_2 emission in some SSA countries.

3. Methodology

3.1. Model

Following the empirical literature, it is plausible to form the relationship between CO_2 emissions, economic growth, energy consumption and foreign trade, with a view forward testing the effect of those variables on CO_2 emissions as follows:

$$C_t = \alpha_0 + \alpha_1 Y_t + \alpha_2 E_t + \alpha_3 T_t + \varepsilon_t \quad (1)$$

where C_t is CO_2 emissions per capita, E_t is energy use per capita, Y_t is per capita real income, T_t is sum of importation and exportation per capita used as a proxy for foreign trade; and $\mathcal{E}_t$ is the regression error term assumed to be normally distributed with zero mean and constant variance.

As for the expected signs, one expects α_1 to be positive; it indicates that an increase in economic growth is linked with high CO_2 emissions. The sign of α_2 is expected to be positive because a higher level of energy consumption should result in greater economic activity and stimulate CO_2 emissions. The expected sign of α_3 is mixed in economic literature. For Kohler (2013), it depends on the level of the economic development stage of a country. In the case of developed countries, it is expected to be negative as countries develop; they cease to produce certain pollution intensive goods and begin to import these from other countries with less restrictive environmental protection laws. In the case of developing countries, this sign expectation is reversed as they tend to have dirty industries with a high share of pollutants. Because in SSA there are developing countries, this sign is expected to be positive.

3.2. Data

Based on the specification detailed above, annual time series on carbon dioxide (CO_2) emissions, income, energy consumption and trade openness have been collected for eight SSA countries, namely Botswana (BWA), Cameroon (CMR), Ivory Coast (CIV), Gabon (GAB), Kenya (KEN), Senegal (SEN), South Africa (ZAF) and Togo (TGO). The choice of these countries included in the study was based on the availability of data on the variables incorporated in the work. The period covered by the data varies across countries: 1981-2010 for Botswana; 1971-2010 for Cameroon, Kenya, South Africa, Senegal and Togo; 1971-2008 for Ivory Coast; and 1971-2007 for Gabon. The per capita CO_2 emissions (measured in metric tons) are used as a proxy for the environmental quality. Gross domestic product per capita at constant price of 2005 expressed in US dollar serves as a proxy for real income per capita. Energy consumption is proxied by total energy use per capita (measured in kgs of oil equivalent per capita). Data on trade openness is proxied by the ratio of total trade (sum of importation and exportation at constant 2005 US dollar) to population. Table 1 shows the summary statistics of the variables for each selected country. All the data are collected from the World Development Indicators (WDI, 2013) provided by the World Bank, and are converted to natural logarithms.

Table 1: descriptive statistics for the selected countries

		mean	median	maximum	minimum	standard deviation	skewness	kurtosis
BWA	C	1.897	2.238	2.657	0.912	0.367	-0.512	1.624
	Y	3917.805	3558.471	6295.876	1708.1	1405.662	0.145	1.864
	E	941.334	965.352	1149.242	730.229	122.983	-0.420	1.987
	T	3856.063	3993.204	5640.222	2138.245	830.289	-0.161	2.801
CMR	C	0.283	0.217	0.674	0.089	0.166	1.299	3.531
	Y	942.752	915.991	1356.138	689.188	171.402	0.806	2.919
	E	394.434	396.442	429.407	326.368	24.939	-1.173	4.209
	T	400.327	428.834	583.459	227.974	100.451	-0.277	2.061
CIV	C	0.526	0.517	0.809	0.323	0.121	0.519	2.499
	Y	1199.604	1104.489	1759.053	932.792	252.806	0.720	2.239
	E	423.072	403.626	570.109	355.112	61.652	1.069	3.233
	T	752.848	746.128	985.624	545.104	102.857	0.252	2.489
GAB	C	4.903	4.612	10.918	0.859	3.162	0.246	1.606
	Y	7270.897	7124.092	12451.72	4961.261	1358.628	1.778	7.750
	E	1584.896	1378.122	2474.94	1176.041	385.199	0.633	2.078
	T	8300.617	8873.008	11743.05	4683.855	1899.172	-0.351	2.056
KEN	C	0.283	0.271	0.386	0.192	0.056	0.189	1.907
	Y	516.544	512.007	575.060	424.036	29.178	-0.464	4.110
	E	450.297	450.296	482.024	430.172	10.733	0.653	3.700
	T	280.727	279.677	414.455	178.476	63.591	0.307	2.439
SEN	C	0.440	0.435	0.602	0.311	0.069	0.300	2.561
	Y	723.375	719.728	813.792	634.353	47.674	0.000	2.072
	E	250.471	250.702	285.546	207.759	23.853	-0.059	1.868
	T	538.374	514.862	715.572	435.730	64.207	0.797	3.219
ZAF	C	8.855	9.001	10.357	7.306	0.947	-0.107	1.880
	Y	5006.923	4967.908	5848.042	4472.486	363.991	0.651	2.769
	E	2547.905	2574.123	3007.979	1997.498	260.066	-0.525	2.438
	T	2272.221	2268.399	3460.257	1647.61	466.423	0.854	3.345
TGO	C	0.223	0.221	0.523	0.129	0.064	2.447	13.099
	Y	425.420	425.521	533.540	319.663	44.738	0.285	2.976
	E	362.426	332.655	446.161	303.179	48.798	0.497	1.503
	T	526.72	487.519	1029.723	275.133	167.035	0.820	3.486

C indicates per capita carbon dioxide emissions in metric tons, Y indicates per capita real GDP in constant 2005 $ US, E indicates per capita energy consumption in kgs oil equivalent and T indicates sum of importation and exportation in constant 2005 $ US per capita.

The results of Table 1 show that Gabon (US \$ 7,270.90) and South Africa (US \$ 5,006.92) have the highest mean of income per capita while Togo has the lowest (US \$ 425.42). The high value of CO_2 emission per capita is displayed in South Africa (8.86 metric tons per capita) and the lowest in Togo (0.22 metric tons per capita). Gabon and South Africa have a high level of energy consumption relatively to the population and a high degree of participation in international trade along with Botswana. Gabon shows a great variation in all the variables with respect to the standard deviation. In general the degree of asymmetric distribution falls within an interval of -1 and 1, but some exceptions exist. In the case of Togo for example, the values of skewness (2.45) and Kurtosis (13.10) suggest that CO_2 emission distribution doesn't match with Gaussian distribution.

3.3. The ARDL bound testing cointegration approach

We apply the ARDL bounds testing cointegration approach developed by Pesaran, Shin, and Smith (2001) to investigate whether a long run dynamic relationship exists between economic growth, energy consumption, trade openness and carbon emissions. Various approaches have been applied to test the presence of cointegration between variables in numerous studies. Two of these approaches are taken from Engle and Granger (1987) in the bivariate case and Johansen and Juselius (1990) when multivariate, and require that all the series should be integrated at the order of integration I(1). The ARDL bounds testing approach is more appropriate compared to those traditional cointegration approaches. The approach avoids endogeneity problems and the inability to test long run relationships of variable associates with the traditional Engel-Granger method. Both short run and long run parameters are calculated simultaneously and the ARDL approach can be used regardless of whether the data are integrated of order I(0) or I(1). Narayan (2005) argues that the ARDL approach is superior in small samples to other single and multivariate cointegration methods. As set out in Halicioglu (2009) and Kohler (2013), the ARDL representation is formulated as follows:

$$\Delta C_t = b_0 + \sum_{i=1}^{m} b_{1i}\Delta C_{t-i} + \sum_{i=0}^{m} b_{2i}\Delta Y_{t-i} + \sum_{i=0}^{m} b_{3i}\Delta E_{t-i} + \sum_{i=0}^{m} b_{4i}\Delta T_{t-i} + b_5 C_{t-1} + b_6 Y_{t-1} + b_7 E_{t-1} + b_8 T_{t-1} + \vartheta_t \quad (2)$$

The bounds test is based on the Wald's statistic, where the null hypothesis joint significance test implies no relationship (i.e. $H_0 = b_5 = b_6 = b_7 = b_8 = 0$), and the alternative implies cointegration (i.e. $H_1 \neq b_5 \neq b_6 \neq b_7 \neq b_8 \neq 0$). This approach does not use a normal distribution, thus Pesaran, Shin, and Smith (2001) have computed critical values for given significance levels. However, because of the small sample size used in this study, critical value ranges of the F-statistic as set out in Narayan (2005) are used as they are more appropriate. If the computed F-statistic exceeds the upper bound, H_0 is rejected, if it falls below the lower bound, H_0 cannot be rejected, and if lies between both bounds, the test is inconclusive. Therefore, there is need to choose the appropriate number of lags in the model. The lag orders of the variables can be the selected Schwarz's Bayesian information criterion (SBIC), the Hannan and Quinn information criterion (HQIC), and the Akaike's information criterion (AIC). The SBIC selects the smallest possible lag length while AIC is employed to select maximum relevant lag length. The long run relationship among variables can be estimated after the selection of the ARDL model by AIC or SBIC criterion. Once a long-run relationship has been established, a general error correction model of eq. (2) is formulated as follows:

$$\Delta C_t = c_0 + \sum_{i=1}^{m} c_{1i}\Delta C_{t-i} + \sum_{i=0}^{m} c_{2i}\Delta Y_{t-i} + \sum_{i=0}^{m} c_{3i}\Delta E_{t-i} + \sum_{i=0}^{m} c_{4i}\Delta T_{t-i} + \lambda EC_{t-1} + \mu_t \quad (3)$$

where λ is the speed of the adjustment parameter, and EC_{t-1} is the residuals that are obtained from the estimated cointegration model of eq. (2).

3.4. Toda and Yamamoto causality test

To complement our study, we have also carried out the Granger non-causality test using the Toda and Yamamoto (1995) procedure. The issue of causality between variables in the literature has been undertaken via the Engle and Granger causality test. Nevertheless, this approach has been criticized for its low power test, restrictive nature and small sample properties (Kofi Adom et al., 2012). Consequently, we use the Toda and Yamamoto (T-Y) procedure to test the causal link between CO_2, income, energy consumption and international trade. The advantage of this method is that it is valid regardless of whether a series is I (0), I (1) or I (2), cointegrated or not-cointegrated. The T-Y Granger causality test augments a VAR model in level with extra lags (the maximum order of integration d of the series). This ensures that the Wald statistics possess the necessary power properties. Then the augmented VAR model with a total of (k+d) lags is then estimated on levels of the selected variables (not on their first difference) and restricting the first k-lags to zero. Thus using this approach, we estimate the following VAR model to determine the causal dynamics between CO_2 emission, income, energy consumption and international trade. The augmented VAR model is represented as follows:

$$C_t = \eta_1 + \sum_{i=1}^{k} \beta_{1i} C_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{1j} C_{t-j} + \sum_{i=0}^{k} \gamma_{1i} Y_{t-i} + \sum_{j=k+1}^{k+d_{max}} \gamma_{1j} Y_{t-j} + \sum_{i=0}^{k} \theta_{1i} E_{t-i} + \sum_{j=k+1}^{k+d_{max}} \theta_{1j} E_{t-j} + \sum_{i=0}^{k} \varphi_{1i} T_{t-i} + \sum_{j=k+1}^{k+d_{max}} \varphi_{1j} T_{t-j} + \omega_{1t} \quad (4)$$

$$Y_t = \eta_2 + \sum_{i=0}^{k} \beta_{2i} C_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{2j} C_{t-j} \sum_{i=1}^{k} \gamma_{2i} Y_{t-i} + \sum_{j=k+1}^{k+d_{max}} \gamma_{2j} Y_{t-j} + \sum_{i=0}^{k} \theta_{2i} E_{t-i} + \sum_{j=k+1}^{k+d_{max}} \theta_{2j} E_{t-j} + \sum_{i=0}^{k} \varphi_{2i} T_{t-i} + \sum_{j=k+1}^{k+d_{max}} \varphi_{2j} T_{t-j} + \omega_{2t} \quad (5)$$

$$E_t = \eta_3 + \sum_{i=0}^{k} \beta_{3i} C_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{3j} C_{t-j} + \sum_{i=0}^{k} \gamma_{3i} Y_{t-i} + \sum_{j=k+1}^{k+d_{max}} \gamma_{3j} Y_{t-j} + \sum_{i=1}^{k} \theta_{3i} E_{t-i} + \sum_{j=k+1}^{k+d_{max}} \theta_{3j} E_{t-j} + \sum_{i=0}^{k} \varphi_{3i} T_{t-i} + \sum_{j=k+1}^{k+d_{max}} \varphi_{3j} T_{t-j} + \omega_{3t} \quad (6)$$

$$T_t = \eta_4 + \sum_{i=0}^{k} \beta_{4i} C_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{4j} C_{t-j} + \sum_{i=0}^{k} \gamma_{4i} Y_{t-i} + \sum_{j=k+1}^{k+d_{max}} \gamma_{4j} Y_{t-j} + \sum_{i=0}^{k} \theta_{4i} E_{t-i} + \sum_{j=k+1}^{k+d_{max}} \theta_{4j} E_{t-j} + \sum_{i=1}^{k} \varphi_{4i} T_{t-i} + \sum_{j=k+1}^{k+d_{max}} \varphi_{4j} T_{t-j} + \omega_{4t} \quad (7)$$

After estimating the above systems of eqs. (4-7), the T-Y approach is based on the Wald statistic test for the significance of the first k lags by restricting the coefficients to zero, under a null hypothesis of no causality.

4. Empirical results

4.1. Unit roots tests

Before performing the ARDL bound test, it may be useful to test for unit roots. Here, the augmented Dickey and Fuller (1981) test, the Phillips and Perron (1988) test and the modified Dickey and Fuller test proposed by Elliot, Rothenberg, and Stock (1996) are used to identify the order of integration of our variables. The null hypothesis in those tests is that the series have unit roots contrary to the alternative of stationarity. The results of the Augmented Dickey Fuller (ADF), Phillip-Perron (PP) and Elliot-Rothenberg-Stock (ERS) unit-root tests on the natural logarithm of the level and the first differences of the variables are summarized in Table 2. The result suggests that all series are stationary in first differences, indicating that none of the variables is I(2) or beyond. This validates the use of ARDL bounds testing for cointegration.

Table 2: Test for integration

country		level				first difference			
		lag	ADF	PP	ERS	lag	ADF	PP	ERS
Botswana	C	0	0.694	0.694	-0.579	0	-5.648***	-5.648***	-6.136***
	Y	0	-2.318	-2.318	0.263	0	-3.931***	-3.931***	-3.711***
	E	0	-2.581	-2.581	-2.672	0	-5.683***	-5.683***	-6.174***
	T	4	-2.838	-2.561	-1.540	3	-3.324**	-4.974***	-2.717**
Cameroon	C	0	-3.169**	-3.169**	-2.607**	1	-6.575***	-7.188***	-6.340***
	Y	4	-3.352**	-2.014	-2.448**	4	-1.781*	-4.117***	-1.812
	E	1	-0.727	-0.865	-0.668	0	-4.394***	-4.394***	-4.475***
	T	0	1.005	1.005	-0.842	0	-5.032***	-5.032***	-5.118***
Ivory Coast	C	0	-3.772**	-3.772**	-3.526**	0	-7.914***	-7.914***	-7.742***
	Y	1	-1.069	-1.459	-0.775	3	-2.639**	-3.775***	-3.202***
	E	0	0.511	0.511	-1.021	0	-6.999***	-6.999***	-7.059***
	T	1	-1.731	-1.731	-1.470	0	-5.791***	-5.791***	-5.809***
Gabon	C	0	-0.985	-0.985	-1.005	0	-6.008***	-6.008***	-6.058***
	Y	1	-4.609**	-3.515**	-2.639	0	-4.317***	-4.317***	-4.046***
	E	2	-1.016	-2.798	-1.313	4	-1.283	-5.911***	-1.510
	T	1	-3.712**	-2.924	-1.881	0	-4.338***	-4.338***	-4.190***
Kenya	C	3	-3.053**	-2.236	-2.081*	0	-3.673***	-6.245***	-6.235***
	Y	1	-1.314	-3.337**	-0.415	4	-2.009 ***	-5.672***	-0.583
	E	1	0.465	0.592	-1.806	0	-5.069***	-5.069***	-4.856***
	T	4	-1.684	-1.958	-1.403	4	-2.627***	-6.478***	-1.123
Senegal	C	0	-3.491***	-3.491***	-2.308*	0	-8.370***	-8.370***	-8.201***
	Y	0	0.144	0.144	-1.454	0	-7.423***	-7.423***	-6.504***
	E	3	-0.133	-0.373	-1.437	2	-2.044***	-6.270***	-1.884
	T	0	-2.837*	-2.837*	-2.876	2	-5.350***	-8.435***	-4.945***
South Africa	C	4	-2.450	-1.871	-1.518	0	-5.821***	-5.821***	-5.586***
	Y	1	0.788	0.936	-0.99	0	-3.820***	-3.820***	-3.868***
	E	0	-2.025	-2.025	-0.693	0	-5.788***	-5.788***	-5.890***
	T	0	-1.864	-1.864	-1.383	0	-4.940***	-4.940***	-4.441***
Togo	C	0	-4.988***	-4.988***	-3.383***	0	-10.049***	-10.049***	-8.954***
	Y	0	-2.850	-2.850	-2.692	3	-4.128***	-6.307***	-3.081***
	E	0	-2.134	-2.134	-1.788	0	-6.293***	-6.293***	-6.446***
	T	1	-3.188	-2.449	-2.983*	0	-4.734***	-4.734***	-4.670***

*, ** and *** indicate significance level at 10%, 5% and 1%; C indicates per capita carbon dioxide emissions in metric tons, Y indicates per capita real GDP in constant 2005 $ US, E indicates per capita energy consumption in kgs of oil equivalent and T indicates sum of importation and exportation in constant 2005 $ US per capita.

4.2. ARDL test result

The cointegration test consists firstly of determining the optimum lag length m to be considered in the estimation of equation (2). To do this, we used the AIC, SBIC and HQIC criteria within an unrestrictive autoregressive (VAR) model. This allowed us to obtain appropriate lag levels for each country. Then the F-test is applied to the equation (2) to determine whether or not a long-term relationship exists between the dependent and independent variables. The results are summarized in Table 3. Compared with the critical values of Narayan (2005), the ARDL test suggests the existence of a long-term relationship between our variables in South Africa and Togo. According to these results, we will therefore estimate a short-term relationship in Botswana, Cameroon, Ivory Coast, Gabon, Kenya and Senegal where the cointegration relationship has not been proven and a long-term relationship for South Africa and Togo.

Table 3: Result for the F-test for cointegration

result of the F-test of cointegration Fc(C/Y, E, T)						
country	AIC, SBIC optimal lag		F-statistic		result	
Botswana	1		2.21		No cointegration	
Cameroon	1		2.86		No cointegration	
Ivory Coast	1		1.98		No cointegration	
Gabon	2		3.29		No cointegration	
Kenya	1		0.23		No ointegration	
Senegal	1		3.07		No cointegration	
South Africa	1		4.34*		cointegration	
Togo	1		7.50***		cointegration	
	n=30		n=35		n=40	
Critical value	Lower I(0)	Upper I(1)	Lower I(0)	Upper I(1)	Lower I(0)	Upper I(1)
1%	5.333	7.063	5.198	6.845	5.018	6.610
5%	3.710	5.018	3.615	4.913	3.548	4.803
10%	3.008	4.150	2.958	4.100	2.933	4.020

*, **, *** denote significance level at 10%, 5% and 1% respectively.

The estimated short-run relationship is presented in Table 4. We observe that the energy consumption has a significant effect on the variation of CO_2 in Botswana (1.61), Kenya (2.79), South Africa (0.81) and Togo (3.62) in the short term. This means that the energy consumption increases CO_2 emissions for these countries. However, the proportion is more or less high depending on the country's development stage. Indeed, it should be noted that this proportion is high for the poorest countries. From these four countries, Kenya and Togo, classified by the World Bank as "Low income" compared to Botswana and South Africa ("middle income"), have larger effects of energy consumption. In addition, the effect of international trade is statistically significant in Kenya and South Africa. Trade openness has a positive effect in reducing the level of CO_2 emissions in South Africa contrary to that of Kenya. One can also assume that this is consistent with the hypothesis of Halicioglu (2009), which postulated that the effect of trade on pollution depends on the country level of development. In comparison to others studies, our results for South Africa are consistent with those of Kohler (2013) and Shahbaz, Kumar Tiwari, and Nasir (2013), who found that energy consumption contributes to the deterioration of the environment while trade openness improves it. Moreover Kohler (2013) found a non-significant effect of income growth in rising CO_2 emissions. However, they contradict those of Onafowora and Owoye (2014) who found that trade increases CO_2 emissions level in South Africa.[3] It is only in Togo that income has a significant effect during the period with a negative coefficient. This might suggest that income growth would support a reduction in the level of CO_2. However in Togo, while the level of CO_2 was increasing, the product per capita fell. The risk here is that even with resumption of economic growth, this will not be accompanied by an improvement in weather conditions. The results also show that in other countries (Cameroon, Ivory Coast, Gabon and Senegal), none of our variables significantly influence the variation in the level of pollution. This could be explained by the level fluctuation of the variables over the period as shown by the standard deviation (Table 1) and the stability tests of Brown, Durbin, and Evans (1975), known as the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) test, based on recursive regression residuals. The test-statistics are given in the Appendix. When these statistics fall inside the critical bounds of 5% significance, one could assume that the coefficients of the given regression are stable. Thus on the graphs, we can observe that in almost all countries, the CUSUM and the CUSUMSQ statistics don't fall outside the critical bounds during all the period covered.

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[3] Onafowora and Owoye (2014) estimated an ordinary least squares model on levels of the variables (not on their first difference) to check for the long run dynamic between CO_2 emissions, income, energy consumption, population density and foreign trade.

Table 4 : Short run results based on ARDL model

	BWA	CMR	CIV	GAB	KEN	SEN	ZAF	TGO
ΔY	-0.408	0.105	0.167	-0.326	0.564	-0.336	0.206	-1.486*
	(0.68)	(1.58)	(0.77)	(0.78)	(0.67)	(0.72)	(0.35)	(0.80)
ΔE	1.617***	2.547	0.587	0.901	2.798**	0.410	0.815***	3.625**
	(0.38)	(3.52)	(0.46)	(0.61)	(1.33)	(0.74)	(0.17)	(1.20)
ΔT	-0.095	0.227	0.188	0.530	0.361*	-0.040	-0.235*	-0.149
	(0.29)	(0.90)	(0.44)	(0.63)	(0.20)	(0.25)	(0.12)	(0.32)
constant	0.031	0.033	-0.010	-0.022	-0.011	0.016	-0.002	-0.016
	(0.03)	(0.08)	(0.03)	(0.05)	(0.02)	(0.02)	(0.01)	(0.04)
R^2	0.455	0.020	0.072	0.093	0.278	0.015	0.477	0.251
dof	25	35	33	32	35	35	35	35

*, ** and *** indicate significance level at 10%, 5% and 1%; standards errors are in parentheses; and dof denotes degree of freedom; C indicates per capita carbon dioxide emissions in metric tons, Y indicates per capita real GDP in constant 2005 $ US, E indicates per capita energy consumption in kgs of oil equivalent and T indicates sum of importation and exportation in constant 2005 $ US per capita; BWA stands for Botswana, CMR for Cameroon, CIV for Ivory Coast, GAB for Gabon, KEN for Kenya, SEN for Senegal, ZAF for South Africa, and TGO for Togo.

The estimation of an error correction model has allowed the observation of the effect in the long term of our different variables on emissions in South Africa and Togo (Table 5). The error correction term (EC_{t-1}) is statistically significant and has the correct sign (negative) in both countries, which confirms the existence of a long term relationship between CO_2 emissions, income, energy consumption, and foreign trade in South Africa and Togo. This term shows the speed of an adjustment process following a short run shock. The high level of the error correction term coefficient in both countries in absolute value suggests a high speed of adjustment to the long run equilibrium following an external shock in the short term. In other words, when per capita CO_2 emission moves away from its equilibrium level, it adjusts by almost 66.2% within one year in South Africa and 92.1% in Togo. Furthermore, income that affects the variation of CO_2 in the short term is not significantly involved in the decrease of the pollution level in Togo.

Table 5: ECM long run result based on ARDL model

	ZAF	TGO
ΔY	-0.066	-0.869
	(0.29)	(0.54)
ΔE	0.850***	2.755***
	(0.14)	(0.82)
ΔT	-0.219**	-0.262
	(0.09)	(0.21)
EC_{t-1}	-0.662***	-0.921***
	(0.15)	(0.14)
constant	-0.001	-0.010
	(0.00)	(0.03)
R^2	0.669	0.674
dof	34	34

*, ** and *** indicate significance level at 10%, 5% and 1%; standards errors are in parentheses; and dof denotes degree of freedom; C indicates per capita carbon dioxide emissions in metric tons, Y indicates per capita real GDP in constant 2005 $ US, E indicates per capita energy consumption in kgs of oil equivalent and T indicates sum of importation and exportation in constant 2005 $ US per capita; ZAF stands for South Africa, and TGO for Togo.

4.3. Causality test result

Since we focused on the effect of income, energy consumption and international trade on the variation of CO_2 level in some SSA countries, it may be useful to conduct causality tests between CO_2, income, energy consumption and trade openness in order to determine which variable causes each other in the sense of Granger. The results of the causality test based on T-Y approach are summarized in Table 6. The results show that income and CO_2 emissions are mutually dependent in Gabon, and that previous values of emissions are useful in predicting the income level of Kenya and Togo. What needs to be noted is that, in none of these countries, does income lead to CO_2 emissions. This fact is consistent with our estimation where we don't find any significant effect of income in explaining the variation of carbon dioxide emissions level. Furthermore, energy consumption is found to lead to higher pollution levels in Gabon, South Africa and Togo. This confirms the hypothesis postulated that energy is an important factor in explaining the variation of CO_2 levels. The result in Gabon concerning emission-trade causality also confirms the role that trade openness can play in dealing with the pollution level. However, the low degree of integration of SSA countries in international trade explains why in the rest of sample, both variables have an independent distribution.

Concerning the economic structure variables (income, energy consumption and international trade), results suggest a bi-directional relationship between energy consumption and income in Botswana and Gabon, and a unidirectional relationship running from energy to income in Kenya. This means that energy consumption is an important factor in the production process of these countries. Consequently, energy consumption measures may have an adverse effect on economic growth. Yet the previous results prove that energy consumption contributes mostly to a deteriorating environment. Thus an investment in efficient energy measures and renewable energy must be conducted in order to control for the pollution level and to promote economic growth. Energy conservation policy would not have an adverse effect on economic growth in Ivory Coast, where it is income which leads to energy consumption. On the other hand, in Cameroon, Senegal, South Africa and Togo the neutrality hypothesis between energy consumption and economic growth is supported. Our results are consistent with Akinlo (2008) for Cameroon and Togo and with Wolde-Rufael (2009) for Ivory Coast and Gabon but contradict the results of both authors in the case of Kenya and Senegal.[4]

For the trade-income relationship, results suggest that international trade and income are mutually dependent in Botswana and that income causes trade in Gabon and Senegal in the sense of Granger. In the rest of the sample, we find that there are neutral relationships between both variables. What needs to be pointed out is that, in none of these cases, does international trade lead to income. This could mean that international trade is dominated by importation, or that these countries have a low degree of participation in world trade. We demonstrate that trade is an important factor that can be involved in reducing emissions level. The important part of necessity goods in these countries prevents trade from contributing to reducing pollution. This fact can also be seen in the energy-trade relationship. Indeed, most of the countries are dependent on the importation of oil for their energy consumption, so that energy consumption is independent of international trade if we consider oil as a necessity commodity. The exception is Gabon, where both variables have dependent evolutions. This can be explained by the fact that the main export product in Gabon is oil.

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[4] The difference might be due to the sample, the approach adopted or the additional variables used. Akinlo (2008) uses the Granger causality test and considers price and government expenditure to study income and energy causality. His sample is from World development indicators of 2005. Wolde-Rufael (2009) uses T-Y Granger causality test but adds stock of capital and labour to income and energy consumption. His sample is from World Development Indicators of 2004 and 2007.

Table 6: Toda and Yamamoto causality test

country	BWA	CMR	CIV	GAB	KEN	SEN	ZAF	TGO
Y→C	0.071	0.270	2.404	8.201*	0.080	2.582	0.255	0.276
C→Y	0.642	1.398	0.266	9.040*	5.092**	1.489	0.269	6.334**
E→C	0.134	0.010	0.454	7.854*	0.879	0.480	2.720*	4.152**
C→E	2.156	0.015	1.979	3.069	5.573**	1.078	0.485	0.054
T→C	0.010	0.335	0.080	8.149*	0.368	0.448	2.406	1.123
C→T	1.040	3.146*	0.022	6.169	1.337	0.010	0.033	1.980
E→Y	6.548**	0.205	0.238	40.866***	14.355***	0.918	0.006	0.857
Y→E	2.770*	1.232	4.100**	29.699***	0.811	0.605	0.055	2.057
T→Y	3.523*	1.072	1.475	2.111	1.181	0.010	0.009	0.785
Y→T	5.611**	0.029	0.377	21.19***	2.693	3.284*	0.123	0.944
T→E	0.613	1.297	0.495	33.958***	0.600	0.106	1.223	0.757
E→T	5.127**	0.111	0.163	33.671***	1.265	0.079	0.227	1.527

*, **, *** denote significance level at 10%, 5% and 1% respectively, C indicates per capita carbon dioxide emissions in metric tons, Y indicates per capita real GDP in constant 2005 $ US, E indicates per capita energy consumption in kgs of oil equivalent and T indicates sum of importation and exportation in constant 2005 $ US per capita; BWA stands for Botswana, CMR for Cameroon, CIV for Ivory Coast, GAB for Gabon, KEN for Kenya, SEN for Senegal, ZAF for South Africa, and TGO for Togo.

5. Discussion and conclusion

The results of this study us helped to learn more about the impact of various economic factors on changes in the level of CO_2 in some SSA countries. Thus we observed that countries where energy consumption strongly influenced CO_2 emissions include Botswana, Kenya, South Africa and Togo. The extent of this effect depends on the level of development. Indeed, the more the country has a high income per capita, the less is the impact of its energy consumption on CO_2 compared to countries with low per capita income. These countries were not able to develop innovative technology, and thus their energy consumption is less efficient and therefore more polluting. As was pointed out, the effect of international trade was also dependent on the development of the country and its integration rate in the world trade level. In poorer countries such as Kenya, it has an amplifying effect on CO_2, unlike the case of South Africa. Data from the CIA World Factbook show that Kenya exports mainly natural resources and imports manufactured goods. Fluctuations in commodity prices also compromise the possibility of purchasing efficient technologies with priority given to basic necessities. South Africa has a relatively developed industrial sector, allowing it to have a diversified commercial sector, so that we have a positive effect of trade on improving the level of emissions.

From these results, what emerges is that SSA countries should pay particular attention to energy and trade sectors to reduce CO_2 emissions and to stimulate economic activity. In order to propose an appropriate economic policy for each country, it was necessary to study the nature of the relationship between these factors. The T-Y causality test result is consistent with our estimation and reveals that each country has its own specificity. For example, in Kenya, energy consumption stimulates economic activities, whereas it is economic growth which promotes energy consumption in Ivory Coast. Furthermore, rather than international trade stimulating growth, it is the reverse in Gabon and Senegal while the two variables have an independent trend in the rest of the countries. This could highlight the importance of imports compared with exports in the international trade of SSA countries or the fact that trade is dominated by imports of vital commodities so that their volume is not affected by the economic situation.

Thus the specificity of each country (low or middle income country, dependent or not on energy, the importance of international trade), must be considered in economic policy decisions that use energy consumption and international trade as instruments.

What also needs to be emphasized is the non-significant effect of income on the variation of CO_2 levels. This could mean that an increase in income doesn’t affect the variation of pollution emissions considering the low level of CO_2 in absolute terms and the per capita income in the sub-Saharan region. This result is supported by the T-Y causality test suggesting that income doesn’t lead to CO_2 emission, except in Gabon where both variables are mutually dependent.

These econometric results contribute to learning more about the environmental policy to consider in SSA while pursuing a goal of increasing per capita income. However, they cannot be generalized to all countries in SSA because as we see with the results, each country has its own specificities in terms of its level of development. In addition they must be considered with particular attention, owing to the weak stability of the coefficients suggested by the Brown, Durbin, and Evans (1975) test. According to these authors, the fact that significance is not achieved by the cusum squares of the recursive residuals plot may be due to shifts in values of regression coefficients. This could underline the fact that the SSA countries concerned by this study have experienced exogenous shocks during the period covered. For future research, the present study may be reinvestigated by taking into account the possible presence of structural breaks in the data series and the threshold effect in the dynamic relationship between CO_2 emissions, income, energy consumption and foreign trade.

References

AfDB, 2013. African Development Report 2012: Towards Green Growth in Africa. African Development Bank (AfDB) Group.

Akinlo, A.E., 2008. Energy consumption and economic growth: Evidence from 11 Sub-Sahara African countries. Energy Economics 30, 2391–2400.

Bhattarai, M., Hammig, M., 2001. Institutions and the Environmental Kuznets Curve for Deforestation: A Crosscountry Analysis for Latin America, Africa and Asia. World Development 29, 995–1010.

Brown, R.L., Durbin, J., Evans, J.M., 1975. Techniques for Testing the Constancy of Regression Relationships over Time. Journal of the Royal Statistical Society. Series B (Methodological) 37, 149–192.

Culas, R.J., 2007. Deforestation and the environmental Kuznets curve: An institutional perspective. Ecological Economics 61, 429–437.

Dickey, D.A., Fuller, W.A., 1981. Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica 49, 1057–1072.

Dinda, S., 2004. Environmental Kuznets Curve Hypothesis: A Survey. Ecological Economics 49, 431–455.

Ebohon, O.J., 1996. Energy, economic growth and causality in developing countries: A case study of Tanzania and Nigeria. Energy Policy 24, 447–453.

Elliot, B.E., Rothenberg, T.J., Stock, J.H., 1996. Efficient tests of the unit root hypothesis. Econometrica 64, 13–36.

Engle, R.F., Granger, C.W., 1987. Co-integration and error correction: representation, estimation, and testing. Econometrica 55, 251–276.

Fagnart, J.-F., Hamaide, B., 2012. Environment and economic development : An introduction. Reflets et perspectives Tome LI, 5–8 (in French).

Fondja Wandji, Y.D., 2013. Energy consumption and economic growth: Evidence from Cameroon. Energy Policy 61, 1295–1304.

Grossman, G.M., Krueger, A.B., 1991. Environmental Impacts of a North American Free Trade Agreement (Working Paper No. 3914). National Bureau of Economic Research.

Halicioglu, F., 2009. An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 37, 1156–1164.

Hugon, P., 2006. Can we talk of a crisis or a renewal of development economics in the last decade? Revue Tiers Monde n° 187, 591–619 (in French).

Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. Oxford Bulletin of Economics and Statistics 52, 169–210.

Kofi Adom, P., Bekoe, W., Amuakwa-Mensah, F., Mensah, J.T., Botchway, E., 2012. Carbon dioxide emissions, economic growth, industrial structure, and technical efficiency: Empirical evidence from Ghana, Senegal, and Morocco on the causal dynamics. Energy, Asia-Pacific Forum on Renewable Energy 2011 47, 314–325.

Kohler, M., 2013. CO2 emissions, energy consumption, income and foreign trade: A South African perspective. Energy Policy 63, 1042–1050.

Kraft, J., Kraft, A., 1978. On the relationship between energy and GNP. Journal of Energy and Development 3, 415–427.

Liousse, C., Assamoi, E., Criqui, P., Granier, C., Rosset, R., 2014. Explosive growth in African combustion emissions from 2005 to 2030. Environ. Res. Lett. 9, 035003.

Menyah, K., Wolde-Rufael, Y., 2010. Energy consumption, pollutant emissions and economic growth in South Africa. Energy Economics 32, 1374–1382.

Narayan, P.K., 2005. The saving and investment nexus for China: evidence from cointegration tests. Applied Economics 37, 1979–1990.

Nourry, M., 2007. Economic growth is it a way to fight pollution? Revue française d'économie 21, 137–176 (in French).

Odhiambo, N.M., 2010. Energy consumption, prices and economic growth in three SSA countries: A comparative study. Energy Policy, Greater China Energy: Special Section with regular papers 38, 2463–2469.

Onafowora, O.A., Owoye, O., 2014. Bounds testing approach to analysis of the environment Kuznets curve hypothesis. Energy Economics 44, 47–62.

Ouédraogo, I.M., 2010. Electricity consumption and economic growth in Burkina Faso: A cointegration analysis. Energy Economics 32, 524–531.

Panayotou, T., 1993. Empirical tests and policy analysis of environmental degradation at different stages of economic development (ILO Working Paper No. 292778). International Labour Organization.

Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. J. Appl. Econ. 16, 289–326.

Phillips, P.C., Perron, P., 1988. Testing for a unit root in time series regression. Biometrika 75, 335–346.

Saboori, B., Sulaiman, J., 2013a. CO2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: A cointegration approach. Energy 55, 813–822.

Saboori, B., Sulaiman, J., 2013b. Environmental degradation, economic growth and energy consumption: Evidence of the environmental Kuznets curve in Malaysia. Energy Policy 60, 892–905.

Shafik, N., Bandyopadhyay, S., 1992. Economic Growth and Environmental Quality: Time-series and Cross-country Evidence. World Bank Publications.

Shahbaz, M., Kumar Tiwari, A., Nasir, M., 2013. The effects of financial development, economic growth, coal consumption and trade openness on CO2 emissions in South Africa. Energy Policy 61, 1452–1459.

Tamba, J.G., Njomo, D., Limanond, T., Ntsafack, B., 2012. Causality analysis of diesel consumption and economic growth in Cameroon. Energy Policy 45, 567–575.

Toda, H.Y., Yamamoto, T., 1995. Statistical inference in vector autoregressions with possibly integrated processes. Journal of Econometrics 66, 225–250.

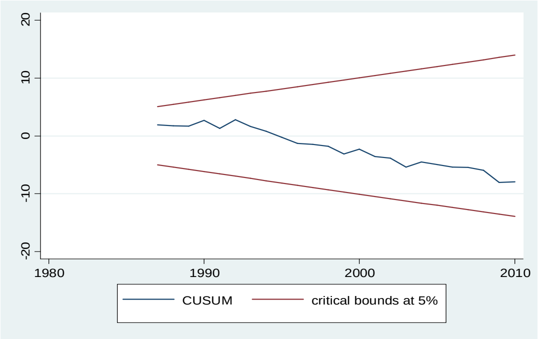
Wolde-Rufael, Y., 2005. Energy demand and economic growth: The African experience. Journal of Policy Modeling 27, 891–903.

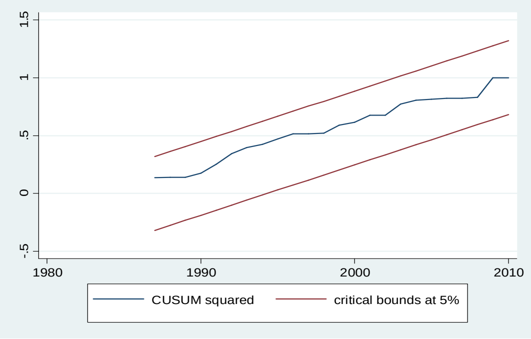
Wolde-Rufael, Y., 2009. Energy consumption and economic growth: The experience of African countries revisited. Energy Economics 31, 217–224.

6. Appendix: CUSUM and CUSUMSQ test graph

6.1. Short run stability test results

1. Botswana





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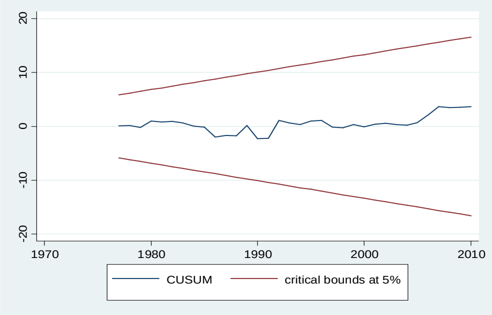

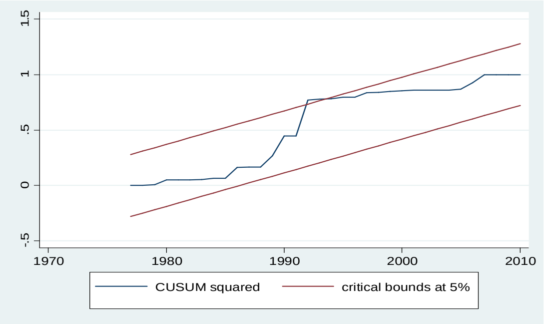

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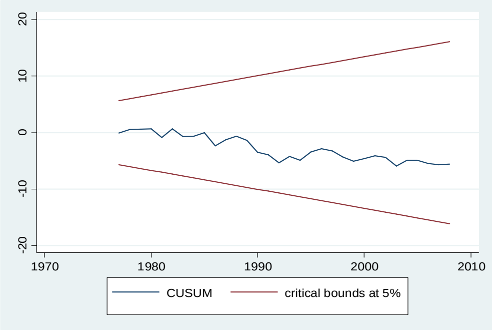

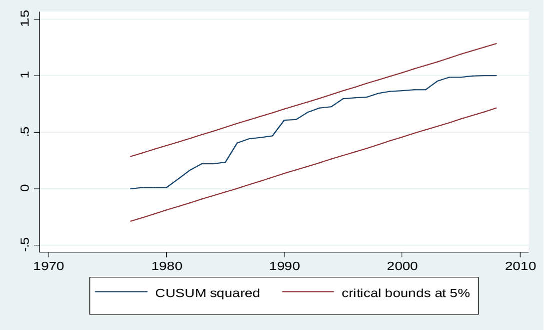

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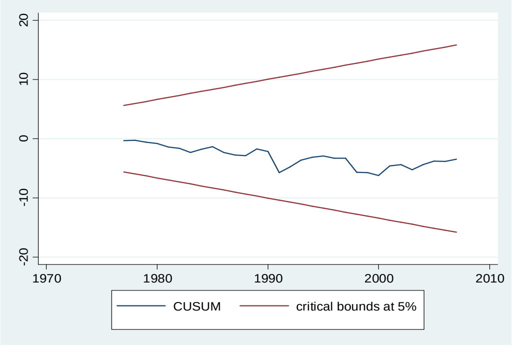

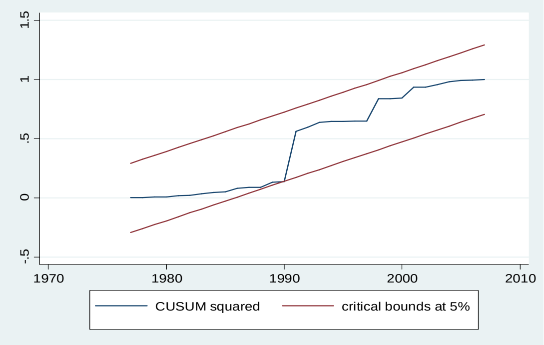

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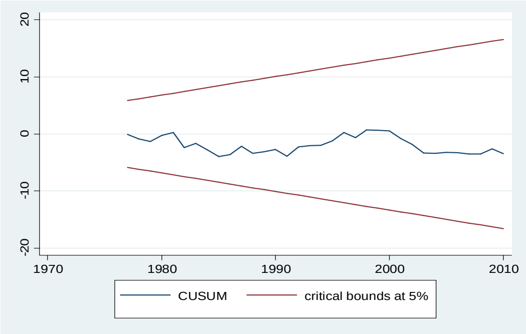

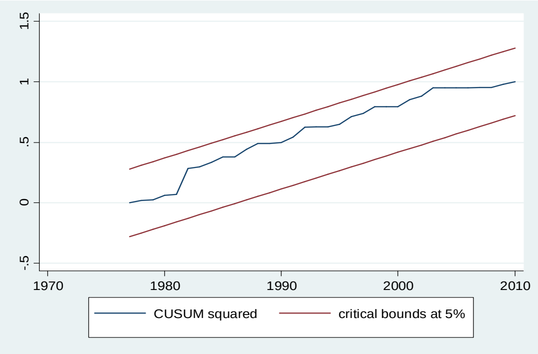

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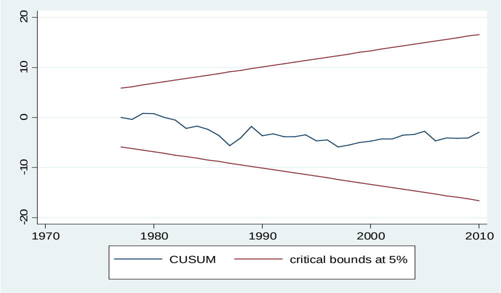
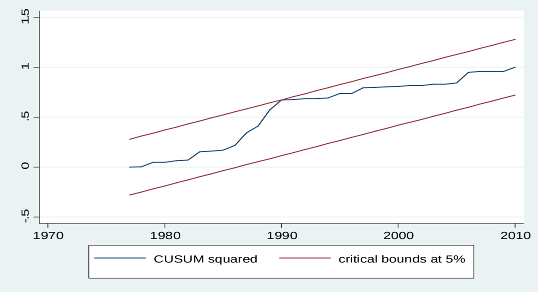
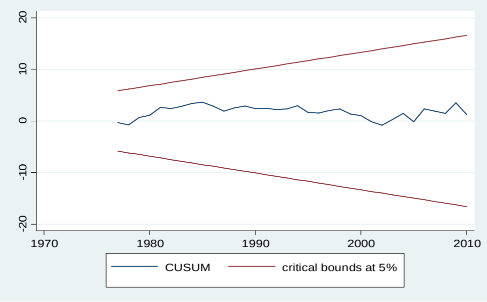
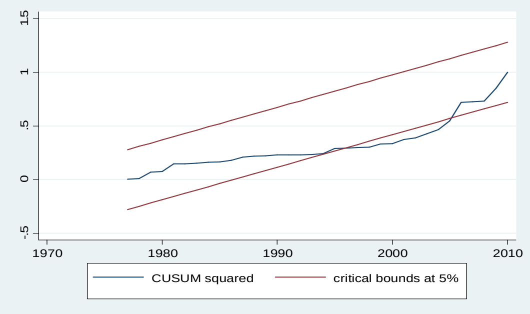


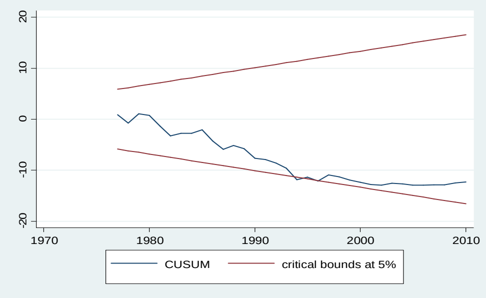


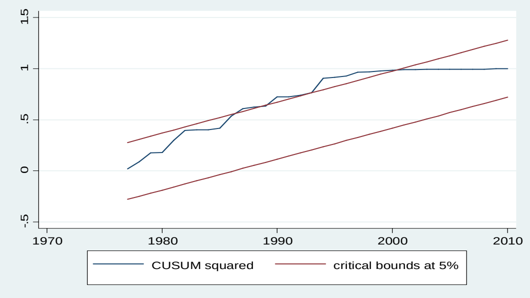
7. South Africa





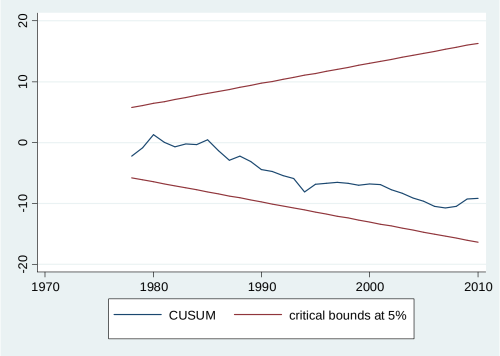
8. Togo

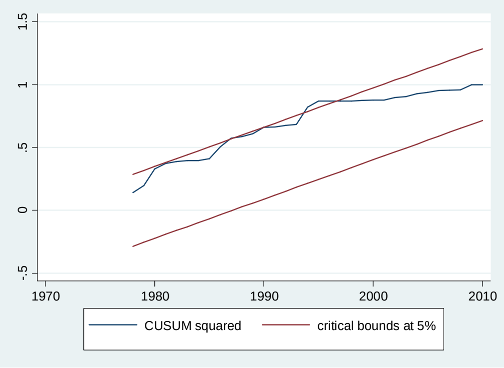




6.2. ECM long run stability test results

1. Togo





2. South Africa