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Growth and environmental quality in WAEMU countries: a panel data analysis

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Abstract

This paper analyzes the impact of economic growth on carbon dioxide emissions (ECO2) in the countries of the West African Economic and Monetary Union (WAEMU) zone over the period 1995 to 2021. After root tests unit and cointegration, we found that there is a long-term relationship between the logarithm of carbon dioxide emissions (LECO2) and the explanatory variables. By using the Pooled Mean Group estimator on several series of regressions and with a dynamic panel, our results show a positive and significant impact of Gross Domestic Product and fossil fuel consumption on CO2 emissions, and we obtain an empirical validity of an inverted "U" curve or Environmental Kuznets Curve (EKC), when we considered the heterogeneity between these states, the relationship remains positive for Côte d'Ivoire and negative for Mali. Thus, to avoid or mitigate the impact of the growth and use of renewable energies on ECO2, governments and actors working to preserve the quality of the environment must (i) resort to additive technologies in the process of production ; (ii) reduce the use of fossil fuels and turn to renewable energies which emit less pollutants into the atmosphere; and (iii) encourage green innovation with subsidies for research and development (R&D), facilitation of substitution between polluting technologies and clean technologies and the use of a carbon tax.

Keywords: *Gross Domestic Product, WAEMU, Cointegration, Pooled Mean Group, EKC*

Introduction

The economic system used by many countries today has meant that we are now faced with major environmental problems. Indeed, the industrial revolution that began in the 19th century brought about an unprecedented change in society. It resulted in the transition from a predominantly agrarian and artisanal society to an industrial society. This period will be marked by the rise of mechanization, the development of transport, and an increase in growth. If this growth has merits, it is also necessary to know that it is at the origin of several disasters in particular its impact on the environment. Indeed, it is a very complex process that results in the exploitation of natural resources and their transformation, resulting in air pollution. The work of Georgescu-Roegen (1971) emphasizes that environmental degradation is essentially due to economic activity (production and consumption), which leads to the depletion of natural resources, the accumulation of waste, and the concentration of pollutants in the air. The empirical analysis of Kraft and Kraft (1978) of the relationship between energy consumption and economic growth shows the preponderance of Energy in the production process. Moreover, analyzes by Luptfáčik and Schubert (1982) and Van Der Ploeg and Withagen (1991) showed that pollution is a by-product of production in the process of growth and energy consumption. The rapid population growth caused by a high fertility rate has favored a dramatic increase in the world population. It was around one (01) billion in 1800, two (02) billion around 1930 and three (03) billion in 1960. In 2000, it reached six (06) billion and in 2011 it exceeded seven billion of residents (Unfpa, 2011). The growth of the human population contributes to many pressures on the environment, it leads to significant costs in terms of land degradation, water pollution, overexploitation of natural resources, and deforestation. In the least developed countries (LDCs) or middle-income countries, their environmental problems are essentially linked to the use and direct management of natural resources: mines, land, water, and forests. In developing countries (DCs), the environmental problem is perceived from two angles: (i) that of the constraints imposed on the limitation of agricultural and food production because of the multiple threats that this generates, in particular, soil degradation, water, natural resources, and air quality; and (ii) that of the loss of

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biodiversity, due to large-scale pollution, as well as emissions of other greenhouse gases (GHGs) which threaten health, the climate, the ozone layer and contribute to the warming of the atmospheric layer which is the physical manifestation of climate change. To alleviate poverty, economic growth policies have been strongly supported by developing countries, notably the countries of the West African Economic Monetary Union (WAEMU). Economic growth is only possible through the development of economic activities and the intensification of productive activities. However, the latter are responsible for the release of polluting substances that deteriorate the quality of the environment. This pollution emanating from economic activities within these countries is due to the production of greenhouse gases responsible for global warming. This is the case for carbon dioxide (CO2), ozone (O3), and methane (CH4); carbon dioxide (CO2) being considered the main pollutant of all GHGs. Like all countries, Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo face environmental problems of various kinds. Thus, according to Ehrlich and Mooney (1983), population is considered to be one of the main causes of environmental degradation. Population growth can constitute a direct threat to the environment and to remedy this state of affairs, sustainable development proposes to find a balance between the current way of life (based on revenues from mining and oil extraction) and the limits of our planet. It aims to reconcile economic and social development, environmental protection, and conservation of natural resources. We have to admit that after a few years of implementing this new way of life, we can see an improvement in the quality of the environment and the pursuit of economic growth in the developed countries, while at the level of the developing countries, statistics show a low rate of growth with an upsurge in environmental degradation.

Faced with these various concerns, important questions are increasingly being asked about the future of our planet and the type of environment to bequeath to the future generation. Therefore, the main question of our research is as follows: What is the impact of economic growth on the quality of the environment in the countries of the WAEMU zone? The general objective of our research is to measure the impact of economic growth on the quality of the environment in the countries of the UEMOA zone. In other words, we seek to verify whether growth would be harmful to the quality of the environment in the countries of this zone. Specifically, this will involve: (i) First, assessing the impact of economic growth on carbon dioxide emissions; (ii) Secondly, to show the influence that consumption of fossil fuels has on carbon dioxide emissions. The interest of this paper is threefold: (1) it will contribute to fueling the debates on the relationship between economic growth and environmental quality, in particular on CO2 emissions in developing countries, in particular those in the WAEMU zone ; (2) it will alert political decision-makers to the climate emergency that this area is going through and the need for everyone to preserve the environment and natural resources; and (3) the results of this research can be used by decision-makers for the implementation of more sustainable environmental policies.

The rest of this paper is structured in two sections. First, we present the materials and methods adopted for this research. Finally, before concluding, the second section is devoted to the presentation and discussion of the results.

MATERIALS AND METHODS

Choice, conceptualization of variables, and expected signs of variable coefficients.

In the literature on the relationship between growth and the environment, the endogenous variables all correspond to indicators linked to the quality of the environment; they relate to air quality (carbon dioxide emissions and suspended particles), soil quality (fertilizer consumption), and water quality (nitrate concentration, faecal organisms, etc.). As part of our research, the emission of carbon dioxide (ECO2) is used as an indicator of the quality of the environment and is expressed in Kilotonnes (Kt). This choice is justified by the fact that CO2 is the main (in quantity) greenhouse gas (GHG) responsible for environmental pollution and climate change and that data on CO2 emissions are available and accessible in regarding the countries of the WAEMU zone. The dataset used in this research is composed of a dynamic panel of eight (08) countries over the period of 1995-2021. The data is mainly taken from the World Bank database (World Development Indicators, WDI) of the World Bank 2022. Stata 17 software is used for the econometric estimations.

Table 1: Dictionary of variables

VARIABLES	MEANING OF THE VARIABLES	DEFINITIONS	EXPECTED SIGNS
PIBH	Gross Domestic Product per capita	Expressed at a constant price in 2015 US dollars and per capita income proxy, it captures the impact of increased income on the quality of the environment. When income increases, each person's consumption increases and the impact on the environment increases. The GDP per capita had increased in recent years in the countries of the WAEMU zone and would have increased its impact on the environment.	+
PIBH2	The quadratic form of the Gross Domestic Product per capita	It is used to verify the presence of a possible threshold effect. In other words, it is to test the hypothesis of the decline of CO2 emissions when the country in question reaches high levels of income. These last two variables are called variables	-

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		of interest.	
CEF	Fossil fuel consumption	Expressed as a percentage of total energy consumption, it has been used in several studies, including the relationship between growth and the environment. Cole et al. (1997) justified this choice by the preponderance of energy in all production and transformation activities. The most polluting industries are the major consumers of fossil fuels.	+
CER	Renewable energy consumption	Expressed as a percentage of total energy consumption, it is used to measure its ability to contain or reduce carbon dioxide emissions.	-
POP	Population growth	Expressed as an annual percentage, it is an important variable that can explain environmental degradation. Indeed, a population increase in the countries of the WAEMU zone will lead to an increase in food, medical, and housing needs leading to overexploitation of the environment and an increase in polluting emissions. This analysis is shared by several authors such as Van and Azomahou (2007) who state that: "Demographic variables also require a particular attention since population is recognized as one of the main causes of environmental pollution."	+
IND	The added value of the industrial sector	Expressed as a percentage of GDP, it captures the effects of industrial activities on carbon dioxide emissions. Although the member countries of WAEMU have not succeeded in industrializing like some developing countries, there are at least a few dilapidated and polluting industrial installations within the Union. Authors like Al-Mulali and Ozturk (2015) included this variable in their model.	+
Q_INST	The quality of institutions	It is an indicator of the quality of governance. In our research, we used the quality of public administration, the score varies between 1 (low-quality institutions) and 6 (good-quality institutions). It is used in our context to find out to what extent virtuous governance could promote the implementation of pro-environmental policies capable of reducing carbon dioxide emissions. Ouattara (2021), in his paper on institutional quality and environmental pollution in ECOWAS, uses regulatory quality and efficiency which are both indicators of governance.	-

Source: Authors

Model Specification

Most studies on the relationship between economic growth and the environment in panels have been based on the model of the Environmental Kuznets Curve (EKC), taken up by Grossman and Krueger (1991). It is represented by equation (1):

$y_{it} = \alpha_i + \beta_1 x_{it} + \beta_2 x2_{it} + \beta_3 z_{it} + \varepsilon_{it}$ (1)

where y represents the environmental variable, x represents per capita income and z designates the control variables, i.e., any other variable that can influence the quality of the environment. The index i denotes the country and the index t indicates the time. α is a constant and the βk are the coefficients of the k exogenous variables. Equation (1) allows us to test all possible forms of the relationship between growth and environmental quality.

When we apply this model in our context, which is that of the relationship between growth and environmental quality in the countries of the WAEMU zone, we obtain the model which is described by equation (2):

$LECO2_{it} = \alpha_i + \beta_1 PIBH_{it} + \beta_2 PIBH2_{it} + \beta_3 CEF_{it} + \beta_4 CER_{it} + \beta_5 POP_{it} + \beta_6 IND_{it} + \beta_7 Q\_INST_{it} + \varepsilon_{it}$ (2)

The necessary condition for obtaining an inverted "U" curve or the environmental curve of Kuznets (1955) is the following: $\beta1>0$ and $\beta2<0$ and statistically significant.

In view of what has been cited above, it is important for us to know what is the empirical validity of the EKC hypothesis regarding the countries of the WAEMU zone? The answer to this question is a modest attempt to contribute to debates about the environmental Kuznets curve (EKC).

Estimation method

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Stationarity test: The objective is to examine the stationary character or not of the variables. Estimation methods only apply to stationary series otherwise we could have spurious regressions. Regarding panel data, there are two types of unit root tests: first-generation tests and second-generation tests. The most widely used first-generation tests in the literature are the Levin and Lin (1992) tests, the Levin et al. (2002), the test of Im et al. (2003); Maddala and Wu (1999) are inspired by the Dickey-Fuller (1979) tests. These tests assume of independence between the individuals in the panel. These tests have in common the null hypothesis which states that each series contained in the panel contains a unit root and the alternative holds that all series are stationary. Formally, we have: H0: $\rho = 1$ vs H1: $\rho < 1$. The application of this test requires a balanced panel, i.e., the absence of missing observation in the database. The most widely used second-generation tests are the Choi (2006) and Phillips and Sul (2007) tests. These tests attempted to lift the independence hypothesis by postulating an interdependence between individuals. We chose for this work the unit root test of Levin et al. (2002) and Im et al. (2003) which are the most powerful tests of the first generation, and which give the best results.

Cointegration test: Two variables are cointegrated if there is at least one linear combination of them such that their combination gives a stationary variable, i.e., integrated of order 0. For example, if xt and yt are I (1) and cointegrated, then Δxt, Δyt, and xt + αyt for a given α are stationary (I (0)). Using this definition and the tests developed by several researchers, we will test a possible cointegration of our variables. In general, cointegration tests are performed on time series. However, authors such as Pedroni (1999), Kao (1999) and Westerlund (2007) have proposed cointegration tests that apply to panel data. The use of cointegration techniques in panel data makes it possible to test the presence of a long-term relationship between integrated variables. One of the advantages of cointegration tests on panel data is the increase in terms of gain in the power of the test. We will review the tests developed by the authors cited above. In this thesis, we use the cointegration test of Pedroni (1999). The null hypothesis corresponds to the non-cointegration, against the alternative hypothesis of the cointegration of the variables.

Pooled-Mean Group (PMG) estimation technique, long-term relationship: After having determined the existence of a cointegration relationship, it is then necessary to efficiently estimate the cointegration relationship based on a technique of effective estimation. Two more sophisticated estimation methods are often used to estimate panel data models. The first called Pooled Mean Group or PMG involves averaging separate estimates for each panel group. According to Pesaran and Smith (1995), this estimator is designed on the assumption that the constant of the model, as well as the short-term coefficients and the variances of the errors, can differ according to the individuals, the long-term coefficients being however constrained to be identical in all countries. Pirotte (1999) also shows that PMGs provide efficient long-term estimators for a large sample. It allows parameters to be freely independent between groups and ignores potential homogeneity between groups. The second method is the usual panel method (random or fixed effects). These models force the parameters to be identical across countries and could lead to inconsistent and misleading long-term coefficients, a possible problem that is exacerbated when the period is long. One of the advantages of PMG is that it can allow the short-term dynamic specification to differ from country to country while limiting the long-term coefficients to be the same. Moreover, unlike dynamic OLS (DOLS) and fully modified OLS (FMOLS), the PMG estimator highlights the dynamics of adjustment between the short term and the long term.

RESULTS AND DISCUSSION

Through Figure 1, we already observe an upward trend in carbon dioxide emissions in WAEMU. Indeed, throughout the study period, carbon dioxide emissions are recorded in each country, these emissions are higher in certain states such as Côte d'Ivoire and Senegal with peaks of 10 619 Kt and 10 829 Kt in 2019. In this same period, we can also see significant quantities of carbon dioxide (CO2) released in Benin, Burkina Faso, and Mali with peaks above the average emissions. This is explained, on the one hand, by population growth and the evolution of the economic structure with the proliferation of industries and, on the other hand, by the form of energy and the quantity consumed by households. About Guinea-Bissau, Niger, and Togo, we observe emissions below the average. This is justified firstly by the fact that these countries are less industrialized than the others and, secondly, they have a relatively weak economic structure and low population growth, CO2 emissions being of anthropogenic origin.

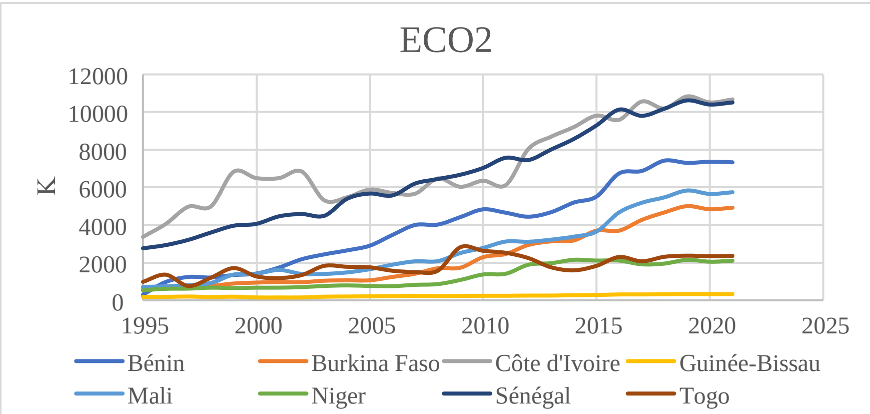

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Figure 1: Evolution of ECO2 in WAEMU from 1995-2021. Source: Author based on World Bank data (WDI, 2022)

Overall, the countries of the region have low and heterogeneous per capita income levels (Figure 2). Some States stand out positively with higher gross domestic products (GDP) per capita, this is the case of Côte d'Ivoire, the region's locomotive with a strong GDP per capita (GDP) still above 1500 US dollars (USD) over the entire period of the study with a peak of 2327.74 USD in 2019. It is part of the developing economies and is dominated by the export of cash crops, in particular coffee and cocoa, which explains the "boom" of its GDP. Senegal is ranked the second largest GDPH in the area with a GDP per capita well above 1000 USD. This growth is explained, among other things, by the significant investments made in public infrastructure and the export of fishery products. The six (06) other countries show very low GDPH over the entire study period. This is explained by the fact that they are less industrialized, a factor limiting their production capacity. Added to this is the security crisis experienced by these countries since 2012, which prevents them from recording good economic performance.

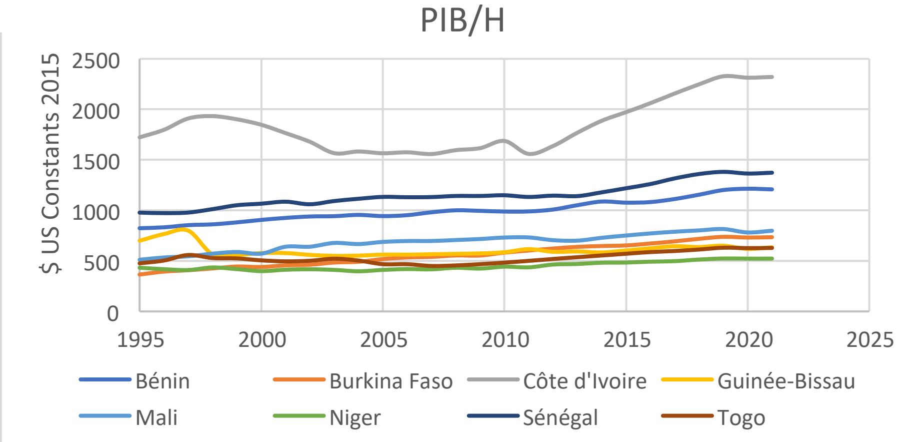

Figure 2: Evolution of GDP/H in WAEMU from 1995-2021. Source: Elaborated by the author using data from the World Bank (WDI, 2022)

Figure 3 shows an evolution of fossil fuel consumption in WAEMU countries from 1995 to 2021, it is expressed as a percentage of total energy consumption.

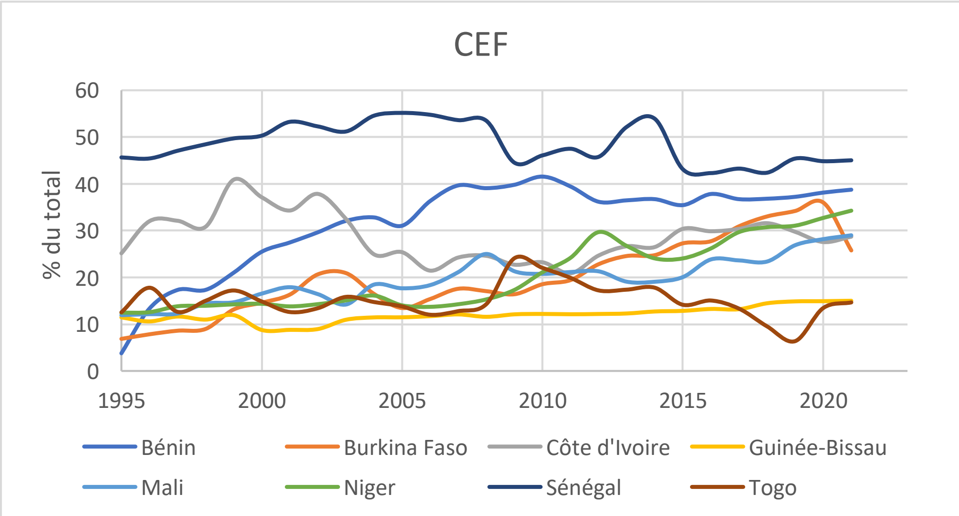

Figure 3: Evolution of CEF in WAEMU from 1995-2021. Source: Authors based on World Bank data (WDI, 2022)

We see a significant use of this form of energy in the area with Senegal in the lead for a consumption of 53%. For the seven (07) other countries, we note that Côte d'Ivoire and Benin stand out for their increased consumption of fossil energy with peaks of 40.89% in 1999 and 41.55% in 2010 respectively. In the 1990s, these countries experienced an industrialization that functioned only based on fossil fuels. Burkina Faso, Niger, Mali, and Togo showed low fossil fuel consumption, as they are countries with fewer processing industries. Petroleum products were largely used in the transport sector of these countries.

For the purposes of the econometric study, it is important to look at descriptive statistics to synthetically decipher the information contained in the data (Table 2).

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Table 2: Descriptive statistics of data in the WAEMU zone from 1995 to 2021

Variables	Obs	Mean	Std. Dev.	Min	Max
LECO2	216	7.588	1.138	5.011	9.29
PIBH	216	1.375	3.641	-29.413	11.943
PIBH2	216	15.084	60.575	0	865.142
CEF	216	24.501	12.483	3.781	55.165
CER	216	72.7	15.163	36.15	94.772
POP	216	2.838	.469	1.843	4.467
IND	216	19.319	4.034	10.905	32.591
Q_INST	216	2.757	.426	2	3.5

Source: Authors

We can notice that the variables do not have the same degree of dispersion. In aggregate, the average carbon dioxide emissions (ECO2) is 7.588 Kt with a minimum emission of 5.011 Kt observed in Guinea-Bissau and a maximum of 9.29 Kt emission observed in Côte d'Ivoire. For this variable, the recorded standard deviation is 1.138, which means that the values are grouped around the mean, and this suggests a homogeneous population. The average GDPH growth is 1.375% with a minimum of -29.413% observed in Guinea-Bissau, which reflects a recession, and a maximum of 11.943% observed in Mali, which reflects a good economic performance. As for fossil fuel consumption (CEF), the average in the union is 24.501% with a minimum consumption of 3.781% for Benin and 55.165% for Senegal. We observe for this variable a relatively high standard deviation of 12.483, which means that the values are scattered around the mean. Renewable energy consumption (CER), population growth (POP), and the added value of the industrial sector (IND) are positive in the area with an average of 72.7% respectively; 2.838% and 19.319. This already allows us to justify the existence of a relationship between the presence of industries and the consumption of fossil fuels. Regarding institutional quality (Q_INST), it has an average score of 2.757 with a very low standard deviation of 0.426. The values are less dispersed around the average, and we can say with certainty that the WAEMU countries do not have good institutions.

Table 3 highlights the correlation between the endogenous variable and the different explanatory variables.

Table 3: Correlation matrix

VARIABLES	LECO2	PIBH	PIBH2	CEF	CER	POP	IND	Q_INST
LECO2	1.000							
PIBH	0.121* (0.077)	1.000						
PIBH2	-0.150** (0.027)	-0.454*** (0.000)	1.000					
CEF	0.751*** (0.000)	0.020 (0.766)	-0.114* (0.096)	1.000				
CER	-0.746*** (0.000)	-0.044 (0.521)	0.108 (0.112)	-0.918*** (0.000)	1.000			
POP	0.050 (0.465)	0.075 (0.270)	-0.161** (0.018)	-0.012 (0.863)	0.106 (0.119)	1.000		
IND	0.459*** (0.000)	0.182*** (0.007)	-0.128* (0.060)	0.426*** (0.000)	-0.349*** (0.000)	0.290*** (0.000)	1.000	
Q_INST	0.273*** (0.000)	0.171** (0.012)	-0.070 (0.308)	0.412*** (0.000)	-0.371*** (0.000)	0.202*** (0.003)	0.488*** (0.000)	1.000

Note: ***, **, and * respectively indicate the significance level at 1%, 5% and 10%.

Source: Authors

In aggregate, we see that our variable of interest (GDPH) is positively correlated with carbon dioxide emissions (ECO2). This correlation is significant at 10%, which already allows us to say that an increase in per capita income in the WAEMU zone will be

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likely to cause ECO2, all other things being equal. The quadratic form of GDPH is negatively correlated (significant at 5%) with ECO2. This means that at a higher level of per capita income, CO2 decreases. Based on these two pieces of information, we can already hypothesize the existence of an inverted “U” curve or an Environmental Kuznets Curve (EKC) in the WAEMU zone. The correlation between the first control variable (CEF) and the ECO2 is positive and significant at 1%. In addition, renewable energy consumption (CER) is negatively correlated with ECO2. It is statistically significant at 1%, which means that renewable energies are likely to reduce the ECO2, all other things being equal. Moreover, the quality of institutions (Q_INST) and the IND variable are positively and significantly correlated at 1% with ECO2.

The scatter plots below and the regression lines provide an overview of the nature of the relationship (positive or negative) between the ECO2s and each exogenous variable.

Table 4: Graphic representation of the correlation between the endogenous variable and the explanatory variables

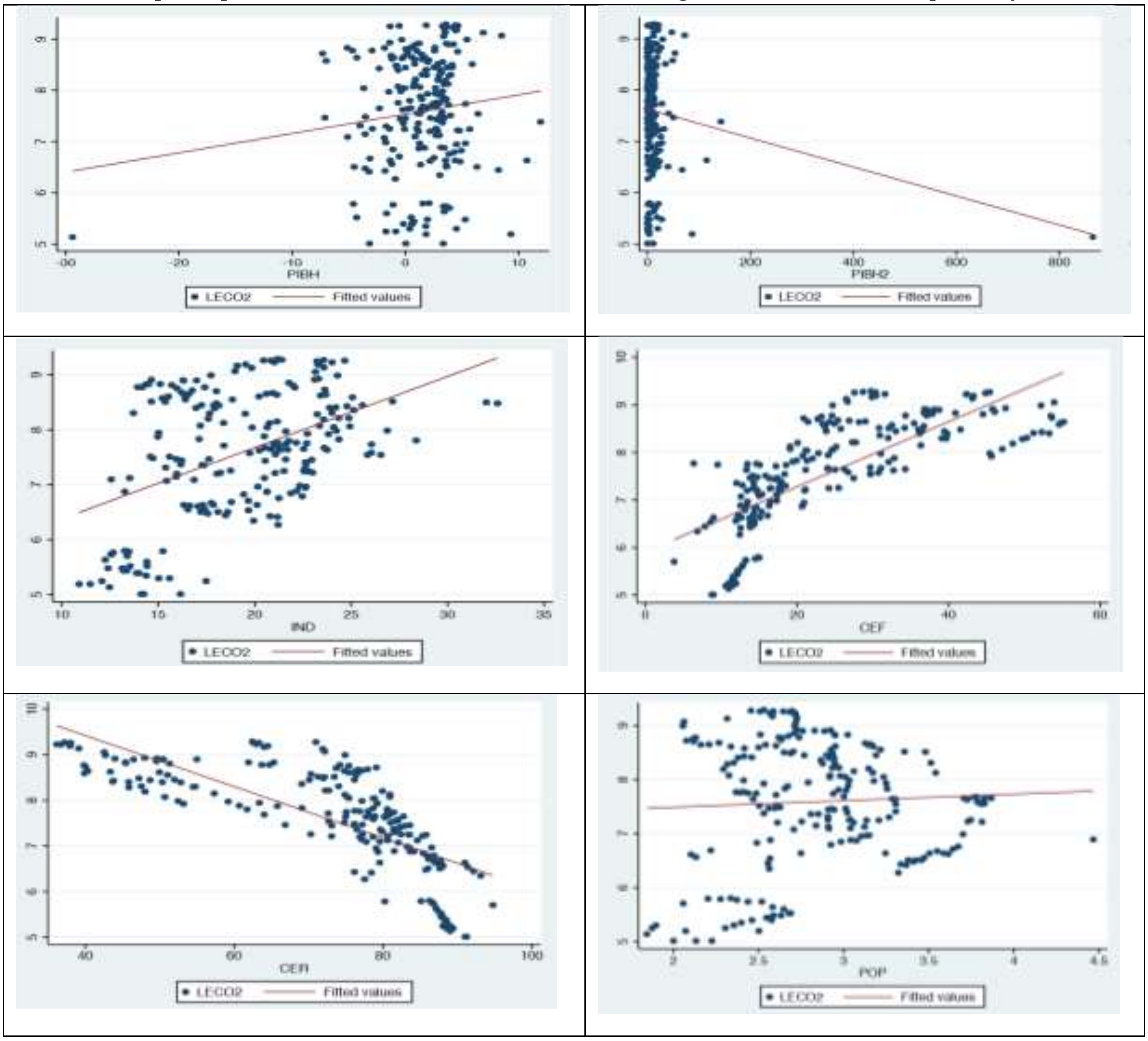

Figure 4: Scatter plot and regression line. Source: Authors

We proceeded to the implementation of hypothesis tests, estimation, and verification of the normality of our residuals. After implementation, the test results give Prob>chi2 equal to 0.0867 which is greater than 5%. We cannot therefore reject the null hypothesis (H0) then the residuals follow a normal distribution.

For the heteroscedasticity test, we use the test of Breusch and Pagan (1980) which is a powerful test based on the Lagrange multiplier. The null hypothesis (H0) of this test holds that the model is homoscedastic and the alternative hypothesis (H1) states that the model is heteroscedastic. The test result gives Prob > chi2 = 0.2866 which is greater than 5%, which does not allow us to reject H0. We therefore conclude that the model is homoscedastic. Table 5 presents the results of the unit root tests at level and in first difference.

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Table 5: Stationarity tests

	Levin-Lin-Chu			Im-Pesaran-Shin		
	In level	In first difference	Décision	In level	In first difference	Décision
LECO2	-2.3019**	-2.6945***	I (0)	-3.0395***	-8.4007***	I (0)
	(0.0107)	(0.0035)		(0.0012)	(0.0000)	
PIBH	-4.5399***	-8.0830***	I (0)	-7.0509***	-9.9815***	I (0)
	(0.0000)	(0.0000)		(0.0000)	(0.0000)	
PIBH2	-4.8389***	-9.4547***	I (0)	-6.7715***	-9.8896***	I (0)
	(0.0000)	(0.0000)		(0.0000)	(0.0000)	
CEF	-1.4305*	-5.5370***	I (0)	-2.8050***	-7.2489***	I (0)
	(0.0763)	(0.0000)		(0.0025)	(0.0000)	
CER	-1.9320**	-4.2523***	I (0)	-2.2394**	-7.4613***	I (0)
	(0.0267)	(0.0000)		(0.0126)	(0.0000)	
POP	-4.6458***	-2.9606***	I (0)	-3.3514***	-5.1651***	I (0)
	(0.0000)	(0.0015)		(0.0004)	(0.0000)	
IND	0.7179	-3.6827***	I (1)	-3.4765***	-8.3804***	I (0)
	(0.7636)	(0.0001)		(0.0003)	(0.0000)	
Q_INST	1.1055	-6.6407***	I (1)	0.9797	-7.8694***	I (1)
	(0.8655)	(0.0000)		(0.8364)	(0.0000)	

Note: ***, **, and * indicate respectively the significance threshold at 1%, 5%, and 10% of the rejection of the null hypothesis of non-stationarity. The coefficients in parentheses represent the P-Values.

Source: Authors

With the stationarity test of Levin, Lin, and Chu (2002), all our variables are stationary at level (but with different significances) except the added value of the industrial sector (IND) and the quality of institutions (Q_INST). In first difference, they all become stationary at the 1% threshold. It is the same level with the test of Im, Pesaran, and Shin (2003) except the quality of institutions (Q_INST) which is not stationary. Also in first difference, they all become stationary at the 1% threshold. The stationarity test, preferably that of Im, Pesaran, and Shin (2003) shows that our variables are stationary at level except for only one which is integrated of order 1. We tested the existence of a long-term relationship between the endogenous variable and the exogenous variables with the cointegration tests of Pedroni (1999) and Westerlund (2007) which consider heterogeneity through parameters which may be different between individuals. The results of the two tests are summarized in Table 6

Table 6: Cointegration test

		T-STATISTIC	PROB.
PEDRONI	Panel v-Statistic	-4.2430***	0.0000
	Panel rho-Statistic	3.2610***	0.0006
	Panel PP-Statistic	1.7446**	0.0405
	Panel ADF-Statistic	2.4297***	0.0076
	Group rho-Statistic	4.1251***	0.0000
	Group PP-Statistic	2.0094**	0.0222
	Group ADF-Statistic	2.6976***	0.0035
WESTERLUND	Panel v-Statistic	3.0378***	0.0012
	Group v-Statistic	6.6846***	0.0000

Source: Authors

Pedroni presents seven (07) statistical tests of which the first four (04) are based on the within dimension and the last three (03) on the between dimension. As the results show, both tests reject the null hypothesis of non-cointegration between the endogenous variable and the exogenous variables. We can therefore conclude that there is a long-term relationship

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between the logarithm of carbon dioxide emissions (LECO2) and the explanatory variables. After determining the existence of a cointegration relationship, it seems imperative for us to estimate this relationship. To do this we use the Pooled Mean Group (PMG) estimator developed by Pesaran et al. (1999) which highlights the short- and long-term effects. This estimator allows the short-term parameters or coefficients to differ between groups and constrains the long-term parameters to be identical. Table 7 presents the results of the first regression where the long-term effects are mentioned in the upper part and the short-term effects in the lower part.

Table 7: Regression 1 (PMG)

	Dependent variable: LECO2		
Variables	Coefficient	Std. Err.	P-Value
Long-term			
PIBH	0.0440**	0.0215	0.040
PIBH2	0.0002	0.001	0.842
CEF	0.0328***	0.0109	0.003
CER	-0.0508***	0.0104	0.000
POP	0.271	0.293	0.354
IND	0.0310	0.0242	0.201
Q_INST	0.593**	0.262	0.024
Short-term			
ECT	-0.0826***	0.0313	0.008
PIBH	-0.00101	0.0032	0.754
PIBH2	0.0002	0.0006	0.698
CEF	0.0166	0.0114	0.145
CER	-0.00826	0.0051	0.111
POP	0.144	0.145	0.321
IND	-0.000654	0.0029	0.826
Q_INST	0.0583	0.0605	0.335
Constant	0.6139***	0.2168	0.005
Observations	208	208	208
Country	8	8	8
Log Likelihood	306.8728	306.8728	306.8728

Note: ***, **, and * respectively indicate the significance level at 1%, 5% and 10%. Standard. Err. is the standard error, it denotes the estimate of the standard deviation of the sampling distribution.

Source: Authors

The main condition for the validity of this estimate is that the error correction term (ECT) must be negative, between 0 and 1 (in absolute value), and statistically significant. Our results confirm a long-term equilibrium relationship between carbon dioxide emissions and the explanatory variables since the error correction term is equal to -0.0826. This term indicates that the speed of adjustment is about 12.10% for a return to equilibrium. We find that gross domestic product per capita has a positive and statistically significant effect at the 5% threshold on carbon dioxide emissions. Indeed, an increase in per capita income of 1 USD in WAEMU countries results in a 4.40% increase in carbon dioxide emissions, all other things being equal. This result seems logical since if we refer to the Keynesian theory (the fundamental psychological law) of consumption, individuals tend to increase their consumption as their income increases. To meet growing consumer demands, production companies will produce more, and this will lead to unprecedented CO2 emissions. This result is consistent with that of Fongnikin and Lanha (2020). Indeed, these authors showed in their paper that the increase in per capita income resulted in CO2 emissions in four (04) WAEMU States. Fossil fuel consumption also has a positive and statistically significant impact on CO2 emissions at the 1% threshold. A one-unit increase in fossil fuel consumption results in CO2 emissions of around 3.28%. This is explained by the fact that in the countries concerned, fossil energy is used more by households and industries in their production process. This result corroborates that of Acheampong et al. (2022) who use energy consumption as the control variable to measure its impact on environmental degradation in 46 countries in sub-Saharan Africa. In addition, the consumption of renewable energies has a negative and significant effect on carbon dioxide emissions. Indeed, an increase of one unit in renewable energy consumption translates enormously into a 5.08% drop in CO2 emissions. This is because, in recent years, these countries have started to turn to the consumption of solar energy, which is abundantly available and less expensive. Moreover, the impact of institutional quality on carbon dioxide emissions is positive. We note that CO2 emissions increase by 59.3%. This is explained by the fact that in the WAEMU countries, the institutions are not at all favorable to environmental policies. Governments do not give priority to environmental concerns: they rarely take part in summits and less ratify agreements on the fight against greenhouse gas emissions. This result contradicts that of Ouattara (2021) who used government effectiveness in his paper as an indicator of institutional quality to see the impact on environmental pollution in the countries of the Economic Community of West African States (ECOWAS). He finds that better government efficiency helps reduce polluting emissions.

Table 8 presents the results of the second regression where we highlighted four (04) scenarios. The error correction term (ECT) for all scenarios is negative and statistically significant, which allows us to say that our results are credible. In the short term, we observe that all our variables are not statistically significant, which is not surprising because the objective here is to know the long-term dynamics of pollution. Scenario (1) alone measures the impact of our variable of interest (GDP) on ECO2. The result shows that GDPH has a positive effect on ECO2. Indeed, an increase in per capita income of 1 USD is accompanied by a 6.94% increase in ECO2. Scenario (2) measures the effect of the variable of

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interest and its quadratic form on the ECO2s. The idea here is to verify the existence of a threshold effect, in other words, to know in the second step the nature of the emissions if the per capita income doubles. In a scientific logic, through this scenario, we want to know if there is an Environmental Kuznets Curve (EKC) in the WAEMU countries. In the long-term, the results show that first, the increase in GDPH of 1 USD translates into a gigantic increase of 8.14% in carbon dioxide emissions and secondly, when per capita income continues to increase, we observe a slight drop in ECO2 of around 1.3%. We can therefore affirm that there is an Environmental Kuznets Curve (EKC) in the WAEMU zone even if these countries are still in a process of development.

Table 8: Regression 2 (PMG)

	Dependent variable : LECO2			
Variables	(1)	(2)	(3)	(4)
Long-term				
PIBH	0.0694***	0.0814***	0.0808*	0.0324*
	(0.008)	(0.004)	(0.050)	(0.054)
PIBH2		-0.013***		0.0008
		(0.007)		(0.910)
CEF				0.042***
				(0.000)
CER				-0.047***
				(0.000)
POP				0.3176*
				(0.089)
IND			0.1292***	
			(0.000)	
Q_INST			0.8733***	0.4303**
			(0.004)	(0.026)
Short-term				
ECT	-0.0958***	-0.1069**	-0.0657***	-0.1089***
	(0.002)	(0.016)	(0.001)	(0.003)
D.PIBH	-0.0020	-0.0006	-0.0006	-0.0011
	(0.470)	(0.860)	(0.829)	(0.722)
D.PIBH2		-0.0006		0.0002
		(0.639)		(0.711)
D.CEF				0.0167
				(0.142)
D.CER				-0.0077
				(0.111)
D.POP				0.2007
				(0.188)
D.IND			-0.0070	
			(0.325)	
D.Q_INST			0.0304	0.0269

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			(0.688)	(0.469)
Constant	0.8111***	0.9062***	0.2271***	0.8645***
	(0.001)	(0.008)	(0.001)	(0.001)
Observations	208	208	208	208
Country	8	8	8	8
Log Likelihood	198.5172	210.686	206.5665	304.6629

Note: ***, ** and * respectively indicate the statistical significance threshold at 1%, 5% and 10%. The values in parentheses represent the P-Values. ECT (error term)

Source: Authors

This result is due to the fact that when per capita income increases, individuals buy goods that are even more respectful of the environment, in particular with the acquisition of electric cooking equipment and the abandonment of wood and charcoal cooking techniques. We also note more and more the acquisition of electric vehicles which emit less CO2 than gasoline vehicles. This result is consistent with that of Lazăr et al. (2019). These authors in their paper tried to explain the relationship between economic growth and pollution in the countries of Central Europe. They find an inverted "U" relationship, i.e., an Environmental Kuznets Curve in the Czech Republic, Hungary and Latvia. Scenario (3) shows the results of the impact of our variable of interest in relation to two (02) other variables: the added value of the industry sector as a percentage of GDP and the institutional quality (quality of public administration). The idea here is to see if the government puts in place policies to regulate production at the industry level since they are the main responsible for ECO2. In the long term, there is a positive effect of industries on carbon dioxide emissions. Indeed, in the countries concerned, an increase of one unit in industrial added value necessarily translates into a 12.92% increase in ECO2. In these countries, industries still use outdated equipment and consume fossil fuels to produce; the public administration also does not put in place policies to modernize industries, which means that pollution continues to intensify. Scenario (4) presents the results of the impact of GDPH and all our control variables except the added value of the industrial sector. We observe the same effects as in regression 1, but the coefficients differ. GDPH always has a positive and significant impact at the 10% threshold on carbon dioxide emissions. A one-unit increase in per capita income results in a 3.24% increase in CO2 emissions. Fossil fuel consumption still has the same effect on CO2 emissions, it contributes significantly to carbon dioxide emissions in the area. Renewable energies as in regression 1 always contribute to reducing carbon dioxide emissions, this effect is statistically significant at the 1% level. The increase of one unit of renewable energy consumption translates into a 4.7% drop in CO2 emissions. As for population growth, it has a positive and significant effect at the 10% threshold on CO2 emissions. Indeed, an increase in population results in an increase in CO2 emissions of 31.76%. This result supports the basic idea of Van and Azomahou (2007).

Regression 3 (Table 9) highlights the nature of the relationship between environmental quality and growth in three countries of the WAEMU zone: Côte d'Ivoire, Senegal, and Mali. We have chosen these countries because they have the highest GDP per capita in the area, with Côte d'Ivoire as the driving force, followed by Senegal and finally Mali (WAEMU, 2020).

Table 9: Regression 3 (PMG)

Variables	Dependent variable: LECO2 (Kt)		
	Côte d'Ivoire	**Sénégal**	**Mali**
ECT	-0.0305*	-0.0376**	-0.1723**
	(0.086)	(0.046)	(0.046)
PIBH	0.0098***	-0.0037	-0.0209***
	(0.004)	(0.421)	(0.008)
PIBH2	-0.0005	0.0005	0.0029***
	(0.383)	(0.775)	(0.000)

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CEF	0.0131***	-0.0036	-0.0185
	(0.006)	(0.164)	(0.408)
CER	-0.0060	-0.0073**	-0.0022
	(0.152)	(0.015)	(0.926)
POP	-0.1171	-0.1457	0.2613*
	(0.350)	(0.480)	(0.088)
IND	0.0078	0.0079	-0.0033
	(0.371)	(0.467)	(0.748)
Q_INST	0.1845*	-0.0405	-0.1027
	(0.069)	(0.483)	(0.418)
Constant	0.2327	0.2237	1.1735
	(0.289)	(0.365)	(0.306)
Observations	104	104	104
Country	4	4	4
Log Likelihood	159.6613	159.6613	159.6613

Note: ***, **, and * respectively indicate the statistical significance threshold at 1%, 5%, and 10%. The values in parentheses represent the P-values. ECT (error correction term)

Source: Authors

The error correction term (ECT) is always negative and statistically significant for all three (03) states, which validates a long-term equilibrium association between our variables for each of these countries. As in the aggregate model, we note that in Côte d'Ivoire the gross domestic product per capita has a positive and statistically significant effect at 1% on CO2 emissions. Indeed, an increase in per capita income of 1 USD translates into an increase of almost 1% in carbon dioxide emissions. The same effect is found on the consumption of fossil fuels, it also results in CO2 emissions of around 1.31%. As for institutions, we note that they do not play a big role in reducing pollution since it continues to increase. In Senegal, we see that the consumption of renewable energies makes it possible to reduce pollution, this effect is statistically significant at the 5% threshold. Finally, for Mali, we observe firstly that when per capita income increases, this translates into a drop in carbon dioxide emissions and secondly, as per capita income continues to increase, there is a slight increase in emissions, this relationship is called a U-shaped relationship.

Conclusion

The results of our econometric regressions have provided some answers to our main research question on the relationship between growth and the environment. It was a question for us of measuring the impact of economic growth on the quality of the environment of the countries of the WAEMU zone. To do this, two (02) hypotheses have been formulated: the first stipulates the presence of a positive relationship between economic growth and carbon dioxide emissions and the second stipulates that the consumption of fossil fuels leads to carbon dioxide emissions. Upstream of the measurement of the empirical relationship, we approached a vast review of the literature on the subject with the teachings of the Environmental Kuznets Curve (EKC). We then developed descriptive statistics for all our variables, which allowed us to identify the main stylized facts and finally implement hypothesis tests to ensure that we had non-misleading results. Using the Pooled Mean Group (PMG) estimator on three (03) regression series, the results of regressions 1 and 2 show that economic growth has a positive and significant impact on carbon dioxide emissions in the WAEMU zone. This result confirms our first research hypothesis and corroborates that of Fongnikin and Lanha (2020). The consumption of fossil fuels also leads to an increase in carbon dioxide emissions in the area. The main rationale was that these low-income states still used fossil fuels in the production process. This result also confirms our second hypothesis. It is important to remember that this study attempted to verify the existence of an Environmental Kuznets Curve (EKC) in the WAEMU zone even if this was not part of our initial objectives. The results of regression 2 show the existence of the EKC in the WAEMU zone, which is new in

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the literature since most studies focus on demonstrating this existence in developed or transition countries. Considering the heterogeneity between states within WAEMU, the results of regression 3 show a positive and significant effect of per capita income and fossil fuel consumption on carbon dioxide emissions in Côte d'Ivoire. For Mali, the relationship found is called a "U" relationship because at first, we observe a negative impact of gross domestic product on carbon dioxide emissions, and when per capita income increases, this relationship becomes positive.

In view of these results, environmental policy recommendations emerge: To avoid or mitigate the impact of the growth and use of renewable energies on carbon dioxide (CO2) emissions, we recommend that governments and stakeholders who work for the preservation of the quality of the environment the use of additive technologies in the production process. Indeed, these technologies are based on installations and equipment designed to combat carbon dioxide emissions. These States must also reduce the use of fossil fuels and turn to renewable energies that emit less pollutants into the atmosphere. In addition, they will be able to encourage green innovation through several incentive instruments such as subsidies for research and development (R&D), the facilitation of substitution between polluting technologies and clean technologies and not excluding the use of a tax carbon.

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