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Article

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Energy Consumption, CO_2 Emissions and Economic Growth in Togo: A Causal Analysis

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Abstract

The sole purpose of this article is to examine the relationship between energy consumption, CO_2 emission and their impact on economic growth in Togo. This is done so as to capture its future perspective from an econometric analysis based on the tests of Auto Regressive Distributed Lag (ARDL) and the Granger Causality Test. The findings indicate the existence of a long-term relationship between all variable's energy consumption. The results also indicate bidirectional, unidirectional and causal relationships between energy consumption and certain variables. The findings of our study show a long-term interaction between energy use and all variables (CO_2, GDP, Energy, Agriculture Service, Industry) and reveals how understanding these relationships can help decision makers understand the risks that may exist between these relationships. The contribution of this article lies in the various of variables incorporated into the study model, unlike studies that are conducted with only two variables, the present study is different in that its multi-dimensional.

Keywords

Emission; Economic; Energy; Growth; ARDL, ECM, EKC

JEL Codes: F63, O13, P18, Q43

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1. Introduction

Energy plays a driving role in the development of a country. It is now one of the major concerns of decision-makers and an essential parameter for developing countries in achieving the Sustainable Development Goals (SDGs). However, this concern must respond to the concerns for preserving the environment in order to ensure sustainable development in the long term. Climate change is a tangible reality which countries have to adapt too. This is why national energy policies must take into account adaptation to climate change. As a result of the increasing use of fossil fuels and biomass, carbon dioxide emissions have increased significantly in the 20th century, with a direct link to economic growth and development (Lau *et al.*, 2009; Soytas *et al*., 2007). The relationship between CO_2 emissions, growth and energy consumption is therefore at the heart of the economic problems of the 21st century (Kraft and Kraft, 1978). This is the basis of many initiatives and conferences such as Cop21 to find consensus on alternative sources of sustainable energy to fossil fuels for developing countries. Indeed, global warming, caused by the accumulation of Greenhouse Gases (GHGs), whose main component is carbon dioxide (CO_2), could cost the global economy up to $ 550 billion (Stern, 2006) if governments do not take radical measures. It should be noted that the analysis of the determinants of environmental degradation has become a question that many scientists are trying to answer, as well as economists who would like to provide an answer through economic theory by verifying the hypothesis of environmental degradation. Environmental Kuznets Curve (EKC) between economic growth and indicators of environmental degradation (Grossman and Krueger, 1995; Panayotou, 1993, 1995; Shafik and Bandyopadhyay, 1992).

The EKC hypothesis therefore suggests that the level of development of a country (most often expressed in terms of average per capita income) is likely to have a positive effect on the environment. The input data is therefore the GDP/inh, and the output data (resultant) the degree of pressure on the environment (the environment is most often understood here as "living environment"). One of the major challenges of the 21st century lies in this agreement. Industry, utilities, municipalities and individuals are all looking for tailor-made solutions to achieve their economic and environmental goals, while ensuring an increasingly independent, decentralized and grid-connected power supply (Halicioglu, 2009).

Energy plays a major role in human and economic development as well as in the well-being of society. Electricity and other forms of energy are indispensable in contemporary economies characterized by the activities of industrial production and manufacturing goods and services, the omnipresence of information, communication and digital technologies (Omoju, 2014). Thus, the provision of electricity based on non-polluting alternative sources is of paramount importance to meet the basic needs of the population (health services, education and access to information). The economies of African countries continue to grow and energy challenges are an obstacle to the continent's overall growth, including the achievement of the Sustainable Development Goals (SDGs). Despite being endowed with important sources of energy, which remain very often unexploited, the African continent is marked by the weakness of its energy services. The imbalance between demand and supply of electricity is increasing today; which exposes more and more African countries to energy crises. This energy shortage, aggravated by soaring prices for petroleum products, increases the costs of transport and those of industrial and commercial activities. The dominant development model facing the world presents multiple simultaneous crises, depletion of natural resources and market failures that marked the first decades of the new millennium

The main aim of our study is to determine the relationship between energy consumption, CO_2 emission and economic growth in Togo. Specifically, the study will:

-Apply new tests in econometrics through the error-correction model (ARDL)

- Identify the main sectors of CO_2 emission across the sectors of activity and the energy sources used.

2. Literature review

The aim of this study is to examine the relationship between Energy Consumption, CO_2 Emissions and Economic Growth in Togo. The literature review is summarized in the Table 1 (a, b) below.

Table 1a. Time Series Panel Data

Author (s) and years of publication	Country and data	Methodology	Conclusion (s)
Florian Grosset and Phu Nguyen-Van December 2015	29 of sub-Saharan Africa from 1980-2011	Pesaran (2006), or that proposed by Eberhardt and Teal (2010)	Presence of the CKE in Cameroon, Democratic Republic of Congo, Mauritius and Zambia
Sahbi Farhani and Jaleleddine Ben Rejeb (2012)	Panel Data for 15 MENA countries to 1973-2008	Panel unit root tests, panel co-integration methods and panel causality. The use FMOLS and DOLS	- No causal link between GDP and EC; and between CO_2 emissions and EC in the short run - In the long run, there is a unidirectional causality running from GDP and CO_2 emissions to EC
Mohamed El Hedi Arouri and Al March (2012)	Panel Data for 12 Middle East and North African Countries (MENA) to 1981-2005	Panel error correction models (ECM) in order to examine the interactions between short and long run dynamics	- Regional-level We have EKC relations but in - Country-Level EKC is not verified for the studied countries except for Jordan
Kais Saidi and, Sami Hammami, 2015	Europe and North Asia, Latin America and Caribbean, and Sub- Saharan, North African and Middle Eastern	Generalized Method of Moments (GMM) for the period 1990–2012	-positive impact of CO_2 emissions on energy consumption for four global panels. -Economic growth has a positive impact on energy consumption and statistically significant only for the four panel.
Fei Li, Suocheng Dong, Xue Li, Quanxi Liang and Wangzhou Yang, 2010	30 provinces in mainland China from 1985 to 2007	panel unit root, heterogeneous panel co-integration and panel-based dynamic OLS to re-investigate the co-movement	positive long-run co-integrated relationship between real GDP per capita and energy consumption variables
(Yoo, 2006) Bidirectional between electricity consumption and economic growth (Singapore and Malaysia)	ASEAN (Thailand, Singapore, Indonesia, Malaysia) 1971- 2002	Granger causality	Bidirectional between electricity consumption and economic growth (Singapore and Malaysia)

Table 1b. Time Series

Author (s) and years of publication	Country and data	Methodology	Conclusion (s)
Sotamenou Joel and Cyrille Nanko Nguepdjio March 2019	Cameroon from 1975 to 2013	The correction models of error (ARDL)	-No long-term relationship between energy consumption and CO2 emissions. -Existence of a short-term relationship between fossil energy consumption on the one hand and electricity consumption on the other contribute positively to CO_2 emissions. -Economic growth has also a negative effect on the degradation of the environment
Palakiyèm Kpemoua September 2016	Togo from 1960 to 2011	ARDL and co-integration, Granger causality in the sense of Toda and Yamamoto apply to STIRPAT or the Kaya equation	-A positive and significant long-term correlation between CO2 emissions and economic growth, - bidirectional causality in the sense of Toda and Yamamoto between CO_2 emissions and economic growth
Nkengfack Hilaire1, Kaffo Fotio Hervé	Cameroon, Congo, Gabon and the Democratic Republic of Congo (DRC) over the period 1978-2012	ARDL	Presence of a long-term relationship between variables with economic growth that positively impacts CO_2 emissions in these countries
Rim Berahab March 2017	Morocco from 1971 to 2014	ARDL	-The existence of a positive long-term relationship between CO_2 emissions and real GDP and the meaning of this relationship goes from economic growth towards CO2 emissions - The hypothesis of CEK is validated
Hlalefang Khobai, Pierre Le Roux, 2017	The Case of South Africa 1971-2013	Johansen test of co-integration	-a long run relationship between energy consumption, CO_2 emission, economic growth, trade openness and urbanization in South Africa - bidirectional causality flowing between energy consumption and economic growth in the long run - a unidirectional causality flowing from CO2 emissions, economic growth
Fidimanantsoa Andriamanga November, 2017	Madagascar from 1995-2015	ECM model	- electricity, hydrocarbon and GDP are linked by co-integration equations in the short and long term - In the long term, these three variables tend to evolve together
(NjindanIyke, 2015)	Nigeria 1971-2011	VECM	Energy Consumption led Economic Growth

3. Methodology of research

3.1. Data used

In this article, the data used come from the World Bank database (WDI 2019) covering the period 1971-2014. In this study, we will use the EVIEWS 10 software for data analysis. The variables selected are the following:

lCO_2: the natural logarithm of carbon dioxide emissions (metric tons per capita)

ly: the natural logarithm of the Gross Domestic Product per capita (2010 constant US $)

lvagr: the natural logarithm of Value added to agriculture per worker (2010 constant US $)

lvids: the natural logarithm of industry sector real value added (in constant 2010 US $)

lvsrv: the natural logarithm of the added value of the service sector (constant 2010 US $)

leb: the natural logarithm of energy consumed from biomass (% of total energy use)

lef: the natural logarithm of energy consumed from fossil fuels (% of total energy use)

lephe: the natural logarithm of energy consumed from hydropower (% of total energy use)

3.2. Method and approach of analysis

The methodology to be followed in this work to identify the main sectors of CO_2 emission through the energy sources used in Togo over the period (1971-2014) will be based on the staged delay model ARDL initially put in place by Pesaran and Shin (1999) and improved a few years later by Pesaran et al., 2001. It is a model that is well adapted to small samples while allowing to treat in a single equation the dynamics of long term as well as that of short term.

Our model is written as follows:

$$\begin{aligned} lCO_{2t} = {} & \beta_1 + \sum_{i=1}^{p-1} \beta_2 \, \Delta lCO_{2t-i} + \sum_{i=0}^{p-1} \beta_3 \, \Delta ly_{t-i} + \sum_{i=0}^{p-1} \beta_4 \, \Delta lvarg_{t-i} \\ & + \sum_{i=0}^{p-1} \beta_5 \, \Delta lvids_{t-i} + \sum_{i=0}^{p-1} \beta_6 \, \Delta lvsrv_{t-i} + \sum_{i=0}^{p-1} \beta_7 \, \Delta leb_{t-i} \\ & + \sum_{i=0}^{p-1} \beta_8 \, \Delta lef_{t-i} + \sum_{i=0}^{p-1} \beta_9 \, \Delta lephe_{t-i} + \rho_{10} lCO_{2t-1} + \rho_{11} ly_{t-1} \\ & + +\rho_{12} lvarg_{t-1} + \rho_{13} lvids_{t-1} + \rho_{14} lvsrv_{t-1} + \rho_{15} leb_{t-1} \\ & + \rho_{16} lef_{t-1} + \rho_{17} lephe_{t-1} + \varepsilon_t \; avec \; \varepsilon_t \sim N(0, \sigma^2). \end{aligned} \quad (1)$$

Or:

Δ represents the first difference operator,

β_1 is the drift component, and

ε_ (t) a white noise.

(P) the optimal delay number of the autoregressive vector model VAR (P) from which the error correction model is derived.

The different tests that will be applied are the following:

(I). Stationarity test of time series;

(Ii). Selection of the optimal delay number;

(Iii). "Bound Test" to establish the long-term relationship;

(Iv). Estimation of long-term and short-term coefficients;

(V). Stability test of the model through residue analysis and the technique of CUSUM and CUSUMSQ.

3.3. Results

The implementation of the different stationarity tests for each series leads to the results summarized in Table 2 below. These results reflect the application properties of the bound test because the variables must be integrated, either I (1) or I (0) or both.

Table 2. Unit Root Test

	Augmented Dicker-fuller unit root test			Phillips Perron Tests (PP)		
Level	(1)	(2)	(3)	(1)	(2)	(3)
lCO_{2t}	-4,74	-3,25	-1,10	-4,73	-3,22	-1,24
ly_t	-1,72	-1,71	0,11	-1,98	-1,84	0,11
$lvagr_t$	-2,48	-0,96	2,20	-2,42	-0,87	3,61
$lvids_t$	-3,11	-1,77	1,30	-3,18	-1,68	2,50
$lvsrv_t$	-1,95	-0,59	1,47	-2,24	-0,57	1,54
lef_t	-4,05	-3,58	-0,16	-3,73	-3,55	0,16
leb_t	-2,02	-0,90	-1,25	-2,05	-0,86	-1,41
$lephe_t$	-3,16	-2,24	-2,3	-3,13	-2,24	-2,29

First difference						
ΔlCO_{2t}	-9,74*	-9,86*	-9,91*	-13,19*	-13,33*	-11,73*
Δly_t	-6,32*	-6,31*	-6,38*	-6,32*	-6,31*	-6,38*
$\Delta lvagr_t$	-7,62*	-7,70*	-6,88*	-8,46*	-8,33*	-6,90*
$\Delta lvids_t$	-6,42*	-6,50*	-6,36*	-7,92*	-8,30*	-6,58*
$\Delta lvsrv_t$	-6,50*	-6,48*	-6,26*	-6,50*	-6,48*	-6,27*
Δlef_t	-8,10*	-8,16*	-8,26*	-23,03*	-16,15*	-15,66*
Δleb_t	-6,68*	6,76*	-6,60*	-6,67*	-6,79*	-6,62*
$\Delta lephe_t$	-7,27*	-7,34*	-7,39*	-7,70*	-7,75*	-7,71*

Notes: * indicates a level of significance at the 5% threshold. (1), (2) and (3) respectively indicate the models "with constant and trend", "with constant only" and "without constant or trend". The ADF and PP tests assume that there is no unit root.

The number of delays is automatically selected according to the Schwarz information criterion which is recorded in Table 3 (Annex). The results show us a minimum delay of 0 provided by the criterion of SC (BIC) and a maximum delay of 3 provided by the criterion AIC. This information allows us to test the co-integration relationship across the bound test. The result of this test (Table 4 in the appendix) allows us to confirm the existence of a co-integration relation between the variables because the F-Statistic is greater than the critical values at 1% and 5%. Moreover, the Granger causality test reveals a causality:

- unidirectional between CO_2 emission and economic growth at the 5% threshold,

- unidirectional between energy consumption and value-added growth of the industrial sector at the 10% threshold,

- bidirectional between the energy consumption from hydropower and the emission of CO_2 at 10%

4. Interpretations

At the end of these results, the estimation of the long- and short-term coefficients of the ARDL model by considering the CO_2 emissions per inhabitant ($lCO_{2}t$) as a dependent variable, makes it possible to have a precision on the significance and the signs of the variables expected. However, the estimated long-run coefficients, which also represent the long-run elasticities, are shown in Table 5 (Appendix). At the threshold of 1%, fossil energy consumption (LEB) and value added in the industrial sector (LVIDS) are significant and present the expected signs. Thus, the 1% increase in LEB and LVIDS increases CO_2 emission by 0.9 and 0.6 of its unit respectively. At the threshold of 10%, energy consumption from hydropower (LEPHE), value added to agriculture per worker (LVAGRI) and Gross Domestic Product per capita (LY) are significant, respectively with the signs positive and negative for the last two; hence, a LEPHE increase of 1% leads to an increase in CO_2 emissions of 0.19 (unit), but an increase in the agricultural sector's share of GDP and GDP of 1% results in a decrease of CO_2 emission of 0.71 and 1.84, respectively.

In the short term, the results of the estimation of the ECM (Table 6 annex) make it possible to confirm that the coefficient of the ECM (-1) error correction term is significant at 1% and has the expected sign which is negative. Therefore, the speed of adjustment in the short term to reach equilibrium is significant. In addition, this term is equal to -0.9098, which means that when CO_2 emissions per capita are above or below their equilibrium value, they would adjust to 90% per year. In the short term, the variables LEPHE and LY have negative and significant coefficients respectively at 5% and 1%. The LVAGRI variable has a positive and significant coefficient of 5%. The increase in consumption of the EPHE 1% results in a reduction of the CO_2 emission of 0.10 units.

The diagnostic tests carried out on the residues whose results presented in Table 7 (annex) confirm the absence of auto-correlation through the LM auto-correlation test, reinforced by the correlogram (Figure 2). In addition, the test reveals an absence of heteroscedasticity of the residues through the White test. These residues follow a normal distribution according to the results of the Jarque-Béra normality test. The Ramsey test confirms that the model is well specified and that there is no problem with the functional form of the model. On the other hand, the observation of the results of the CUSUM and CUSUMQ statistics of the graph (Figure 1), remain within the range of critical values at the 5% threshold, which implies that the coefficients of the model are stable.

5. Conclusions and recommendations

The main objective of this study is to examine the nature of the energy-growth-CO_2 emission relationship in Togo over the period 1971-2014. The ARDL (black box) methodology was used in this work while considering per capita CO_2 emissions as an indicator of environmental conditions. We have found a long-term relationship between economic growth, CO_2 emissions and energy consumption in Togo, but the services sector can be developed without any emissions risks. In the short term, the results of the estimates are significant, which means that there is a positive correlation in the short term between economic growth and energy consumption. Moreover, the Granger causality test indicates the existence of a one-way causality between CO_2 emissions and economic growth at the 5% threshold and between energy consumption and value-added growth of the industrial sector at the 10% threshold. On the other hand, there is a two-way relationship between energy consumption from hydropower and CO_2 emission at 10%.

These results show that the Togolese State would benefit from the sustainable development of the non-polluting services sector, particularly the digital economy. From another angle, he will have to:

• ensure steady growth in energy production to drive economic growth;

• improve production through diversification of sources of electricity generation;

• short term:

- rehabilitate and replace aging infrastructure and obsolete, inefficient and overloaded facilities, causing interruptions and outages, damaging to growth;

- increase consumer awareness of the efficient use of electricity (through media campaigns).

• long-term:

- diversify the sources of electricity production;

- to explore the possibility of producing renewable and less polluting energies (Installation of solar power plants on a large scale).

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Annexes

Table 3. Statistics and selection criteria for the selection of the optimal model delay

Lag	*Log*	*LR*	*FPE*	*AIC*	*SC*	*HQ*
0	*266.3552*	*NA*	*3.39e-16*	*-12.91776*	*-12.57998**	*-12.79563**
1	*330.9153*	*100.0682*	*3.51e-16*	*-12.94577*	*-9.90578*	*-11.84660*
2	*389.5553*	*67.43596*	*6.83e-16*	*-12.67776*	*-6.935573*	*-10.60157*
3	*508.1976*	*88.78176**	*1.58e-16 **	*-15.40788**	*-6.965483*	*-12.35665*

*Notes: * indicates the delay selected by the selected criterion. LR: Sequential modified LR test statistic.*
AIC: Akaike information criterion.
SC: Schwarz information criterion.
HQ: Hannan-Quinn information criterion.

Table 4. Result of ARDL Bound Test

F-Bounds Test — *Null Hypothesis: No levels relationship*

Test Statistic	*Value*	*Signif.*	*I (0)*	*I (1)*
			Asymptotic: n=1000	
F-statistic	*10.26664*	*10%*	*1.92*	*2.89*
K	*7*	*5%*	*2.17*	*3.21*
		2.5%	*2.43*	*3.51*
		1%	*2.73*	*3.9*

Table 5. Granger causality test

Null hypothesis	*F-Statistique*	*Prob.*
DLEPHE does not Granger cause DLCO2	*3.95872*	*0.0279**
DLCO2 does not Granger cause DLEPHE	*2.60636*	*0.0877**
DLCO2 does not Granger cause DLY	*4.43796*	*0.0189**
DLEF does not Granger cause DLVIDS	*2.76191*	*0.0766**

Table 6. ARDL model and estimated coefficients of variables (long term)

Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LEB	0.049670	0.345494	0.143765	0.8868
LEF	0.908307	0.300100	3.026683	0.0055
LEPHE	0.191100	0.113215	1.687945	0.1034
LVAGRI	-0.714142	0.400354	-1.783778	0.0861
LVIDS	0.699891	0.196889	3.554748	0.0015
LVSRV	0.376476	0.321835	1.169777	0.2527
LY	-1.842779	0.983708	-1.873299	0.0723
C	0.713537	8.478811	0.084155	0.9336

*EC = LCO2 - (0.0497*LEB + 0.9083*LEF + 0.1911*LEPHE -0.7141*LVAGRI + 0.6999*LVIDS + 0.3765*LVSRV -1.8428*LY + 0.7135)*

Table 7. ECM model estimate (short term)

ARDL Error Correction Regression
Dependent Variable: D(LCO2)
Selected Model: ARDL (1, 0, 0, 2, 3, 0, 0, 1)
Case 2: Restricted Constant and No Trend
Date: 09/28/19 Time: 00 :12
Sample: 1971 2014
Included observations: 41

ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LEPHE)	-0.104009	0.048094	-2.162632	0.0399
D (LEPHE (-1))	-0.281471	0.054766	-5.139570	0.0000
D(LVAGRI)	0.652109	0.253728	2.570112	0.0162
D (LVAGRI (-1))	1.659257	0.233143	7.116910	0.0000
D (LVAGRI (-2))	0.740497	0.228732	3.237400	0.0033
D(LY)	-3.942206	0.485072	-8.127055	0.0000
CointEq (-1) *	-0.909881	0.082774	-10.99229	0.0000

R-squared	0.838673	Mean dependent var	0.017758
Adjusted R-squared	0.810203	S.D. dependent var	0.283580
S.E. of regression	0.123543	Akaike info criterion	-1.190196
Sum squared resid	0.518941	Schwarz criterion	-0.897635
Log likelihood	31.39902	Hannan-Quinn criter.	-1.083662
Durbin-Watson stat	2.247892		

** p-value incompatible with t-Bounds distribution.*

F-Bounds Test *Null Hypothesis: No levels relationship*

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	10.26664	10%	1.92	2.89
k	7	5%	2.17	3.21
		2.5%	2.43	3.51
		1%	2.73	3.9

Table 8. Residue Tests for ARDL Regression

LM Autocorrelation test of Breusch-Godfrey Serial			
Null hypothesis: Absence of autocorrelation			
F-statistic	*0.838882*	*Prob. F (1,25)*	*0.3685*
*Obs.*R-square*	*1.331100*	*Prob. Chi-square (1)*	*0.2486*
White Heteroskedasticity Test			
Null hypothesis: Absence of heteroscedasticity			
F-statistic	*1.276431*	*Prob. F (14.26)*	*0.2854*
*Obs.*R- square*	*16.70095*	*Prob. Chi-square (14)*	*0.2725*
Scaled explained SS	*9.471024*	*Prob. Chi-square (14)*	*0.7997*
Normality test of Jarque Bera			
Null hypothesis: Normality			
Jarque-Bera	*2.905074*	*Prob.*	*0.233976*
Ramsey RESET Test			
Null hypothesis: The model is correctly specified			
T-statistic	*0.333823*	*Prob.*	*0.7413*
F-statistic	*0.111438*	*Prob.*	*O.7413*

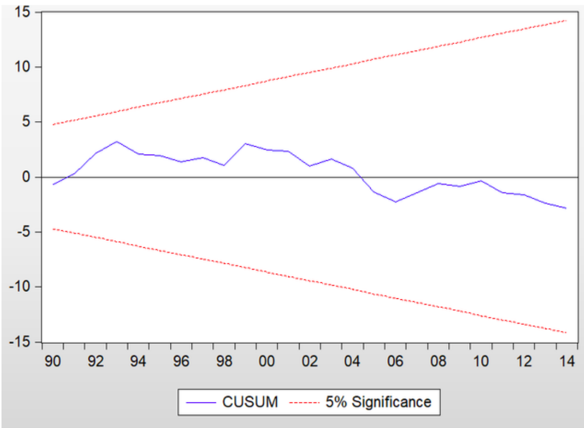

Figure 1. CUSUM and CISUMQ stability tests

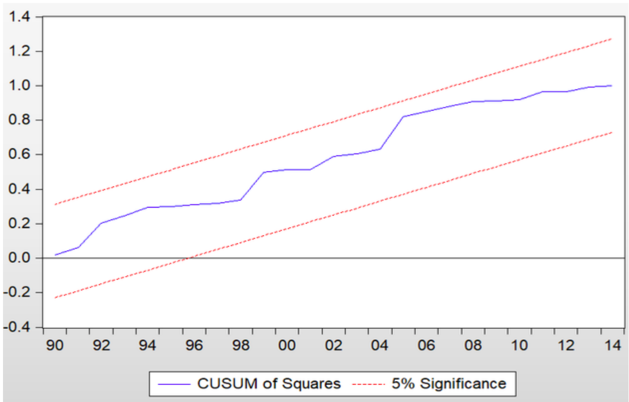

Figure 2. Correlogram of the residues of the ARDL regression (white noise, no autocorrelation)