

## Effects of Economic Growth on CO<sub>2</sub> Emissions in the “Congo Basin” Countries

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Received: October 30, 2014

Accepted: November 18, 2014

Online Published: December 25, 2014

doi:10.5539/ijef.v7n1p107

URL: <http://dx.doi.org/10.5539/ijef.v7n1p107>

### Abstract

This study examines the effects of economic growth on the carbon dioxide (CO<sub>2</sub>) emissions of a sample of four countries of the Congo Basin. Cointegration tests by the distributed lags or Autoregressive Distributed Lags (ARDL) developed by Pesaran et al. (1997, 2001) is applied to data on Cameroon, Congo, Gabon and the Democratic Republic of Congo for the period from 1978 to 2012 and indicates the existence of a long term relationship between the variables. The results show that the economic growth has a positive impact on CO<sub>2</sub> emissions in these countries. Also, the consumption of energy, population density and industrial activities increase CO<sub>2</sub> emissions significantly in these countries, while the commercial opening does not have a significant impact.

**Keywords:** economic growth, CO<sub>2</sub> emissions, ARDL

### 1. Introduction

The attention given to environmental problems (climate change, deforestation, loss of the biodiversity, salinisation of the soil, etc.) is alarming and occupies a significant media space. In fact, according to Stern (2006), climate change due to the accumulation of Greenhouse gases (GES), mainly carbon dioxide (CO<sub>2</sub>), constitutes the principal threat for humanity, and could cost the world economy up to 550 billion dollars if the governments do not take radical measures.

Moreover, a rise of 2°C in average temperatures would lead to a fall of 4 to 5% in average yearly per capita consumption in Africa and Asia (Nordhaus & Boyer, 2000), whereas it would result to significantly lower losses in the high income countries (Nordhaus, 2008). According to the World Bank (2010), climate change is likely to reverse economic progress that was hard to realise; and developing countries will pay the higher tribute, between 75 and 80% of the costs of the damage caused by climate change (Hope, 2009).

According to the Intergovernmental Group of Experts on the Evolution of Climate (GIEC), the acceleration of environmental pollution is mainly due to human factors (demographic growth, deforestation, industrialization, agriculture, trade) (GIEC, 2007, 2013).

Therefore, the analyses of the determinants of environmental degradation has become a very important issue in economic literature and an important number of studies seek to check the hypothesis of Kuznets' Environmental Curve (KEC) between economic growth and the indicators of environmental degradation (Grossman & Krueger, 1995; Panayotou, 1993, 1995; Shafik & Bandyopadhyay, 1992, etc.). The importance of the KEC lies in the fact that it advances the possibility for poor countries of improving environmental quality as they develop, on condition that as the standard of living of the individuals improves, there is growing support for environmental consciousness (World Bank, 1992). Many authors have done a detailed review of empirical work on the relationship between economic growth and environmental quality (Dinda, 2004; Nourry, 2007). The diversity of studies confirms the fact that environmental problems differ from one region to another, giving rise to the need for solutions specific to each region in order to limit the environmental disaster.

Regarded as a taboo in developing countries, the problems of environment became more and more extensive since the holding of the first Summit of Rio in 1992. This awakening is even more relevant since the increase in CO<sub>2</sub> emissions was accelerated by economic growth in developing countries. In fact, during the 1990–2000, the CO<sub>2</sub> emissions increased by 48% in these countries, and 81% during the following decade (2000–2010), while

they decreased by 7% and 1% respectively in the developed countries during the same period (ONU, 2013). After a long period of permanent fluctuations, we are witnessing a positive evolution of carbon dioxide emissions in the countries of the Congo Basin (Note 1) in recent years (see Appendix A).

However, the analyses of the long-term economic performances of these countries shows that economic growth since independence has had a small impact on poverty (Note 2). The structural transformation or "emergence" of these countries therefore requires a rupture in the dynamic of economic growth and a restructuring of the industrial apparatus, with risks of a critical increase in the damage to the environment.

To explain and understand the relationship between macroeconomic variables and air pollution constitute the principal centre of interest of this study, which aims at testing the relationship between economic growth and air pollution in four countries of the Congo Basin, namely Cameroon, Congo, Gabon and the Democratic Republic of Congo in order to propose strategies of structural transformation compatible with the objectives of sustainable development.

The rest of the study is organized as follows: section 2 presents the literature review, section 3 presents the methodology, section 4 is reserved for the analysis of the results and a last section presents the conclusion and some recommendations for environmental economic policy.

## 2. Literature Review

The 1990s marked the advent of the first studies aimed at giving empirical contents to the relationship between the economic growth and environmental quality. The principal objective of these studies is to test the hypothesis of Kuznets's environmental curve (Note 3) or the existence of an inverted U curve relationship between economic growth and the indicators of environmental quality (CO<sub>2</sub>, SO<sub>2</sub>, deforestation, volatile particles, etc). Instead of describing economic growth as a threat for the environment and recommend stopping it, KEC supposes compatibility between environmental protection and future economic growth.

To understand this mechanism, we use the decomposition of total emissions proposed by Grossman and al. (1995), and Antweiler and al. (2001):

$$\hat{E}_i = \hat{Y}_i + \sum_j^n \hat{\gamma}_{ij} + \sum_j^n \hat{e}_{ij} \quad (1)$$

Where  $E_i$  are the total emissions,  $i$  represents the country and  $j=1, 2, \dots, N$  represents the various economic sectors.  $Y_j$ , which is often the GDP, captures the size of the economy of country  $i$ .  $\hat{\gamma}_{ij}$  represents the share of the value added of the sector  $J$  in the economy of country  $i$  and indicates the composition of the economy, and  $e_{ij}$  represents the intensity of pollution of sector  $J$  in the economy of country  $i$ .

The scale effect refers to the increase in environmental nuisances following increases in production. Assuming that the state of technology and the structure of the economy remain unchanged, any increase in production will result in an increase in environmental nuisances of the same amount.

The composition effect captures the effect of a change in the structure of production on the environment. The structural transformation witnessed by developed countries i.e. the passage from a primarily agricultural economy to an industrial economy resulted in a rise in the intensity of pollution, the level of technology remaining unchanged.

The technical effect finally captures the impact of technical progress on environmental quality. Thus, any improvement of the technical coefficients will result in a deceleration of the rate of increase of environmental degradation. Moreover, the installation of rigorous environmental regulation, due to environmental consciousness will also enable a reduction of environmental degradation.

Grossman and Krueger (1994, 1995), Panayotou (1993, 1995), Shafik and Bandyopadhyay (1992) and Selden and Song (1994) are among the first authors to empirically test the effects of economic growth on environmental indicators (SO<sub>2</sub>, NO<sub>x</sub>, CO<sub>2</sub>, CO, municipal waste, suspended particles, etc). Grossman and Krueger are the first to obtain a reversed U shaped curve in their *Working Paper* on the environmental effects of the North American free trade agreement. They study the Kuznets relationship for air and water pollution with points of reversal fixed at 5000\$ and 8000\$ respectively.

Panayotou, Shafik et al., Selden and Song also obtain Kuznets's environmental curve for various indicators with points of reversal ranging between 5000 and 12 041 \$ for various environmental indicators and study areas.

Other studies (Shukia & Parik, 1996; Carson et al., 1997; Halicioglu, 2009; Akpan et al., 2011; etc.) do not lead to the reversed U shaped relationship. These authors obtain various alternative forms according to the econometric model used (Note 4).

Many additional variables were introduced into the analysis of the determinants of environmental quality. Shi (2003), Cole and Neumayer (2004) Shahbaz et al. (2010), Halicioglu (2009) and Akpan et al. (2012), and Adib Ismael et al. (2012) amongst others obtain a positive relationship between CO<sub>2</sub> emissions and a set of macroeconomic variables like commercial opening, power consumption, and population (density and rate of urbanization).

The use of CO<sub>2</sub> emissions as proxy for environmental degradation poses a problem of relevance according to the author.

In fact, certain authors justify the absence of a reversed U shaped relationship between growth and the emissions of CO<sub>2</sub> by the fact that there is no incentive to reduce emission of pollutants, the cost of reduction of climate change being local and their benefit global (Nourry, 2005).

However, the use of this variable as proxy of air pollution could be justified in various ways:

- ✓ Firstly, CO<sub>2</sub> is the principal greenhouse gas responsible for the climate change; its regulation thus becomes a very important intergovernmental question (Talukdar & Meisner, 2001). Such a study will lead to the proposal of a plan of convergence of the CO<sub>2</sub> emissions for countries of the Congo Basin;
- ✓ Moreover, the data bases on CO<sub>2</sub> emissions are accessible, unlike the other indicators for which there only exists very little data, especially as concerns the countries targeted by this study.

### 3. Methodology

#### 3.1 Econometric Model and Description of Variables

This research relies on the following equation, in which the explanatory variables have been selected going from a varied literature:

$$co = f(pibh, ener, dpop, vaine, ouv) \quad (2)$$

Where: *CO* represents the carbon dioxide emissions (in million tons). Used as proxy of air pollution, this variable is extracted from the data base of *the International Atomic Energy Agency* (IAEA, 2013). *PIBH* is the Gross Domestic Product per Capita, *ENERG* is the fossil consumption of energy in % of the total power consumption, *DPOP* is the density of the population, *VAIND* is the added value of the industrial sector in % of gross domestic product and *OUV* is the degree of commercial openness (Exports + Importations/PIB). These indicators are extracted from *World Development Indicators* (2013).

In its log-linear form, equation 2 can be rewritten as follows (Note 5):

$$\ln CO_t = \alpha_0 + \alpha_1 \ln pibh_t + \alpha_2 \ln ener_t + \alpha_3 \ln dpop_t + \alpha_4 \ln vaine_t + \alpha_5 \ln ouv_t + \varepsilon_t \quad (3)$$

PIBH captures the impact of the level of development on the environment. Theoretically, going from the assumptions of the KEC, environmental pollution is accelerated in the developing countries, while the opposite effect is observed when these countries reach a certain level of income. Being given the weak economic performances associated the weak technological development of the countries of study, one can hope that any unit increase in the GDP per capita is associated an increase in the total carbon dioxide emissions. Thus, the sign hoped for  $\alpha_1$  is positive.

Power consumption refers to the use of coal, fuel and natural gases as source of energy. At the global level, the power consumption constitutes the second most important source of emissions of GES. If the increase in the consumption of fossil energy is due to the good performance in the productive sector, the expected sign for  $\alpha_2$  is positive.

Demography is also a significant determinant of environmental quality. In fact, a rise in the population induces an increase in the food needs, which results in the overexploitation and the reduction of the natural resources and an increase in pollution. This analysis is shared by several authors (Malthus, 1894; Azomahou et al., 2007 amongst others). Thus, the expected sign of the coefficient of the variable DPOP is positive.

The value added of the industrial sector captures the effects of industrial activities on CO<sub>2</sub> emissions. Given the outdated nature of industrial facilities in the majority of the Developing countries, the sign of the coefficient is positive.

The level of trade openness captures the effects of international trade on environmental quality. In the developed countries, the imposition of a strong environmental regulation generally results in the movements or delocalization of polluting industries into the countries with weak environmental regulations (this is referred to as the "haven of pollution" hypothesis). Thus, the sign of the coefficient of OUV varies according to the level of development of countries (Grossman & Krueger, 1994; Halicioglu, 2009). In developed countries, the trade

openness reduces environmental degradation, while the opposite effect is observed in developing countries.

### 3.2 Technique of Data Analysis

Various tests make it possible to test the existence or not of a cointegration relationship between the variables of an econometric model. However, the test of cointegration by the distributed lags or Autoregressive Distributed Lags (ARDL) approach to cointegration proposed by Pesaran et al. (1999, 2001) is more and more used in the research. This choice is due to the fact that this technique has the advantage of being more efficient for studies with a small sample and applies to series that are integrated of order 1, level 0 or mutually integrated, unlike the traditional tests of cointegration such as those of Engle and Granger (1987), Johansen (1988) and Johansen & Juselius (1990). However, the technique ceases being applicable when the order of integration of the series is higher than 1. Another importance of this method is that it allows estimating the long and short run models in the same econometric model (Akpan et al., 2012).

The test of cointegration is carried out on the following equation:

$$\Delta \ln CO_t = \alpha_0 + \alpha_1 \ln CO_{t-1} + \alpha_2 \ln PIB_{t-1} + \alpha_3 \ln ENER_{t-1} + \alpha_4 \ln DPOP_{t-1} + \alpha_5 \ln VAIN_{t-1} + \alpha_6 \ln OUV_{t-1} + \sum_{i=1}^a \alpha_{7i} \Delta \ln CO_{t-i} + \sum_{i=0}^b \alpha_{8i} \Delta \ln PIB_{t-i} + \sum_{i=0}^c \alpha_{9i} \Delta \ln ENER_{t-i} + \sum_{i=0}^d \alpha_{10i} \Delta \ln DPOP_{t-i} + \sum_{i=0}^d \alpha_{11i} \Delta \ln VAIN_{t-i} + \sum_{i=0}^f \alpha_{12i} \Delta \ln OUV_{t-i} + \varepsilon_t \quad (4)$$

Where; the terms on level capture the long term dynamics while the terms in first difference capture the short term dynamics of; ln is the Nepierian logarithm. The other variables remain as described above.

The application of the test of cointegration proceeds in two stages:

The first consists in determining the optimal lag by estimating equation (IV) by Ordinary Least Squares. The optimal maximum lag is selected using the criteria of information of Scharwz (SIC) or of Akaike (AIC).

The second consists in testing the cointegration as defined by Pesaran et al. (2001). This test is based on the following hypotheses:

$$H_0: \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$$

$$H_1: \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq 0$$

The F-statistics or Wald statistics resulting from the estimation of equation (4) are compared at the lower and higher boundaries simulated by Pesaran et al. One of the following decision rules is respected: if the F-statistics is higher than the upper limit, then we accept the hypothesis of cointegration, if the F-statistics lies between the two boundaries, we don't conclude, and if the F-statistics is lower than the lower boundary, then we accept the hypothesis of absence of cointegration.

If the hypothesis of cointegration is accepted, then we estimate equation (2) which represents the dynamics of long term by the method of Ordinary least squares. The residuals obtained from the estimation of equation (2) are then introduced in their lagged form into the error correction model as follows:

$$\Delta \ln CO_t = \alpha_0 + \sum_{i=1}^a \alpha_i \Delta \ln CO_{t-i} + \sum_{i=0}^b \alpha_{2i} \Delta \ln PIB_{t-i} + \sum_{i=0}^c \alpha_{3i} \Delta \ln ENER_{t-i} + \sum_{i=0}^d \alpha_{4i} \Delta \ln DPOP_{t-i} + \sum_{i=0}^d \alpha_{5i} \Delta \ln VAIN_{t-i} + \sum_{i=0}^f \alpha_{6i} \Delta \ln OUV_{t-i} + \eta ECT_{t-1} + \varepsilon_t \quad (5)$$

Where:  $ECT_{T-1}$  is the error correction term and  $\eta$  its coefficient. The hypothesis of cointegration is confirmed if the coefficient of ECT is negative and significant.

## 4. Results of the Estimates and Discussion

### 4.1 Stationnarity Tests

Table 1. Result of ADF and PP stationnarity tests

Country	lnCO		lnPIBH		lnENER		lnDPOP		lnVAIN		lnOUV	
	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP
Cameroon	I(1)	I(1)	I(0)	I(1)	I(1)	I(1)	I(0)	I(0)	I(0)	I(0)	I(1)	I(1)
Congo	I(1)	I(1)	I(0)	I(0)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
Gabon	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	I(0)	I(0)	I(1)	I(1)	I(0)	I(0)
RDC	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	I(0)	I(1)	I(1)	I(1)	I(1)

Note. I(1) and I(0) denote stationnarity at first difference and at level respectively and RDC = Democratic Republic of Congo.

The Augmented Dickey-Fuller (DFA) and Phillips-Perron (PP) stationnarity tests were carried out in order to

ensure that no variable is integrated of an order higher than 1, condition under which the ARDL ceases being valid (Note 6). These tests indicate that all the variables respect the standards of application of ARDL, the maximum order of integration of the variables being 1 (see Table 1).

#### 4.2 Cointegration Test

Table 2 shows the result of the Pesaran cointegration test. These results reject the hypothesis of absence of cointegration at the 1% significance level for all the models.

Table 2. Estimates of the optimal model and results of the cointegration test

Country	Optimal lag		F-statistics		Decision	
Cameroon	2		4.3799		Cointegration	
Congo	3		4.094		Cointegration	
Gabon	3		6.8790		Cointegration	
RDC	3		4.48		Cointegration	
Critical values of Pesaran	10%		5%		1%	
	1.99	2.94	2.27	3.28	2.88	3.99

Note. S: The terms between brackets are the optimal lags of each variable obtained by the Bayesian information criteria. The upper boundary of pesaran is read in table CI(ii), Case II: restricted intercept and No trend, K = 6.

#### 4.3 Estimation Results of the Basic Model

Table 3 shows the estimation results of the effect of economic growth and its determinants on the CO<sub>2</sub> emissions in the countries under study. The tests of validation of Ordinary Least Squares (normality, autocorrelation and heteroskedasticity tests) are all positive at the 5% significance level all estimated models. In addition, the adjusted coefficients of determination indicate that the CO<sub>2</sub> emissions are explained at 98.5%, 95.1%, 86.9% and 89.2% by the variables considered by the models for Cameroon, Congo, Gabon and the RDC respectively.

Table 3. Results of the cointegrating relationship

Dependent variable (lnCO)	Cameroon	Congo	Gabon	RDC
lnPIBH	0.6622 *** (0.1325)	0.5219 *** (0.1314)	0.4913 * (0.2759)	0.9992 * (0.1445)
lnENER	1.9799 *** (0.3967)	3.1890 *** (0.1190)	2.0169 *** (0.1706)	0.0313 (0.3367)
lnDPOP	0.6697 *** (0.1307)	0.9214 *** (0.0793)	1.8623 *** (0.1717)	0.9584 *** (0.3385)
lnVAIND	0.3422 ** (0.1255)	0.1723 * (0.0987)	0.5165 *** (0.1587)	0.0795 (0.1057)
lnOUV	-0.2498 *** (0.0816)	0.0428 (0.0893)	0.2078 (0.2279)	0.0532 (0.0824)
C	19.1602 *** (0.28786)	-3.7823 *** (1.0787)	-6.3363 * (2.7787)	6.0148 *** (1.8820)
R <sup>2</sup>	0.9415	0.9744	0.8920	0.9044
adjusted R <sup>2</sup>	0.9311	0.9699	0.8728	0.8874
<b>Tests of validity of OLS estimates</b>				
Normality test	0.8940	0.6762	0.4806	0.6706
Breusch-Godfrey	0.1976	0.9631	0.1260	0.2648
Breusch-Pagan	0.6538	0.5255	0.6197	0.7999
F-statistic	90.2655	213.9518	46.2891	53.0372
(Prob. F-stat)	0.0000	0.0000	0.0000	0.0000

Note. () is the standard deviation. \*\*\*, \*\*, \* indicates significance at 1%, 5%, and 10% respectively.

From this table, we notice that economic growth (**PIBH**) has a positive and significant effect on CO<sub>2</sub> emission in all the countries. This indicates that these countries are in the ascending phase of Kuznets's environmental curve. Although  $\alpha_1$  is positive, it should be noted that this coefficient lower than those is obtained in other studies. For

example, Sharma (2010) obtains a larger elasticity on a panel of low income countries for the period from 1985 to 2005.

In addition, power consumption and demographic growth constitute the principal determinants of air pollution in the countries under study. Except the RDC where the consumption of fossil energy has a non significant positive impact on the CO<sub>2</sub> emissions, the consumption of fossil energy contributes significantly to the air pollution in the other countries. This impact is accentuated by fast demographic growth in these countries and the strong dependence of the population on wood as source of energy (more than 89% of the population of the Congo Basin depends on wood as source of energy) (Note 7). This result is in conformity with that of Halicioglu (2009), Akpan et al. (2012) who find that an increase in the consumption of power results in the rise of CO<sub>2</sub> emissions in Turkey and Nigeria respectively. Also, Brajer et al. (2007) show that an increase in the population density is associated an increase in the carbon dioxide emissions in China.

Although the impact of the industrial sector is positive and significant for Cameroon, Congo and Gabon, it should be noted that the contribution of this variable to increases in the CO<sub>2</sub> emissions was marginal over the study period. This result can be explained by the industrialisation witnessed by these countries during the crisis from 1986–1994.

Lastly, we find that international trade is not a major determinant of CO<sub>2</sub> emissions in the countries under study. In fact, a unit increase in the degree of openness results in a non significant increase in the CO<sub>2</sub> emissions in Congo, Gabon and in RDC, while it would tend to reduce the pollutant emissions in Cameroon. Contrary to the theoretical predictions, this result indicates that commercial liberalization does not necessarily result in the migration of polluting companies from the developed countries into developing countries, who are less strict as regards environmental protection.

Appendix B shows the results of the error correction model for each country. From this table, we can confirm the hypothesis of cointegration since the coefficient of the error correction term (ECT<sub>T-1</sub>) is negative and significant for all the models. Moreover, these coefficients being less than one, we can conclude on the period of adjustment of differences between the long run and the short run, which in this case is less than one year. In addition, the tests of validity of Ordinary Least Squares as well as tests of stability of parameters (Cumulative Sum and Cumulative Sum of Square) show that the results are all stable at the 5% level (see appendix C).

Just as in the long run, we find that the consumption of fossil energy is the principal determinant of CO<sub>2</sub> emissions in the short run in the countries under study. This can be explained by their strong dependence on wood-energy, whose contribution to greenhouse gases is more and more evident. Variables like economic growth and openness have mixed impacts on the emissions of CO<sub>2</sub> in the short run. If growth has a significant impact in Gabon and RDC, such is not the case for Cameroon and Congo whose impacts are positive and negative respectively and non significant.

We find that the industrial sector does not contribute significantly to the CO<sub>2</sub> emissions in the countries under study. This result can be explained, as in the long run by the strong dependence of these countries on extractive activities (Wood, fuel and minerals) which contribute more and more to economic growth.

## 5. Conclusion and Recommendations

The main objective of this study was to examine the effects of economic growth on the CO<sub>2</sub> emissions in four countries of the Congo Basin, namely: Cameroon, Congo, Gabon and the Democratic Republic of Congo. Using time series from 1978 to 2012 and applying the test of cointegration by the distributed lags or AutoRegressive Distributed Lags (ARDL) developed by Pesaran et al. (1997, 2001) in order to overcome the limits of traditional cointegration tests, it globally appears that the consumption of energy is the principal determinant of CO<sub>2</sub> emissions in the countries covered by the study. Also, the density of the population and economic growth also play a significant role in increasing pollution by CO<sub>2</sub>. Lastly, the impact of the industrial activities is marginal over the study period, while commercial opening does not have a significant impact on CO<sub>2</sub> emissions.

On the political level, these results suggest that the growth targets be accompanied by adaptation measures. It is therefore necessary to incorporate programmes of adaptation to strategies of development, such as the Ethiopian initiative which includes limits to emissions, an increased productivity and a better usage of resources. These objectives can also be reached through the development of renewables such as solar and wind energy as alternative to fossil fuels.

In addition, these countries should promote an Inclusive Green Growth, which necessarily passes through the fight against inequality of opportunities, investments in Research and Development, the sensitisation of the population on environmental risks and finally, the collection and the follow-up of the environmental indicators.

## Acknowledgments

The authors wish to thank blind peer-reviewers who criticized the manuscript and made suggestions for its improvement.

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## Notes

Note 1. In the absence of data on certain key variables of the study for the Central African Republic and Chad, the name Congo Basin in the rest of the study will refer to Cameroon, Gabon, the Republic of Congo and the Democratic Republic of Congo.

Note 2. For further information, see the Regional Economic Program 2010-2015 of the Economic and Monetary Community of Central Africa entitled: “CEMAC 2025: vers une économie régionale intégrée et émergente”, Volume 2.

Note 3. This curve is thus called in reference to the Inequality-Incomes curve drawn by Kuznets in 1955. It indicates that inequalities evolve and tend to reduce as economic growth takes place, giving an inverted U relationship.



Note 4. See Akpan et al. (2011) for a discussion of the possible types of curves as a function of the degree of the equation to be estimated.

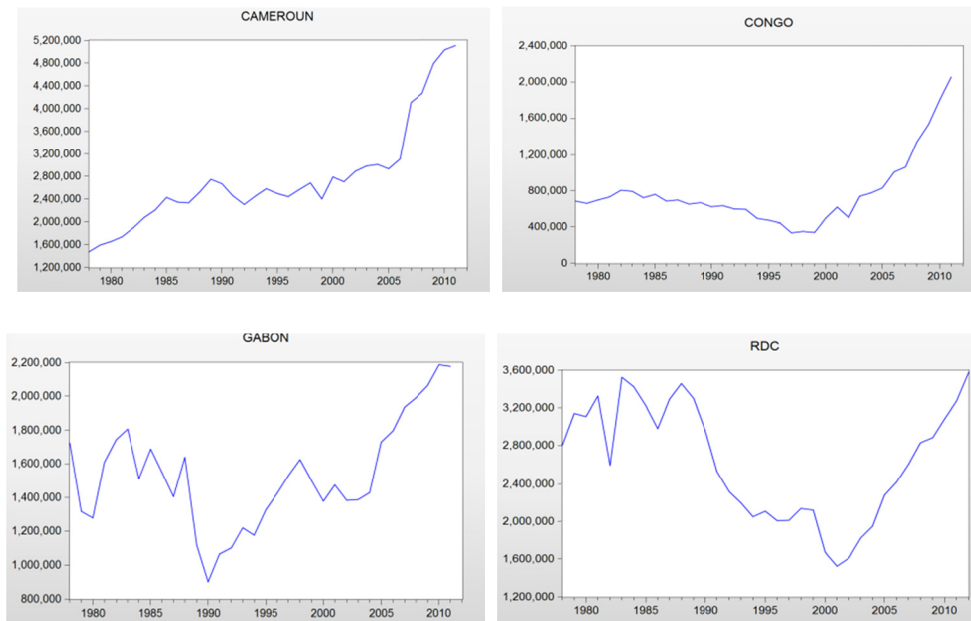
Note 5. This equation will be estimated for each country.

Note 6. In fact, Ouattara (2004) and Akpan and al. (2011) affirm that one of conditions of application of the cointegration test using Distributed lags of Pesaran and al. is that no series must be integrated of an order than 1.

Note 7. For more details, see «Les forêts du Bassin du Congo, Etats des forêts», 2008.

## Appendix A

### Evolution of the CO<sub>2</sub> Emissions in Million Tons between 1978 and 2012



Source: Authors using data from IAEA (2013).

## Appendix B

### Results of the Error Correction Model

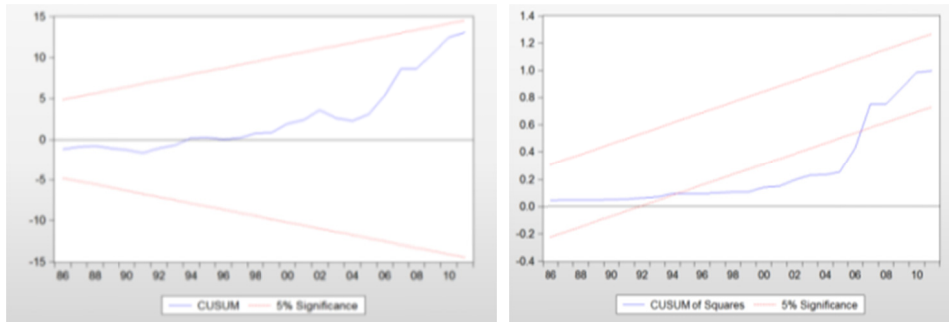
Dependent Variable: $\Delta \ln \text{CO}$	Cameroon	Congo	Gabon	RDC
$\Delta \ln \text{PIBH}$	0.1924 (0.2331)	- 0.0169 (0.2470)	0.3952 * (0.2218)	1.0495 *** (0.3182)
$\Delta \ln \text{ENER}$	- 0.3648 (0.4671)	2.8588 *** (0.2765)	1.9454 *** (0.1970)	0.1085 (0.5780)
$\Delta \ln \text{DPOP}$	- 0.1468 (6.2047)	2.5450 (7.5265)	5.8848 (6.8080)	- 2.6244 (2.39418)
$\Delta \ln \text{VAIND}$	0.1546 (0.1222)	0.1182 (0.0880)	- 0.3900 *** (0.1345)	0.0524 (0.0873)
$\Delta \ln \text{OUV}$	- 0.0136 (0.0819)	0.1086 (0.0820)	- 0.1943 (0.1757)	0.0579 (0.0587)
Ect(-1)	-0.6228 *** (0.1503)	- 0.0910 *** (0.2140)	- 0.6884 *** (0.1658)	- 0.8313 *** (0.2081)
R <sup>2</sup>	0.4635	0.8273	0.8120	0.5806
Adjusted R <sup>2</sup>	0.3397	0.7875	0.7686	0.4839
<b>Tests of validation of the MCO</b>				
Test of normality	0.5872	0.9438	0.9680	0.9500
Breusch-Godfrey	0.7406	0.16	0.1321	0.6310
Breusch-Pagan	0.5602	0.7445	0.1213	0.8684
F-statistics	3.744	20.7647	18.7172	6.0009
Prob. F-stat	0.0081	0.0000	0.0000	0.0004

Note.  $\Delta$  is the CSOp erator of difference first, the values between brackets are the standard deviations. \*\*\*, \*\*, \* respectively represents the significativity with 1%, 5% and 10%.

### Appendix C

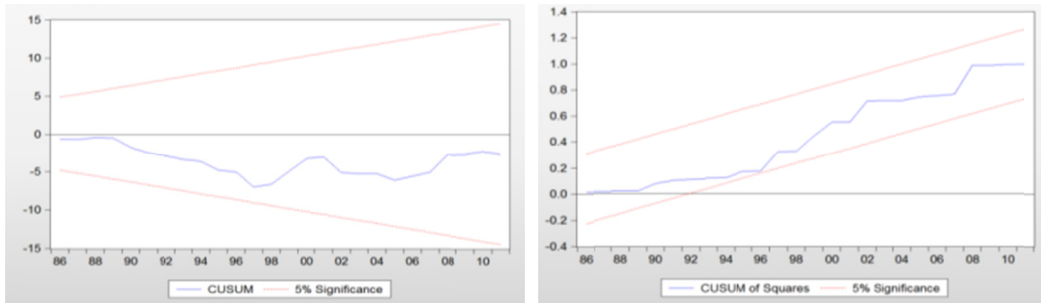
#### Results of the Test of Stability of the Parameters

##### CAMEROON



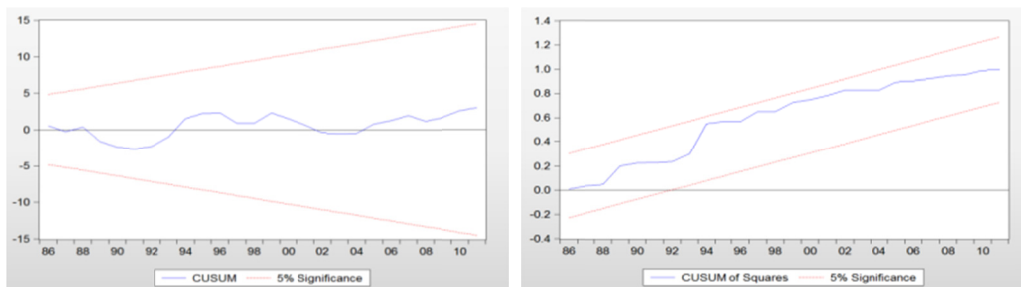
CUSUM CUSUMQ.

##### CONGO



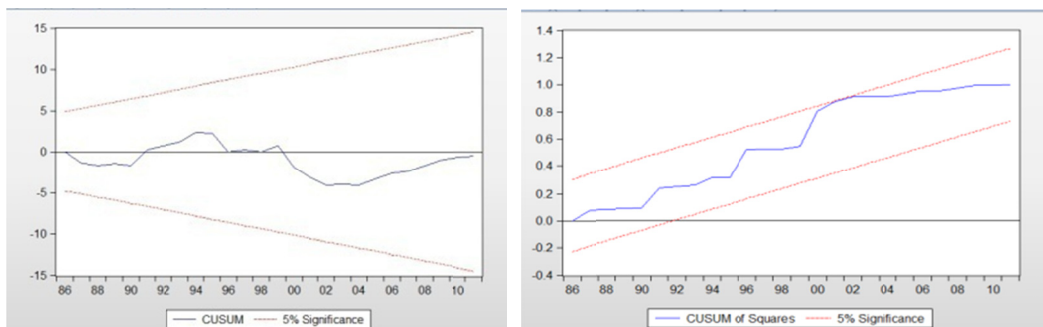
CUSUM CUSUMQ.

##### GABON



CUSUM CUSUMQ.

##### DEMOCRATIC REPUBLIC OF CONGO



CUSUM CUSUMQ.

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