IRJEMS International Research Journal of Economics and Management Studies
Published by Eternal Scientific Publications
ISSN: 2583 – 5238 / Volume 3 Issue 1 January 2024 / Pg. No: 33-42
Paper Id: IRJEMS-V3I1P104, Doi: 10.56472/25835238/IRJEMS-V3I1P104

Original Article

The Effect of Economic Growth on the Environment in the Economic and Monetary Community of Central Africa: A Study by the Autoregressive Model with Lagged Lags (ARDL) for the Period from 1990 to 2019

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Received Date: 20 December 2023 Revised Date: 25 December 2023 Accepted Date: 31 December 2023 Published Date: 03 January 2024

Abstract: *This article aims to examine the effect of economic growth on the environment in the Economic and Monetary Community of Central Africa (CEMAC) and to verify in parallel the validity of the hypothesis of the environmental curve of Kuznets (CEK). To do this, we use an Autoregressive Scaled Lag (ARDL) model on annual data over the period 1990-2019. Econometric estimates show that in the short term, inflation has a negative impact on the environment. In the long term, the environment is affected by gross domestic product per capita, inflation and foreign direct investment. Furthermore, these estimates confirm the validity of the environmental Kuznets curve. They also show different effects depending on the country.*

Keywords: *Economic Growth, Environment, Foreign Direct Investment, ARDL.*
JEL Classification: *C22, O13, F23, Q56.*

I. INTRODUCTION

The issue of environmental concerns and economic growth is very old (Godard and Beaumais, 1993). It dates back to the 1870s when global temperature increased at an average of 0.8°C per year (Ndour and Faye, 2021). This increase has several consequences. Thus, faced with the consequences it engenders, the query of how economic expansion and environmental protection are related has become one of the major challenges facing humanity (Berahab, 2017). As such, the whole world is mobilizing, in particular, through various channels, such as public awareness campaigns and various international summits, to combat environmental deterioration in order to encourage growth that is sustainable.

Within the Economic and Monetary Community of Central Africa (CEMAC), people are experiencing real environmental problems and the deterioration of their living environment. Ecosystems are disturbed, and biodiversity is threatened. In this regard, the sources of pollution and nuisances (industrial, domestic, commercial, and transportation) have a strong impact on the environment and the health of populations.

In the CEMAC, empirical research that has analyzed the ecological consequences of economic expansion and/or examined the reliability of the environmental Kuznets curve is non-existent, to our knowledge.

The study aims to analyze whether, in the context of CEMAC, growth in the economy affects the environment and whether this impact confirms the hypothesis of the environmental Kuznets curve. The effect of economic expansion on the environment has been the subject of several studies in both industrialized and developing nations, yet the issue is still up for dispute and controversy in these places.

To analyze this impact and check the validity of the environmental Kuznets curve, we will use carbon dioxide (CO_2) emissions as the explained variable of the environment (Kauffmann et *al.,* 1998; Ben Saad, 2017) and a method, the Autoregressive model with Stepped Lags (ARDL) over the period from 1990 to 2019.

The arrangement of the article is as follows: In section 2, the literature evaluation on the effects of economic growth on the environment is covered. The methodological elements are presented in Section 3. Section 4 concludes with the model's results and remarks.

II. ECONOMIC GROWTH AND THE ENVIRONMENT: A REVIEW OF THE LITERATURE

The theoretical and empirical literature on the impact of economic growth on the environment is oriented towards various approaches but with disparate results.

A) Theoretical Review

The economic review of the impact of economic growth on the environment has been marked, among others, by authors such as Kuznets (1955). Indeed, Kuznets studied the relationship between the environment and economic progress.

By emphasizing the level of per capita income of countries and social inequalities, he finds in developed and developing countries an « inverted U curve » between environmental degradation and economic growth, which he describes as « Kuznets-CEK environmental curve ». For this author, two phases of development (increase in the level of pollution and environmental degradation; improvement of the environment up to the point of inflection) and economic development have three environmental implications (scale effect, sectoral composition, technical effect) that characterize the CEK.

Inspired by the work of Kuznets (1955), Grossman and Krueger (1995), as well as Gale and Mendez (1998), explored, in developed countries, the links between environmental degradation and per capita income. Thus, Grossman and Krueger (1995) will show that the economic development of a country goes through two stages, in particular, the insufficiency of polluting emissions and the increase in pollution caused by industrialization on the one hand and awareness by the population from a certain level of income, of the importance of the environment and its consequences in the economic development of countries, on the other hand. These writers claim that the environmental Kuznets curve is the result of the relationships between per capita income and environmental degradation.

On the other hand, for Gale and Mendez (1998), the increase in the domestic product per capita reduces the level of pollution, whatever the income of the country. Thus, capital growth is correlated with increased pollution and decreases the production of labor and cultivable land.

B. Empirical Review

Many empirical studies have attempted to analyze the impact of economic growth on the environment, in particular, on the environmental Kuznets curve. For example, Dietz and Adger (2001) and Harbaugh et *al.* (2002) study the impact of economic growth on government stability, institutional quality and the environment in developed and developing countries. They reveal a negative impact of the quality of institutions on the environment in developing countries and a positive impact of these variables in rich countries. Friedl and Getzner (2003) and Biswas et *al.* (2012) from developed countries show that good governance has a positive impact on the environment. Furthermore, Jayanthakumaran et *al.* (2012) analyzed the effects of economic growth on air pollution in the context of China and India. The results of their work showed for China that per capita income, energy consumption and structural changes positively and significantly influence CO_2 emissions. For India, these results revealed an absence of causality between structural changes and CO_2 emissions, results that these authors justify by the informal nature of the Indian economy.

However, the works that have dealt with the relationship between the environment and economic growth have multiplied since 2013, in particular, Shahbaz and *al.* (2013), Bozkurt and Akan (2014), Neelakanta and *al.* (2014), Berahab (2017), Ben Saad (2017), Dargaud Fofack and *al.* (2019), Nkengfack and Kaffo Fotio (2019), Nkwenka and *al.,* (2019), Gharnit Said and *al.,* (2020) and Jun, Hamid and Zakaria (2020). Thus, based on Indonesian data, Shahbaz et *al.* (2013) analyzed the effects of economic growth on energy consumption, financial development, international trade and CO_2 emissions over the period from 1975 to 2011. The authors' results revealed that economic growth and energy consumption exert a positive and significant influence on CO_2 emissions. Conversely, openness to trade and financial development have a detrimental impact on CO2 emissions.

Bozkurt and Akan (2014) examined the correlation between Turkey's economic growth, energy use, and CO2 emissions using yearly data from 1960 to 2010. Using the cointegration tests, they arrive at the results that economic growth has a negative impact on CO_2 emissions while energy consumption has a positive impact on CO_2 emissions.

The pollution haven hypothesis was investigated by Neelakanta *et al.* (2014). Thus, these authors explored this hypothesis using data from India over the period from 1978 to 2009. Using the ARDL model and the Granger causality technique on the variables (foreign direct investment, GDP per capita, pollution), they reveal, in the short term, a bidirectional causality relationship going from GDP to Foreign Direct Investment (FDI) and from FDI to CO_2 and in the long term, they obtain a one-way causal relationship running from GDP to FDI, from GDP to CO_2 and from FDI to CO_2.

In addition, Berahab analyzes, in 2017, the effects of growing economies on the environment in Morocco over the period from 1971 to 2014. Its objective was to evaluate the environmental Kuznets curve's validity. To do this, he used the ARDL model and the explanatory variables, in particular, energy consumption and international trade. His results revealed a long-term positive relationship between GDP and CO_2 emissions, as well as a one-way causal relationship between economic growth and CO_2 emissions. According to this author, in Morocco, economic growth determines the level of emissions.

Ben Saad (2017) conducts a study of the effect of economic complexity on air pollution in 133 countries over the period from 1984 to 2014. The author uses an environmental Kuznets curve approach and the economic complexity index. Its results show that the increase in economic complexity causes the threshold of reversal of the level of pollution to be reached, as does the variation in GDP/capita. Ben Saa (2017) suggests that to reduce pollution in these countries, the mode of growth and productive specializations are as necessary as growth and the level of economic development.

Dargaud Fofack et *al.* (2019) conducted an investigation in Canada to examine the connection between air pollution and economic growth. They use econometric techniques (vector error correction model - VECM, cointegration tests, causality tests) and the period from 1960 to 2014. The results obtained from the VECM model show that in the long term, economic growth and international trade exert a positive and negative influence on air pollution, respectively. Regarding cointegration tests, these results indicate a positive and significant relationship between economic growth, international trade and air pollution. As for the causality tests carried out, the authors note an absence of causality between economic growth and atmospheric pollution.

Nkengfack and Kaffo Fotio (2019), placed within the framework of four (4) Congo Basin countries (Cameroon, Congo, Gabon, Democratic Republic of Congo - RDC), have processed, based on annual data from these countries (1978 to 2012), the impact of economic growth on carbon dioxide emissions. Using the ARDL model, these authors showed that in the long term, economic growth, energy consumption, population density and industrial activities positively influence CO_2 emissions. In Cameroon, trade openness has a negative and significant impact on CO_2 emissions. Meanwhile, in Congo, Gabon, and RDC, this impact is not significant. According to these authors, in the four (4) countries, the pollution haven hypothesis is not verified.

In a study published in 2019, Nkwenka, Ngassa Nya and Kaffo-Fotio conducted research on the effect of economic growth on the environment and trade openness in the context of Cameroon over the period from 1971 to 2011. They use the ARDL model and find that in the short term, economic growth reduces the environment. On the other hand, in the long term, economic growth increases the environment, and trade openness deteriorates the environment.

Gharnit Said et *al.* (2020) analyze the impact of foreign direct investment on carbon dioxide emissions in Morocco with a view to studying the validity of the pollution paradise hypothesis. They use the cointegration approach with time series data over the period 1960-2018. These authors show a positive long-term relationship between foreign direct investment and carbon dioxide emissions. According to the results of the Engle-Granger causality test, in the short term, FDI decreases carbon dioxide emissions and increases them in the long term.

Jun, Hamid and Zakaria (2020) question the interaction between economic growth, air pollution and trade openness in China. They use two techniques (wavelet coherence phase difference) and a causality test from Breitung and Candelon (2006). Their results indicate that trade openness exerts a positive influence on pollution and, therefore, on the existence of the « pollution paradise hypothesis ». In terms of causality tests, the results obtained show that in the short, medium and long term, trade openness positively influences carbon emissions.

Recent literature on the effect of economic growth on the environment emphasizes agrarian practices. Thus, by focusing their work on four (4) UEMOA countries (Benin, Ivory- Coast, Senegal and Togo) over the period from 1974 to 2014 and using the FMOLS and DOLS models, Fongnikin and Lanha (2020) have provided very instructive results, namely that in these countries, population density has no effect on carbon dioxide emissions. On the other hand, gross GDP per capita, agrarian practices and urbanization have a positive impact on CO_2 emissions.

The theoretical and empirical literature shows the abundant nature of the work carried out on the link between economic growth and the environment and overall mixed results. To better appreciate this problem, it is necessary to conduct an empirical study in the context of the CEMAC countries. It will allow us to confront the theoretical approaches with reality in order to highlight some elements of economic policy, allowing us to understand the problems of the impact of economic growth on the environment properly. To do this, we present the methodology and data of the research used.

III. STUDY METHODOLOGY AND DATA

We present the research methodology (A) and the data used (B).

A) Methodology

The analysis model adopted is inspired by those used in studies on the impact of economic growth on the environment, and in particular by Soytas and *al.* (2007), Ang (2008), Hamaide and *al.* (2012), Ben Saad (2017) and Ndour and Faye (2021). These authors have, for the most part, analyzed this problem by emphasizing the theoretical framework of the environmental Kuznets curve, ARDL models and Error Correction Vector Models (VECM).

In order to study the impact of economic growth on the environment in CEMAC, we will draw inspiration from the empirical work of Ndour and Faye (2021) on the effects of international trade and economic growth on the environment in Senegal. To do this, these authors use the following model:

$$CO_{2t} = \beta_0 + \beta_1 GDP_t + \beta_2 GDP^2{}_t + \beta_3 ENER_t + \beta_4 OUV_t + \beta_5 POP_t \qquad (1)$$

With CO_2, CO_2 emissions per capita (in metric tons). The variable GDP represents the rate of economic growth. GDP^2 indicates the long-term average GDP per capita. ENER stands for energy consumption per capita. The OUV variable represents the degree of trade openness. As for the variable POP, it indicates the population, which can be divided between the rural population (POPR) and the urban population (POPU).

Thus, in this model, Ndour and Faye (2021) retain carbon dioxide (CO_2) emissions as the explained variable and, as explanatory variables, the economic growth rate, the long-term average GDP per capita, the energy consumption per capita, the degree of trade openness and the population.

Thus, in our specification, we retain the following model:

$$CO_{2it} = \beta_0 + \beta_1 PIB/Hit + \beta_2 PIB^2/H_{it} + \beta_3 TDC_{it} + \beta_4 IGLC_{it} + \beta_5 TIF_{it} + \beta_6 IDE_{it} \quad (2)$$

With *t*, time index; *β*, the unknowns or parameters to be estimated. The model is estimated on a sample of six (6) CEMAC countries covering the period from 1990 to 2019.

B) Data

The values of CO_2, GDP/H, GDP^2/H, TDC, IDE and TIF are taken from the World Bank database. Those of IGLC come from the World Perspectives database. Table 1 gives the definition and source of the variables used.

Table 1: Definition and sources of variables

Variables	Definition	Sources
CO_2	Carbon dioxide emissions in metric tons per capita	WDI
PIB/H	Gross domestic product per capita in current dollars	WDI
PIB^2/H	Gross domestic product per capita squared	WDI
TDC	Exchange rate	WDI
IGLC	Global Civil Liberty Index	World Perspectives
TIF	Inflation rate	WDI
IDE	Foreign direct investment, net inflows	WDI

***Source**: Author*

The dependent variable is the environment. Based on the work of (Shafik et *al.*, 1992 Kaufmann et *al.*, 1998 and Ben Saad, 2017), we used carbon dioxide (CO_2) emissions per capita in metric tons. This variable corresponds to a colorless, odorless and non-toxic gas.

The explanatory variables are gross domestic product per capita (GDP/H) and gross domestic product squared per capita (GDP^2/H), which represent the variables of interest. Thus, the GDP/H is considered an adequate indicator to compare the economies between them. This variable is supposed to have a positive influence on CO_2 emissions (Jayanthakumaran et *al.*, 2012; Neelakanta et *al.*, 2014; Berahab, 2017; Nkengfack and Kaffo Fotio, 2019; Fongnikin and Lanha, 2020). GDP^2/H measures the average GDP per capita over the long term. This significance confirms the downward trend in environmental degradation above a certain income threshold. A positive relationship is expected between GDP^2/H and $C0_2$ emissions (Wang and *al.*, 2011; Hamaide and *al.*, 2012; Ndour and Faye, 2021).

The control variable is the exchange rate (TDC), which expresses the value of a currency in relation to another currency. A negative sign is expected between the exchange rate and CO_2 emissions (Ekodo and Nkot, 2017; Ozyurt et *al.*, 2019). The range of the Global Civil Liberty Index (IGLC) is 1 to 7. The numbers 1 and 7 stand for civil liberty and repression, respectively. The lowest scores (1 and 2) on Freedom House's civil liberties scale are assigned to countries respecting freedom of expression, the right to assembly, association, education and religion. The highest scores (6 and 7) correspond to states offering few freedoms to their citizens. The expected sign is positive. The rate of inflation (TIF) is the growth rate of the general price level over a given period. A negative relationship is expected between inflation and CO_2 emissions (Pillot and Naccache, 2022). Foreign Direct Investment (FDI), according to the literature, FDI can have positive or negative effects on the environment. They can lead to the relocation of highly polluting multinational firms, which degrade the environment, particularly in low-income countries (Shofwan and Fong, 2011; Gharnit Said and *al.*, 2020). FDI can also improve the quality of the environment by bringing modern technologies (Birdsall and Wheeler, 1993; Riti et *al.*, 2016; Solarin et *al.*, 2017; Ben Saad, 2017).

IV. MODEL RESULTS AND DISCUSSIONS

We first present the results of the specification tests of the model (A) and then the results of the econometric estimations (B).

A) Analysis Model Specification Test Results

To avoid the problems of spurious regressions, we used the stationarity tests of Levin, Lin and Chu (LLC, 2002) and Im, Pesaran and Shin (IPS, 2003) for all CEMAC countries (table 2) and the Dickey-Fuller (1981) and Phillips-Perron (PP, 1988) tests for each CEMAC country (table 3). We also used the cointegration tests of Pedroni (2001), correlation and causality in the sense of Toda-Yamamoto (1995). The results of these tests are recorded respectively in Tables 2,3,4,5 and 6.

It appears from the results of Table 2 that the variables are stationary after taking the first difference. Whether adding a trend or not, the variables remain stationary. They are, therefore, integrated into order 1. In other words, these results suggest that, for the variables, the odds of incorrectly rejecting the unit root null hypothesis on the level variables are higher than 5%: CO_2, GDP /H, GDP^2/H, TDC, IGLC, TIF and IDE. At the same time, these probabilities are almost zero when the same tests are implemented on their first differences. This leads us to conclude that the seven (7) series are assigned a unit root, or in other words, they are integrated of orders 0 and 1, respectively, in level *I (0)* and in first difference *I (1)*.

Table 2: Results of CEMAC LLC (2002) and IPS (2003) unit root tests

		In level						**In first difference**					
Variables Uroot		**St-IPS**	**Prob**	**Decision**	**St-LLC**	**Prob**	**Decision**	**St-IPS**	**Prob**	**Decision**	**St-LLC**	**Prob**	**Decision**
CO_2	Inter	-0.523	0.300	Ho Acc.	-0.222	0.411	Ho Acc.	-5.779	0.000	Ho Rej.	-4.704	0.000	Ho Rej.
	Trend	-0.003	0.498	Ho Acc	0.713	0.762	Ho Acc.	-4.506	0.000	Ho Rej.	-3.595	0.000	Ho Rej.
PIB/H	Inter	1.060	0.855	Ho Acc.	0.108	0.543	Ho Acc.	-5.441	0.000	Ho Rej.	-3.364	0.000	Ho Rej.
	Trend	0.978	0.836	Ho Acc.	1.214	0.887	Ho Acc.	-4.081	0.000	Ho Rej.	-2.012	0.022	Ho Rej.
PIB^2/H	Inter	0.683	0.752	Ho Acc.	0.369	0.644	Ho Acc.	-6.408	0.000	Ho Rej.	-4.285	0.000	Ho Rej.
	Trend	0.773	0.780	Ho Acc.	1.040	0.851	Ho Acc.	-5.091	0.000	Ho Rej.	-2.936	0.001	Ho Rej.
TDC	Inter	-2.626	0.004	Ho Rej.	-2.442	0.007	Ho Rej.	-6.378	0.000	Ho Rej.	-5.479	0.000	Ho Rej.
	Trend	-0.250	0.401	Ho Acc.	-0.453	0.325	Ho Acc.	-5.527	0.0000	Ho Rej.	-4.333	0.000	Ho Rej.
IGLC	Inter	-0.797	0.212	Ho Acc.	-0.653	0.256	Ho Acc.	-8.468	0.000	Ho Rej.	-3.896	0.000	Ho Rej.
	Trend	-1.796	0.036	Ho Rej.	-0.688	0.245	Ho Acc.	-7.011	0.000	Ho Rej.	-2.970	0.001	Ho Rej.
TIF	Inter	-7.263	0.000	Ho Rej.	-8.651	0.000	Ho Rej.	-12.09	0.000	Ho Rej.	-7.661	0.000	Ho Rej.
	Trend	-6.444	0.000	Ho Rej.	-8.006	0.000	Ho Rej.	-10.67	0.000	Ho Rej.	-4.952	0.000	Ho Rej.
IDE	Inter	-1.355	0.087	Ho Acc.	-2.067	0.019	Ho Rej.	-8.712	0.000	Ho Rej.	-6.420	0.000	Ho Rej.
	Trend	-1.991	0.023	Ho Rej.	-2.437	0.007	Ho Rej.	-7.306	0.000	Ho Rej.	-4.457	0.000	Ho Rej.

Source: *Author, from E views 9.*

Table 3: Results of ADF-PP Stationarity Tests by Country

Country	**CO_2**		**PIB/H**		**PIB^2/H**		**TDC**		**IGLC**		**TIF**		**IDE**	
Test	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**
Cameroon	I (0)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	I(0)	I(1)	I(0)
Congo	I(1)	I(0)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	I(0)	I(0)	I(1)	I(1)
Gabon	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	I(0)	I(1)	I(1)
Guinea	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	I(0)	I(0)	I(0)
RCA	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	I(0)	I(1)	I(1)
Chad	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I (1)	I(1)	I(0)	I(0)	I(0)	I(1)

Source: *author, from Eviews 9; NB. I (0) and (I) mean the degree of integration of the series.*

According to the results of Table 3, no variable is integrated with an order higher than 1, the condition under which our ARDL model ceases to be valid. In other words, these results indicate that all the variables meet the application standards of the ARDL model, with the maximum integration order of the variables being 1. Therefore, we will proceed with the cointegration test to check if these variables are cointegrated.

Table 4: Results of the Pédroni Cointegration Test (2001)

Series: CO_2 GDP/H GDP^2/H TDC IGLC TIF IDE Sample: 1990 2019 Included observations: 180 Trend assumption: Linear deterministic trend Lags interval (in first differences): 1 1

Alternative hypothesis: common AR coefs. (Within-dimension) Weighted				
	Statistic	**Prob.**	**Statistic**	**Prob.**
Panel v-Statistic	-1.022591	0.8467	-0.884104	0.8117
Panel rho-Statistic	0.654794	0.7437	1.775232	0.9621
Panel PP-Statistic	-1.587531	0.0562	-0.005781	0.4977
Panel ADF-Statistic	0.625322	0.7341	1.567299	0.9415
Alternative hypothesis: individual AR coefs. (Between-dimension)				
	Statistic		**Prob.**	
Group rho-Statistic	2.744252		0.9970	
Group PP-Statistic	0.350080		0.6369	
Group ADF-Statistic	2.315058		0.9897	

Source: *author, from Eviews 9*

The results of the Pédroni cointegration test show that the probabilities associated with the Panel PP Statistic and ADF-Statistic, as well as the Group PP-Statistic and ADF-Statistic, are not lower than the 5% threshold. These results support the null hypothesis of no cointegration. Thus, we can conclude that there is no cointegration relationship between CO_2, GDP/H, GDP^2/H, TDC, IGLC, TIF and FDI.

Table 5: Correlation Test

	CO_2	PIB/H	PIB^2/H	TDC	IGLC	TIF	IDE
CO_2	1.000000	0.855701	0.767751	0.028146	0.166450	0.126408	0.097211
PIB/H	0.855701	1.000000	0.933546	-0.033391	0.160787	0.051750	-0.047349
PIB^2/H	0.767751	0.933546	1.000000	-0.053796	0.259988	0.050047	-0.038989
TDC	0.028146	-0.033391	-0.053796	1.000000	0.030995	0.085355	0.094438
IGLC	0.166450	0.160787	0.259988	0.030995	1.000000	-0.067592	0.229515
TIF	0.126408	0.051750	0.050047	0.085355	-0.067592	1.000000	-0.062515
IDE	0.097211	-0.047349	-0.038989	0.094438	0.229515	-0.062515	1.000000

Source: *author, from E views 9.*

The results of the correlation tests carried out show that there is no correlation between the dependent variable, CO_2 dioxide emissions and the explanatory variables (exchange rate, global index of civil liberty, inflation rate and foreign direct investments); their degrees of association do not exceed 5%. On the other hand, there is a link between GDP per capita and long-term GDP per capita. These results suggest that economic growth decreases or increases CO_2 emissions in the CEMAC zone.

Table 6: Results of the Toda-Yamamoto Causality Test

Dependent variables				Explanatory or causal variables (Probabilities)			
	CO_2	PIB/H	PIB^2/H	TDC	IGLC	TIF	IDE
CO_2	-	0.0000	0.0000	0.4243	0.8258	0.0000	0.9120
PIB/H	0.3315	-	0.0287	0.2926	0.9503	0.0090	0.8339
PIB^2/H	0.0975	0.0000	-	0.3380	0.3258	0.9007	0.9092
TDC	0.8959	0.9612	0.3948	-	0.7067	0.0942	0.8258
IGLC	0.1634	0.3130	0.2109	0.8182	-	0.3855	0.3210
TIF	0.2833	0.6153	0.5697	0.1297	0.8939	-	0.3226
IDE	0.1981	0.6203	0.6733	0.8346	0.4015	0.0797	-

Source: *author, from E views 9.*

From this table, we note at the 10% threshold, two bidirectional causalities between CO_2 and GDP^2/H, but also between GDP/H and GDP^2/H. These results suggest that CO_2 emissions have an impact on long-term gross domestic product per capita and that the latter, in turn, influences CO_2 emissions. The same goes for GDP/H and GDP^2/H. We also note the existence of several unidirectional causalities (GDP/H and CO_2; TIF and FDI).

B) Results of Econometric Estimates and Interpretation

We first present the results of the estimation of the effect of economic growth on the environment (7) and then their interpretations (8).

a. Presentation of the Results

The main results of our research obtained from the ARDL model (for all CEMAC countries) are presented in Tables 7 and 8, and those obtained by the Ordinary Least Squares (OLS) model for each country are shown in Table 9.

Table 7: Results of Estimation of Short-Term Coefficients

Variable	Coefficient	Std. Error	T-Statistic	Prob. *
Short Run Equation				
COINTEQ01	-0.225398	0.086569	-2.603677	0.0104
D(PIB/H)	0.000210	0.000342	0.615132	0.5396
D(PIB^2/H)	-3.62E-08	8.32E-08	-0.435118	0.6643
D(TDC)	-0.000558	0.000494	-1.130867	0.2604
D(IGLC)	0.169839	0.174521	0.973169	0.3324
D(TIF)	-0.003169	0.001306	-2.426115*	0.0167
D(IDE)	5.26E-05	0.001485	0.035402	0.9718
C	0.257021	0.146821	1.750571	0.0826
@TREND	-0.009660	0.006140	-1.573203	0.1183

Source: *author, from E views 9, * indicates significant coefficients.*

Table 8: Results of the Estimation of Long-Term Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob. *
Long Run Equation				
PIB/H	0.000240	0.000135	1.773335 *	0.0787
PIB^2/H	-4.78E-09	9.63E-09	-0.496517	0.6204
TDC	0.000237	0.000252	0.938838	0.3497
IGLC	0.076235	0.053549	1.423649	0.1571
TIF	0.020568	0.005822	3.532548*	0.0006
IDE	0.013690	0.006908	1.981944*	0.0498

Source: *author, from Eviews 9, * indicates significant coefficients*

Table 9: OLS Model Estimation Results for Each Country

	Variables	Coefficient	T-statistic	Probability
Cameroon	PIB/H	0.000734	2.124387 *	0.0441
	PIB^2/H	-3.32E-07	-2.191522*	0.0384
	TDC	0.000639	4.045236*	0.0005
	IGLC	-0.055872	-1.363736	0.1853
	TIF	0.006330	3.636651 *	0.0013
	IDE	-0.012189	-0.934088	0.3596
Congo	PIB/H	0.000902	2.549002*	0.0176
	PIB^2/H	-1.83E-07	-2.531251*	0.0183
	TDC	0.000262	0.576787	0.5695
	IGLC	0.027153	0.314655	0.7557
	TIF	0.001402	0.407803	0.6870
	IDE	-0.016529	-2.559475 *	0.0172
Gabon	PIB/H	0.000676	2.135135*	0.0432
	PIB^2/H	-5.73E-08	-2.783969*	0.0103
	TDC	-0.001137	-0.910372	0.3717
	IGLC	0.605754	1.765687*	0.0902
	TIF	0.011502	1.211975	0.2373
	IDE	-0.154454	-3.981835 *	0.0006
Guinea	PIB/H	0.000730	3.816988*	0.0008
	PIB^2/H	-1.61E-08	-1.859179 *	0.0753
	TDC	0.006000	1.900030 *	0.0695
	IGLC	-0.261152	-1.131802	0.2689
	TIF	0.023143	1.384478	0.1790
	IDE	0.011985	0.971920	0.3408
RCA	PIB/H	9.91E-05	3.602748 *	0.0014
	PIB^2/H	-6.56E-08	-1.536203	0.1376
	TDC	5.71E-05	7.203131*	0.0000
	IGLC	0.000944	1.028720	0.3139
	TIF	-0.000181	-1.290369	0.2092
	IDE	-0.000149	-0.233330	0.8175
Chad	PIB/H	6.36E-05	1.996375*	0.0574
	PIB^2/H	-4.94E-08	-1.872964 *	0.0733
	TDC	1.10E-05	0.907969	0.3729
	IGLC	0.008466	5.029358 *	0.0000
	TIF	0.000131	0.958421	0.3474
	IDE	7.81E-05	0.463207	0.6474

b. Results Interpretation

From the results of the model (Tables 7 and 8), it appears that the catch-up towards the equilibrium value of CO_2 emissions is negative and significant at the 5% threshold with regard to COINTEQ01. This indicates an error-correction mechanism and the speed at which any imbalance between desired and actual levels of CO_2 emissions per capita is resolved within a year.

1. Interpretation of CEMAC results

The econometric results given in Table 7 indicate that in the short term, only inflation explains CO_2 emissions. Its impact is negative. When it is increased to the threshold of 5%, the degradation of the environment decreases by 0.003169 units of $C0_2$. This result was highlighted by Pillot and Naccache (2022). In the case of CEMAC, it means that the authorities of these countries have invested more in policies to reduce CO_2 emissions than in monetary policy.

Moreover, in the long term (table 8), three (3) variables affect the environment in CEMAC: gross domestic product per capita (GDP/H), inflation (TIF) and foreign direct investment (FDI). Indeed, the GDP/H exerts positive effects at the threshold of 10% on the environment. An increase in per capita income would accelerate the deterioration of CO2 emissions by 0.000240 units. This result is consistent with those of Jayanthakumaran et al. (2012), Neelakanta et al. (2014), Berahab (2017), Nkengfack and Kaffo Fotio (2019) and Fongnikin and Lanha (2020). In the context of CEMAC, it suggests that environmental degradation has been pronounced.

The « inflation rate » variable has a positive impact on CO2 emissions at the 5% threshold. A 1% increase in inflation results in an increase of 0.020568 units of CO2 emissions. This finding contrasts with the work of Pillot and Naccache (2022). Regarding CEMAC, the States of these countries have not invested in sectors exposed to CO2 emissions.

With regard to the « foreign direct investment » variable, the results obtained show positive effects on CO2 emissions. When FDI increases by 1%, CO2 emissions increase by 0.013690 units. This result agrees with those of Shofwan and Fong (2011) and Gharnit Said et al. (2020). In the case of CEMAC, it suggests that industries in these countries have failed to comply with CEMAC environmental regulations and standards.

From the results on CEMAC, it appears that the environment tends to degrade as its countries reach high-income levels, although their impact is not significant.

2. Interpretation of Results by Country

A few specific features emerge from the results in Table 9. The long-term GDP/H negatively impacts the environment in all CEMAC countries. This result is consistent with those of Ben Jebli et al. (2016), Zoundi (2017) and El Moummy et al. (2020). But, contrary to those of Hamaide and al. (2012), Wang and al. (2011) and Ndour and Faye (2021). We also find, with the exception of Cameroon, that inflation does not impact CO2 emissions in all other CEMAC countries.

The GDP/H variable positively influences CO2 emissions in all CEMAC countries at the 5% threshold, except for Chad, whose conclusive results are only slightly significant at the 10% threshold. A 5% increase in this degrades the environment by 0.00073 units for Cameroon, 0.000902 units in Congo, 0.000676 units in Gabon, 0.000730 units in Guinea and 9.91E-05 units for RCA. In Chad, a 10% increase in economic growth deteriorates the environment by 6.36E-05 units. This result has been validated by authors such as Jayanthakumaran et al. (2012), Neelakanta et al. (2014), Berahab (2017), Nkengfack and Kaffo Fotio (2019) and Fongnikin and Lanha (2020).

The « exchange rate »variable exerts a positive influence on CO2 emissions in Cameroon, Guinea and RCA. A 10% increase in the exchange rate translates into a deterioration in CO2 emissions of around 0.000639 units in Cameroon and 0.006000 units in Guinea, and a 1% deterioration in the exchange rate implies an increase in CO2 emissions of around 5.71E-05 units in RCA.

Civil liberty degrades the environment in Gabon (at the 10% threshold) and in Chad (at the 5% threshold). An increase in the latter degrades the environment by 0.605754 units in Gabon and 0.008466 units in Chad.

The inflation rate has a positive impact on the environment in Cameroon. A 10% rise in inflation degrades the environment by 0.006330 units. This result goes in the opposite direction to those of Pillot and Naccache (2020). In the context of Cameroon, this result suggests a lack of investment in sectors exposed to CO2 emissions.

In Congo and Gabon, foreign direct investment has negative effects on the environment. At the 5% threshold, an increase in FDI flows reduces CO2 emissions by 0.016529 units in Congo and by 0.154454 units in Gabon. These results are in line with the work of Birdsall and Wheeler (1993), Riti et al. (2016), Solarin et al. (2017) and Ben Saad (2017), who find a positive and significant coefficient synonymous with the degradation of the environment through foreign direct investment. Degradation is certainly linked to the relocation of polluting activities to less developed countries (Ben Saad, 2017).

V. CONCLUSION

The objective of this essay was to examine how the environment in the CEMAC has been affected by economic expansion between 1990 and 2019. The ARDL model's findings demonstrate that inflation has a short-term detrimental environmental impact. The environment is impacted throughout time by the gross domestic product per capita, inflation, and foreign direct investment. The findings also demonstrate the presence of a long-term connection between environmental sustainability and economic growth. The concept of the U-shaped environmental Kuznets curve for CEMAC is thus confirmed by the negative coefficient of long-term GDP per capita.

Moreover, the results obtained from the OLS model for each CEMAC country show, however, differentiated effects. They show that in Cameroon, the gross domestic product per capita, the exchange rate and inflation degrade the environment. In Congo and Gabon, the long-term gross domestic product per capita and foreign direct investment have harmful effects on the environment. In the Central African Republic, the gross domestic product per capita and the exchange rate have adverse effects on CO_2 emissions. Similarly, in Chad, gross domestic product per capita and civil liberty degrade the environment.

Insofar as gross domestic product per capita, inflation and foreign direct investment degrade the environment in the CEMAC, and we suggest that the public authorities of the community put in place more radical measures to support growth objectives by incorporating adaptation programs into development strategies, such as the Ethiopian initiative which provides for emission limits, increased productivity and better resource efficiency.

Given this dynamic, the CEMAC countries must make inclusive green growth their main weapon in the fight against opportunity disparities. This will involve investing in research and development, educating the public about environmental risks, and gathering and tracking environmental indicators. Each of these will help raise the standard of the community's surroundings.

At the end of this study, it should be emphasized that the results obtained deserve to be confirmed on the methodological level, whether in the specification of the model or the choice of variables. A reflection in this direction can constitute a future extension of this work.

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