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# Environmental Kuznets Curve hypothesis and the role of globalization in selected African countries

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ABSTRACT

The present study incorporates globalization and energy intensity into the $CO_2$ emissions function and investigates the presence of Environmental Kuznets Curve (EKC) in 19 African countries for the time period of 1971–2012. We have applied the ARDL bounds testing approach for cointegration to examine the long run relationship in the variables. Our results confirmed the presence of cointegration between the series in Africa, Algeria, Angola, Cameroon, Congo Republic, Ghana, Kenya, Libya, Morocco, Nigeria, South Africa, Sudan, Tanzania, Togo, Tunisia, Zambia and Zimbabwe. The results indicated the positive effect of energy intensity on $CO_2$ emissions in Africa, Algeria, Angola, Cameroon, Congo Republic, Ghana, Kenya, Libya, Morocco, Nigeria, South Africa, Sudan, Togo, and Tunisia while energy intensity declines $CO_2$ emissions in the case of Zambia and Zimbabwe. Globalization decreases $CO_2$ emissions in Africa, Angola, Cameroon, Congo Republic, Egypt, Kenya, Libya, Tunisia and Zambia but increases $CO_2$ emissions in Ghana, Morocco, South Africa, Sudan and Tanzania. The EKC exists in Africa, Algeria, Cameroon, Congo Republic, Morocco, Tunisia and Zambia but U-shaped relationship is found between economic growth and $CO_2$ emissions in Sudan and Tanzania.

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## 1. Introduction

The world is facing rapid climate change, which is attributed to increasing global warming and emission of greenhouse gases. Consequently, various aspects of environment, including the validity of Environmental Kuznets Curve (EKC) hypothesis have been placed under much scrutiny in the existing literature of environmental economics. The hypothesis has asserted that initially economic growth will lead to environmental degradation but eventually as income level increases, this degradation will decrease and a clean environment takes place in prosperous countries. However, there are still several aspects of the EKC hypothesis that have not received adequate attention. Arising from the recent advances in the econometrics sphere, the subject-matter has progressed with most papers using additional variables and concentrating on various sub-regions. One of the largely ignored variables in the existing literature is globalization. Without an adequate econometrics analysis, it is difficult to hypothesize the specific impact of globalization on emissions as it may reduce or exacerbate pollution. The first argument is that globalization is associated with human activities that breed pollution including industrial production, transportation and, more indirectly, deforestation. Globalization, which is partly synonymous with rising international trade, is partly linked to the growth of these three human activities (Huwart and Verdier, 2013). Globalization has allowed multinational corporations to relocate factories from high-income countries to low-income countries. These companies do not only pay lower wages than what it is expected in the home countries, but also do not often meet the environmental standards that are often imposed in high-income countries (Hubbard and O'Brien, 2013).

On other hand, it is also believed that globalization can reduce emissions level. The globalization of trade and research is associated with green technologies. Industry, global movements of capital, globalized research and innovation promote vector of "green growth" and are particularly effective instruments to fight pollution and climate change on a global scale. Globalization and

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production network can help to foster new activities and new products and also new production processes (Huwart and Verdier, 2013). Globalized information and knowledge have made it possible for the public to be more aware of ecological issues and this has generated greater mobilization. Globalization can make environmental conservation compatible with economic development. This is because of international economic competition, which is mainly facilitated by globalization, helps in resolving many environmental problems as companies try to outwit each other in terms of abiding to environmental standards. Multinational corporations are precious allies in combating global warming, as they are knowledgeable about environmental standards and practices in developed countries and are vital vehicles for transferring green technology and good-practice (Huwart and Verdier, 2013). Therefore, pollution level moves to a horizontal line of maximum emissions as globalization forces a "race to the bottom" in environmental standards (Dasgupta et al., 2002).

Arguably, the least studied region in terms of EKC is African continent. This is largely due to the fact that the continent's fossil-fuel $CO_2$ emissions are low in relative terms. The total emissions in the continent was about 14%, 28% and 19% of the total carbon generated in North America, China and Europe in 2012. The emissions in the continent amount to 3.68% of the global carbon in the same year (Energy Information Administration, 2014). However, the pollution in some African countries is well ahead of some of their counterparts in Europe. For example, Egypt and Algeria generated 206 million metric tons of carbon (29th in the world) and 133 million metric tons of carbon (31st in the world), respectively in 2012. Greece and Austria generated 87 million metric tons of carbon (43rd in the world) and 67 million metric tons of carbon (or 52nd in the world), respectively in 2012 (Energy Information Administration, 2014). Emissions from all fuel sources are growing in the continent as total emissions for Africa has increased five-fold since 1960 and more than two-fold since 1980. The total emissions reached almost 1.2 billion metric tons of carbon in 2012 (World Bank, 2014; Energy Information Administration, 2014). South Africa, which accounted for almost 40% of the total emissions in the continent, has experienced increasing emissions level as it generated 473 million metric tons in 2012 compared to 235 million metric tons in 1980 (Energy Information Administration, 2014). Fossil-fuels accounted for more than 42% of the total emissions in the continent for the year of 2012 (Energy Information Administration, 2014).

The direct impact of the growing global emissions (inclusive of those generated in Africa) is climate change. Despite the fact that African countries have contributed the least to climate change caused by humans, there are widespread fears that Africa will be the worst hit. Floods, droughts and rising sea levels are just some of environmental impacts of climate change on Sub Saharan Africa. Climate change will have serious and adverse consequences for many development sectors in Africa, and threatens the economies and livelihoods of many African countries. The adverse impacts of climate change impose an additional cost on vulnerable countries to achieve their development goals. Reduced agricultural production, worsening food security, increased flooding and drought, spreading diseases and an increased risk of conflict over scarce land and water resources – which are all impact of climate change – will provide additional burden for African countries to achieve their developmental goals (Solarin, 2014a,b; Ibrahim and Law, 2015; Zaman et al., 2015; Zou et al., 2015).

The aim of this paper is to examine the EKC hypothesis in 19 selected African countries, while providing for energy intensity and a proxy for globalization. We focus on the African continent, which is not only largely understudied, but also the region that is most affected by the consequences of the growing global emissions. This paper contributes to the existing energy economics literature by five ways: (i), this paper examines the presence of the EKC using multi-country data set for African countries, (ii) globalization is added to the $CO_2$ emissions function to avoid specification bias, (iii) energy intensity is used instead of energy consumption to add a new dimension to $CO_2$ emissions function in Africa and capture technological advancement in production function, (iv) the bounds testing and combined cointegration approaches are used to examine the presence of cointegration between the variables, (v) short-and-long run impacts of economic growth, energy intensity and globalization are checked by applying ECM (error correction method) and OLS (ordinary least square) respectively.

The remainder of the paper is prepared as follows: Section 2 deals with a brief survey of papers on EKC. The model and data are discussed in Section 3, while the methodological framework is detailed in Section 4. The results are provided in Section 5, and Section 6 contains the conclusions and policy recommendations.

## 2. Literature review

The validity of EKC effect has been examined by a number of studies, which have utilized different econometrics methods and focused on different regions. Despite the lack of consensus among the results, the existing literature can be divided into two categories. The first fold examines the pollution – economic growth nexus for individual countries. The second strand examines the pollution – economic growth nexus for a cross-section and/or panel of countries (see Almulali et al., 2015, 2016). Due to the fact that we are conducting a multi-country study, our literature review will focus on the multi-country papers.[3] The literature is divided into two sections, with the first part concentrating on papers wherein the individual country's long-run and short-run estimates are not provided while the second part involves papers wherein the individual country's long run and short run estimates are provided.

The first set of the papers include Martínez-Zarzoso and Bengochea-Morancho (2004) who examined the relationship between carbon dioxide emissions and real output in 22 OECD countries for the period, 1975–1998. Using the Pooled Mean Group (PMG) method, the authors were able to establish the existence of EKC in the countries. Apergis and Payne (2009) examined the relationship in $CO_2$ emissions, energy consumption, and output in six Central American countries for the period, 1971–2004. Using the Pedroni cointegration test and the Fully Modified Ordinary Least Square (FMOLS), the study supports the existence of EKC hypothesis in the Central American nations. In a similar study, Apergis and Payne (2010) explored the validity of EKC in 11 Commonwealth of Independent States for the period, 1992–2004. The study provided evidence for EKC hypothesis. Tamazian et al. (2009) examined the validity of EKC hypothesis in a panel of countries that include US, Japan, Brazil, Russia, India and China for the period, 1992–2004. The variables included in the model include real gross domestic product (GDP), energy consumption, oil consumption, industrial share in GDP, research and development expenditure, net energy imports, carbon dioxide emissions, financial development indicators and real output. With the use of random-effect method, the study was able to establish the existence of EKC hypothesis in the countries. Vollebergh et al. (2009) examined the relationship between income growth and pollutants emissions. Their analysis revealed a strong evidence of EKC hypothesis as $SO_2$ emissions is used as an indicator of pollution compared to $CO_2$ emissions. Using Bayesian approach, Musolesi et al. (2010) investigated the EKC hypothesis using the data of 109 countries of the globe. They found that EKC hypothesis exists in advanced countries but a positive

[3] We will ignore the causality aspect of these papers since it has little consequence on our paper.

correlation is found between economic growth and $CO_2$ emissions in low income countries. Tamazian and Rao (2010) used the Generalized Methods of Moments (GMM) method to explore the existence of EKC hypothesis in 24 transition economies for the period, 1993–2004. The variables included in the model are energy consumption, energy imports, trade openness, financial liberalization, price liberalization, foreign direct investment (FDI), inflation, foreign trade, liberalization, GDP per capita and the study support the EKC.

Iwata et al. (2011) utilized the data of 28 countries to examine the relationship between nuclear energy, carbon dioxide emissions and real output for the period, 1960–2003. Using the PMG method, the study provides evidence for EKC hypothesis in the sample countries. Pao and Tsai (2011) used the data of Brazil, Russia, India and China to investigate the relationship between $CO_2$ emissions, energy consumption, FDI and GDP and square of GDP for the period, 1992–2007. The study provides evidence for EKC hypothesis in the countries. Rehman et al. (2012) investigated the validity of EKC effect in Pakistan, India, Bangladesh and Sri Lanka with the use of Fixed Effects Model (FEM) for the period, 1984–2008. Providing for corruption, and trade openness, the results support the existence of EKC hypothesis in these countries. Cho et al. (2014) used the data of 22 OECD countries to examine the relationship between carbon dioxide emissions, energy use and GDP for the period, 1971–2000. Using the FMOLS, test statistics provided support for EKC hypothesis in the countries. Farhani and Shahbaz (2014) utilized the data of 10 Middle East and North Africa (MENA) countries to examine the relationship between $CO_2$ emissions, renewable and non-renewable electricity consumption and economic growth for the period, 1980–2009. After using the Kao (1999) cointegration test to establish long run relationship in the series, the authors adopted the FMOLS and Dynamic Ordinary Least Square (DOLS) to estimate the long run estimates. The results provide evidence for EKC hypothesis in the countries. Mazzanti and Musolesi (2014) applied the GMM approach to examine the presence of EKC hypothesis for North America, Oceania, South Europe and North Europe but found EKC hypothesis is valid in the North European region. Kasman and Duman (2015) investigated the hypothesis in the case of 15 new and potential EU member countries, while including trade openness and urbanization as control variables for the period, 1992–2010. After using the cointegration tests of Kao (1999), Pedroni (1999) and Westerlund (2007) to confirm cointegration in the series, the study utilized the panel FMOLS to show that EKC hypothesis exists. Apergis and Ozturk (2015) used the GMM method (in addition to FMOLS and DOLS) to investigate the nexus in 14 Asian countries for the period, 1990–2011. In addition to GDP per capita, the other variables included in the model include population density, land, industry shares in GDP and quality of institutions. The study reveals that EKC hypothesis is present in the sampled countries.

One issue with the foregoing papers is that the results generated at a panel may not be necessarily valid across the sample. For the fact that the panel results support (or otherwise) EKC hypothesis does not necessarily imply that all the countries in the sample will yield similar results. The second part of the literature involves papers wherein the individual country's long run and short run elasticities are provided. These papers include Lean and Smyth (2010) who examined the validity of EKC effect in five ASEAN countries for the period, 1980–2006. Using the Johansen Fisher panel cointegration test; panel DOLS, the authors established that EKC hypothesis is present in the Philippines. Acaravci and Ozturk (2010) analyzed the relationship between carbon dioxide emissions, energy consumption, and economic growth by using autoregressive distributed lag (ARDL) bounds testing approach of cointegration for nineteen European countries. The results yield evidence of a long-run relationship between the series in Denmark, Germany, Greece, Iceland, Italy, Portugal and Switzerland and also support the validity of EKC hypothesis in Denmark and Italy. Saboori and Sulaiman (2013) explored the cointegration and causal relationship between economic growth, carbon dioxide ($CO_2$) emissions and energy consumption in five Association of Southeast Asian Nations (ASEAN) countries for the period 1971–2009. The authors used the ARDL methodology to confirm long run relationship in the series. The long run elasticities of energy consumption with respect to carbon emissions are higher than the short run elasticities. However, the EKC hypothesis is confirmed in Singapore and Thailand.

Pao and Tsai (2010) used the data of Brazil, Russia, India and China to investigate the relationship between $CO_2$ emissions, energy consumption, FDI and GDP and the square of GDP for the period, 1971–2005. The study provides evidence for EKC hypothesis in Russia, India and China. Hossain (2011) explored the nexus in nine newly industrialized countries for the period, 1971–2007. The variables included in the model include carbon dioxide emissions, energy consumption, economic growth, trade openness and urbanization. Using the Johansen Fisher panel cointegration test and GMM, the evidence suggests that EKC hypothesis is present in Philippines. In a related paper, Jayanthakumaran et al. (2012) examined the nexus, while providing for trade liberalization in China and India for the period, 1971–2007. The results show that EKC hypothesis exists. Chandran and Tang (2013) used the data of Indonesia, Malaysia, Singapore and Thailand to examine the relationship between transport energy consumption, foreign direct investment, income and $CO_2$ emissions for the period of 1971–2008. The results are unable to find any evidence for EKC hypothesis. Ozcan (2013) examined the existence of EKC hypothesis in 12 Middle East countries for the period, 1990–2008. The variables included in the model are carbon dioxide emissions, energy consumption, per capita real GDP, square of per capita real GDP. Using the Westerlund (2008) panel cointegration test and the FMOLS, the authors are able to provide evidence for EKC hypothesis in three countries, including UAE, Egypt, and Lebanon. Shahbaz et al. (2015a) explored the relationship between coal consumption, industrial production, and $CO_2$ emissions in China and India for the period, 1971–2011. Using the Bayer and Hanck (2013) cointegration test and Granger causality test, the results provide evidence for EKC hypothesis in only India. Shahbaz et al. (2015b) utilized the Pedroni cointegration test and Johansen cointegration test to analyze the relationship between economic growth, energy intensity and $CO_2$ emissions in 12 African countries for the period, 1980–2012. The results show that while EKC hypothesis is present at panel level, it is present in only South Africa, Congo Republic, Ethiopia and Togo.

The foregoing review revealed that papers with individual country's long-run and short-run elasticities tend not to provide uniform results across the countries in the sample. Therefore, it is better to provide for individual country's long-run and short-run elasticities in the estimation. Moreover, it is observed that the study on African countries is very limited. Furthermore, although related variables such as FDI and trade openness have been used in the literature, proxy of globalization has been rarely adopted as a control variable in the EKC framework.

## 3. Model construction and data collection

The existing energy economics empirical literature provides various determinants of $CO_2$ emissions while investigating the presence of Environmental Kuznets Curve. For example, energy consumption is major indicator of $CO_2$ emissions by Ang (2007), Soytas et al. (2007), Zhang and Cheng (2009), Chang (2010), Wang et al. (2011), Halicioglu (2009), Ozturk and Acaravci (2010), Pao and Tsai (2011), Alam et al. (2011, 2012), Shahbaz et al. (2013a,b) and Solarin (2014a,b) for France, United States, China, for Turkey, India, Bangladesh and Malaysia. Xepapadeas (2005), Menyah and Wolde-Rufeal (2010), Lotfalipour et al. (2010), Bloch et al. (2012), Lean and Smyth (2010), Hossain (2011), Pao and Tsai (2011), Roca and AlcaHntara (2001) and Hatzigeorgiou et al. (2011)[4] use capital, fossil fuels consumption, coal consumption, electricity consumption, openness, urbanization, foreign direct investment, energy intensity as potential determinants of economic growth as well as $CO_2$ emissions while investigating the presence of EKC hypothesis. Recently, Shahbaz et al. (2015c) incorporated globalization as additional determinant of economic growth and environmental degradation in $CO_2$ emissions function for Indian economy. Following the existing literature, we construct a general form of $CO_2$ emissions function as given below:

$$C_t = f(Y_t, Y_t^2, EI_t, G_t) \tag{1}$$

All the series are transformed into natural logarithmic form following Lean and Smyth (2010). The log-linear specification presents consistent and efficient empirical results compared to simple linear modeling (Shahbaz et al., 2015b). The log-linear specification is modeled as following:

$$\ln C_t = \beta_1 + \beta_2 \ln Y_t + \beta_3 \ln Y_t^2 + \beta_4 \ln EI_t + \beta_5 \ln G_t + \mu_i \tag{2}$$

where $\ln C_t$, $\ln Y_t$ ($\ln Y_t^2$), $\ln EI_t$ and $\ln G_t$ are the natural-log of $CO_2$ emissions, real GDP (square of real GDP) per capita, energy intensity and globalization. $\mu_i$ is error term with normal distribution in period $i$. The relationship between economic growth and $CO_2$ emissions is termed as Environmental Kuznets Curve hypothesis (EKC). The EKC hypothesis proposes that economic growth is initially accompanied with high $CO_2$ emissions then declines it after a threshold level of real income per capita as economy achieves maturity level (Copeland and Taylor, 1995, 2004; Mani and Wheeler, 1998). We expect $\beta_2 > 0$, $\beta_3 < 0$ if relationship between economic growth and $CO_2$ emissions is inverted U-shaped, i.e. EKC hypothesis otherwise $\beta_2 < 0$, $\beta_3 > 0$ if the relationship is U-shaped between economic growth and $CO_2$ emissions. We use energy intensity rather than energy consumption for measuring energy consumption. This measure of energy use is superior to the conventional energy consumption because it controls the income effect of the country, i.e. energy consumption/total GDP. Energy intensity shows energy efficiency level of the country as well as technological advancement in the country (Shahbaz et al., 2015b). We expect $\beta_4 > 0$ otherwise $\beta_4 < 0$.

The impact of globalization can be viewed through a channel of scale, technique and composition effects. Holding other things constant, increases in pollution would boost gross national output vis-à-vis foreign trade and investment and vice versa, through scale effect. This implies that under the ceteris paribus condition, the level of pollution would alter in an economy because of structural changes in the economy. This further follows that an inclination toward pollution intensive production would leads to more pollution, which is known as composition effect. When the structure and scale of an economy remain intact, new production methods or new technology for foreign trade and investment would change the level of pollution emitted per unit of output. This is known as technique effect of globalization. The decomposition effect reveals that investment liberalization and foreign trades act like double-edged sword simultaneously which could be a blessing or a curse for a country. Since both of these factors can operate in a different direction and interact concurrently, the net environmental effect can therefore only be examined empirically. Recently, Shahbaz et al. (2015c) examined the globalization-emissions nexus in Indian context and found that globalization (economic globalization, cultural globalization, political globalization) deteriorates environmental quality. We expect $\beta_5 > 0$ if scale effect dominates technique effect and if technique effect dominates scale effect then $\beta_5 < 0$ (Duy, 2010).

The data span of the present study is 1971–2012[5].[6] We have used World Development Indicators (CD-ROM, 2014) as our data source and collected data on energy consumption (kg of oil equivalent), $CO_2$ emissions (metric tons) and real GDP (USD) from there. We have used total population collected from the same source to convert all the variables into per capita units following Lean and Smyth (2010). We have borrowed globalization index by Dreher (2006) who generated globalization index by three sub-indices, i.e. economic globalization, social globalization and political globalization. Economic globalization involves two sub-indexes including (i) actual economic flows (trade, foreign direct investment and portfolio investment) and (ii) restrictions to trade and capital (which include restrictions on trade and capital using hidden import barriers, mean tariff rates, taxes on international trade as a share of current revenue and an index of capital controls). For political globalization, Dreher (2006) used number of embassies in country, membership in international organizations, participation in UN secretary council membership and international treaties to generate the index (Fig. 1).

## 4. Methodological framework

Existing applied economics literature provides various cointegration approaches to examine the presence of cointegration between variables. For example, Engle and Granger (1987) developed the residual based univariate tests which have their own limitations due to their low explanatory power. Similarly, Johansen and Juselius (1990) introduced a maximum likelihood test and later on, Stock and Watson (1993) developed the DOLS test to examine the cointegration between variables. These cointegration tests require that all variables must be stationary at unique order of integration, which means that if any variable is found to be stationary then these cointegration tests become invalid. This paper aims to examine the presence of environmental Kuznets (EKC) curve by accommodating globalization as an additional determinant of $CO_2$ emissions in the case of African countries. The empirical investigation of the EKC hypothesis may help policy makers in designing an appropriate environmental policy for sustainable economic development. To avoid the incorrect inferences, we must need an appropriate cointegration approach to examine the long-run relationship between the variables. In doing so, Narayan and Smyth (2005) argued that the bounds testing approach developed by Pesaran et al. (2001) is an appropriate choice for investigating the cointegration relationship between the variables. This approach presents consistent and efficient empirical results if the sample size is relatively small. The bounds testing approach is applicable if variables are integrated at $I(0)$ or $I(1)$ or $I(0)/I(1)$, i.e. none of the variables should be stationary at second difference. The critical values are easily available for small sample size for comparison with the calculated $F$-statistics. In doing so, we employ the unrestricted error correction method (UECM) to examine the presence of cointegration between the variables. The UECM version of the bounds testing equation is modeled as

[4] Mazzanti and Musolesi (2013) discussed the issue of heterogeneity while investing the environmental Kuznets curve in advanced countries. They provided the different threshold points in various sampled regions.

[5] Algeria, Angola, Cameroon, Congo, Côte d'Ivoire, Egypt, Gabon, Ghana, Kenya, Libya, Morocco, Nigeria, South Africa, Sudan, Tanzania, Togo, Tunisia, Zambia and Zimbabwe.

[6] The availability of data on $CO_2$ emissions has restricted to sampled countries.

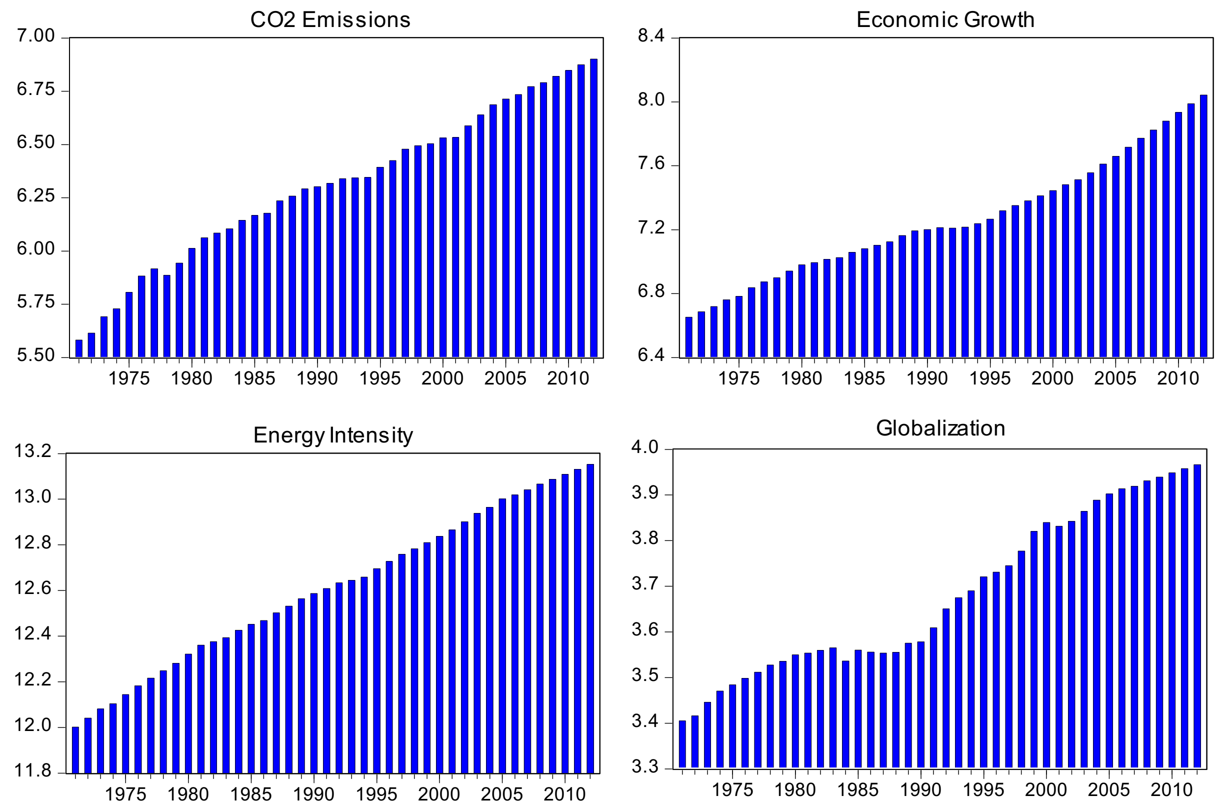


**Fig. 1.** Trends in $CO_2$ emissions, energy intensity, growth and globalization in Africa. (This figure shows natural-log of emissions, energy intensity, growth and globalization.)

following:

$$\Delta \ln C_t = \alpha_1 + \alpha_2 T + \alpha_3 \ln C_{t-1} + \alpha_4 \ln Y_{t-1} + \alpha_5 \ln Y^2_{t-1} + \alpha_6 \ln EI_{t-1} + \alpha_7 \ln G_{t-1} + \sum_{i=1}^{a} \beta_1 \Delta \ln C_{t-i} + \sum_{i=0}^{b} \beta_2 \Delta \ln Y_{t-i} + \sum_{i=0}^{c} \beta_3 \Delta \ln Y^2_{t-1} + \sum_{i=0}^{d} \beta_4 \Delta \ln EI_{t-i} \sum_{i=0}^{e} \beta_5 \Delta \ln G_{t-1} + \mu_i \quad (3)$$

where $\Delta$ and $\mu_i$ are difference operator and standard error respectively. The $\alpha_i$, $i = 3, 4, \ldots, 7$ covers long-run estimates while short-run coefficients is shown by $\beta_i$, $i = 1, 2, \ldots, 5$. The selection of optimal lag order selection is based on Akaike information criterion (AIC). The results of ARDL F-test vary with various lag order selection. We follow AIC for optimal and appropriate lag length selection due to its superior explanatory properties. The null hypothesis of no cointegration is $H_n : \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = \alpha_7 = 0$ while alternate hypothesis for presence of cointegration is $H_a : \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq \alpha_7 \neq 0$. In absence of cointegration, we are unable to accept alternate hypothesis. Pesaran et al. (2001) provided critical bounds (upper and lower) to compare with calculated ARDL *F*-statistic. Narayan (2005) argued that critical bounds generated by Pesaran et al. (2001) are not suitable for small sample data set as in our case, i.e. 42 observations. The critical bounds provided by Narayan (2005) ranges from 30 to 80 observation at all levels of significance using different lag lengths. We will accept null hypothesis (which implies no cointegration) if computed ARDL *F*-statistic is lower than critical bound which confirms. The presence of cointegration is valid if upper critical bound is less than calculated ARDL *F*-statistic.

After determining the long-run relationship between the variables, we move to examine short-run relationship by using unrestricted error correction model as following:

$$\Delta \ln C_t = \alpha_1 + \sum_{i=1}^{a} a_1 \Delta \ln C_{t-i} + \sum_{i=0}^{b} a_2 \Delta \ln Y_{t-i} + \sum_{i=0}^{c} a_3 \Delta \ln Y^2_{t-1} + \sum_{i=0}^{d} a_4 \Delta \ln EI_{t-i} + \sum_{i=0}^{e} a_5 \Delta \ln G_{t-1} + \delta EC_{t-1} + \mu_i \quad (4)$$

where speed of adjustment is indicated by $\delta$, i.e. estimate of $EC_{t-1}$. The statistical significance of $\delta$ with negative sign confirms cointegration between the variables. This estimate, i.e. $\delta$ determines speed of the short-run adjustment to reach equilibrium path in long-run. We also apply diagnostic tests such as normality of error term, serial correlation, auto-regressive conditional heteroskedasticity (ARCH), white heteroskedisticity and functional form of empirical model. The stability of short-run as well as long-run is determined by applying CUSUM and CUSUMsq tests suggested by Pesaran et al. (2001).

## 5. Results and their discussion

To apply any standard cointegration approach for examining the long-run relationship between the variable, testing unit root properties is necessary. In doing so, we have applied Augmented Dickey–Fuller (ADF) by Said and Dickey (1984) and Phillips–Perron

**Table 1**
Unit root analysis.

| Countries | Variables | ADF unit root test | | PP unit root test | |
|---|---|---|---|---|---|
| | | *T*-statistic | Prob. value | *T*-statistic | Prob. value |
| Africa | $\ln C_t$ | −2.9327 (3) | 0.1631 | −2.8910 (3) | 0.1768 |
| | $\Delta \ln C_t$ | −4.5687 (1)* | 0.0044 | −5.2544 (3)* | 0.0007 |
| | $\ln EI_t$ | −2.6147 (1) | 0.2764 | −2.7354 (3) | 0.2292 |
| | $\Delta \ln EI_t$ | −4.2135 (1)** | 0.0108 | −4.7040 (3)* | 0.0030 |
| | $\ln Y_t$ | −0.4404 (1) | 0.9820 | −0.1456 (3) | 0.9220 |
| | $\Delta \ln Y_t$ | −4.3231 (1)** | 0.0105 | −4.0460 (6)** | 0.0188 |
| | $\ln Y_t^2$ | 0.0490 (2) | 0.9939 | 0.4949 (3) | 0.9988 |
| | $\Delta \ln Y_t^2$ | 3.6790 (1)** | 0.0201 | −5.3552 (3)* | 0.0005 |
| | $\ln G_t$ | −1.3430 (1) | 0.8605 | −1.3145 (3) | 0.8686 |
| | $\Delta \ln G_t$ | −4.5691 (1)* | 0.0043 | −4.5833 (3)* | 0.0041 |
| Algeria | $\ln C_t$ | −2.4266 (1) | 0.3605 | −2.4266 (3) | 0.3605 |
| | $\Delta \ln C_t$ | −4.2758 (0)* | 0.0090 | −4.2758 (3)* | 0.0090 |
| | $\ln EI_t$ | −2.0881 (1) | 0.5341 | −2.0513 (3) | 0.5538 |
| | $\Delta \ln EI_t$ | −4.8640 (1)* | 0.0021 | −5.2042 (3)* | 0.0008 |
| | $\ln Y_t$ | −1.8051(1) | 0.6813 | −1.8051 (3) | 0.6813 |
| | $\Delta \ln Y_t$ | −7.6685 (0)* | 0.0000 | −7.6885 (6)* | 0.0000 |
| | $\ln Y_t^2$ | −2.2118 (2) | 0.4686 | −1.4769 (3) | 0.8204 |
| | $\Delta \ln Y_t^2$ | −6.7095 (1)* | 0.0000 | −6.7095 (3)* | 0.0000 |
| | $\ln G_t$ | −1.6282 (1) | 0.7616 | −1.6282 (3) | 0.7616 |
| | $\Delta \ln G_t$ | −4.2624 (1)* | 0.0095 | −4.2624 (3)* | 0.0095 |
| Angola | $\ln C_t$ | −2.8603 (1) | 0.1864 | −2.8603 (3) | 0.1864 |
| | $\Delta \ln C_t$ | −4.8840 (1)* | 0.0020 | −9.0458 (3)* | 0.0000 |
| | $\ln EI_t$ | −1.9204 (2) | 0.6227 | −1.4158 (3) | 0.8396 |
| | $\Delta \ln EI_t$ | −4.3214 (3)* | 0.0087 | −6.4749 (6)* | 0.0000 |
| | $\ln Y_t$ | −0.1994 (1) | 0.9906 | −0.1994 (3) | 0.9906 |
| | $\Delta \ln Y_t$ | −3.4934 (1)*** | 0.0557 | −3.9271 (3)** | 0.0210 |
| | $\ln Y_t^2$ | 0.3607 (1) | 0.9983 | 0.3607 (3) | 0.9983 |
| | $\Delta \ln Y_t^2$ | −3.5184 (0)*** | 0.0524 | −3.5184 (3)** | 0.0524 |
| | $\ln G_t$ | −1.4553 (1) | 0.8264 | −1.4553 (3) | 0.8264 |
| | $\Delta \ln G_t$ | −4.8418 (0)* | 0.0021 | −4.8418 (3)* | 0.0021 |
| Cameroon | $\ln C_t$ | −2.1197 (2) | 0.5183 | −2.0275 (3) | 0.5675 |
| | $\Delta \ln C_t$ | −3.7672 (1)** | 0.0307 | −7.3685 (3)* | 0.0000 |
| | $\ln EI_t$ | −0.4164 (1) | 0.9831 | 0.6913 (3) | 0.9994 |
| | $\Delta \ln EI_t$ | −4.9047 (1)* | 0.0019 | −5.6633 (3)* | 0.0002 |
| | $\ln Y_t$ | −2.1656 (1) | 0.4935 | −1.8492 (3) | 0.6602 |
| | $\Delta \ln Y_t$ | −3.4116 (1)*** | 0.0661 | −4.0441 (3)** | 0.0159 |
| | $\ln Y_t^2$ | −2.0586 (1) | 0.5504 | −1.7856 (3) | 0.6914 |
| | $\Delta \ln Y_t^2$ | −3.7353 (1)** | 0.0325 | −3.7326 (3)** | 0.0327 |
| | $\ln G_t$ | −1.9316 (1) | 0.6137 | −2.3895 (3) | 0.3787 |
| | $\Delta \ln G_t$ | −4.4376 (2)** | 0.0064 | −9.1466 (3)* | 0.0000 |
| Congo | $\ln C_t$ | −1.5128 (3) | 0.8053 | −1.3887 (3) | 0.8478 |
| | $\Delta \ln C_t$ | −3.4029 (1)*** | 0.0673 | −5.6596 (3)* | 0.0002 |
| | $\ln EI_t$ | −0.7880 (1) | 0.9585 | −1.1045 (3) | 0.9147 |
| | $\Delta \ln EI_t$ | −3.7137 (1)** | 0.0345 | −6.3908 (3)* | 0.0000 |
| | $\ln Y_t$ | −2.2349 (1) | 0.4569 | −1.9156 (3) | 0.6263 |
| | $\Delta \ln Y_t$ | −3.4480 (0)*** | 0.0607 | −3.4513 (3)*** | 0.0604 |
| | $\ln Y_t^2$ | −2.0920 (1) | 0.5326 | −1.8707 (3) | 0.6493 |
| | $\Delta \ln Y_t^2$ | −3.9481 (4)** | 0.0234 | 3.9381 (3)** | 0.0204 |
| | $\ln G_t$ | −2.5530 (1) | 0.2323 | −3.0618 (3) | 0.1302 |
| | $\Delta \ln G_t$ | −5.2677 (1)* | 0.0007 | −8.4741 (6)* | 0.0000 |
| Côte d'Ivoire | $\ln C_t$ | −1.6541 (1) | 0.7501 | −1.4985 (3) | 0.8121 |
| | $\Delta \ln C_t$ | −3.6083 (1)** | 0.0435 | −5.8143 (3)* | 0.0002 |
| | $\ln EI_t$ | −1.5052 (1) | 0.8092 | −2.3084 (3) | 0.4192 |
| | $\Delta \ln EI_t$ | −4.5840 (2)* | 0.0043 | 9.7012 (3)* | 0.0000 |
| | $\ln Y_t$ | −3.1571 (5) | 0.1110 | −2.5987 (3) | 0.2830 |
| | $\Delta \ln Y_t$ | −3.4743 (4)*** | 0.0595 | −3.8692 (3)** | 0.0240 |
| | $\ln Y_t^2$ | −2.9692 (5) | 0.1560 | −2.5009 (3) | 0.3218 |
| | $\Delta \ln Y_t^2$ | −3.3467 (5)*** | 0.0775 | −3.8428 (3)** | 0.0249 |
| | $\ln G_t$ | −1.2969 (1) | 0.8727 | −1.2237 (3) | 0.8909 |
| | $\Delta \ln G_t$ | −4.4934 (0)* | 0.0052 | −4.4934 (3)* | 0.0052 |
| Egypt | $\ln C_t$ | −1.3803 (1) | 0.8498 | −1.5586 (3) | 0.7900 |
| | $\Delta \ln C_t$ | −4.0428 (1)** | 0.0162 | −5.8629 (3)* | 0.0001 |
| | $\ln EI_t$ | −1.3067 (1) | 0.8702 | −1.6135 (3) | 0.7682 |
| | $\Delta \ln EI_t$ | −4.2085 (1)** | 0.0109 | −6.3613 (3) | 0.0000 |
| | $\ln Y_t$ | −2.3090 (1) | 0.4186 | −1.2168 (3) | 0.8922 |
| | $\Delta \ln Y_t$ | −3.9593 (1)** | 0.0197 | −3.4945 (3)*** | 0.0551 |
| | $\ln Y_t^2$ | −2.4183 (1) | 0.3645 | −1.7441 (3) | 0.7110 |
| | $\Delta \ln Y_t^2$ | −3.9452 (2)** | 0.0207 | −3.5153 (3)*** | 0.0528 |
| | $\ln G_t$ | −2.0473 (1) | 0.5565 | −2.5253 (3) | 0.3060 |
| | $\Delta \ln G_t$ | −3.9871 (1)** | 0.0185 | −6.7717 (3)* | 0.0000 |

Table 1 (*Continued*)

| Countries | Variables | ADF unit root test | | PP unit root test | |
|---|---|---|---|---|---|
| | | *T*-statistic | Prob. value | *T*-statistic | Prob. value |
| Gabon | $\ln C_t$ | −2.4852 (1) | 0.3330 | −2.1450 (3) | 0.5048 |
| | $\Delta\ln C_t$ | −3.7650 (1) ** | 0.0308 | −5.6016 (3) * | 0.0003 |
| | $\ln EI_t$ | −2.6729 (1) | 0.2530 | −2.1832 (3) | 0.4845 |
| | $\Delta\ln EI_t$ | −4.0734 (1) ** | 0.0151 | −5.3583 (3) * | 0.0005 |
| | $\ln Y_t$ | −2.7715 (4) | 0.2178 | −2.4943 (3) | 0.1545 |
| | $\Delta\ln Y_t$ | −3.7039 (1) ** | 0.0353 | −4.3176 (3) * | 0.0081 |
| | $\ln Y_t^2$ | −1.8752 (4) | 0.6430 | −3.1953 (3) | 0.1010 |
| | $\Delta\ln Y_t^2$ | −4.0907 (3) ** | 0.0150 | −4.5132 (3) * | 0.0050 |
| | $\ln G_t$ | −2.3608 (1) | 0.3926 | −2.8643 (3) | 0.1851 |
| | $\Delta\ln G_t$ | −4.7408 (1) * | 0.0029 | −7.9921 (3) * | 0.0000 |
| Ghana | $\ln C_t$ | −1.1356 (2) | 0.9081 | −1.1356 (3) | 0.9081 |
| | $\Delta\ln C_t$ | −7.1377 (1) * | 0.0000 | −7.1377 (3) * | 0.0000 |
| | $\ln EI_t$ | −2.7112 (1) | 0.2421 | −2.7012 (3) | 0.2421 |
| | $\Delta\ln EI_t$ | −5.2143 (1) * | 0.0008 | −5.2143 (3) * | 0.0008 |
| | $\ln Y_t$ | −1.5134 (1) | 0.8061 | −1.5134 (3) | 0.8062 |
| | $\Delta\ln Y_t$ | −4.4232 (2) * | 0.0066 | −4.7609 (3) * | 0.0027 |
| | $\ln Y_t^2$ | −1.0796 (1) | 0.9187 | −1.0877 (3) | 0.9176 |
| | $\Delta\ln Y_t^2$ | −4.8612 (1) * | 0.0021 | −6.7601 (3) * | 0.0000 |
| | $\ln G_t$ | −1.6644 (2) | 0.7654 | −1.6135 (3) | 0.7682 |
| | $\Delta\ln G_t$ | −4.7688 (2) * | 0.0028 | −5.4308 (3) * | 0.0004 |
| Kenya | $\ln C_t$ | −3.0532(3) | 0.1335 | −2.5362 (3) | 0.3100 |
| | $\Delta\ln C_t$ | −4.4333 (2) * | 0.0064 | −6.0372 (3) * | 0.0001 |
| | $\ln EI_t$ | −1.8177 (1) | 0.6752 | −08538 (3) | 0.9507 |
| | $\Delta\ln EI_t$ | −3.9409 (1) * | 0.0206 | −7.0826 (3) * | 0.0000 |
| | $\ln Y_t$ | −1.7345 (1) | 0.7149 | −3.1895 (3) | 0.1051 |
| | $\Delta\ln Y_t$ | −4.0209 (2) ** | 0.0174 | −5.0742 (3) * | 0.0011 |
| | $\ln Y_t^2$ | −2.1845 (1) | 0.4843 | −2.7054 (3) | 0.2404 |
| | $\Delta\ln Y_t^2$ | −2.7478 (2) ** | 0.0324 | −4.4271 (3) * | 0.0062 |
| | $\ln G_t$ | −1.6583 (1) | 0.7537 | −1.8747 (3) | 0.6473 |
| | $\Delta\ln G_t$ | −3.5326 (2) ** | 0.0516 | −5.4178 (3) * | 0.0005 |
| Libya | $\ln C_t$ | −2.8208 (1) | 0.1995 | −2.9246 (3) | 0. 2122 |
| | $\Delta\ln C_t$ | −4.2529 (1) * | 0.0098 | −7.9583 (3) * | 0.0000 |
| | $\ln EI_t$ | −2.3025 (2) | 0.4217 | −2.4942 (3) | 0.2918 |
| | $\Delta\ln EI_t$ | −5.8240 (0) * | 0.0001 | −5.8400 (3) * | 0.0001 |
| | $\ln Y_t$ | −1.6617 (1) | 0.7474 | −1.7482 (3) | 0.7091 |
| | $\Delta\ln Y_t$ | −4.2142 (1) ** | 0.0107 | −5.5465 (3) * | 0.0003 |
| | $\ln Y_t^2$ | −1.5648 (1) | 0.7848 | −1.6288 (3) | 0.7619 |
| | $\Delta\ln Y_t^2$ | −4.1893 (1) ** | 0.0114 | −5.4515 (3) * | 0.0004 |
| | $\ln G_t$ | −2.6669 (2) | 0.2555 | −2.5627 (3) | 0.2984 |
| | $\Delta\ln G_t$ | −4.3440 (2) * | 0.0080 | −4.4263 (3) * | 0.0062 |
| Morocco | $\ln C_t$ | −2.9849 (4) | 0.1537 | −1.5058 (3) | 0.4356 |
| | $\Delta\ln C_t$ | −4.5298 (3) * | 0.0049 | −5.2848 (3) * | 0.0006 |
| | $\ln EI_t$ | −2.5645 (1) | 0.2976 | −2.7490 (3) | 0.2242 |
| | $\Delta\ln EI_t$ | −4.0593 (1) ** | 0.0156 | −6.0006 (3) * | 0.0001 |
| | $\ln Y_t$ | −2.2395 (1) | 0.4545 | −2.9550 (3) | 0.1581 |
| | $\Delta\ln Y_t$ | −4.8585 (1) * | 0.0021 | −9.7534 (3) * | 0.0000 |
| | $\ln Y_t^2$ | −1.5551 (1) | 0.7922 | −3.0886 (3) | 0.1238 |
| | $\Delta\ln Y_t^2$ | −4.9767 (1) * | 0.0015 | −10.0943 (3) * | 0.0000 |
| | $\ln G_t$ | −2.7058 (1) | 0.2404 | −1.6705 (3) | 0.7442 |
| | $\Delta\ln G_t$ | −3.7748 (2) ** | 0.0305 | −4.0220 (3) ** | 0.0168 |
| Nigeria | $\ln C_t$ | −3.0308 (1) | 0.1379 | −3.1100 (3) | 0.3081 |
| | $\Delta\ln C_t$ | −4.2826 (2)* | 0.0055 | −6.2418 (3) * | 0.0000 |
| | $\ln EI_t$ | −2.3428 (1) | 0.4016 | −2.1305 (3) | 0.5125 |
| | $\Delta\ln EI_t$ | −4.9215 (2)* | 0.0018 | −6.5315 (3) * | 0.0000 |
| | $\ln Y_t$ | −0.7708 (1) | 0.9591 | −1.0306 (6) | 0.9271 |
| | $\Delta\ln Y_t$ | −4.1302 (2)** | 0.0132 | −5.7965 (3) * | 0.0002 |
| | $\ln Y_t^2$ | −0.4707 (1) | 0.9805 | −0.6784 (3) | 0.9674 |
| | $\Delta\ln Y_t^2$ | −4.0720 (2)** | 0.0151 | −5.6917 (6) * | 0.0022 |
| | $\ln G_t$ | −2.6422 (1) | 0.2652 | −2.3541 (3) | 0.3961 |
| | $\Delta\ln G_t$ | −3.6492 (3)** | 0.0407 | −5.1023 (3) * | 0.0011 |
| South Africa | $\ln C_t$ | −2.6883 (5) | 0.2476 | −2.9631 (3) | 0.1558 |
| | $\Delta\ln C_t$ | −5.4273 (2) | 0.0060 | −6.2935 (3) * | 0.0000 |
| | $\ln EI_t$ | −2.8256 (1) | 0.1987 | −2.4312 (3) | 0.2212 |
| | $\Delta\ln EI_t$ | −4.9600 (2)* | 0.0016 | −4.8940 (3) * | 0.0018 |
| | $\ln Y_t$ | −1.4490 (1) | 0.8114 | −0.9466 (3) | 0.9393 |
| | $\Delta\ln Y_t$ | −3.8540 (3)** | 0.0252 | −3.9202 (3) ** | 0.0213 |
| | $\ln Y_t^2$ | −1.1752 (1) | 0.9007 | −0.5813 (3) | 0.9743 |
| | $\Delta\ln Y_t^2$ | 3.7861 (2)** | 0.0294 | −3.8649 (3) ** | 0.0242 |
| | $\ln G_t$ | −1.5318 (1) | 0.7995 | −1.4590 (3) | 0.8257 |
| | $\Delta\ln G_t$ | −4.3975 (2)* | 0.0067 | −4.4345 (3) * | 0.0061 |

Table 1 (*Continued*)

| Countries | Variables | ADF unit root test | | PP unit root test | |
|---|---|---|---|---|---|
| | | *T*-statistic | Prob. value | *T*-statistic | Prob. value |
| Sudan | $\ln C_t$ | −1.1936 (3) | 0.8968 | −1.9863 (3) | 0.5893 |
| | $\Delta\ln C_t$ | −6.1792 (1)* | 0.0001 | −12.1764 (3)* | 0.0000 |
| | $\ln EI_t$ | −2.2026 (2) | 0.4739 | −3.0607 (6) | 0.1287 |
| | $\Delta\ln EI_t$ | −5.8712 (1)* | 0.0001 | −15.3984 (3)* | 0.0000 |
| | $\ln Y_t$ | −1.6191 (1) | 0.7612 | −0.7358 (3) | 0.9626 |
| | $\Delta\ln Y_t$ | −4.3982 (3)* | 0.0068 | −4.2209 (3)** | 0.0104 |
| | $\ln Y_t^2$ | −0.4880 (2) | 0.9796 | 0.7577 (3) | 0.9995 |
| | $\Delta\ln Y_t^2$ | −4.1762 (2)** | 0.0118 | −4.1829 (3)** | 0.0114 |
| | $\ln G_t$ | −3.0128 (1) | 0.1428 | −2.7195 (3) | 0.2351 |
| | $\Delta\ln G_t$ | −6.0555 (2)* | 0.0001 | −7.4494 (3)* | 0.0000 |
| Tanzania | $\ln C_t$ | −0.6868(1) | 0.9697 | −0.6868 (3) | 0.9667 |
| | $\Delta\ln C_t$ | −3.9001 (1)** | 0.0241 | −3.9006 (3)** | 0.0241 |
| | $\ln EI_t$ | −0.8197 (1) | 0.9545 | −0.8228 (3) | 0.9541 |
| | $\Delta\ln EI_t$ | −6.0706 (2)* | 0.0001 | −6.0808 (3)* | 0.0001 |
| | $\ln Y_t$ | −0.5327 (1) | 0.9771 | 0.4195 (3) | 0.9986 |
| | $\Delta\ln Y_t$ | −3.4995 (2)** | 0.0546 | −3.4752 (3)*** | 0.0574 |
| | $\ln Y_t^2$ | 0.4090 (3) | 0.9985 | 1.7121 (3) | 1.0000 |
| | $\Delta\ln Y_t^2$ | 3.7970 (2)** | 0.0342 | −3.5241 (3)** | 0.0500 |
| | $\ln G_t$ | −1.1932 (1) | 0.8969 | −1.1723 (3) | 0.9016 |
| | $\Delta\ln G_t$ | −4.9572 (1)* | 0.0016 | −4.9220 (3)* | 0.0014 |
| Togo | $\ln C_t$ | −2.6158 (1) | 0.2761 | −2.8791 (3) | 0.1311 |
| | $\Delta\ln C_t$ | −3.8735 (3)** | 0.0248 | −8.4399 (3)* | 0.0000 |
| | $\ln EI_t$ | −2.7933 (1) | 0.2090 | −2.3797 (3) | 0.3011 |
| | $\Delta\ln EI_t$ | −4.9396 (2)* | 0.0018 | −7.3143 (3)* | 0.0000 |
| | $\ln Y_t$ | −2.9624 (1) | 0.1563 | −3.1729 (3) | 0.1055 |
| | $\Delta\ln Y_t$ | −4.1818(2)** | 0.0116 | −6.2239 (3)* | 0.0000 |
| | $\ln Y_t^2$ | −2.6117 (3) | 0.2753 | −2.7677 (3) | 0.2175 |
| | $\Delta\ln Y_t^2$ | 4.0549 (2)** | 0.0158 | −6.0383 (3)* | 0.0001 |
| | $\ln G_t$ | −2.0410 (1) | 0.5593 | −2.3817 (3) | 0.3825 |
| | $\Delta\ln G_t$ | −4.1183 (2)** | 0.0138 | −4.5348 (3)* | 0.0047 |
| Tunisia | $\ln C_t$ | −1.2527 (1) | 0.8840 | −0.9787 (3) | 0.9349 |
| | $\Delta\ln C_t$ | −4.8289 (2)* | 0.0023 | −8.0640 (3)* | 0.0000 |
| | $\ln EI_t$ | −1.2757 (1) | 0.8785 | −0.2488 (3) | 0.9893 |
| | $\Delta\ln EI_t$ | −5.3700 (1) | 0.0006 | −9.9963 (3)* | 0.0000 |
| | $\ln Y_t$ | −1.8948 (2) | 0.6364 | −2.2021 (3) | 0.3451 |
| | $\Delta\ln Y_t$ | −4.1815 (2)** | 0.0116 | −9.4420 (3)* | 0.0000 |
| | $\ln Y_t^2$ | −0.1571 (1) | 0.9917 | −1.2769 (3) | 0.8782 |
| | $\Delta\ln Y_t^2$ | −4.2324 (1)* | 0.0103 | −8.5988 (3)* | 0.0000 |
| | $\ln G_t$ | −1.6885 (2) | 0.7357 | −1.8387 (3) | 0.6654 |
| | $\Delta\ln G_t$ | −4.2527 (2)* | 0.0098 | −5.8815 (6)* | 0.0001 |
| Zambia | $\ln C_t$ | −2.6619 (1) | 0.2578 | −2.8453 (3) | 0.1811 |
| | $\Delta\ln C_t$ | −5.3871 (1)* | 0.0005 | −6.9825 (3)* | 0.0000 |
| | $\ln EI_t$ | −3.1067 (2) | 0.1205 | −2.2924 (3) | 0.3241 |
| | $\Delta\ln EI_t$ | 3.6011 (3)** | 0.0447 | −5.4260 (3)* | 0.0004 |
| | $\ln Y_t$ | 0.7233 (2) | 0.9995 | 0.2962 (3) | 0.9979 |
| | $\Delta\ln Y_t$ | −4.0769 (1)** | 0.0165 | −7.0216 (3)* | 0.0000 |
| | $\ln Y_t^2$ | 1.2079 (1) | 0.9998 | 0.9913 (3) | 0.9998 |
| | $\Delta\ln Y_t^2$ | −3.7827 (1)** | 0.0296 | −6.5978 (3)* | 0.0000 |
| | $\ln G_t$ | −2.0310 (1) | 0.5652 | −2.9668 (3) | 0.1548 |
| | $\Delta\ln G_t$ | −5.8207 (1)* | 0.0002 | −9.3597 (3)* | 0.0000 |
| Zimbabwe | $\ln C_t$ | 0.2379 (1) | 0.9896 | −0.4436 (3) | 0.9819 |
| | $\Delta\ln C_t$ | −5.6744 (1)* | 0.0002 | −5.6859 (3)* | 0.0002 |
| | $\ln EI_t$ | −2.1461 (2) | 0.4993 | −2.8342 (3) | 0.1948 |
| | $\Delta\ln EI_t$ | −4.8821 (2)* | 0.0027 | −5.7749 (3)* | 0.0002 |
| | $\ln Y_t$ | 0.9461 (1) | 0.9998 | 0.9461 (3) | 0.9998 |
| | $\Delta\ln Y_t$ | −4.0701 (2)** | 0.0149 | −4.0701 (3)** | 0.0149 |
| | $\ln Y_t^2$ | 0.9576 (1) | 0.9998 | 0.6139 (3) | 0.9993 |
| | $\Delta\ln Y_t^2$ | −4.0888 (1)** | 0.0143 | −4.0885 (3)** | 0.0143 |
| | $\ln G_t$ | −1.7617 (2) | 0.7027 | −.7616 (3) | 0.7020 |
| | $\Delta\ln G_t$ | −4.3256 (2)* | 0.0080 | −4.1612 (3)** | 0.0120 |

*Note*:
* Significance at 1% level.
** Significance at 5% level.
() are lags and bandwidth of ADF and PP unit root tests.

(PP) by Phillips and Perron (1988) to test whether the variables contain unit root problem or not. Table 1 reports the results of both tests and we find that $CO_2$ emissions, energy intensity, economic growth and globalization show unit root problem at level with intercept plus time trend. All the variables are found to be stationary at first difference at 1%, 5% and 10% significance levels respectively. This shows that $CO_2$ emissions, energy intensity, economic growth and globalization are integrated at $I(1)$ and therefore we proceed to the cointegration test with the use of the bounds testing approach. The bounds test is sensitive to lag length selection and we have

**Table 2**
ARDL bounds testing analysis.

| Bounds testing to cointegration | | | | Diagnostic tests | | |
|---|---|---|---|---|---|---|
| Country | Estimated models | Optimal lag length | *F*-statistics | $\chi^2_{NORMAL}$ | $\chi^2_{ARCH}$ | $\chi^2_{RESET}$ |
| Africa | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 2 | 7.381** | 0.3916 | [1]: 0.1573 | [1]: 0.2453 |
| Algeria | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 1, 2, 2, 2 | 10.579* | 1.1513 | [1]: 0.7693 | [2]: 2.0525 |
| Angola | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 2 | 6.128*** | 1.3810 | [4]: 1.9194 | [2]: 1.1602 |
| Cameroon | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 2 | 5.825*** | 3.6312 | [2]: 1.2625 | [1]: 1.5008 |
| Congo Republic | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 2 | 8.426** | 3.6801 | [1]: 1.6994 | [2]: 0.3541 |
| Côte d'Ivoire | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 1, 2, 2, 1 | 1.695 | 2.4637 | [1]: 0.4330 | [1]: 0.0634 |
| Egypt | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 1 | 2.722 | 0.2281 | [1]: 1.2978 | [1]: 0.0491 |
| Gabon | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 2 | 1.210 | 1.4820 | [1]: 0.0016 | [2]: 0.6178 |
| Ghana | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 1, 1, 1 | 5.804*** | 5.3840 | [1]: 0.2198 | [1]: 0.0982 |
| Kenya | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 1 | 7.066** | 0.0817 | [2]: 1.9100 | [1]: 0.0023 |
| Libya | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 1, 2, 2, 1 | 5.819*** | 1.8245 | [1]: 0.2350 | [4]: 0.3314 |
| Morocco | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 2 | 14.679* | 0.3709 | [2]: 0.3085 | [2]: 0.8992 |
| Nigeria | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 1, 2, 2, 2 | 7.707** | 1.2446 | [2]: 3.1636 | [1]: 0.0072 |
| South Africa | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 1, 1, 2 | 6.835** | 0.1399 | [1]: 0.0033 | [4]: 2.4176 |
| Sudan | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 2 | 7.650** | 0.9360 | [1]: 0.0864 | [2]: 1.5446 |
| Tanzania | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 1, 2, 2, 1 | 7.759** | 1.4806 | [1]: 0.1803 | [2]: 4.3005 |
| Togo | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 1, 2, 2, 1 | 11.089* | 0.3233 | [1]: 0.2551 | [1]: 0.5958 |
| Tunisia | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 2 | 8.182* | 0.6887 | [1]: 0.1949 | [2]: 0.0547 |
| Zambia | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 2, 2, 2, 2 | 8.003** | 0.3965 | [1]: 1.3936 | [1]: 2.9737 |
| Zimbabwe | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | 2, 1, 2, 2, 1 | 8.451** | 3.3762 | [1]: 0.0630 | [2]: 0.1124 |

| Significant level | Critical values | |
|---|---|---|
| | Lower bounds *I*(0) | Upper bounds *I*(1) |
| 1% level | 7.527 | 8.503 |
| 5% level | 5.687 | 6.437 |
| 10% level | 4.447 | 5.420 |

*Note*:
* Significance at 1% level.
** Significance at 5% level.
*** Significance at 10% level.

used the Akaike information criterion (AIC) to select appropriate lag order of the variables. It is reported by Lütkepohl (2006) that the dynamic linkages between the series can be captured if appropriate lag length is chosen. The results are reported in Table 2. We use critical bounds from Narayan (2005) to make decision on whether cointegration exists or not.

The results reported in Table 2 reveal that the calculated *F*-statistic is greater than upper critical bound as we use energy intensity, economic growth and globalization as forcing variables. This shows that hypothesis of no cointegration is rejected in Africa (5%), Algeria (1%), Angola (10%), Cameroon (10%), Congo Republic (5%), Ghana (10%), Kenya (5%), Libya (10%), Morocco (1%), Nigeria (5%), South Africa (5%), Sudan (5%), Tanzania (5%), Togo (1%), Tunisia (1%), Zambia (5%) and Zimbabwe (5%). We accept the hypothesis of no cointegration for Côte d'Ivoire, Egypt and Gabon. We conclude that bounds testing analysis confirms the presence of cointegration in energy intensity, economic growth, globalization and $CO_2$ emissions (see Table 2) for Africa, Algeria, Angola, Cameroon, Congo Republic, Ghana, Kenya, Libya, Morocco, Nigeria, South Africa, Sudan, Tanzania, Togo, Tunisia, Zambia and Zimbabwe. The empirical results confirm the absence of autoregressive conditional heteroskedisticity and presence of normality of error term while validating the well-specification of the empirical model.

The ARDL bounds testing method is only robust in the presence of a single cointegration scenario, among other issues (Bayer and Hanck, 2013)[7]. To overcome some of the deficiencies of the previous cointegration methods including the ARDL method, Bayer and Hanck (2013) developed a new cointegration technique by combining all non-cointegrating tests to obtain uniform and reliable cointegration results. The application of the combined cointegration test provides robust and efficient results compared to individual t-test. Furthermore, combined cointegration approach is suitable once all the variables have unique order of integration. The results are reported in Table 3. The empirical results show that our calculated *F*-statistic is greater than tabulated *F*-statistic, i.e. EG-JOH and EG-JOH-BO-BDM at 1% level of significance. This reveals that null hypothesis 'no cointegration' is rejected in favor of alternate hypothesis. We may note that cointegration is valid in the case of Africa, Algeria, Angola, Cameroon, Congo Republic, Ghana, Kenya, Libya, Morocco, Nigeria, South Africa, Sudan, Tanzania, Togo, Tunisia, Zambia and Zimbabwe for the period of 1971–2012 and similar is not true for Côte d'Ivoire, Egypt and Gabon. This empirical evidence confirms the robustness of empirical results reported in Table 2 and unveils that cointegration results are consistent and efficient for the period of 1971–2012.

After examining the cointegration in the variables, we turn to disclose the impact of energy intensity, economic growth and globalization on $CO_2$ emissions. The empirical evidence is shown in Table 4. We note that energy intensity has positive and significant impact on $CO_2$ emissions. All else is same, a 1% increase in energy intensity boosts $CO_2$ emissions in Africa, Algeria, Angola, Cameroon, Congo Republic, Ghana, Libya, Morocco, Nigeria, South Africa, Sudan, Togo and Tunisia by 0.4643%, 0.8666%, 2.1802%, 0.6381%, 1.0549%, 0.2640%, 1.0598%, 0.5328%, 2.2710%, 1.1444%, 1.4419%, 0.9134% and 0.9847% respectively. Energy intensity is negatively linked with $CO_2$ emissions in Zambia and Zimbabwe.[8]

The results indicate that a 1% increases in real GDP raises $CO_2$ emissions by 5.0820% (Africa), 0.9410% (Algeria), 2.4823% (Cameroon), 0.8336% (Congo Republic), 2.4835% (Morocco),

[7] For theoretical background (see Bayer and Hanck, 2013).

[8] For Tanzanian economy, energy intensity lowers $CO_2$ emissions insignificantly.

**Table 3**
The results of Bayer and Hanck cointegration analysis.

| Empirical model | $F_{C_t}(C_t/EI_t, Y_t, Y_t^2, G_t)$ | | | |
|---|---|---|---|---|
| Country | EG-JOH | EG-JOH-BO-BDM | Lag Order | Cointegration |
| Africa | 33.6224* | 96.8537* | 2 | Exists |
| Algeria | 20.9417* | 37.2783* | 2 | Exists |
| Angola | 20.369* | 36.6140* | 2 | Exists |
| Cameroon | 56.1260* | 80.8398* | 2 | Exists |
| Congo Rep. | 16.7952* | 31.0433* | 2 | Exists |
| Côte d'Ivoire | 3.3545 | 5.7564 | 2 | No |
| Egypt | 6.0645 | 13.4811 | 2 | No |
| Gabon | 5.4559 | 5.7352 | 2 | No |
| Ghana | 18.1337* | 34.0993 | 2 | Exists |
| Kenya | 21.1086* | 36.8447* | 2 | Exists |
| Libya | 21.4771* | 40.5117* | 2 | Exists |
| Morocco | 18.7818* | 78.5158* | 2 | Exists |
| Nigeria | 20.3902* | 32.7181* | 2 | Exists |
| South Africa | 16.9776* | 32.5660* | 2 | Exists |
| Sudan | 16.7976* | 31.6056* | 2 | Exists |
| Tanzania | 61.5320* | 85.4163* | 2 | Exists |
| Togo | 17.6603* | 33.9257 | 2 | Exists |
| Tunisia | 16.1698* | 31.3132* | 2 | Exists |
| Zambia | 21.1469* | 31.1701* | 2 | Exists |
| Zimbabwe | 23.6494* | 38.2154* | 2 | Exists |

*Note*:
* Significance at 1% level.
Critical values at 1% level are 16.259 (EG-JOH) and 31.169 (EG-JOH-BO-BDM) respectively. Lag length is based on minimum value of AIC.

**Table 4**
Long run results.

| Dependent variable: $\ln C_t$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Countries | Constant | $\ln EI_t$ | $\ln Y_t$ | $\ln Y_t^2$ | $\ln G_t$ | $R^2$ | $\chi^2_{NORMAL}$ | $\chi^2_{SERIAL}$ | $\chi^2_{ARCH}$ | $\chi^2_{HETERO}$ | $\chi^2_{RESAY}$ |
| Africa | -19.7136* | 0.4643* | 5.0820* | −0.3037* | −0.1860*** | 0.9972 | 0.1653 | 3.8035 | 2.6576 | 3.0004 | 3.3710 |
| Algeria | −7.4521* | 0.8666* | 0.9410** | −0.0805*** | −0.0011 | 0.9983 | 3.3406 | 2.1983 | 0.1520 | 1.1598 | 12.0811 |
| Angola | −14.7476* | 2.1802* | −0.4378 | 0.0552 | −0.6242** | 0.9744 | 0.1430 | 0.2200 | 2.1023 | 2.5557 | 0.2680 |
| Cameroon | −8.4561* | 0.6381* | 2.4823* | −0.2811** | −0.3251*** | 0.9628 | 1.6242 | 0.8685 | 0.5696 | 4.6035 | 1.6351 |
| Congo Republic | 0.5785 | 1.0549** | 0.8336** | −0.6662* | −1.7887* | 0.5292 | 1.4492 | 1.9884 | 1.9076 | 1.1919 | 2.2214 |
| Ghana | −2.9442 | 0.2640*** | −0.9268 | 0.2317 | 0.6638** | 0.9386 | 0.2518 | 3.6543 | 0.1025 | 2.5104 | 2.9234 |
| Kenya | 1.1573 | 0.3097 | −1.1349** | 0.2784* | −0.4538** | 0.9529 | 0.8079 | 2.7421 | 0.6883 | 0.5161 | 3.3497 |
| Libya | −0.6444 | 1.0598* | −1.5564 | 0.1957 | −0.5754** | 0.9918 | 2.0000 | 0.3427 | 2.4337 | 1.5037 | 0.1242 |
| Morocco | −8.9403* | 0.5328* | 2.4835* | −0.2252* | 0.2156** | 0.9963 | 0.9178 | 1.4667 | 0.4043 | 1.3405 | 2.5124 |
| Nigeria | −19.0249** | 2.2710* | −1.5106 | 0.0181 | 0.9790 | 0.8816 | 2.1184 | 0.5861 | 1.9914 | 4.5793 | 1.1403 |
| South Africa | −7.4189*** | 1.1444* | 0.1956 | −0.0303 | 0.1254** | 0.9747 | 2.5269 | 2.2738 | 2.1144 | 1.2038 | 1.3266 |
| Sudan | −6.2800* | 1.4419* | −4.0209* | 0.5234* | 0.8548* | 0.9686 | 0.8351 | 0.6201 | 0.2055 | 1.2039 | 1.0562 |
| Tanzania | 2.8319 | −0.0675 | −3.3140* | 0.7665* | 0.5765* | 0.9599 | 2.4700 | 0.2805 | 2.3221 | 2.6806 | 1.8100 |
| Togo | −5.2144 | 0.9134* | −2.0633 | 0.6994 | −0.0408 | 0.8815 | 4.0000 | 1.2751 | 0.3694 | 3.2640 | 0.0943 |
| Tunisia | −6.8287* | 0.9847* | 1.1141* | −0.1379* | −0.2494*** | 0.9985 | 0.8419 | 3.1815 | 0.2096 | 0.6677 | 2.2054 |
| Zambia | 3.5940 | −1.3224** | 11.5145** | −2.3579** | −1.4120* | 0.8595 | 0.5168 | 2.1956 | 0.0006 | 0.8128 | 0.6840 |
| Zimbabwe | −4.4274 | −0.2421** | 3.7993 | −0.3810 | −0.2271 | 0.8112 | 1.4115 | 1.6303 | 3.2941 | 1.6526 | 3.2559 |

*Note*:
* Significance at 1% level.
** Significance at 5% level.
*** Significance at 10% level.

1.1141% (Tunisia) and 11.5145% (Zambia). In these countries, real GDP has a negative impact on $CO_2$ emissions which means that EKC hypothesis is valid in these nations. This finding supports the presence of the EKC hypothesis which reveals that $CO_2$ emissions increase in the initial stage of economic growth and decline after a threshold point. The results are similar with Latifa et al. (2014) for Algeria and Abdou and Atya (2013) for Egypt. The U-shaped relationship is also found between economic growth and $CO_2$ emissions in case of Kenya, Sudan and Tanzania but the relationship seems insignificant for Angola, Ghana, Libya, Nigeria, South Africa, Togo and Zimbabwe. The results are contrary for case of South Africa as Shahbaz et al. (2013a,b) reported the validation of EKC hypothesis. Similarly, Onafowora and Owoye (2015) noted that EKC hypothesis is valid for Nigeria. The linkage between globalization and $CO_2$ emissions is negative indicating that globalization improves environmental quality via lowering $CO_2$ emissions. A 1% increase in globalization lowers $CO_2$ emissions by 0.1860%, 0.6242%, 0.3251%, 1.7887%, 0.4538%, 0.5754%, 0.2494% and 1.4120% for Africa, Angola, Cameroon, Congo Republic, Kenya, Libya, Tunisia and Zambia respectively. Globalization is positively and statistically linked with $CO_2$ emissions in, Ghana, Morocco, South Africa, Sudan and Tanzania[9]. The diagnostic analysis reveals the absence of serial correlation and white heteroskedisticity. Furthermore, residual term is normally distributed and long run model is well specified.

Table 5 shows the results of short-run dynamics. The results indicate that energy intensity is positively linked with $CO_2$ emissions except in case of Congo Republic and Zimbabwe.[10] The EKC hypothesis exists significantly in Africa, Egypt, Morocco and Tunisia but in case of Gabon, Kenya and Sudan, the relationship between

[9] The impact of globalization on $CO_2$ emissions is statistically insignificant for Algeria, Nigeria, Togo, Zambia and Zimbabwe.
[10] Energy intensity is positively but insignificantly related with $CO_2$ emissions for Cameroon, Côte d'Ivoire, and Tanzania.

**Table 5**
Short run results.

| Dependent variable: $\Delta \ln C_t$ | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Countries | Constant | $\Delta \ln EI_t$ | $\Delta \ln Y_t$ | $\Delta \ln Y_t^2$ | $\Delta \ln G_t$ | $ECM_{t-1}$ | $R^2$ | $\chi^2_{NORMAL}$ | $\chi^2_{SERIAL}$ | $\chi^2_{ARCH}$ | $\chi^2_{HETERO}$ | $\chi^2_{RAMSEY}$ |
| Africa | −0.0119 | 1.0447** | 4.5407** | −0.2778** | −0.0773 | −0.5731* | 0.6075 | 0.1650 | 1.9342 | 0.0048 | 0.7494 | 0.0654 |
| Algeria | 0.0038 | 0.8296* | 0.0944 | 0.0076 | −0.0574 | −0.4652* | 0.9045 | 3.3081 | 0.4288 | 0.0146 | 0.7833 | 1.2578 |
| Angola | −0.0619** | 3.5927* | 0.2581 | −0.0472 | 0.5984 | −0.4841** | 0.7993 | 1.0246 | 0.0605 | 1.6607 | 1.2039 | 1.2161 |
| Cameroon | 0.0109 | 0.7282 | 2.5606 | −0.3362 | −0.0986 | −0.4909** | 0.3322 | 1.3570 | 2.4142 | 0.0292 | 0.2206 | 2.0550 |
| Congo Republic | 0.0078 | −0.3678 | 0.1622 | −0.0223 | −0.4726 | −0.2543** | 0.1630 | 0.3614 | 1.4140 | 2.1744 | 1.7630 | 1.5673 |
| Côte d'Ivoire | −0.017 | 0.4255 | −1.2663 | 0.3498 | 0.9015 | −0.5456 | 0.5271 | 1.4493 | 0.9174 | 0.0110 | 0.4575 | 0.2578 |
| Egypt | 0.0056 | 1.0234* | 1.2151** | −0.1375** | 0.0394 | −0.6122 | 0.9357 | 0.3124 | 0.5492 | 1.2222 | 0.8045 | 2.3575 |
| Gabon | −0.0195** | 2.2628* | −0.8268*** | 0.2506*** | 0.0250 | −0.1026 | 0.9230 | 0.1191 | 2.0855 | 0.6910 | 0.6518 | 2.7830 |
| Ghana | −0.0369 | 2.2644* | −1.9781 | 0.3552 | −0.1563 | −0.3830** | 0.5848 | 0.2516 | 0.1391 | 0.2532 | 0.5630 | 1.6046 |
| Kenya | −0.0407*** | 1.0669** | −1.9596*** | 0.4754** | −0.2189 | −0.4270** | 0.5003 | 0.4499 | 0.3555 | 0.0123 | 0.4468 | 0.0022 |
| Libya | 0.0150 | 0.8126* | −1.8513 | 0.2381 | −0.4312** | −0.5368* | 0.7079 | 2.1742 | 0.8370 | 1.5082 | 2.4366 | 0.3491 |
| Morocco | 0.0219* | 0.5419* | 2.4495* | −0.2672* | 0.0775 | −0.5551* | 0.7100 | 1.1115 | 2.0151 | 0.0940 | 0.7597 | 0.0022 |
| Nigeria | −0.1451* | 7.0661* | −0.0373 | −0.0016 | 0.0781 | −0.0724*** | 0.9237 | 1.4039 | 2.5901 | 0.1674 | 1.9052 | 1.5200 |
| South Africa | 0.0041 | 1.1485* | −3.1948 | 0.2424 | 0.2124* | −0.7491* | 0.6120 | 0.7928 | 0.2228 | 0.0812 | 1.1671 | 1.0508 |
| Sudan | −0.0264*** | 2.3079* | −2.6138* | 0.3700* | 0.0488 | −0.5429* | 0.8906 | 0.2512 | 0.6253 | 0.0044 | 0.5587 | 1.7916 |
| Tanzania | −0.0414 | 0.3418 | −0.1564 | 0.3012 | 0.8178** | −0.4436* | 0.4720 | 2.4738 | 0.0369 | 0.0198 | 0.9024 | 2.6682 |
| Togo | −0.0874* | 3.3939* | 1.5971 | −0.2739 | −0.6519 | −0.4523* | 0.8593 | 4.3406 | 1.9984 | 0.2685 | 0.2368 | 1.5362 |
| Tunisia | −0.0023 | 1.1121* | 0.7464** | −0.0990*** | −0.1952 | −0.5080* | 0.8430 | 1.0338 | 0.7215 | 1.0532 | 1.1607 | 2.6824 |
| Zambia | −0.0976* | 4.3251* | −3.5430 | 0.8348 | −0.2987 | −0.1648*** | 0.7444 | 1.4382 | 1.5440 | 0.0611 | 3.1378 | 0.1743 |
| Zimbabwe | −0.0004 | −0.0084 | 0.7417 | −0.0081 | 0.1602 | −0.2450** | 0.2380 | 0.1235 | 0.7178 | 0.0689 | 0.5404 | 0.0001 |

*Note*:
* Significance at 1% level.
** Significance at 5% level.
*** Significance at 10% level.

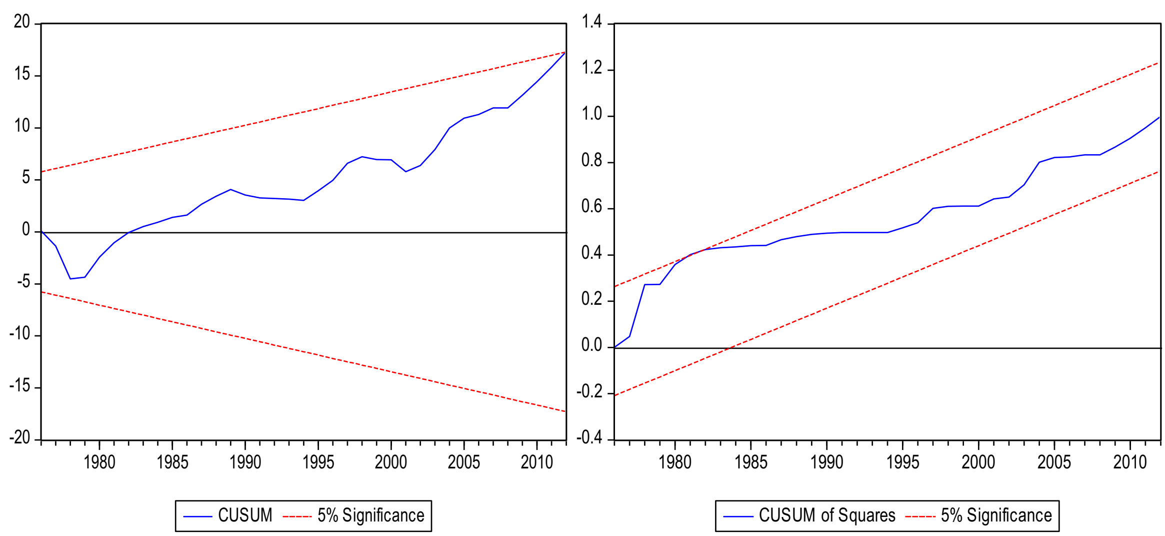


**Fig. 2.** The CUSUM and CUSUMsq in Africa.

economic growth and $CO_2$ emissions is U-shaped and statistically significant. Globalization increases (lowers) $CO_2$ emissions in case of South Africa and Tanzania (Libya) significantly. The negative and statistically significant estimates for $ECM_{t-1}$ support the long run relationship amid energy intensity, economic growth, globalization and $CO_2$ emissions in case of Africa (−0.5731), Algeria (−0.4652), Angola (−0.4841), Cameroon (−0.4909), Congo Republic (−0.2543), Ghana (−0.3830), Kenya (−0.4270), Libya (−0.5368), Morocco (−0.5551), Nigeria (−0.0724), South Africa (−0.7491), Sudan (−0.5429), Tanzania (−0.4436), Togo (−0.4523), Tunisia (−0.5080), Zambia (−0.1648) and Zimbabwe (−0.2450).[11] This indicates the short run deviations toward long run equilibrium path. Similar to the bounds test and combined cointegration tests, the results reject the possibility of long run relationship in the variables for Côte d'Ivoire, Egypt and Gabon. The diagnostic tests suggest we can accept the null hypothesis of normal distribution and that the model is devoid of serial correlation and ARCH problems. The Ramsey reset test demonstrates that functional form for the specifications of the short run models is adequate. The CUSUM and CUSUMsq tests are also applied for checking the stability of the parameters. The results are shown in Fig. 2.[12] The diagrams of CUSUM and CUSUMsq confirm the stability of ARDL parameters. This further validates the efficiency of long-run as well as short-run estimates.

[11] The estimates of $ECM_{t-1}$ are provided in small parenthesis and found significant at 1%, 5% and 10% significance levels.

[12] We have inserted CUSUM and CUSUMsq tests for Africa to conserve space. The results of CUSUM and CUSUMsq test are available upon request from authors for rest of countries.

## 6. Conclusion and policy implications

The present study aimed to investigate whether the Environmental Kuznets Curve (EKC) exists in a $CO_2$ emissions function that contains real GDP, real GDP square, energy intensity and globalization in African economies for the period of 1971–2012. Augmented with a recently introduced combined cointegration test, the bounds testing approach is employed for examining the long run link in the variables. We find that cointegration is present between the series in most of the countries. Furthermore, energy intensity increases $CO_2$ emissions in Africa, Algeria, Angola, Cameroon, Congo Republic, Ghana, Kenya, Libya, Morocco, Nigeria, South Africa, Togo and Tunisia while energy intensity declines $CO_2$ emissions in case of Zambia and Zimbabwe. Globalization decreases $CO_2$ emissions in Africa, Angola, Cameroon, Congo Republic, Egypt, Kenya, Libya, Tunisia and Zambia while in Ghana, Morocco, South Africa, Sudan and Tanzania, globalization is positively linked with $CO_2$ emissions. The EKC hypothesis is true for Africa, Algeria, Cameroon, Congo Republic, Morocco, Tunisia and Zambia while U-shaped relationship exists between economic growth and $CO_2$ emissions in case of Sudan and Tanzania.

Globalization is shown to have a decreasing impact on emissions at the panel level. The implication of these results is that fostering openness and stimulating market integration with trading partners by lowering or removing the trade barriers, will improve environmental quality. By facilitating the importation of greener technologies and by spreading the message of better environmental regulations and standards, globalization helps in the reduction of pollution generated in the local community. Therefore, more openness in Africa can reduce pollution. Our results support the findings of Copeland and Taylor (2004) who claims that it would be unwise for countries to use trade protection as a means of improving their environments. Aside from improving the environment, these outward policies are also likely to facilitate export diversification, opening up new markets, create employment, foreign exchange earnings and reduce balance of payment problem. With the continent currently accounting for less than 3% of the global trade, these policies are also likely to improve the share of Africa in the global trade. It can also reduce poverty by generating growth through increased commercial opportunities and investment, as well as broadening the productive base through private sector development.

However, there must be the introduction of environmental policies that will ensure more openness does not lead to more environmental degradation in the continent. For instance, globalization is also associated with the increasing number of fright in and out of the continent. $CO_2$ emissions from international road freight transport are increasing all over the world, and there is not yet a sign that this trend is to be curbed soon. A mix of measures, such as road pricing, higher fuel taxes, stricter fuel efficiency standards for vehicles, use of alternative fuels and logistical improvements, will be needed to address the environmental degradation (OECD, 2010). Since the results are in support of EKC hypothesis at the panel level, the implication is that economic development decreases the environmental degradation with higher levels of economic growth. In other words, beyond a threshold level of real output, an increase in real output may actually reduce emissions as the demand for environmental quality increases and these economies grow. With more globalized countries in the continent, less environmental degradation is possible.

The positive impact of energy intensity on emissions increases the need for policy-makers to search and employ renewable energy sources (solar, wind, geothermal sources and bio-diesel fuel) and green investment technologies should be promoted because of the apparent influence of energy consumption on emissions. As the production and use of modern bio-energy is currently limited in the continent, Africa could have a substantial competitive edge as a biofuel producer and consumer. On a regional basis, Africa has the largest unexploited potential of hydroelectricity, which stands at 93% of total hydroelectricity potentials (World Bank, 2009). So far, an unattractive investment climate and poor infrastructure have hampered such development. As energy use is still vital to meeting the fundamental needs and achieving Africa's development aims and at the same time, the findings indicate that energy is a key determinant of emissions and authorities must promote attitudinal change towards energy use in order to achieve growth-free emissions (Shahbaz et al., 2015b).

The analysis of each country shows different results. While the results for most of the countries suggest that globalization decreases emissions, globalization enhances emissions in seven countries. Since the impact of globalization is found to be insignificant in the short run, it might take some times before the effect of globalization is realized. For the countries, which show that globalization decreases emissions such as Angola Cameroon Congo Republic, Ghana and Kenya, there is the need to implement extensive outward oriented policies which would promote openness in these economies. For countries that globalization enhances emissions such as Cote D'Ivoire and South Africa, unrestrained global economic integration should be rejected and there should a reduction of fossil-fuel usage in outward oriented industries. Most of the exports-based industries in South Africa are powered by coal, which accounts for 70% of the country's total energy mix (Energy Information Administration, 2013).

Only six countries follow the EKC hypothesis, which suggests that economic development decreases the environmental degradation with higher levels of economic growth in these countries. For the other countries which fail to show any evidence for EKC hypothesis, there is no positive effect of economic activities on emissions, which suggests that expanding economic activities might not seriously contribute to emissions in these countries. Therefore these countries are not expected to drop their ambitious growth plans and none of the countries need to sacrifice economic growth in order to reduce carbon dioxide emissions. With the exception of Zambia and Zimbabwe, most of the countries show that energy consumption has positive impact on emissions level. These implies that rising energy intensity in most countries is causing more emissions, thus it is very essential to apply some sorts of pollution control actions to the whole panel in respect of energy consumption. A policy option in this case is to increase the share of renewable energy in the energy-mix in the continent. As very few countries in the region have significant energy usage, the increasing level of energy intensity generated in the continent might not be chiefly responsible for the climate change problem faced in the continent. While the mandatory actions on the part of governments in African countries may not fully address the problem of environmental degradation; however, this will definitely stimulate more awareness and may coerce the developed countries to follow suit as authorities in the continent may now be seen as being serious about their environment (Solarin, 2014a,b).

The present study is not without its limitations as the role of population, land use and government spending (subsidy) on emissions have not been analyzed in this research. The impact of population growth on environment is an issue that is highly debated yet under-researched. During the industrial phase, while death rates decline birth rates remain initially high, so that population growth is strong (Galeotti et al., 2011). Population density could affect energy use and consequently $CO_2$ emissions. The effect of large populations on fossil fuel consumption can stem from the increased energy demand for power generation, industry and transport which increases $CO_2$ emissions. In Africa, population growth has been described as one of the major factors of emissions in the continent. The continent has witnessed a rise in population from less than 500,000 million in 1980 to more than one billion people in 2012 (United Nations, 2015). The continent has a large and faster-than-average growing population and per capita income that could drive future energy demand and, if unconstrained, emissions (Calvin et al., 2013).

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecolind.2016.03.024.

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