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CARBON DIOXIDE EMISSIONS AND ECONOMIC GROWTH IN ECOWAS: A COMPARATIVE ANALYSIS USING THE KUZNETS ENVIRONMENTAL CURVE APPROACH

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Abstract

The Kuznets environmental curve establishes an inverted U-shaped relationship between per capita income and carbon emissions. This study conducts a comparative analysis of ECOWAS countries over the period 1980-2018 by using the Kuznets environmental curve approach. The empirical results obtained from a descriptive analysis of data and a vector model of the environmental curve of ECOWAS countries generally show the existence of a long-term U-shaped relationship, thus invalidating the hypothesis of inverted U-shaped curve of Kuznets. More particularly, for poor ECOWAS countries (Niger, Sierra Leone, Mali, Burkina Faso, Liberia, Togo, Guinea Conakry, Guinea Bissau, and to a lesser extent Benin and Gambia), per capita carbon dioxide emissions decrease when per capita income increases and for countries with higher per capita income (Ghana, Senegal, Cape Verde, Nigeria and Cote d'Ivoire), an improvement in the standard of living leads to an increase in the per capita carbon dioxide emissions. The study suggests, among other things, that a common policy of environmental protection be implemented within ECOWAS.

Keywords: Carbon dioxide; Economic growth; ECOWAS; Kuznets environnemental curve

INTRODUCTION

The different types of human activities in terms of work and transport are at the origin of the degradation of the environment which is characterized by the emission of greenhouse gases such as carbon dioxide (CO_2), nitrate dioxide (NO_2) and methane (CH_4). In fact, the combustion of fossils, which are mainly coal, petroleum products and natural gas, as well as deforestation, agriculture, livestock, the artificialization of soils and the combustion of wood is responsible for the emissions of CO_2 according the World Meteorological Organization, 2012 (WMO), the NO_2 emissions being largely from industrial agriculture. The CH_4 releases are mainly due to ruminants, flooded areas such as rice fields, agriculture and cattle breeding. For example, in Asia, 44 percent of CH_4 emitted is linked to agricultural activities (FAO, 2016). Likewise, in France, activities linked to agriculture and forestry alone are believed to be responsible for 89 percent of CH_4 emissions according to the Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique, 2013 (CITEPA). As part of the impact of Covid-19 on CO_2 emissions, global CO_2 emissions from fossil fuel combustion and cement production have decreased by 1,048 million tons of CO_2 ($MtCO_2$) over the first four months of the year 2020, which is 8.6 percent less than the same period in 2019 (le Quéré et al., 2020), and that global GDP could decline as much as 0.9% in 2020, which could translate into a reduction of almost 10 percent in CO_2 emissions. It is then obvious that the Covid-19 pandemic has led to a drop in CO_2 emissions due to a decrease in economic activities.

Thus, understanding the impact of economic growth on the quality of the environment becomes crucial in a global context where climate change is becoming more and more a major concern. The relationship between economic growth and the environment has been empirically modeled by the economic literature. The majority of these studies have been formulated using the Kuznets Environmental Curve (KEC) approach. The idea of the KEC in reality is that the solution to environmental problems is simply economic growth. The rich countries would pollute less since they had sufficient financial means to devote part to improving the environment. Hence, the KEC suggests that there is an inverted U-shaped relationship between environmental degradation and per capita income. At the start of the growth process, pollution and environmental degradation will increase and then, beyond a certain level of per capita income, economic expansion will translate into an improvement of the environment. In other words, at the start of the industrialization and development process, environmental damage will increase as a result of the intensive use of natural resources and polluting production technologies. However, after a certain level of economic expansion, development will result in the use of cleaner technologies and a higher value placed on environmental quality. Therefore, the relationship between income per capita and a measure of pollution can be represented by an inverted U-curve, like the original Kuznets curve. In fact, Kuznets (1955) studies the relationship between social inequalities and the level of development of a country. He finds that this relationship can be represented by a graph in the shape of an inverted U where the y-axis represents inequalities and the x-axis represents the time or the per capita income. The basic hypothesis of Kuznets (1955) was that income inequalities among citizens naturally decrease along the development path.

From this inverted U-shaped relationship between pollutants and per capita income, we ask ourselves if this relationship is always verified or if it is a function of the time and the countries or if it varies from one country to another. More clearly, we are going to check if this relationship is the same for the developed countries as for the developing countries, specifically for the Economic Community of West African States (ECOWAS).

Hence, in the case of developing countries located in the south of the Sahara, this study analyzes the inverted U-shaped relationship between CO2 emissions and economic growth for the countries of ECOWAS .The community is made up of two zones which are the West African Economic and Monetary Union (WAEMU) zone composed of Benin, Burkina Faso, Ivory Coast, Guinea Bissau, Mali, Niger, Senegal and Togo. These eight countries have in common the use of the CFA Franc linked to the monetary cooperation agreements between France and the union which agreements have been theoretically and symbolically terminated since May 20, 2020. The second zone includes five countries resulting from the English colonization that are Gambia, Ghana, Liberia, Nigeria and Sierra Leone and two other countries, Cape Verde and Guinea Conakry. These seven countries have each their own currency. The fifteen ECOWAS countries aim at economic and monetary integration with eventual the creation of a single currency, the ECO.

Thus, through an approach of the KEC, a panel data study is conducted to analyze the relationship between economic growth and environmental pollution from CO2 emissions within ECOWAS in order to allow policy-makers to consider solutions specific to each country when the relationship between economic growth and the environment differs from one country to another (Mouhamadou, 2007).

The rest of the work is structured as follows: section 2 addresses the literature review; Section 3 presents the methodological approach, the results of which are comparatively analyzed in section 4. Section 5 finally concludes the study.

LITERATURE REVIEW

The relationship between environmental conditions and economic growth has instigated a great interest as well for the economists as the policymakers. Numerous studies have shown that the degree of environmental degradation and economic growth follow an inverted U-shaped relationship. This relationship was subsequently used by Grossman and Krueger (1995) who were able to explain the relationship between the different environmental indicators and the income level of a country. They concluded that no evidence shows that the quality of the environment is gradually deteriorating with the growth of the country. On the contrary, for most indicators, economic growth enters an initial phase of deterioration, followed by a phase of improvement. As for Selden and Song (1994) they hypothesized that the relationship between economic growth and environmental quality, whether positive or negative, is not fixed along a path of development of the country. The relationship can change sign depending on whether a country reaches an income level at which the demand of citizens is to provide efficient infrastructure and a cleaner environment. Hence, the denomination of the KEC which relates the degree of pollution and the level of per capita income of a nation. According to the hypothesis of the KEC, economic growth certainly tends in a first phase to increase environmental degradation to a pollution threshold, then, thanks to the increase in per capita income, the environmental impact of growth decreases. Indeed, as soon as a nation exceeds a given wealth threshold, it is able to devote a larger part of its capital to Research and Development activities. Therefore, these activities tend to minimize the ecological impacts of production (Pezzey, 1989; Selden and Song, 1994).

However, the KEC hypothesis has sparked debate and criticism stemming from the growth controversy and related policies (Dinda, 2004). Initially, it was hypothesized that a high level of per capita income would accentuate the degradation of environmental quality and then the hypothesis that, high levels of income can reduce environmental degradation. (Beckerman,1992). Thus, according to Bhagawati (1993), economic growth may be a prerequisite for improving the quality of the environment. This allows Panayotou (1997) to assert that economic growth can be a powerful channel for improving the quality of the environment in developing countries.

The KEC hypothesis is taken from an economic model in which there is no feedback of the quality of the environment on economic growth. The degradation of the quality of the environment is recognized to have perverse effects on the quality of life but not directly on the possibilities of production (Stern, et al., 1996). In the absence of this feedback, growth may be a solution to access a better quality of life in developing countries when the KEC hypothesis is satisfied. However, the assumption that at a high level of income environmental degradation in a country decreases has been the subject of controversy. For example, Dinda (2004) criticized this approach because the reverse direction of this relationship may exist since, according to the author, emissions may be the cause of the increase in GDP. Likewise, Dinda and Coondoo (2006) and Richmond and Kaufmann (2006) studied the causality between GDP and CO2 emissions and found no relationship. Akbostanci et al. (2006) applied two time series and panel data techniques to test the KEC hypothesis for carbon emissions in Turkey and their results are not conform with the principles of this hypothesis. Lise (2006) concluded that the relationship between carbon emissions and income in Turkey is linear. Likewise, the World Bank report (1992), which is based on the work of Shafik and Bandyopadhyay (1992) only verified the KEC type relationship for a limited number of indicators, which does not allow us to admit that economic growth is always an answer to the ecological problem.

According to Ang (2008) who studied the dynamic relationships between economic development, pollutant emissions and energy consumption for the case of Malaysia, the causality is bidirectional between income growth and increase in long-term energy use which implies that part of the economic growth is ensured by industrial growth using energy intensively. For the income-pollution relationship, there is a unique sense of causality from increasing CO2 emissions to long-term economic growth.

Several authors have used elasticity functions to study the interactions between income and environmental quality. For example, McConnell (1997) examined the role of income-demand elasticity of the quality of the environment to interpret this relationship in KEC-type models and this by adapting a statistical model for an infinite number of households. He noticed that pollution is intensified by the consumption of energy and slowed down when the latter decreases. Adededji (1994) found that the demographic explosion results in an increase in energy consumption, the extension of parking lots and the development of industrial activities which lead to various kinds of pollution including that related to the atmosphere. Wang et al. (2011) have shown that industrialization increases CO2 emissions in China and that the phenomenon of urbanization can also degrade the quality of the environment.

Other empirical studies have extended their analysis to other explanatory variables in order to determine their relationships with the environment. The work of Shafik and Bandyopadhyay (1992) focused on testing the KEC hypothesis for about ten indicators. They determined several forms of relationship of these indicators with income. Only the variable, concentration of pollutants in the air, describes with income an inverted U-shaped relationship with a turning point between $3000 US and $4000 US (in 1985 $US). The other indicators describe a neutral relationship (deforestation), a positive linear relationship (the quality of rivers), and a negative linear relationship (lack of drinking water and lack of urban sanitation). On the other hand, in the case of CO2 emissions, the results are ambiguous.

Selden and Song (1994) tested the KEC for four pollutant emission variables, sulfur dioxide (SO2), NO2, Suspended Particulate Matter (SPM) and CO2. This study showed that the KEC hypothesis holds true for all environmental variables in developed countries. On the other hand, the turning points are largely distinct for each type of pollutant. Also, List and Gallet (1999) showed that between 1929 and 1994, the trajectory of SO2 and NO2 emissions per capita, relative to income per capita, was an inverted U- shaped curve in the United States. However, Cole et al. (1997) analyzed the relationship between income and several environmental indicators including SPM, SO2, NO2, CH4 emissions, etc. They found that the KEC is only satisfied for certain pollutants, which have a locally determined impact. On the other hand, for environmental indicators which have a more global or indirect impact on the health of populations, the relationship with income is positive and the turning point is very high. It emerges from their conclusions that implicitly the CO2, which is the main greenhouse gas and whose effects extend widely in time and space, would not satisfy the KEC and that the turning point would be high otherwise.

The results of the KEC for CO2 in the literature are not unanimous. These results are generally influenced by the period of the study, the level of development of the economies studied, the econometric techniques used, and the degree of homogeneity of the sample, the inclusion of control variables or by the quadratic form or cubic of the KEC model. Indeed, Shafik (1994) found that the relationship between GDP and CO2 is positive between 1960 and 1990 in a panel of 149 countries. The inflection point in the positive relationship of CO2 emissions with GDP, thus satisfying the KEC, did not take place, unlike the results obtained by Holtz-Eakin and Selden (1995) in a panel of 131 countries between 1951 and 1986. However, the turning point for the latter is very high ($35428 US). Their results are similar to those of Cole et al. (1997) concerning CO2 emissions and for which the KEC is satisfied with a very high turning point. This leaves some doubt about the change in the trajectory of CO2 emissions as income changes.

Another category of research has focused on the introduction of control variables into the KEC model. These variables are supposed to influence the product and / or the pollution. These additional explanatory variables are generally related to the policy (Torras and Boyce, 1998), the product structure (Panayotou, 1997), trade (Suri and Chapman, 1998) and the energy variable (Jobert and Karanfil, 2010).

Grossman and Krueger (1993, 1995) used a random effects model to analyze the evolution of a range of environmental indicators for several countries. The sample comprises several countries at different stages of development in order to represent the different geographical characteristics of the world. Their results prove the inverted U shape for water pollution and SO2. The values of the turning points alternate between $4000 US and $5000 US (in 1985 $US).

The results of the work of Cropper and Griffth (1994) on deforestation and carried out on a sample of 64 countries for the period 1961-1991 indicated an inverted U-curve for Africa and Latin America. However, the inflection point values found by this study are higher than the per capita income of the majority of the countries belonging to these two regions. Therefore, it seems that the shape of the KEC is determined by some countries whose per capita income is higher than the average of the countries of the studied region.

Studies have found reasonable turning points. Schmalnesee et al. (1998), in a panel of 141 countries between 1951 and 1986 established the turning point between $10,000 US and $17,000 US per head. For Galeotti and Lanza (1999a, 1999b), the turning point is instead between $15,000 US and $22,000 US per head. Panayotou et al. (1999), with a sample of 150 countries between 1960 and 1992 found the turning point to be between $11,500 US and $17,000 US per capita. The income elasticity of CO2 emissions is low (often negative) and when per capita income is low, it increases with income up to a threshold level (the turning point between $10,000 US and $22,000 US), then decreases. This could be explained by the structural change in the economies.

Some studies have shown the effect of the sample of the considered economies on the results of the estimate KEC, mainly the level of turning points. In fact, the studies which, on the one hand, took into account a representative (cosmopolitan) sample have generally found a monotonic relationship between the different types of pollutants and income. In other words, the KEC is not verified. In contrast, the KEC is verified on more uniform or homogeneous samples. This is the case for studies of OECD countries where the economies are structurally similar (Dijkgraaf and Vollebergh, 1998, Selden and Song, 1994, Cole et al. 1997). On the other hand, a sample of economies with fairly large income level differences determines a higher turning point than a sample of economies with very similar income level differences (List and Gallet, 1999, Stern & Common, 2001, Lefohn et al., 1999). However, Hill and Magnani (2002), with a panel of 156 countries showed that the KEC is satisfied, but when they estimated the KEC by group of countries with high, middle and low per capita income, the emissions of CO2 seem to increase with income for all groups, meaning that the KEC is not satisfied. Gianni et al. (2010) found an inverted N-shaped relationship between GDP and CO2 for 55 non-OECD countries with electricity consumption as a control variable.

In order to clarify the relationship between the environment and trade openness, Grossman and Krueger (1993), have shown through their study three main effects of the liberalization of economic trade: the scale effect which refers to the increase in environmental pollution following the increase in production; the composition effect which captures the effect of a change in the production structure on the environment; and finally the technical effect which captures the impact of technical progress on the quality of the environment. Therefore, any improvement in the technical coefficient will result in a deceleration in the rate of growth of environmental degradation. Also, the implementation of rigorous environmental regulations, due to environmental awareness will reduce environmental pressures. Grossman and Krueger (1993) found that these effects act differently depending on the level of development of the countries. Thus, in low-income countries, the effect of scale combined with the effect of composition (due to specialization in polluting industries) dominates and accelerates environmental degradation. However, as countries get richer, they generate significant income allowing them to invest in the least polluting technologies, hence the improvement of the technical coefficient and a consequent reduction of environmental damage

METHODOLOGY

The econometric model

Our study aims to model CO2 emissions per capita considered as indicators of environmental quality. Thus, a vector model of the Kuznets inverted U-environmental curve of CO2 emissions is developed for ECOWAS countries. Most of the authors, *a priori,* have found a long-term relationship between CO2 emissions per capita and level of development of countries. The equation of our long-run model of the semi-log linear form is presented as follows:

$$co2h_{jt} - \sum_{i=0}^{N} \beta_i X_{ij,t} = 0 \qquad (1)$$

$$X_{.j} \in \left\{ \ln GDPh, (\ln GDPh)^2, En, Ind \right\}$$

In this equation, the dependent variable *CO2h* represents per capita carbon dioxide emissions. Regarding the independent variables, *GDPh* is income per capita, (*GDPh*)^2 is the square of income per capita, E*n* is energy consumption and *Ind* is industrial *GDP*. Also, *n* is the number of model variables, *j* is the variable of ECOWAS country *j*, *t* is the time variable, η_{jt} represents the error terms of the model and β_i are the direct parameters to be estimated whose signs are important in the interpretation of the environmental curve.

The short-term equation is related to the long-term equation of the form:

$$\Delta co2h_{jt} = \lambda_j (co2h_{jt-1} - \sum_{i=1}^{N} \beta_i X_{ij,t-1}) + \sum_{i=1}^{N} \sum_{k=0}^{p} \theta_k \Delta X_{ij,t-k} + \eta_{jt} \qquad (2)$$

The importance of this relationship comes from the speed of adjustment which is defined by λ_j and assumed to be homogeneous for all the countries in the panel. For this relationship to be valid, this parameter must be negative. The study of the analysis of CO2 emissions in the environment and its links with economic performance measured by economic growth places particular emphasis on the variables X_{ij} that can facilitate the understanding of CO2 emissions on economic growth. Selden and Song (1994), Holtz-Eakin and Selden (1995) in their analysis of the relationships between GDP and CO2 over a set of countries used per capita CO2 as the variable of interest and the GDP variables and some control variables as explanatory variables.

Thus, the explained variable *CO2* constitutes the CO2 emissions per capita and considered as the indicators for measuring the quality of the environment in ECOWAS countries. With respect to the explanatory variables, the *GDP* per capita, whose indicator is *GDPh*, represents the value of the Gross Domestic Product divided by the total population. This income corresponds to the income of the ascending phase of the KEC. Since most of the ECOWAS countries are developing countries, the low level of per capita income in these countries would lead economic agents to prioritize their average individual well-being over the quality of the environment, Hence, the expected positive sign. *GDP* per capita squared (*GDPh2),* measures the average *GDP* per capita over the long term. This income corresponds to the income of the descending phase of the KEC. From a theoretical point of view, the transfer of clean technologies from developed countries to developing countries, the existence of an ability to pay to preserve the environment, as well as the existence of strict environmental standards will result in the long term in a reduction of the pollution intensity per unit of good produced, hence, the expected negative sign. The control variables chosen for our model are energy consumption and industrial *GDP*. The consumption of energy (*En)* or the use of energy is an important source of CO2 emissions. In Africa in general, and more particularly in ECOWAS, the consumption of energy comes from biomass-energy which causes deforestation and decreases the potential for removal of CO2 from the atmosphere. Hence, the variable *En* is expected to have a positive impact on CO2 emissions. The Industrial GDP is the value added of the secondary sector divided by the GDP at the end of a year. Approximated by the indicator *Ind*, this variable is introduced to take into account the impact of industrial activities on the quality of the environment in ECOWAS countries. The more these industrial activities increase, the greater the environmental pollution.

Estimation of the model

Before starting to estimate the model itself, the time series literature recommends a number of steps in order to avoid spurious regressions. As pointed out by Pedroni (1999), the analysis of panel data in the absence of stationarity tests does not lead to spurious regressions as in the case of one-dimensional time series. The only real problem with panel data is a problem of statistical inference. To stay in the scientific dimension and in the logic of statistical inference, the study approach also involves implementing stationarity tests in panel data. The test of Im, Pesaran and Shin (1997, 2003) is considered. With respect to the Co-integration test, the Westerlund Co-integration test (2007) is preferred to the Pedroni (1999) test.

The unit root test in IPS panel data

Just like the unit root tests of ADF and PP, the tests are done on the following model:

$$\Delta x_{it} = \alpha_i + \tau_i t + \rho_i x_{it-1} + \sum_{j=1}^{h_i} \beta_{ij} \Delta x_{it-j} + \varepsilon_{it} \quad (3)$$

For *i = 1, …… .N* and *t = 1,… .T,* with $x \in \{\ln GDPh,, En, Ind\}$, *i* and *t* correspond to the country and time dimensions respectively, ρ_i is the autoregressive root and h_i is the number of delays. The null hypothesis of the test is that each series of the panel is a non-stationary process, that is $H_O{:}\rho_i = 0 \ \forall i$. This hypothesis assumes heterogeneity of x_{it-1} and the associated alternative hypothesis is as follows:

$H_1{:}\ \rho_i < 0$ for at least one individual i. This test is based on the ADF test approach and defined the t statistic as a simple average of the individual statistic of ADF statistics. For any individual *i*,

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{\rho i} \quad (4)$$

The $t_{\rho i}$ are the ADF statistics assumed independently and identically distributed (iid) and having a finite mean and variance. Im, Pesaran and Shin (1997, 2003) proposed the following unit root test statistic applicable to the heterogeneous panel in cross section:

$$W_{[t-bar]} = \frac{\sqrt{N}\left(\bar{t} - \frac{1}{N}\sum_{i=1}^{N} E\left[t_{iT} \middle| \rho_i = 0\right]\right)}{\sqrt{Var\left[t_{iT} \middle| \rho_i = 0\right]}} \quad (5)$$

Where $E\left[t_{iT}\middle|\rho_i = 0\right]$ and $Var\left[t_{iT}\middle|\rho_i = 0\right]$ correspond to the mean and variance tabulated by Im, Pesaran and Shin (1997, 2003). The statistics $W_{[t-bar]}$ follows a standard normal distribution when *N* and *T* tend to infinity.

The Westerlund Co-integration test (2007)

The idea of the Westerlund (2007) Co-integration test is to test for the absence of Co-integration by determining whether there are any corrections of errors between individual panel members or for the entire panel. We consider the following error correction model where all the variables have integrated of order 1:

$$D y_{it} = c_i + a_{i1} D y_{it-1} + a_{i2} D y_{it-2} + \ldots + a_{ip} D y_{it-p} + \ldots + b_{io} D x_{it} +$$

$$b_{i1} D x_{it-1} + \ldots b_{ip} D x_{it-p} + \ldots + a_i (y_{it-1} - b_i x_{it-1}) + \mu_{it} \qquad (6)$$

a_i is the estimate of the long-run equilibrium adjustment speed

$y_{it} = -\frac{b_i}{a_i} x_{it}$ for the *i* series. (7)

Westerlund (2007) defined statistics Ga and Gt which test the following hypotheses:

$H_O : a_i = 0 \ \forall i$ versus $H_1 : a_i < 0$ (For at least one individual) (8)

The rejection of the null hypothesis can be understood as evidence of Co-integration of at least one of the individuals or countries (in this case). Statistics Pa and Pt defined by the authors make it possible to test the same hypotheses where the rejection of the null hypothesis is an evidence of Co-integration in all the panels. These statistics are calculated in Table 1 which makes it possible to reject the hypothesis of non-Co-integration.

Nature and source of the data

The secondary data used in this study are quantitative and annual. They come from the World Bank database and cover the period 1980 - 2018 for a panel of 15 ECOWAS countries, including eight WAEMU countries. The period is long enough to judge and test the existence of a long- term relationship between per capita CO2 emissions and economic growth in ECOWAS. The 1980s were marked by a period of economic boom in ECOWAS, mainly in the WAEMU countries. The end of the study period (2018) is justified by the availability of recent data.

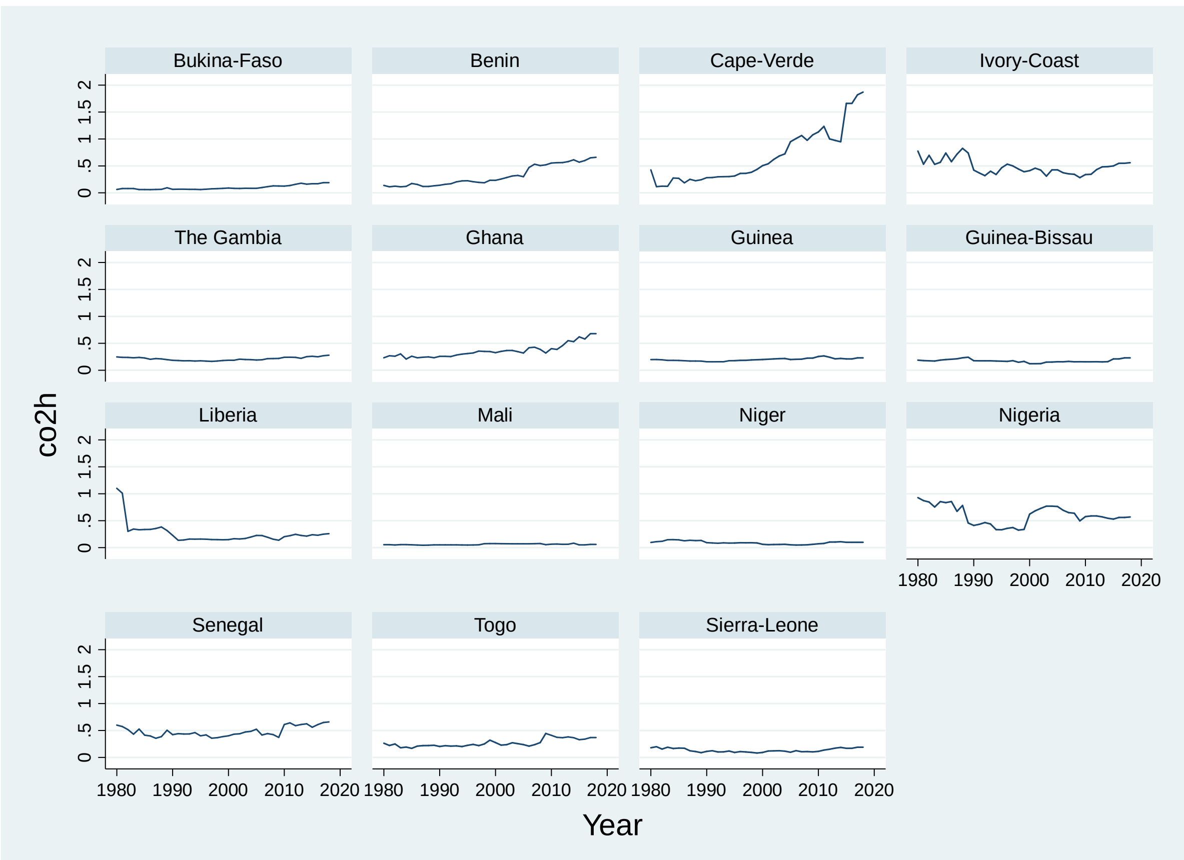
ANALYSIS AND DISCUSSION OF RESULTS

Descriptive analysis

Evolution of the carbon dioxide emissions per capita

As shown in Figure 1, per capita CO2 emissions in ECOWAS countries have shown similar trends except in Cape Verde where emissions have a remarkably increasing trend compared to Nigeria. CO2 emissions per capita also experienced moderate growth from 2010. On the other hand, in Liberia, the trend has been descending since the 1980s. Nigeria, however, experiences an alternation between a fall, an increase and then stability in the last recent years.

Figure 1: Evolution of CO2 emissions per capita

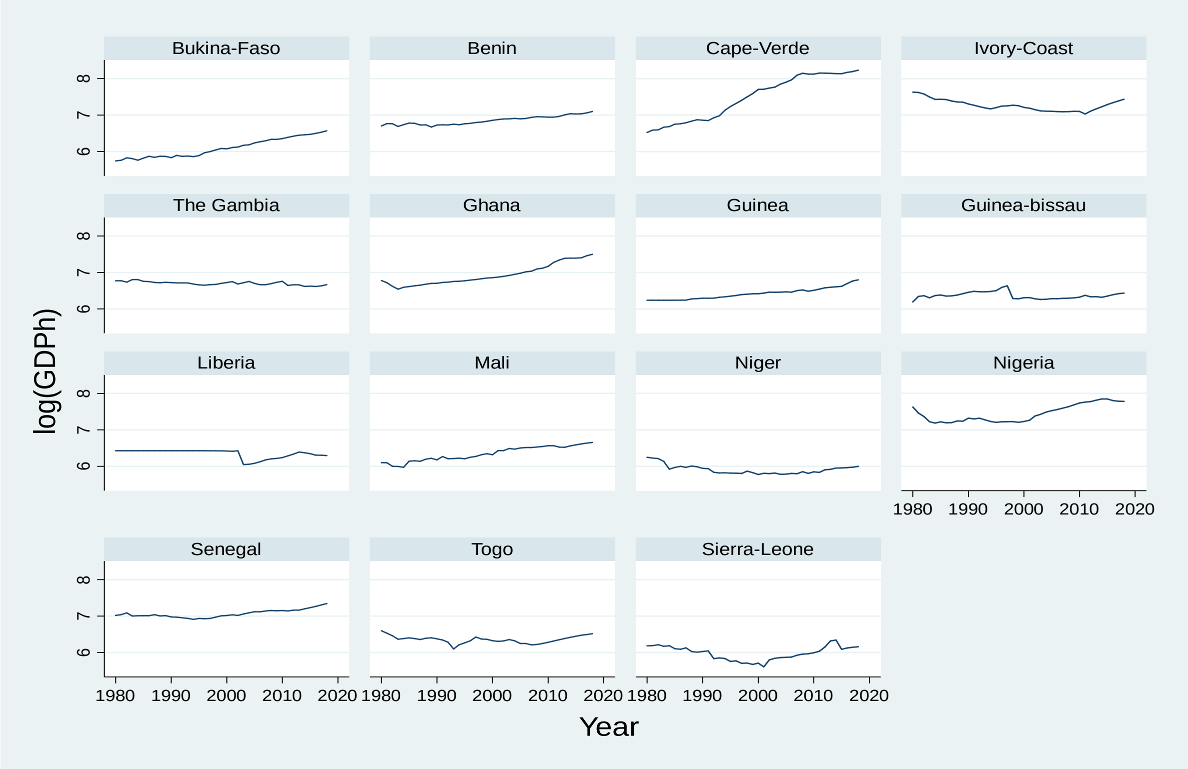


Source: Authors' illustration, WB data, 2020

Evolution of the Gross Domestic Product per capita

For the ECOWAS countries, the GDP is growing, in particular in recent years. However, GDP experienced a slight decline during the years 2000s in Ivory Coast, Nigeria, Sierra-Leone and Niger as shown in Figure 2.

Figure 2: Evolution of the Gross Domestic Product



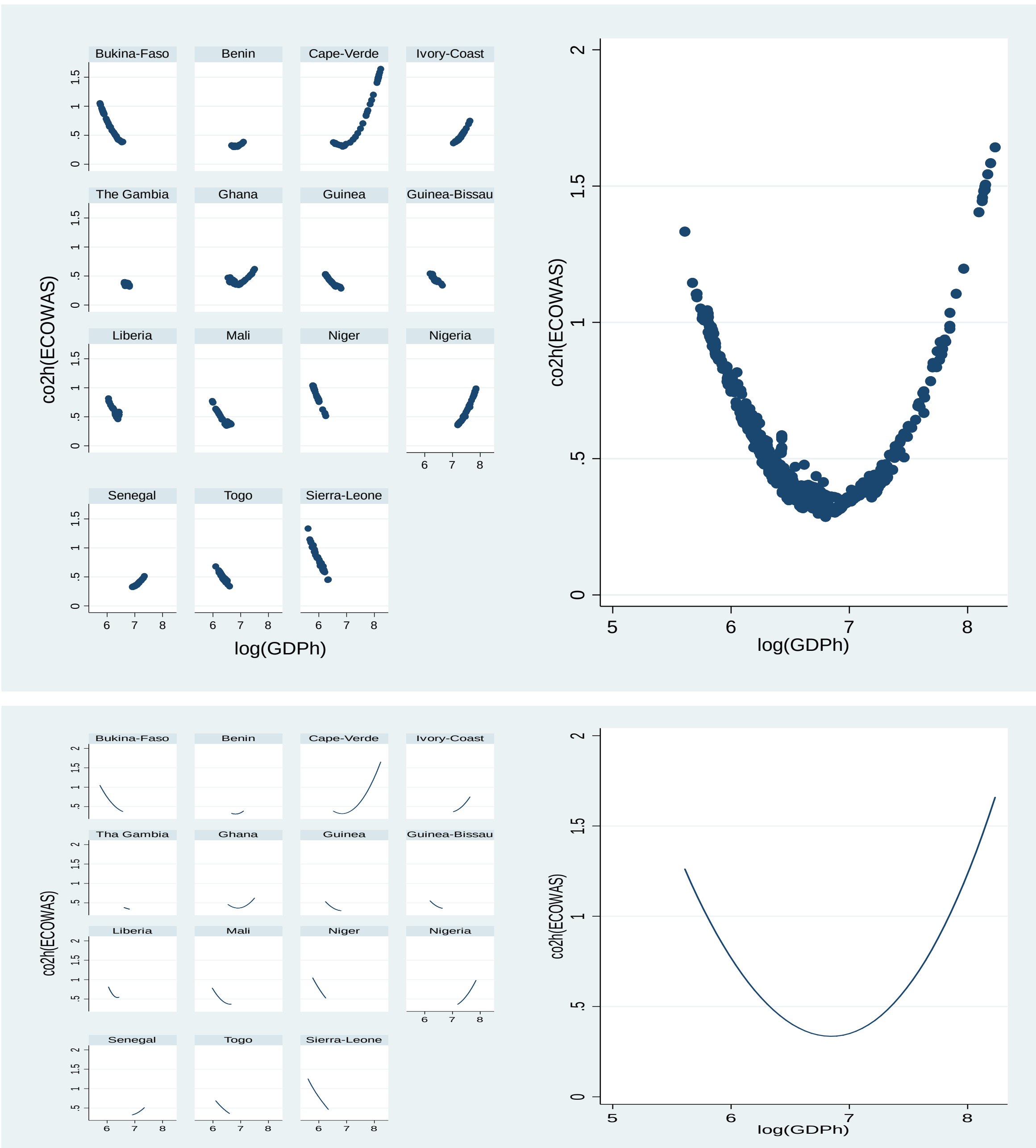
Source: Authors' illustration, WB data, 2020

Kuznets environmental curve by ECOWAS member country

The country by country graphical representation makes it possible to define three types of GDP-CO2 relationship within ECOWAS. The relationship is monotonous and decreasing in Burkina-Faso, Gambia, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Togo and Sierra Leone. The relationship is monotonous and growing in Benin, Ghana, Ivory Coast, Nigeria, Cape Verde and Senegal. On the other hand, the KEC of the inverted U-shape does not seem to be verified for the ECOWAS zone. In fact, the ECOWAS environmental curve appears on average to be U-shaped as shown in Figure 3, confirming the work of Hilali and Ben Zina (2007) who found a U-shaped curve for Algeria and Thailand. For these authors, the level of development of each country remains a determining factor in per capita CO2 emissions. From this point of view, the countries do not have the same skills and availability in the fight against environmental degradation. Under these conditions, the interpretation of the environmental curve could be different.

Some authors (Shafik and Bandyopadhyay, 1992) showed that most environmental indicators initially deteriorate when income increases. However, there is evidence that economies with a too high investment rate and faster growing are putting great pressure on natural resources, especially in terms of pollution. This is exactly what justifies the case of the monotonically growing form of the U-shaped part of the ECOWAS environmental curve. On the other hand, it is theoretically difficult to predict how the quality of the environment will evolve following an increase in GDP per capita. However, there are economies that are small and poor but place great value on the quality of the environment such as tribal peoples (Shafik and Bandyopadhyay, 1992).

Figure 3: The environmental curve by ECOWAS country



Source: Authors' illustration, WB data, 2020.

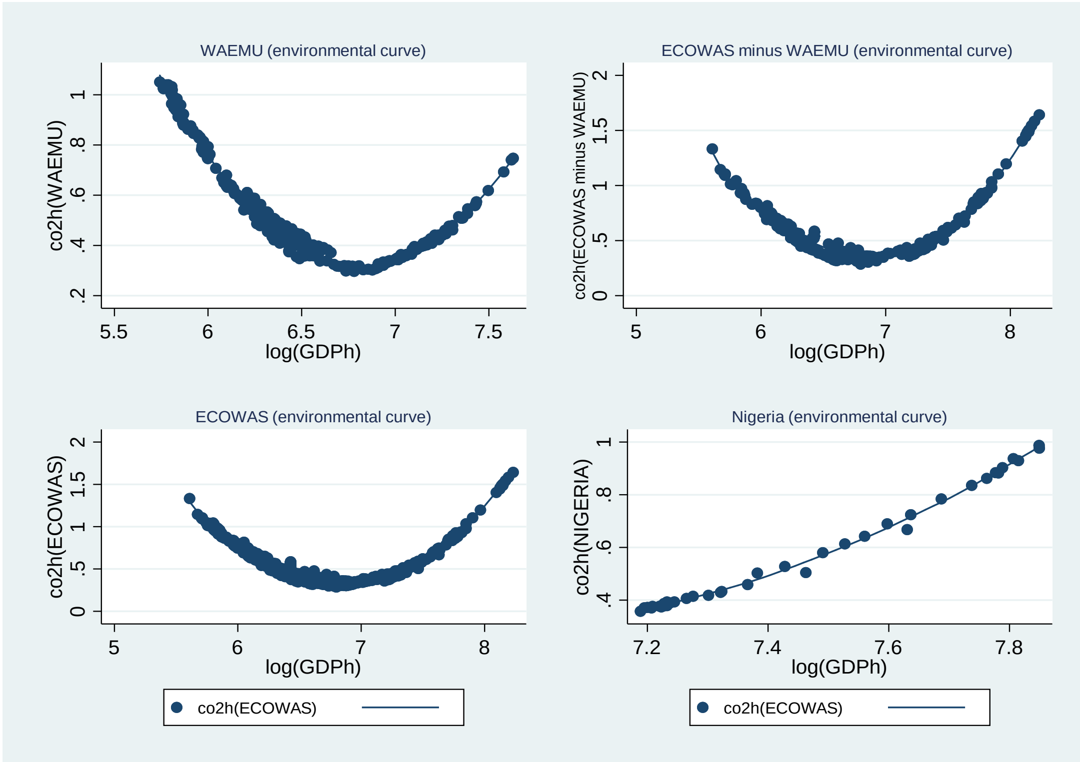
Comparative analysis of the environmental curves of ECOWAS, WAEMU and other ECOWAS countries

On average, the ECOWAS environmental curve is a U-shape as shown in Figure 2. Both at the level of WAEMU, ECOWAS, and other ECOWAS countries, these CO2 emissions curves per capita in the sub-region are U-shaped. WAEMU countries experience two phases in their per capita CO2 emissions as the per capita GDP grows. The first phase knows a monotonous and decreasing emission while the GDP increases until the threshold of $945.75 US (in 2010 $US). This phase seems to justify the low level of industrialization of most of the member countries, but which attach a great value to the quality of the environment in terms of pollution followed by a second phase where emissions are monotonous and increasing. This last phase would be attributed to the countries of the zone having a higher level of development in terms of GDP per capita but which have not yet managed to draw the other countries into the implementation of policies to fight against the degradation of the environment. Their development through massive investments puts pressure on natural resources and therefore, on pollution.

The other ECOWAS countries have the same trends in terms of CO2 emissions except that emissions are an increasing function of GDP per capita. These countries have a tendency that increases emissions at the ECOWAS level and which lead on average the whole zone to increasing CO2 emissions per capita just like Nigeria. Concretely, everything happens as if the poor economies of the zone which place a great value on the quality of the environment in terms of pollution have not yet succeeded in influencing the general policy of combating emissions in the zone. They are 'followers' who let the most industrialized drive the environmental politics of the Zone. The same phenomenon is observed at the level of WAEMU where the poorest are lagging behind the richer countries.

The other aspect that could justify this U-shaped curve relates to compliance with the rules in this zone. As O'Connor (1994) has pointed out, environmental regulations that reflect public preferences for a clean environment are not strictly adhered to by all ECOWAS member countries. The poorest in the zone are making commendable efforts in the fight against pollution and compliance with regulations against the most advanced in terms of GDP per capita who have not yet managed to channel their policy on environmental pollution. Ultimately, per capita CO2 emissions in the WAEMU and other ECOWAS zones require effective supervision and rigorous monitoring to enable high-income countries to pursue policies and invest in environmental protection policies. If this trend continues, the consequences on the environment will be damaging to the people and populations, in particular for countries with an improved standard of living or with a high GDP per capita.

Figure 4: Environmental curve of ECOWAS, WAEMU and NIGERIA.

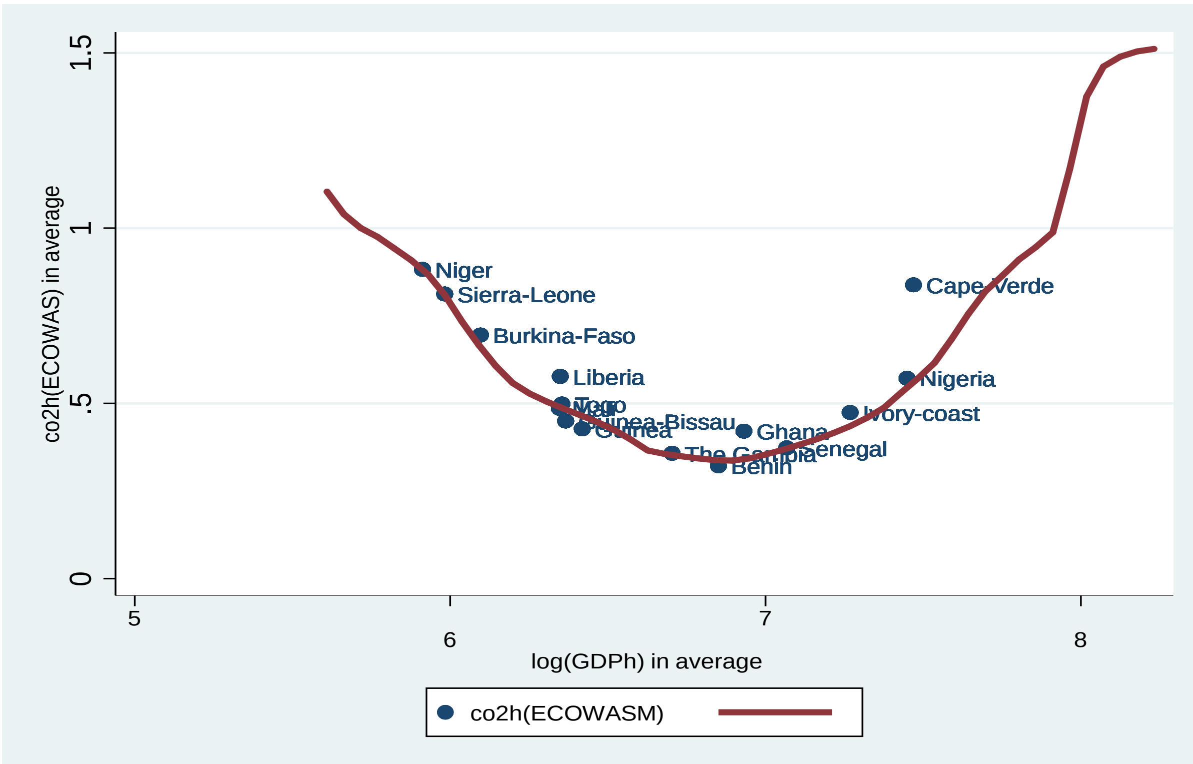


Source: Authors' illustration, WB data, 2020.

Position of each ECOWAS country in per capita CO2 emissions

It is clear that the ECOWAS countries with a relatively low standard of living emit less CO2 than those with a relatively high standard of living. Through these countries, there are those which are practically at the optimum both in their per capita CO2 emissions and in production for the improvement of their well-being. By observing Figure 5, Niger, Mali, Sierra Leone, Burkina-Faso, Liberia, Togo, the two Guineas are the very poor countries of ECOWAS whose per capita CO2 emissions are decreasing over time as GDP per capita increases. This could be justified by the very low level of industrialization and a low human development index (HDI), but which attach great value to the quality of the environment for their well-being. On the other hand, Benin and Gambia are poor countries, but whose average emission levels are around the average optimum at the level of ECOWAS with an average GDP per capita around $951 US (in 2010 $US). This group is followed by Ghana and Senegal, which are among the leading groups in ECOWAS such as Cape Verde, Nigeria and Ivory Coast, where an improvement in living standards generates an increase in the emission of CO2 per capita. This result could be justified by a lack of effective policy and supervision in the provisions to fight against CO2 emissions. The wealth created in these countries does not converge towards a transparent fight in the sector of per capita CO2 emissions to guarantee a green environment. In addition, the policies implemented suffer from a long-term effectiveness.

Figure 5: Country position in per capita CO2 emissions



Source: Authors' illustration, WB data, 2020.

CO2 emissions per capita in WAEMU and other ECOWAS countries

At the WAEMU countries level

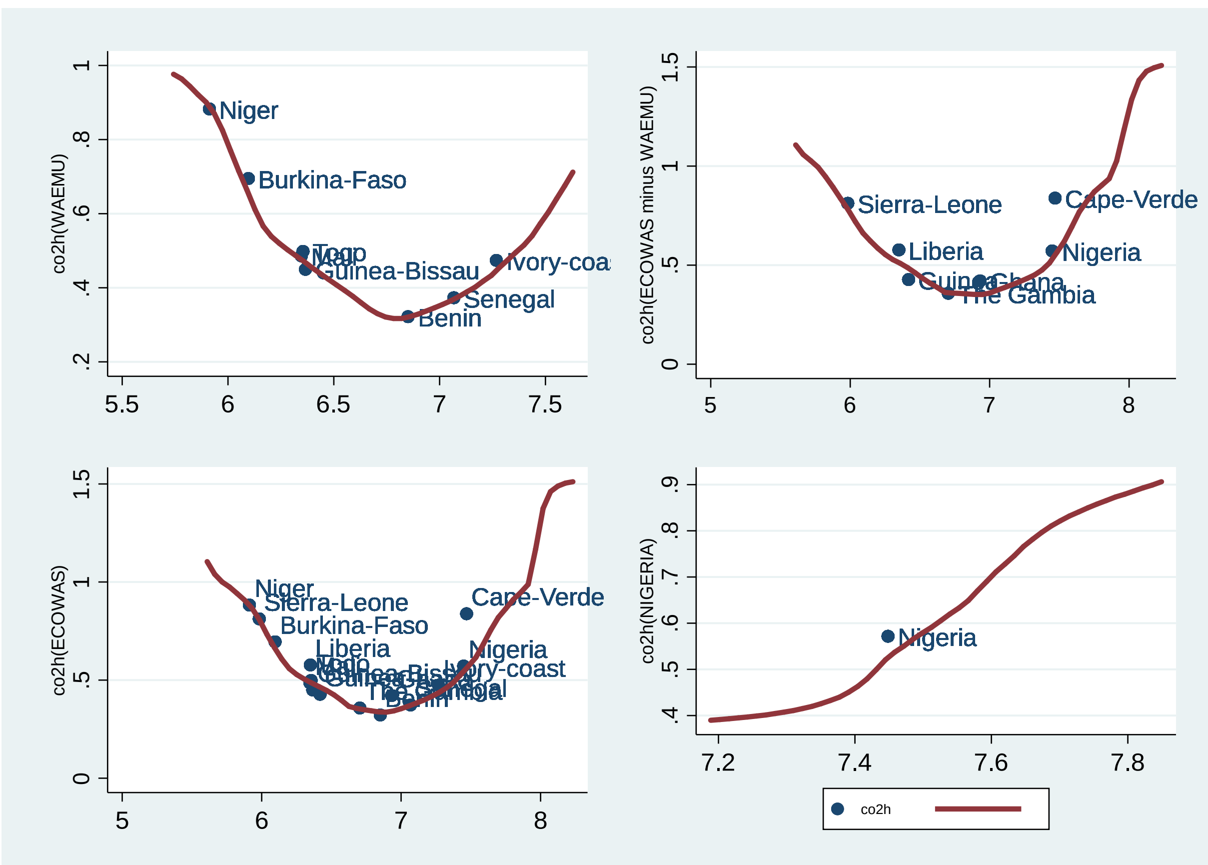
In WAEMU, per capita CO2 emissions are not uniform and depend on the structure of the economy of each member country. Households in Ivory Coast, Senegal and Benin with a relatively high level of GDP per capita have increasing emissions as the standard of living improves. Niger with relatively low income levels is on the downward slope of per capita CO2 emissions. The difference in standard of living between the two groups is relatively significant. In the long term, an increase in the standard of living in Benin, Senegal or Ivory Coast would be accompanied by a relative increase in CO2 emissions per capita while in the second group of countries, namely Niger, Burkina-Faso, Togo, Mali, and Guinea Bissau, any increase in per capita income would inevitably lead to a drop in the level of CO2 per capita. These are committed to compliance with environmental regulations and are consistent with a quality environment.

At the other ECOWAS countries level

Nigeria and the other ECOWAS countries, on the other hand, emit more CO2 per capita than the WAEMU countries. This result is justified by the shift of the environmental curve of ECOWAS and other ECOWAS countries to the right, while that of WAEMU is cut a little more to the left with a shorter tail (Figure 6).

At the level of ECOWAS, per capita CO2 emissions seem to be strongly dependent on the standard of living of each country, thus justifying the investment pressure on the quality of the environment in terms of pollution. On the one hand, we have the very poor and very less industrialized countries with a monotonous decreasing emission according to the standard of living (Niger, Burkina-Faso, Togo, Guinea, Liberia, Sierra-Leone, Mali, Guinea Bissau, and in a lesser extent, Gambia and Benin), and on the other hand the relatively industrialized poor countries with increasing monotonous emissions (Nigeria, Ghana, Ivory Coast, Senegal and Cape Verde) as illustrated in Figure 6.

Figure 6: Average change in CO2 emissions by region (WAEMU, ECOWAS and NIGERIA)



Source: Authors' illustration, WB data, 2020.

Empirical analysis

Results obtained from ECOWAS data

To test the environmental curve on the ECOWAS data, it was necessary to carry out the unit root tests followed by Co-integration tests.

Results of the IPS unit root test

Tables in Appendix 3 contain the results of the panel unit root test of Im, Pesaran and Shin (2003) for ECOWAS. The results are consistent with unit root tests in most macroeconomic series and reveal characteristics that are specific to the countries of the ECOWAS zone. The results show that the variables *CO2h, GDPh,* $(GDPh)^2$, *En* and *Ind* are all non- stationary (p-value > 0.5).

Results of the co-integration tests

In the literature of time series in panel data, once the non-stationary has been found in the series, the best known Co-integration tests are those of Kao (1999), Pedroni (1994, 1999) then that of Westerlund (2007). The tests of Pedroni (1994, 1999) and Weterlund (2007) have been implemented, but only the results of Westerlund (2007) are presented in table 1, the results of the Pedroni (1999) tests are shown in Appendix 4.

Thus, in Table 1, the Gt and Ga Statistics resulting from the results of Westerlund (2007) tests make it possible to test the absence of a Co-integration relation against the alternative of existence of at least one Co-integration relation between the countries. On the other hand, the Pt and Pa statistics gather the information between all the countries and test the absence of Co-integration between all the countries against a Co-integration relationship between the countries of the panel. The idea of these tests seems consistent with the Co-integration tests of Johansen (1988) in time series.

The results of these tests are easy to interpret as it is presented in Table 1. The Pt and Pa statistics both have p-values less than 5% implying that there is a Co-integration relationship between the series for all countries. Although this result builds our expectations, it imposes a constraint of homogeneity between all the countries of the panel. In other words, the Gt statistic rejects the hypothesis of the absence of a long-term relation for all the series against Ga which accepts the null hypothesis of the absence of Co-integration (Table 1, last column).

Table 1: Results of Westerlund Co-integration tests (2007)

Statistics	Value	Z-value	P-value
Gt	-3.454	4,090	0.000
Ga	-14.635	0.848	0.198
Pt	-13.189	4.494	0.000
Pa	-16.334	3,590	0.000

Source: Authors' illustration, WB data, 2020

Results of the vector analysis of the Kuznets environmental curve

Table 2 presents the results of the long-term relationship between per capita CO2 emissions between ECOWAS countries. The KEC hypothesis would be valid if the coefficients (β1) and (β2) of equation (1) are respectively statistically significant positive and negative. As shown in Table 2, these coefficients are respectively -8.932804 for (β1) and 0.6518412 for (β2) with p-values less than 5%. These results invalidate the existence of a long-term relationship in the shape of an inverted U curve, as Kuznets (1955) has underlined, thus reflecting certain African realities. On average, per capita CO2 emissions first decrease as per capita GDPh increases to a threshold of $945.75 US in 2010 $US (Equation 3), and then increases. This GDPh threshold level corresponds to average CO2 emissions of 0.323 tons per capita at the ECOWAS.

Determination of the CO2 emissions threshold per capita in ECOWAS

The existence of the threshold in the analysis of the environmental curve responds to the Kuznets (1955) theory where at the start of the growth process, pollution and environmental degradation will increase. Beyond a certain level of per capita income, economic expansion will translate into an improvement of the environment. The GDPh corresponding to this threshold is such as:

$$\ln \widehat{GDP}h = -\frac{\hat{\beta}_1}{2\hat{\beta}_2} \quad (3)$$

By replacing the corresponding values,

$$\ln \widehat{GDP}h \approx 6.8519 \Leftrightarrow \widehat{GDP}_{ECOWAS} \approx 945.75 \quad (4)$$

$$\ln \widehat{GDP}h \approx 6.8519 \Leftrightarrow co2\hat{h}_{ECOWAS} \approx 0.323 \quad (5)$$

In addition, the coefficient of the return force is negative and significant, which guarantees an error correction mechanism and therefore the existence of a long-term relationship between the variables in study. It takes about two years two months to establish a balance between the long-term and short-term variables (Table 2).

Our results are inversely similar to those of Selden and Song (1994) who found an inverted U-shaped relationship between GDP and CO2 for 30 countries. The same is true for Holtz-Eakin and Selden (1995), but with a high inflection point for 108 countries. With respect to the other control variables *En* and I*nd*, their coefficients are not statistically significant at the conventional threshold of 5 percent.

Table 2: Estimated long-run relationship and short run adjustment

	Coefficient	**Std. Errors.**	**Z**	**P> z**	**[95% Conf.**	**Interval]**
Long term relationship						
lGDPh	-8.932804***	4.381166	-2.04	0.041	-17.51973	-.3458769
lGDPh2	0.6518412***	.3201658	2.04	0.042	.0243278	1.279355
Energy	0.0387246	.1507835	0.26	0.797	-.2568055	.3342548
Industry	0-.0564668	.0777821	-0.73	0.468	-.2089169	.0959832
_cons	30.92034	14.92128	2.07	0.038	1.675162	60.16552
Adjustment speed	**-.4741883**	**.0645173**	**-7.35**	**0.000**	**-.6006399**	**-.3477366**

Source: Authors' illustration, WB data, 2020.

The asterisks*** correspond to the significance at the 5% level.

CONCLUSION

This study conducted a comparative analysis of CO2 emissions and economic growth in ECOWAS countries based on the Kuznets environmental curve approach over the period 1980-2018. According to the logic of the KEC, the relationship between per capita income and environmental pollution can be represented by an inverted U- shaped curve. The long-term and short-term results of our comparative analysis, both descriptive and empirical, suggest that in ECOWAS countries, the relationship between per capita income and CO2 emissions is a U-shaped curve, thus contradicting the relationship by KEC. In other words, at the ECOWAS level the CO2 emissions per capita first decrease when GDP per capita increases to a threshold, then increases. This threshold, for example, is $945.75 US (in 2010 $US) for ECOWAS and $852.95 US for WAEMU. Also, our comparative analysis shows that there is a disparity in per capita income within ECOWAS, constituting on the one hand the poor countries (Niger, Mali, Sierra Leone, Burkina Faso, Liberia, Togo, the two

Guineas and to a lesser extent Benin and Gambia) whose CO_2 emissions per capita decrease as the GDP per capita increases, and on the other hand, the richer countries (Ghana, Senegal, Cape Verde, Nigeria and Côte d'Ivoire) for which an improvement in living standards leads to an increase in CO_2 emissions.

Hence, over the period 1980 - 2018, the CO_2 emissions in West Africa require a new strong policy to break with the current obstacles to a good policy of per capita CO_2 emissions in the more industrialized countries at the level of ECOWAS. The follower countries must stay on this trend before forcing admiration in the maintenance of environmental rules while the leader countries have the responsibility to promote a quality environment through the definition of a monitoring framework for the environment.

The remarks and suggestions for our study are threefold: (1) there is effectively a relationship between CO_2 emissions and per capita income in the ECOWAS zone and this relationship is generally a U-shape curve ; (2) in view of this evidence, countries with higher per capita incomes must review their environmental management policy for the use of cleaner technologies and a greater value placed on the quality of the environment in order to reverse the trend of the environmental curve; and (3) common environmental policies can be put in place at ECOWAS level as a single entity.

However, our study suffers from the fact that the impacts of the other control variables of our model, namely energy consumption and industrial GDP, are not clearly demonstrated by our analyzes in the sense that, as shown by the empirical results, the coefficients of the concerned variables are not statically significant at the 5 percent threshold and their evolutions in the ECOWAS through the descriptive analysis of which the figures are presented in the Appendices 1 and 2 are not explicit. Subsequent research may address this aspect of the study more specifically by also extending it to other control variables such as the degree of trade openness, the urban population and the investment which, like the first two will all have a positive impact on CO_2 emissions (Grossman and Krueger, 1993; Torras and Boyce, 1998; Ang (2008), Panayotou, 1997; Suri and Chapman, 1998; Jobert and Karanfil, 2010). In other words, further studies may use other methods and other control variables to study the relationship between per capita CO_2 emissions and economic growth in ECOWAS.

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REFERENCES

Adededji, M., (1994). “Contribution à l'Evaluation des Sources de Pollution sur le Littoral Béninois“; *Rapport, p.126*.

Ang J., (2008). “Economic Development, Pollutant Emissions and Energy Consumption in Malaysia”. *Journal of Policy Modeling, 30, 271 – 278*;

Akbostanci, E.,Turut-Asik,S.,Tunç,G.I. (2006). “The Relationship between Income and Environment in Turkey: is There an Environmental Kuznets Curve*”. Energy Policy, vol. 37, pp 861-867 ;*

Banque Mondiale (1992). “Rapport sur le Développement dans le Monde, le Développement et l'Environnement*“, Washington D.C ;*

Banque Mondiale (2012), “Les Indicateurs du Développement en Afrique“, *Washington D.C ;*

Beckerman, W. (1992). “Economic Growth and the Environment: Whose Growth? Whose Environment?. *World Development, vol. 20, pp 481-496;*

Bhagwati J. (1993). “The Case for Free Trade”. *Scientific American, pp 42-49;*

Cole M. A, Rayner, A. and Bates, J. (1997). “The environmental Kuznets Curve: An empirical Analysis“. *Environmental and Development Economics, Vol. 2, pp 401-416;*

Cropper,M. and Geiffth, C. (1994). “The Interaction of Population Growth and Environmental Quality*, The American Economic Review, vol. 84, issue 2, pp. 250-254;*

CITEPA (2013). “L'Inventaire National des Polluants par Secteurs d'Activité“.*www.actu-environnement.com ;*

Dijkgraaf, E. and Vollebergh, H. (1998), “A Test for Parameter Homogeneity in CO2 Panel EKC Estimates*”, Environmental and Resource Economics volume 32, pages229–239;*

Dinda, S. (2004). “Environmental Kuznets Curve Hypothesis: A survey”. *Ecological Economics, vol. 49, pp 431-455;*

Dinda S. & Coondoo, D. (2006). “Income and Emissions: A Panel Data-Based Cointegration Analysis”. *Ecological Economics, vol. 57, pp 167-181;*

FAO (2016). “Émissions de Gaz à Effet de Serre Issues de l'Agriculture, de la Foresterie et des Autres Affectations des Terres*“. www.fao.org* ;

Galeotti, M. and Lanza, A. (1999a). “ Desperately Seeking (Environmental) Kuznets“, *World Congress of Environment and Resource Economists, Working Paper, PP-16;*

Galeotti, M. and Lanza, A. (1999b). “Richer and Cleaner? A Study on Carbon Dioxyde Emissions in Develeoping Countries“, *Energy Policy, Volume 27, Issue 10, 1 October 1999, Pages 565-573.*

Gianni, C., Raffa, V., Vittorio, O., Cuschieri, A., Pizzorusso, T., Costa, M. and Bardi, G. (2010) “In Vitro and In Vitro Biocompatibility Testing of Functionalized Carbon Nanotubes*“, Book: Carbon Nanotubes pp 67-83, DOI: 10.1007/978-1-60761-579-8_7 .*

Grossman, G. M. and Krueger, A. B. (1993). “Environmental Impacts of the North American Free Trade Agreement”. *NBER working paper 3914;*

Grossman, G. M., and Krueger, A. B., (1995). “Economic Environment and the Economic Growth”. *Quarterly Journal of Economics, Vol. 110, No. 2, pp. 353-377;*

Hilali, M. and Ben- Zina, N. (2007). “Commerce and Environment: A Rereading of the Kuznets Environmental Curve*“, Unité de Recherches sur la Dynamique Economique et l'Environnement, URDEE : UR/99/06-10 ;*

Hill R. and Magnani E. (2002). “An Exploration of the Conceptual and Empirical Basis of the Environmental Kuznets Curve“, *Wiley online Library*;

Holtz-Eakin, D. and Selden, T. M. (1995). “Stocking the Fires? CO2 Emissions and Economic Growth”. *Journal of Public Economics, Vol. 57, pp 85-101;*

Jobert, T. and Karanfil, F. (2010). “Sectorial Energy Consumption by Source and Economic Growth in Turkey”. *Energy Policy, vol. 35, pp 5447-5456;*

Johansen, S., (1988). “Statistical Analysis of Cointegration Vectors”. *Journal of Economic Dynamics and Control, Vol. 12, issue 2-3, pages 231-254;*

Kao, C. (1999), “Spurious Regression and Residual-Based Tests for Cointegration in Panel Data“. *Journal of Econometrics 90: 1-44;*

Kuznets, S. (1955). “Economic Growth and Income Equality”. *American Economic Review. Vol. 45, pp 1 – 28;*

Lefohn, A., Husar, J. and Husar, B. (1999). "Estimating Historical Anthropogenic Global Sulfur Emission Patterns for the Period 1850-1990",*Atmospheric Environment, Atmospheric Environment, Volume 33, Issue 21, September 1999, Pages 3435-3444;*

Le Quéré, C., Robert, B. Jackson, Matthew, W.; Adam, J. P. , Robbie, M., Anthony J. , David, R., Josep G.,Glen P., (2020). "Temporary Reduction in Daily Global CO2 Emissions during the COVID-19 Forced Containment", *Nature Climate Change, 10, pages 647;*

List, J. A. & Gallet, C. A. (1999). "The Environmental Kuznets Curve: Does One Size Fit All?". *Ecological Economics, Vol. 31, pp 409-423;*

Mc Connell (1997). "Income and the Demand for Environmental Quality*". Environmental and Development Economics", vol 2; 383-400;*

Mouhamadou, M. (2007). "Croissance Economique et Protection de l'Environnement le Cas du CO2 au Sénégal" ; *Mémoire online, Université Gaston Berger* ;

O'Connor, D.(1994) : "La Gestion de l'Environnement dans les Pays en Voie d'Industrialisation Rapide : Leçons Tirées de l'Asie de l'Est", *Centre de Développement de l'OCDE, Paris ;*

OMM, (2012). "Nouveaux Records pour les Concentrations de Gaz à Effet de Serre dans l'Atmosphère", *Communiqué n°980* ;

Panayotou, T. (1993 ou 1997?). "Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development". *Working Paper WP238 Technology and Employment Program, Geneva: International Labor Office*;

Pedroni, P. (2004), "Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis". *Econometric Theory 20: 597-625;*

Pedroni, P. (1999), "Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors". *Oxford Bulletin of Economics and Statistics 61: 653-670;*

Pezzey, J. C. V. (1989). "Economic Analysis of Sustainable Growth and Sustainable Development". *Environment Department Working Paper 15, World Bank;*

Schmalnesee, R., Stoke, M. and Judson, A. (1998). "World Carbon Dioxide Emissions"-*MIT Press;*

Selden, T. and Song, D. (1994). "Environmental Quality and Development: Are There a Kuznets Curve for Air Pollution Emissions", *Journal of Environmental Economics and Management, vol. 27, pp 147-162;*

Shafik, N. (1994). "Economic Development and Environmental Quality: An Econometric Analysis". *Oxford Economic Papers, Vol. 46, pp 757-773;*

Shafik, N., and Bandyopadhyay, S., (1992). "Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence". *Background Paper for the World Development Report 1992, The World Bank, Washington DC;*

Stern, D. I., Common M. S. and Barbier E. B (1996). "Economic Growth and Environmental Degradation: The Environmental Kuznets Curve and Sustainable Development". *World Development, vol 24, pp 1151-1160 ;*

Suri, V. & Chapman, D. (1998). "Economic Growth, Trade and Energy: Implications for the Environmental Kuznets Curve*". Ecological Economics, Vol. 25, pp 198-208;*

Torras, M. & Boyce J. K. (1998). "Income, Inequality and Pollution: A Reassessment of the Environmental Kuznets Curve". *Ecological Economics, Vol. 25, pp 147-160.*

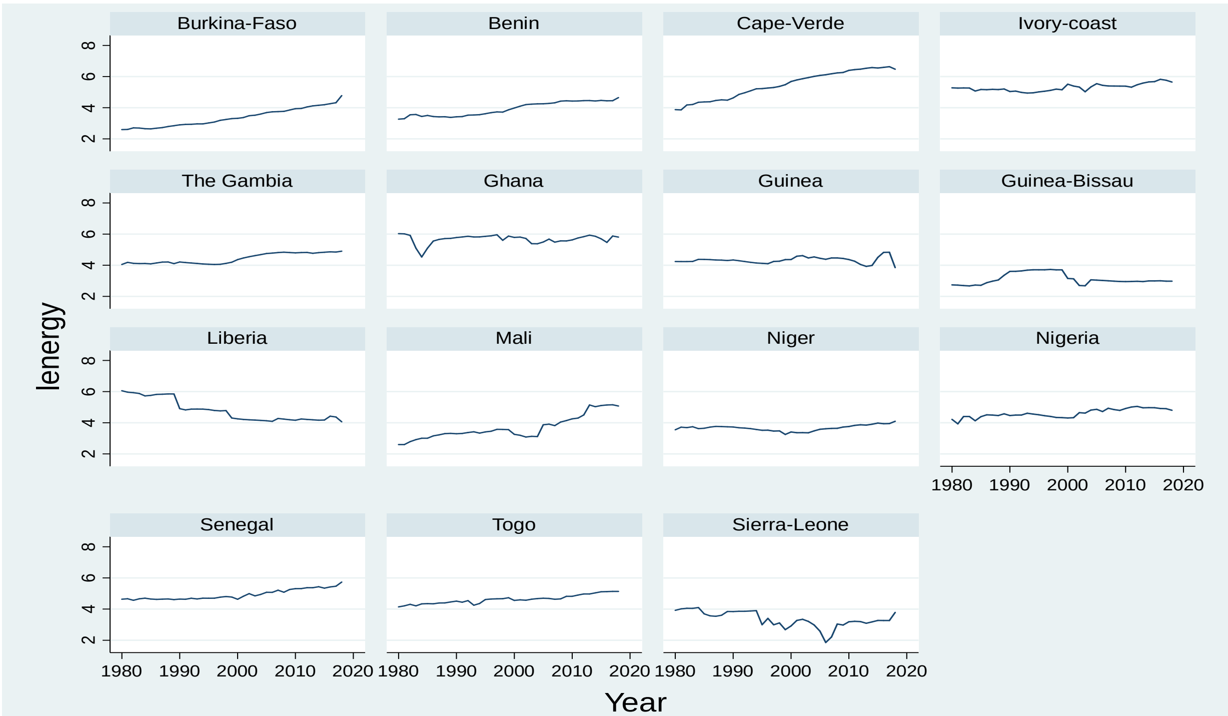
Wang, Z., Shi C., Li Q. and Wang, G. (2011). "Impact of Heavy Industrialization on the Carbone Emissions: An Empirical Study of China*". Energy Procedia, 5, 2610-2616.*

Westerlund, J., (2007), "New Simple Tests for Panel Cointegration", *Econometric Reviews 24:297.*

APPENDICES

1. Evolution of the energy consumption by country

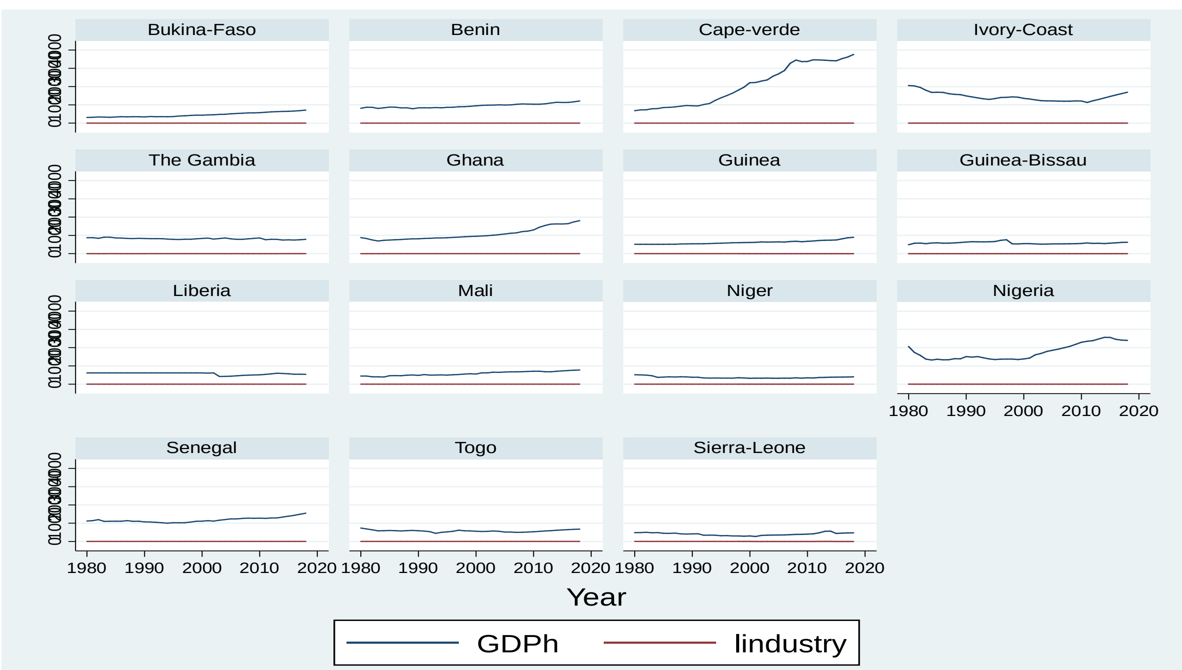
Figure A1: Energy consumption by country



Source: Authors' illustration, WB data, 2020.

2. Evolution of industrial GDP by country.

Figure A2: Evolution of industrial GDP according to ECOWAS countries



Source: Authors' illustration, WB data, 2020.

3. Results of the unit root tests of IPS (CO_2, GDPh, $(GDP)^2$, En et Ind).

Table 1A: Im-Pesaran-Shin unit-root test (xtunitroot)

Im-Pesaran-Shin unit-root test for co2h					
Ho: All panels contain unit roots			Number of panels = 15		
Ha: Some panels are stationary			Number of periods = 39		
AR parameter: Panel-specific			Asymptotics: T,N -> Infinity		
Panel means: Included			sequentially		
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-1.4078		-2.040	-1.900	-1.810
t-tilde-bar	-1.2501				
Z-t-tilde-bar	1.0212	0.8464			
Im-Pesaran-Shin unit-root test for lGDPh					
Ho: All panels contain unit roots			Number of panels = 15		
Ha: Some panels are stationary			Number of periods = 39		
AR parameter: Panel-specific			Asymptotics: T,N -> Infinity		
Panel means: Included			sequentially		
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-0.6511		-2.040	-1.900	-1.810
t-tilde-bar	-0.6188				
Z-t-tilde-bar	4.0836	1.0000			
Im-Pesaran-Shin unit-root test for lGDP2					
Ho: All panels contain unit roots			Number of panels = 15		
Ha: Some panels are stationary			Number of periods = 39		
AR parameter: Panel-specific			Asymptotics: T,N -> Infinity		
Panel means: Included			sequentially		
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-0.5891		-2.040	-1.900	-1.810
t-tilde-bar	-0.5613				
Z-t-tilde-bar	4.3624	1.0000			
Im-Pesaran-Shin unit-root test for energy (En)					
Ho: All panels contain unit roots			Number of panels = 15		
Ha: Some panels are stationary			Number of periods = 39		
AR parameter: Panel-specific			Asymptotics: T,N -> Infinity		
Panel means: Included			sequentially		
Time trend: Included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-1.8236		-2.670	-2.520	-2.440
t-tilde-bar	-1.7143				
Z-t-tilde-bar	-1.2307	0.1092			
Im-Pesaran-Shin unit-root test for industries (Ind)					
Ho: All panels contain unit roots			Number of panels = 15		

Ha: Some panels are stationary	Number of periods = 39	
AR parameter: Panel-specific	Asymptotics: T,N -> Infinity	
Panel means: Included	sequentially	
Time trend: Included		
ADF regressions: 2 lags		
	Statistic	p-value
W-t-bar	-0.8094	0.2092

Source: Authors' illustration, WB data, 2020.

4. Results of Pedroni (1999) tests

Table 2A: Pedroni test for cointegration

Pedroni test for cointegration		
Ho: No cointegration	Number of panels	15
Ha: All panels are cointegrated	Number ofperiods	38
Cointegrating vector: Panel specific		
Panel means: Included	Kernel:	Bartlett
Time trend: Not included	Lags:	3.00 (Newey-West)
AR parameter: Panel specific	Augmented lags:	1
	Statistic	p-value
Modified Phillips-Perron t	0.0469	0.4813
Phillips-Perron t	-4.2325	0.0000
Augmented Dickey-Fuller t	-4.3507	0.0000

Source: Authors' illustration, WB data, 2020.