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# THE ENVIRONMENT AND GROWTH NEXUS: AN EMPIRICAL EXAMINATION OF THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESISIN COTE D'IVOIRE

***Felix Fofana N'Zué**

Université Felix Houphouet Boigny de Cocody, Cote d'Ivoire and Economic Policy Analysis Unit,
ECOWAS, Nigeria

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## ABSTRACT

The objective of this paper is to contribute to a better understanding of the environment and growth nexus in Cote d'Ivoire and assess the EKC hypothesis for $CO_2$.The analysis is extended to investigate the long run relationship between $CO_2$ emissions and Agricultural Value Added, Industrial as well as Services Value Added. The data used ranged from 1960 to 2015. An ARDL model is used to assess long run relationship between $CO_2$ emissions and per capita GDP. We found that $CO_2$ emissions and per capita GDP are not cointegrated. Results also do not support the EKC hypothesis for $CO_2$ in the country. When we considered sectoral contribution to GDP instead of Per capita GDP, we found that $CO_2$ emissions and Agricultural and Services sector's Value Added are cointegrated and moreover, there was long run causality running from Agricultural Value Added and Services Value Added to $CO_2$ emission. In the case of the industrial Sector's Value Added we found no long run relationship with $CO_2$ emissions. However, there is short run causality running from Industrial Value Added to $CO_2$ emissions in the country. The EKC hypothesis is supported in the Agricultural, Industrial and Services sectors.

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## INTRODUCTION

With the increased awareness of health hazard attributed to air pollution and global warming due to human activities and their impacts on the ozone layer, the Intergovernmental Panel on Climate Change (IPCC) identifiedcarbone Dioxide ($CO_2$) emissions as the major source of global warming. Moreover, global warming is closely related to $CO_2$ emissions produced by human activities (Chen and Huang, 2013) and hence need to be reduced drastically. It has been argued that the sharp increase in $CO_2$ emissions from economic development via human activities, has overwelmed the ability of the planet to self regulate (Beck and John, 2015) thus creating disruptions in global environment and environmental problems i.e. change in seasons, flooding in some regions and drought in others. Carbon dioxide ($CO_2$) emissions emanate from the burning of fossil fuels and the manufacture of cement. They include $CO_2$ produced during consumption of solid, liquid, gas fuels and gas flaring (World Bank, 2017). It is thus a major determinant of the greenhouse gas (GHG) implicated in global warming. It geographically propagates more easily than local air pollutants such as sulfur emissions (Aslanidis *et al* (2004). The dangers related to the excessive accumulation of $CO_2$emissions has led several scholars (Beck and John, 2015; Martinez-Zarzoso *et al* 2007; Chen and Huang, 2013; He and Richard, 2009 just to mention a few) to investigate more actively the nexus between economic growth and $CO_2$ emissions and determine whether or not there is a tipping point at which economic growth is less harmful to the environment. In other words to see ifan Environmental Kuznets Curve (EKC) for $CO_2$ exists.The EKC makes reference to Kuznets 's work on Economic Growth and income inequality where he argued that economic growth improves with increased inequality up to a turning point after which there is reduction in inequality with increased growth of income (Kuznets, 1955). The EKC depicts the relationship between environmental quality and economic growth. It hypotheses that, there is an inverted U-shape relation between environmental degradation and economic growth. Hence, as a country registers more growth the higher is its carbon dioxide emission. The $CO_2$ emissions will increase up to a turning point then decline with additional economic growth. This is explained by scale, composition and displacement effects (Sinha and Bhatt, 2017). A recent study

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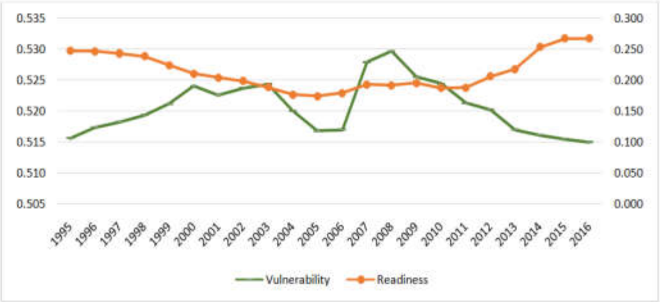
***Corresponding author:*** **Felix Fofana N'Zué**
Université Felix Houphouet Boigny de Cocody, Cote d'Ivoire

by the World Bank (2018) called the attention of Cote d'Ivoire's authorities on the worrying consequences of climate change if no action is taken. The call resulted from analyzing the Notre-Dame Global Adaptation Index (i.e. ND-GAIN). The index measures both vulnerability[1] and readiness[2] to adapt to climate change[3].The country is ranked 147/181[4] making it one of the highly vulnerable country (with vulnerability score of 0.515 in 2016) and with low readiness (with a score of 0.267) to adapt to climate change. Although this call could seem alarming, looking at the trend of the vulnerability score over time for the country (Figure 1), we observe that from its initial upward sloping trend over the period ranging from 1995 to 2003, it declined to reach 0.517 in 2006 before a sharp rise to its highest level at 0.530 in 2008. From that period it has been declining to reach its current level of 0.515 (https://gain-new.crc.nd.edu/country/c-te-d-ivoire). On readiness, it stood at 0.248 in 1995 and declined continuously to reach 0.174 in 2005. Since that period, efforts have been made to improve the country's readiness to climate change. Indeed the country's readiness score rose to 0.267 in 2016 (https://gain-new.crc.nd.edu/country/c-te-d-ivoire) indicating efforts undertaken to render the countrymore resilient to climate change. Despite efforts to reduce vulnerability and improve readiness, the scores presented above clearly show that a lot remains to be done to make the country "totally" resilient to climate change.



Source: https://gain.nd.edu/our-work/country-index/download-data/

**Figure 1. Trends of Cote d'Ivoire's vulnerability and readiness to climate change from 1995 to 2016**

In line with the above and past studies the main objective of this paper is to contribute to a better understanding of the environmental degradation and economic growth nexus in Cote d'Ivoire. More specifically, the study seeks to test the validity of the EKC hypothesis for Cote d'Ivoire and if it is supported, determine the turning point from which an increment in economic performance in Cote d'Ivoire will negatively impact $CO_2$ emissions. The paper does not limit itself to per capita Gross Domestic Product (GDP). It goes beyond to look at sectoral performance i.e Agricultural Value Added, Industrial Value Added and Services Value Added. It investigates the relationship between $CO_2$ emissions and the above sectoral performances. The rest of the paper is organized as follows: some stylized facts on $CO_2$ emissions and the country's economic performance are presented in Section II. Section III reviews selected literature. Section IV presents the method of analysis and the data to be used for this paper. Section V undertakes the empirical analysis while Section VI discusses the findings. Section VII concludes the paper.

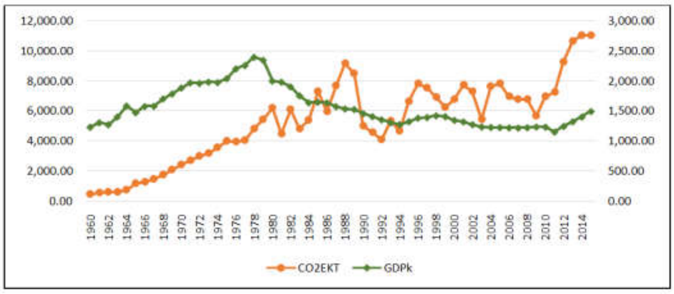
## Stylized facts

Carbon dioxide ($CO_2$) emissions are major determinants of Greenhouse Gas. It is considered to be at least 60% responsible of global warming (Sinha and Bhatt, 2017). In Cote d'Ivoire its trend (Figure 2) is upward sloping although not smooth throughout the entire period of analysis. Indeed,$CO_2$emissions stood at 462.04kt at independence in 1960 and registered sharp increases year after year to reach 6,222.90kt in 1980 representing a 1,247% increase over two decades. This period was tagged the "*Ivorian Miracle*" because also of rapid increase of per capita Gross Domestic Product (GDPk). The trend of $CO_2$emissions was not smooth after the year 1980. Indeed, it combines ups and downs till 2009. After the year 2009, $CO_2$ resumed with continuous increase to reach its highest level in 2014 at 11,045kt (Table 1). The period ranging from 1978 to 2009 coincided with continuous decline of per capita GDP.

**Table 1. Descriptive Statistics**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Gdpk | 56 | 1 560.758 | 328.235 | 1 154.750 | 2 397.090 |
| Agva | 56 | 28.680 | 6.818 | 20.210 | 47.910 |
| Co2ekt | 56 | 5 319.050 | 2 763.561 | 462.040 | 11 045.000 |
| Indva | 56 | 20.328 | 3.427 | 13.140 | 26.270 |
| Serva | 56 | 50.426 | 5.584 | 38.950 | 60.580 |

The average $CO_2$emissions over the period of analysis stood at 5,319kt which is the second highest $CO_2$ emissions in the ECOWAS[5] region after Nigeria with an average emission of 55,727.4kt over the same time period. Ghana comes third with an average $CO_2$emissions of 4,982.078kt.



Source: World Development Indicators (2017)

**Figure 2. Trend of Carbon dioxide ($CO_2$) emissions and per capita GDP in Cote d'Ivoire from 1960 to 2015**

How has $CO_2$ emissions and Agricultural Value Added evolved over time? From Figure 3, it is difficult to make a pronouncement. However, the pairwise correlation results presented in Table 2 show a negative and significant correlation coefficient of -0.866. This result will be investigated further in the empirical analysis section. Let's turn to the trend of $CO_2$with that of Industrial Value Added and Services Value Added (Figure 4). Starting with Industrial Value Added, we observe that it has an upward sloping curve with its highest point standing at 26.27 in 1990 (Highest contribution of Industrial Value Added to GDP).

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[1] The vulnerability measure considers the potential impact of climate change on six areas: food, water, health, ecosystem service, human habitat and infrastructure.

[2] The readiness rank weights portions of the economy, governance and society that affect the speed and efficiency of adaptation projects.

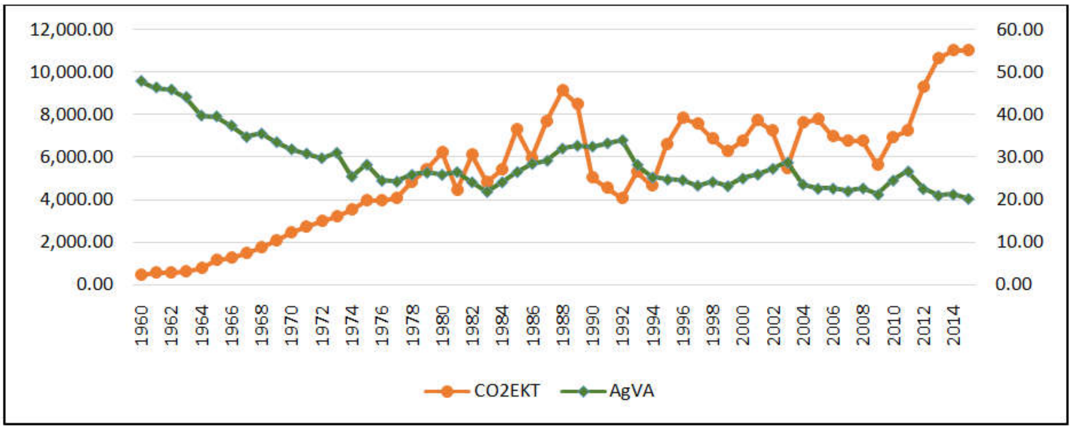
[3] https://www.washingtonpost.com/news/energy-environment/wp/2015/02/03/the-countries-most-vulnerable-to-climate-change-in-3-maps/?noredirect=on&utm_term=.3373c6462a62

[4] https://gain-new.crc.nd.edu/country/c-te-d-ivoire

[5] ECOWAS is the Economic Community of West African States

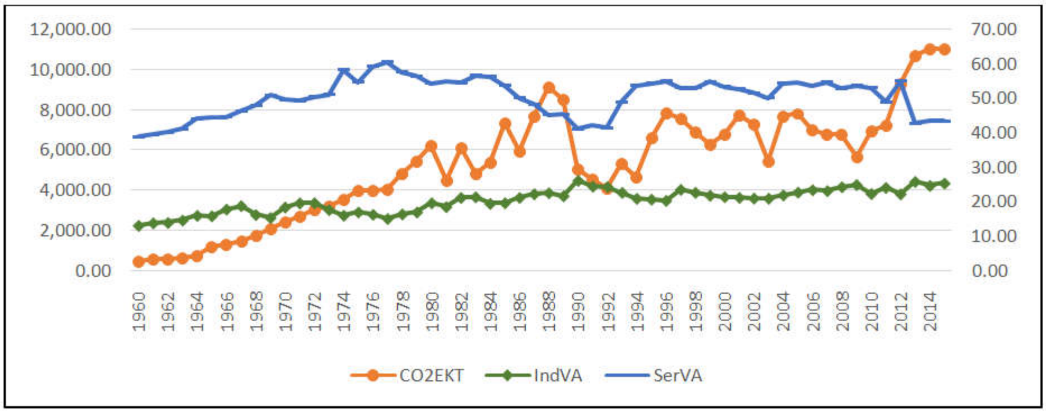
**Table 2. Pairwise correlation**

| Variab | lnco2e | lngdpk | lngdpk^2 | lngdpk^3 | lnagva | lnagva^2 | lnagva^3 | lnindva | lnindva^2 | lnindva^3 | lnserva | lnserva^2 | lnserva^3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lnco2e | 1.000 | | | | | | | | | | | | |
| lngdpk | -0.101 | 1.000 | | | | | | | | | | | |
| | (0.457) | | | | | | | | | | | | |
| lngdpk^2 | -0.099 | 0.999* | 1.000 | | | | | | | | | | |
| | (0.464) | (0.000) | | | | | | | | | | | |
| lngdpk^3 | -0.098 | 0.997* | 0.999* | 1.000 | | | | | | | | | |
| | (0.471) | (0.000) | (0.000) | | | | | | | | | | |
| lnagva | -0.866* | 0.026 | 0.023 | 0.019 | 1.000 | | | | | | | | |
| | (0.000) | (0.847) | (0.866) | (0.884) | | | | | | | | | |
| lnagva^2 | -0.874* | 0.012 | 0.009 | 0.006 | 0.999* | 1.000 | | | | | | | |
| | (0.000) | (0.931) | (0.949) | (0.968) | (0.000) | | | | | | | | |
| lnagva^3 | -0.882* | -0.003 | -0.006 | -0.009 | 0.998* | 0.999* | 1.000 | | | | | | |
| | (0.000) | (0.985) | (0.967) | (0.949) | (0.000) | (0.000) | | | | | | | |
| lnindva | **0.807*** | -0.439* | -0.440* | -0.441* | -0.650* | -0.654* | -0.658* | 1.000 | | | | | |
| | (0.000) | (0.001) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | | | | | | |
| lnindva^2 | 0.799* | -0.452* | -0.453* | -0.454* | -0.642* | -0.646* | -0.649* | 0.999* | 1.000 | | | | |
| | (0.000) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | | | | | |
| lnindva^3 | 0.789* | -0.464* | -0.464* | -0.465* | -0.634* | -0.637* | -0.639* | 0.998* | 0.999* | 1.000 | | | |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | | | | |
| lnserva | 0.506* | 0.351* | 0.355* | 0.359* | -0.694* | -0.704* | -0.714* | 0.086 | 0.066 | 0.047 | 1.000 | | |
| | (0.000) | (0.008) | (0.007) | (0.006) | (0.000) | (0.000) | (0.000) | (0.530) | (0.627) | (0.730) | | | |
| lnserva^2 | 0.502* | 0.353* | 0.358* | 0.362* | -0.692* | -0.702* | -0.712* | 0.079 | 0.060 | 0.041 | 0.999* | 1.000 | |
| | (0.000) | (0.008) | (0.007) | (0.006) | (0.000) | (0.000) | (0.000) | (0.561) | (0.659) | (0.764) | (0.000) | | |
| lnserva^3 | 0.498* | 0.356* | 0.361* | 0.365* | -0.690* | -0.700* | -0.709* | 0.073 | 0.054 | 0.035 | 0.999* | 0.999* | 1.000 |
| | (0.000) | (0.007) | (0.006) | (0.006) | (0.000) | (0.000) | (0.000) | (0.594) | (0.693) | (0.797) | (0.000) | (0.000) | |



Source: World Development Indicators (2017)

**Figure 3. Trend of Carbon dioxide ($CO_2$) emissions and Agricultural Value Added in Cote d'Ivoire from 1960 to 2015**



Source: World Development Indicators (2017)

**Figure 4. Trend of Carbon dioxide emissions ($CO_2$), Industrial and Services Value Added in Cote d'Ivoire from 1960 to 2015**

With Table 2, we observe a positive and significant correlation between Industrial Value Added and $CO_2$emissions with a coefficient of 0.807.

## Related Literature review

Results from past research on the EKC hypothesis are multifold. Indeed, some scholars found support for the EKC

(Panayotou, 1993; Grossman and Krueger, 1995; Jalil and.Mahmud, 2009; Beck and Joshi, 2015; Singh *et al*, 2016; Sinha and Shahbaz, 2017; Dang, 2018; Diputra and Baek,2018; Kılıç and Balan, 2018; etc) while others don't (Choi *et al*, 2010;Tevie *et al*, 2011; Anjum *et al*, 2014; Lacheheb, *et al*., 2015;Wang W., 2018; etc.).

### *Support for the EKC Hypothesis*

Panayotou (1993) provided an early rationale for the existence of an EKC. He argued that "If there were no change in the structure or technology of the economy, pure growth in the scale of the economy would result in a proportional growth in pollution and other environmental impacts". This is called the scale effect. The traditional view that economic development and environmental quality are conflicting goals reflects the scale effect alone. Proponents of the EKC hypothesis argue that "at higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, result in leveling off and gradual decline of environmental degradation". Grossman and Krueger (1995) analyzed the relationship between economic growth and the environment. Using data assembled by the Global Environmental Monitoring System, they examine a reduced form relationship between various environmental indicators and the level of a country's per capita income. They found that for most indicators, economic growth brings an initial phase of deterioration followed by a subsequent phase of improvement.

Lieb (2002) conducted a survey of the empirical evidence on the Environmental Kuznets Curve. He found that most studies agree to an EKC for air pollutants including $CO_2$ emissions. Moreover, EKC is supported for local and flow pollutants whereas pollution-income relationship is monotonically rising for global and stock pollutants. Jalil and. Mahmud (2009), examined thelong-run relationship between carbonemissions and energy consumption, income and foreign trade in the case of China. They used time series data ranging from 1975–2005 and Autoregressive distributedlag (ARDL) methodology. They found results supporting the EKC relationship. Beck and Joshi (2015), in their study titled "An analysis of the Environmental Kuznets Curve for Carbon Dioxide Emissions: Evidence for OECD and Non OECD countries", using dataset ranging from 1980 to 2008 and Generalized Methods of Moments (GMM) estimator found that the OECD countries have an N-shaped curve with income growth whereas the regions of Asia and Africa experience an income-based EKC pattern.

Singh *et al* (2016), investigated the Impact of $CO_2$Emission on Economic Growth and Environmental Kuznets Curve in India. Using data ranging from 1971 to 2009 found support for the Environmental Kuznets Curve Hypothesis in India. Sinha and Shahbaz (2017) estimated the EKC for $CO_2$emissions in India for the period of 1971-2015. Using autoregressive distributed lag (ARDL) approach, they found evidence of inverted U-shaped EKC for India. Diputra and Baek (2018), analyzed the Growth and Environment nexus in Indonesia. Using annual data for the period ranging from 1971 to 2013 and ARDL model found results supportive of the Environmental Kuznets Curve Hypothesis for $CO_2$. Kılıç and Balan (2018) tested the Environmental Kuznets Inverted-U Shaped Curve in a panel-data setting with data ranging from 1996 to 2010 and covering 151 countries. They used a cubic functional form estimated using pooled ordinary least Squares methods to investigate the EKC hypothesis. They found support for the EKC hypothesis. Dang (2018) in a study titled "An Empirical Investigation of the Environmental Kuznets Curve from an International economics perspective: Does the origin of FDI matter?", using a panel dataset covering 51 developed and developing countries ranging from 2001 to 2012 and two way fixed effect econometric model found support for the EKC hypothesis.

### *No support for the EKC hypothesis*

He and Richard (2009) investigated the existence of an environmental Kuznets curve for $CO_2$ emissions in Canada over a period of 57 years (1948 to 2004). They found results somewhat ambiguous with a cubic functional form indicating no such relationship. Even when they use more flexible models i.einvolving non parametric kernel-density estimation, they found no evidence of an Environmental Kuznets curve. Choi *et al* 2010 in their study on the relationships between $CO_2$ emissions, economic growth and openness, using time series data ranging from 1971 to 2006 from China, Korea and Japan found no consistent patterns. Indeed, they found an N-shaped curve for China, a U-shaped curve for Japan and Korea thus rejecting the Environmental Kuznets Curve Hypothesis. Tevie *et al* (2011), tested the Environmental Kuznets Curve Hypothesis for biodiversity risk in the USA usingspatial econometric approach. Their data comprised all 48 contigus states. Biodiversityrisk was measured using an adaptation of the Comprehensive National Biodiversity Risk Assessment Index. Their results did not support the EKC hypothesis for biodiversity risk in the USA. Anjum *et al* (2014) modelled the Emissions-Income relationship using long-run growth rates. The data used covered 143 countries and ranged from 1950 to 2011. They found no support for the EKC hypothesis.

Lacheheb, *et al.* (2015) investigated the Environmental Kuznets Curve Hypothesis in Algeria using data ranging from1971-2009 with autoregressive distributed lag co-integration framework. They found no support for the EKC. Balin *et al.* (2015),in their investigation of the EKC Hypothesis and the Effect of Innovation using Panel Data Analysis on data ranging from 1997 to 2009found an N-shaped relationship between $CO_2$emissions per capita and GDP per capita unlike the traditional inverted U-shaped EKC. Zheng *et al* (2015), investigated the relationship between economic growth and environmental pollution of 111 Chinese prefectural-level cities in the period 2004–2012 and how it might influence the choice of a city's developing pattern. They classified the 111 cities into five different clusters. Their results did not support the EKC hypothesis. Ibrahiem (2016) analyzed the relationship between environmental degradation and economic growth in Egypt. He used time series data ranging from 1980 to 2010 and employed Johansen Cointegration approach to assess the existence of a long run relationship between the variables and tested the Environmental Kuznets Curve (EKC) hypothesis. He found confirmation for the existence of long-run relationship between the variables. However, his results do not support the existence of EKC either in the short or the long run. Sinha and Bhatt (2017) in their paper on Environmental Kuznets Curve for $CO_2$and $NO_2$Emissions: A Case Study of India, tested the EKC hypothesis through an analysis of the relationship between $CO_2$ (in per capita metric tons) and GDP(per capita) using data ranging from 1960 to 2011. They found an N-shaped EKC for both $CO_2$ and $NO_2$. Wang W. (2018)

investigated the EKC hypothesis for Air Pollution in China using a panel data of 41 major cities over the period ranging from 2000 to 2015. They found no support for the EKC hypothesis. Their results are quiet contrary to what is in the literature. Indeed, they found a U-shaped instead of the inverted U-shaped curve. Allard *et al* (2018), in their study titled "The N-shaped environmental Kuznets curve: an empirical evaluation using a panel quantile regression approach", investigated the relationship between $CO_2$ emissions and GDP per capita for 74 countries over a period ranging from 1994 to 2012. They found evidence for the N-shaped EKC in all income groups, except for the upper-middle-income countries.

### *Other results on the EKC Hypothesis*

Panayotou (2001) in his paper titled "Demystifying the Environmental Kuznets Curve: Turning a black box into a policy tool" attempted to incorporate explicit policy considerations into the income environment relationship and to explore its determinants as a step towards a better understanding of this relationship and its potential as a policy tool. He found that at least in the case of ambient $SO_2$ levels, policies and institutions can significantly reduce environmental degradation at low income levels and speed up improvements at higher income levels, thereby flattening the EKC. Webber and Allen (2010) in their study titled "Environmental Kuznets curves: mess or meaning?"reviewed the empirical literature on the environmental Kuznets Curve and came to the conclusion that there is a relationship between specific environmental pollutants and income per capita, however the shape of the relationship is not uniform across pollutants, and turning points, when they exist, they differ across pollutants. Thus, there is no "*single*" relationship between income, environmental quality and the rate of environmental degradation. It results from the above brief review of selected literature that there is no consensus regarding the EKC hypothesis. This paper tries to contribute to the debate by providing evidence from a developing country in West Africa.

## Method of analysis and data

Following past research work on the EKC hypothesis (Grossman and Krueger 1994; Martinez-Zarzoso and Bengochea-Morancho 2004; Figuero and Pasten 2009; Dietz et 2012; Apergis 2014; Stern 2014; Beck and Joshi 2015; Balin and Akan 2015; Sinha and Bhatt 2017 etc) we posit the following reduced-form model of the relationship between $CO_2$ emissions, per capita GDP ($lngdpk_t$), Agricultural Value Added ($lnagva_t$), Industrial Value Added ($lnindva_t$) and Sevices Value Added ($lnserva_t$).

$$lnCO2e_t = \alpha_0 + \alpha_1 lngdpk_t + \alpha_2 (lngdpk_t)^2 + \varepsilon_{1t} \text{ ........(1)}$$

$$lnCO2e_t = \beta_0 + \beta_1 lnagva_t + \beta_2 (lnagva_t)^2 + \varepsilon_{2t} \text{ ........(2)}$$

$$lnCO2e_t = \gamma_0 + \gamma_1 lnindva_t + \gamma_2 (lnindva_t)^2 + \varepsilon_{3t} \text{ ........(3)}$$

$$lnCO2e_t = \delta_0 + \delta_1 lnserva_t + \delta_2 (lnserva_t)^2 + \varepsilon_{4t} \text{ ........(4)}$$

With $t = 1,2, \ldots, T$

Where $lnCO2e_t$ is the natural logarithm of carbon dioxide emissions at time $t$,$lngdpk_t$ is natural logarithm of per capita Gross Domestic Product at time $t$, $lnagva_t$ is natural logarithm of Agricultural Vaue Added at time $t$, $lnindva_t$ is natural logarithm of Industrial Vaue Added at time $t$,$lnserva_t$ is natural logarithm of Services Vaue Added at time $t$. Using the above specifications, for each equation we can determine the turning point level of percapita GDP, Agricultural value Added, Industrial Value Added and Services Value Added by taking the first derivative with respect to the variable of interest and set it equal to zero. Thus, we obtain the following formulas:

$$\widehat{lngdpk} = \frac{-\alpha_1}{2\alpha_2} \quad \rightarrow \widehat{gdpk} = exp^{(-\alpha_1/2\alpha_2)} \text{For equation 1;}$$

$$\widehat{lnagva} = \frac{-\beta_1}{2\beta_2} \quad \rightarrow \widehat{agva} = exp^{(-\beta_1/2\beta_2)} \text{ For equation 2;}$$

$$\widehat{ln\imath ndva} = \frac{-\gamma_1}{2\gamma_2} \quad \rightarrow \widehat{\imath ndva} = exp^{(-\gamma_1/2\gamma_2)} \text{ For equation 3;}$$

$$\widehat{lnserva} = \frac{-\delta_1}{2\delta_2} \quad \rightarrow \widehat{serva} = exp^{(-\delta_1/2\delta_2)} \text{ For equation 4;}$$

The data used for this study is time series obtained from World Development Indicators of the World Bank (World Bank 2018) and cover period ranging from 1960 to 2015. Given the time series nature of the data it is critical to investigate its characteristics. This entails finding out whether the variables to be analyzed are stationary or not. This is done using the traditional Unit Root test i.e. the Augmented Dickey Fuller (ADF) Unit Root Test and the Philip Perron (PP) Unit Root Test. This is important, since a regression of non-stationary variables on other non-stationary variables give rise to what is known as spurious regression.

Following the results on the time series characteristics of the data, whether I(0) or I(1), we will investigate the short and long run relationships between $CO_2$ emissions and the variable of interest using an ARDL approach. To do that, we need to reformulate our model in a way that shows both the short run and long run dynamics. The Autoregressive Distributed Lag (ARDL) model allows us to do that. The generalized ARDL($p,q$) model is given below:

$$Y_t = \alpha_i + \sum_{i=1}^{p} \delta_i Y_{t-i} + \sum_{i=0}^{q} \beta'_i X_{t-i} + \varepsilon_{it} \text{ ......(5)}$$

Where $Y_t$ is the endogenous variable, $X_t$ represents the explanatory variables and are all allowed to be *I(0)* or *I(1)*; α is the constant, δ and β are parameters to be estimated; $p$ and $q$ are optimal lag orders. For the Bounds Test we use the Akaike Information Criterion (AIC) to determine the optimal lag which gives us the unrestricted Error Correction Model (Peseran *et al*. 2004 called it conditional ECM) or put differently, conditional ARDL($p,q$) presented below:

$$\Delta lnCO2e_t = \alpha_1 + \theta_{11} lnCO2e_{t-1} + \theta_{12} lngdpk_{t-1} + \theta_{13}(lngdpk_{t-1})^2 + \sum_{i=0}^{q} \varphi_1 \Delta lnCO2e_{t-i} + \sum_{i=0}^{q} \varphi_{2i} \Delta lngdpk_{t-i} + \sum_{i=0}^{q} \varphi_{3i} \Delta(lngdpk_{t-i})^2 + \varepsilon_{1t} \text{ .....(6)}$$

$$\Delta lnCO2e_t = \alpha_2 + \theta_{21} lnCO2e_{t-1} + \theta_{22} lnagva_{t-1} + \theta_{23}(lnagva_{t-1})^2 + \sum_{i=0}^{q} \varphi_2 \Delta lnCO2e_{t-i} + \sum_{i=0}^{q} \varphi_{2i} \Delta lnagva_{t-i} + \sum_{i=0}^{q} \varphi_{3i} \Delta(lnagva_{t-i})^2 + \varepsilon_{2t} \text{ ...(7)}$$

$$\Delta lnCO2e_t = \alpha_3 + \theta_{31} lnCO2e_{t-1} + \theta_{32} lnindva_{t-1} + \theta_{33}(lnindva_{t-1})^2 + \sum_{i=0}^{q} \varphi_3 \Delta lnCO2e_{t-i} + \sum_{i=0}^{q} \varphi_{2i} \Delta lnindva_{t-i} + \sum_{i=0}^{q} \varphi_{3i} \Delta(lnindva_{t-i})^2 + \varepsilon_{3t} \text{ .......(8)}$$

$$\Delta lnCO2e_t = \alpha_4 + \theta_{41} lnCO2e_{t-1} + \theta_{42} lnserva_{t-1} + \theta_{43}(lnserva_{t-1})^2 + \sum_{i=0}^{q} \varphi_4 \Delta lnCO2e_{t-i} + \sum_{i=0}^{q} \varphi_{2i} \Delta lnserva_{t-i} + \sum_{i=0}^{q} \varphi_{3i} \Delta(lnserva_{t-i})^2 + \varepsilon_{4t} \quad ..(9)$$

The Bounds test is equivalent to testing the following hypotheses for each equation:

$$\begin{cases} H_0: \theta_{i1} = \theta_{i2} = \theta_{i3} = 0 \\ H_1: \theta_{i1} \neq \theta_{i2} \neq \theta_{i3} \neq 0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots(10)$$

The null hypothesis $H_0$ test the absence of a long run equilibrium relationship between the dependent variable and the explanatory variables. The statistics underlying this hypothesis test is the familiar Wald or F-statistics in a Generalized Dicker Fuller type regression used to assess the significance of lagged levels of variables under consideration in an unrestricted equilibrium error correction regression (Peseran *et al* 1999). Thus, if we accept $H_0$ we can conclude that there is no long run relationship between the variables and that they are not cointegrated. However, if we reject the null hypothesis, then, we conclude that there is a long run relationship between the variables. A key assumption in the ARDL Bounds Testing methodology of Peseran *et al* (2001) is that the error terms in the above equations be serially independent i.e. no autocorrelation. Once this condition is satisfied we need to ensure that the model is dynamically stable.

The asymptotic distribution of both Wald and F-statistics are nonstandard under the null hypothesis of no long run relationship irrespective of whether the variables are I(0), I(1) or mutually cointegrated. However, Peseran *et al* (2001) have provided asymptotic critical values bounds for all classifications of the regressors into I(1) and / or I(0). Thus, if the computed F-statistics fall below the lower bound, we accept the null hypothesis of no cointegration. In such situation we proceed to estimate the short run dynamics using Ordinary Least Squares (OLS) regression technic. If the F-statistics is greater than the upper bound, we reject the null hypothesis and conclude that there exist a long run relationship between the variables. When this is the case, estimation of the ARDL model provides us with both the long run (levels equation) and short run dynamics (difference equation). If the F-statistics fall between the bounds, the test is inconclusive. In this case, knowledge of the cointegration rank of the forcing variables (explanatory variables) is required to proceed further (Peseran *et al* 1999). In addition to the F-test above, we can also perform a "Bounds t-test" to cross-check the results. The test is as follows for:

$$\begin{cases} H_0: \theta_{i1} = 0 \\ H_1: \theta_{i1} < 0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots..(12)$$

Here also, the null hypothesis, $H_0$ tests the absence of a long run equilibrium relationship between the dependent variable and the explanatory variables. If the t-statistics is greater than the I(0) bound, tabulated by Peseran *et al* (2001; pp 303-304) and Kripfganz *et al* (2018; pp 30-33), accept the null hypothesis and conclude that there is no cointegration between the variables. If the t-statistics is less than the I(1) bound, reject the null hypothesis and conclude that there is long run relationship between the variables. Here again if the t-statistics falls between the two bounds the test is inconclusive. All computations were done using the statistical software Stata 14.2.

The time series characteristics of the data analyzed via the Unit Root test show that $CO_2$ emissions variable is stationary i.e. I(0) whereas the others three variables of interest i.e. per capita GDP, Agricultural Value Added, Industrial Value Added and Servcies Value Aded are stationary after first differencing i.e. I(1). The Unit Root tests results are presented in the table below.

## Empirical results and discussions

In this section we present and discuss the empirical results.

**Table 3. Unit root tests**

| Variables | Levels | | 1st Difference | |
|---|---|---|---|---|
| | ADF | PPerron | ADF | PPerron |
| *lnco2e, lag(1)* | **-2.963**$^{*}$ | **-3.041**$^{*}$ | | |
| | (0.038) | (0.031) | | |
| *lngdpk, lag(2)* | -1.656 | -1.408 | -2.491 | **-5.401**$^{*}$ |
| | (0.454) | (0.578) | (0.118) | (0.000) |
| *lngdpk^2, lag(2)* | -1.654 | -1.403 | -2.504 | **-5.378**$^{*}$ |
| | (0.455) | (0.581) | (0.114) | (0.000) |
| *lnagva, lag(1)* | -2.171 | -2.155 | **-5.182**$^{*}$ | **-7.434**$^{*}$ |
| | (0.217) | (0.223) | (0.000) | (0.000) |
| *lnagva^2, lag(1)* | -2.307 | -2.297 | **-5.090**$^{*}$ | **-7.407**$^{*}$ |
| | (0.169) | (0.173) | (0.000) | (0.000) |
| *lnindva, lag(1)* | -2.056 | -2.255 | **-5.994**$^{*}$ | **-8.590**$^{*}$ |
| | (0.262) | (0.187) | (0.000) | (0.000) |
| *lnindva^2, lag(1)* | -1.957 | -2.149 | **-5.961**$^{*}$ | **-8.778**$^{*}$ |
| | (0.306) | (0.225) | (0.000) | (0.000) |
| *lnserva, lag(1)* | -2.321 | -2.462 | **-4.368**$^{*}$ | **-8.335**$^{*}$ |
| | (0.165) | (0.125) | (0.000) | (0.000) |
| *lnserva^2, lag(1)* | -2.298 | -2.445 | **-4.398**$^{*}$ | **-8.377**$^{*}$ |
| | (0.173) | (0.129) | (0.000) | (0.000) |

Schwartz-Bayesian Information Criterion (SBIC) was used to determine the optimal lag order.

In line with the above results we cannot use the traditional Granger and Johansen approached to investigate any long run relationship (cointegration). The appropriate approach therefore is to use the Bounds Test proposed by Peseran, Shin and Smith (2001) to investigate any long run relationship. Tables 4 and 5 present the results of the Bounds Test. Let's recall that we have four (04) different models. The first one tests whether there is a long run relationship between $CO_2$ emissions and per capita GDP. The AIC test results indicates optimal lag order of (1, 0, 0). The Bounds Test results gives a F-statistics of 2.803 which is less than the critical value for I(0) at the 5% probability level. The decision is therefore to accept the null hypothesis of No levels relationship. Thus, $CO_2$ emissions and per capita GDP are not cointegrated. In light of this result we move to estimate the short run dynamics between $CO_2$emissions and percapita GDP (Table 6). Although the model exhibit excellent goodness of fit (Adjusted R-squared = 0.948, overall F-statistics = 327.08 and significant, no serial correlation and no heteroskedasticity) none of the variables of interest is significant. Thus, our results do not support the Environmental Kuznets Curve hypothesis. The second model tests whether there is a long run relationship between $CO_2$emissions and Agricultural Value Added and to what extent it is of the EKC type. The AIC test indicates that the optimal lag order to consider is (1, 0, 0). The Bounds test results give a F statistic of 6.412 which is greater than the critical value for I(1) at all probability levels. This leads to reject the null hypothesis and to conclude that there is a long run relationship between $CO_2$emissions and Agricultural Value Added. In other words, $CO_2$emissions and agricultural value added are cointegrated and hence, move together in the long run. In light of this result, we move to estimate both long and short run dynamics. The results are presented in Table 6. The speed of adjustment is negative and significant (-0.229). The coefficient associated with the linear term of Agricultural Value Added (*lnagva*$_t$) is positive and significant at the 10% probability level. The coefficient associated with the quadratic term of Agricultural Value Added (*lnagvasq*$_t$) is negative and significant at the 5% probability level. Hence, there is a long run causality running from Agricultural Value Added to $CO_2$ emissions in the country.

**Table 4. Bounds Test for cointegration among climate andeconomic variables**

| Per capita GDP<br>Bounds Test ARDL(1, 0, 0) | Agricultural Value Added<br>Bounds Test ARDL(1,0,0) |
|---|---|
| $H_0$➔ No levels relationship | |
| F-stat = 2.803 | F-stat = 6.412 |
| Crit. val. at 5% [I(0) I(1)] | [I(0) I(1)] |
| k=2 [3.79 4.85] | k=2 [3.79 4.85] |
| Accept $H_0$ if $F_{stat}<F_\alpha$for I(0) | Reject $H_0$ $F_{stat}> F_\alpha$ for I(1) |
| t-stat= -2.800 | t-stat= -4.219 |
| Crit. val. at 5% [I(0) I(1)] | [I(0) I(1)] |
| k=2 [-2.86 -3.53] | k=2 [-2.86 -3.53] |
| Accept $H_0$ if $t_{stat}>t_\alpha$for I(0) | Reject $H_0$ if $t_{stat}< t_\alpha$ for I(1) |

**Table 5. Bounds Test for cointegration among climate and economic variables**

| Industrial Value Added<br>Bounds Test ARDL(1,0,0) | Service Value Added<br>Bounds Test ARDL(2,0,0) |
|---|---|
| $H_0$➔ No levels relationship | |
| F-stat = 4.579 | F-stat = 5.855 |
| Crit. val. at 5% [I(0) I(1)] | Crit. val. at 5% [I(0) I(1)] |
| k=2 [3.79 4.85] | k=2 [3.79 4.85] |
| Test is inconclusive) | Reject $H_0$ if F > $F_\alpha$ for I(0) |
| t-stat= -2.106 | t-stat= -3.855 |
| Crit. val. at 5%[I(0) I(1)] | Crit. val. at 5%[I(0) I(1)] |
| k=2 [-2.86 -3.53] | k=2 [-2.86 -3.53] |
| Accept $H_0$ if t >$t_\alpha$for I(0) | Reject if $H_0$ if t <$t_\alpha$for I(1) |

These results clearly provide support to the EKC type hypothesis in the Agricultural sector. Thus, there is a threshold level or a turning point of Agricultural Value Added's contribution to GDP from which any additional increment of Agricultural's contribution to GDP will reduce the level of $CO_2$ emissions. Using the estimated coefficients we obtain the following turning point:

$$\widehat{agva} = exp^{(-23.813/(-2*3.894)} = 21.278\%$$

Our next model tests whether there is a long run relationship between $CO_2$emissions and Industrial Value Added and also assess the EKC hypothesis. The AIC test indicates optimal lag order of (1, 0, 0). The Bounds test results give F statistic of 4.579 and falls inside the bounds of the critical values at the 5% probability level. The test is therefore inconclusive. We look at the t-statistic which is -2.106 and greater than the critical value for I(0) at the 5% probability level. We therefore accept the null hypothesis of no long run relationship between $CO_2$emissions and Industrial Value Added in Cote d'Ivoire over the period of analysis. In light of this result, we move to estimate the short run dynamics between these variables. Results show a significantly positive relationships between $CO_2$ emissions and the linear term of Industrial Value Added. The quadratic term is significantly negative. Here, the estimated parameters indicate a short run causality running from Industrial Value Added to $CO_2$ emissions in the country. These results are supportive of the EKC hypothesis. Here also, we have a turning point of Industrial Value Added's contribution to GDP from which any additional increment of Industrial sector's contribution to GDP will reduce the level of $CO_2$ emissions. Using the estimated coefficients we obtain the following turning point:

$$\widehat{indva} = exp^{(-10.679/(-2*1.794)} = 19.615\%$$

The last model tests whether there is a long run relationship between $CO_2$ emissions and Services Value Added and also assess the EKC hypothesis. The AIC test indicates optimal lag order of (2, 0, 0). The Bounds Test give a F-statistic of 5.855which is greater than the critical value for I(1) at the 5% probability level. We therefore reject the null hypothesis of no long run relationship and conclude that $CO_2$ emissions and Services Value Added are cointegrated. We then estimate both the long and short run dynamics (Table 7). The Adjustment coefficient (-0.124) is negative and significant. The linear term is positive and significant. The quadratic term is negative and also significant. Thus there is a long run causality running from Services Value Added to $CO_2$ emissions in the country. These results provide support to the EKC hypothesis in the Services Sector of the economy.We have a turning point of Services Value Added's contribution to GDP from which any additional increment of Services sector's contribution to GDP will reduce the level of $CO_2$ emissions. Using the estimated coefficients we obtain the following turning point:

$$\widehat{serva} = exp^{(-285.721/(-2*36.282)} = 51.290$$

The above results could indicate that due to increased environmental awareness, the country is taking actions towards less $CO_2$ emissions and encouraging the utilization of cleaner technologies in all the sectors of the economy.

**Table 6. Results of the ARDL estimation of the impact of climate on economic growth in Cote d'Ivoire**

| | Per capita GDP | | Agricultural Value Added |
|---|---|---|---|
| | ARDL(1,0,0) | | ARDL(1,0,0) |
| | | **Long run dynamics** | |
| Constant | 12.354 | Constant | -6.282 |
| | (0.734)[a] | | (0.253) |
| *ECT*$_{t-1}$ | | *ECT*$_{t-1}$ | -0.229*** |
| | | | (0.000) |
| *lngdpk*$_t$ | | *lnagva*$_t$ | 23.813* |
| | | | (0.078) |
| *lngdpksq*$_t$ | | *lnagvasq*$_t$ | -3.894** |
| | | | (0.051) |
| | | **Short run dynamics** | |
| $\Delta lnco2e_{t-1}$ | 0.915***[b] | | |
| | (0.000) | | |
| $\Delta lngdpk_t$ | -3.160 | | |
| | (0.747) | | |
| $\Delta lngdpksq_t$ | 0.215 | | |
| | (0.745) | | |
| Adj R-squared | 0.948 | | 0.231 |
| $F_{(3, 51)}$➔ | 327.080*** | $F_{(3, 51)}$➔ | 6.410*** |
| | (0.000) | | (0.001) |
| Breusch-Godfrey LM test for absence of autocorrelation | | | |
| $\chi^2_{(1)}$ | 1.304 | $\chi^2_{(1)}$ | 1.192 |
| | (0.254) | | (0.275) |
| White's test for Ho: homoskedasticity | | | |
| $\chi^2_{(8)}$ | 9.440 | $\chi^2_{(10)}$ | 17.160** |
| | (0.306) | | (0.028) |

For each equation we tested for the absence of serial correlation as well as homskedasticity. The null of no autocorrelation could not be rejected unlike that of homoscedasticity.

[a] Number in parenthesis are p-values

[b] Asterisk indicates significant levels i.e. *➔10%, **➔ 5% and ***➔ 1%

**Table 7. Results of the ARDL estimation of the impact of climate on economic growth in Cote d'Ivoire**

| | **Industrial Value Added**<br>ARDL(1,0,0) | | **Service Value Added**<br>ARDL(2,0,0) |
|---|---|---|---|
| | | **Long run dynamics** | |
| Constant | -14.894$^{**}$<br>(0.048) | Constant | -68.732$^{**}$<br>(0.035) |
| | | $ECT_{t-1}$ | -0.124$^{***}$<br>(0.000) |
| | | $lnserva_t$ | 285.721$^{**}$<br>(0.045) |
| | | $lnservasq_t$ | -36.282$^{**}$<br>(0.048) |
| | | **Short run dynamics** | |
| $\Delta lnco2e_{t-1}$ | 0.893$^{***}$<br>(0.000) | $\Delta lnco2e_{t-1}$ | -0.175<br>(0.166) |
| $\Delta lnindva$ | 10.679$^{**}$<br>(0.038) | | |
| $\Delta lnindvasq_t$ | -1.794$^{**}$<br>(0.037) | | |
| Adj R-squared | 0.952 | | 0.208 |
| $F_{(3,51)}$→ | **357.930**$^{***}$<br>(0.000) | $F_{(4,49)}$→ | **4.490**$^{***}$<br>(0.004) |
| Breusch-Godfrey LM test for absence of autocorrelation | | | |
| $\chi^2_{(1)}$→ | 1.436<br>(0.231) | $\chi^2_{(52)}$→ | 0.057<br>(0.811) |
| White's test for Ho: homoskedasticity | | | |
| $\chi^2_{(8)}$→ | 14.390$^{*}$<br>(0.072) | $\chi^2_{(10)}$→ | 14.960<br>(0.310) |

For each equation we tested for the absence of serial correlation as well as homskedasticity. In both cases, The nulls of no autocorrelation and homoscedasticity could not be rejected.

[a] Number in parenthesis are p-values

[b] Asterisk indicates significant levels i.e. $^{*}$→10%, $^{**}$→ 5% and $^{***}$→ 1%

## Conclusion

This study has investigated the environment and growth nexus via an analysis of the long run relationship between $CO_2$ emissions and per capita GDP, Agricultural Value Added, Industral as well as Services Value Added. The data used ranged from 1960 to 2015. An ARDL model was used to assess long run relationship between $CO_2$ emissions and per capita GDP. The empirical results show no long run relationship between $CO_2$ emission and per capita GDP. They are not cointegrated. Results also do not support the EKC hypothesis for $CO_2$ in Cote d'Ivoire. When we considered sectoral contribution to GDP instead of per capita GDP, we found that the EKC hypothesis is supported in the Agricultural, Industrial and Services sectors. The results also indicate cointegration between the variables of interest and long run causality running from Agricultural and Services sector's Value Added to $CO_2$ emissions. We also have indication of short run causality running from Industrial Value Added to $CO_2$ emissions in the country. We call for actions towards increasing the awareness to reduce $CO_2$ emissions via the adoption of cleaner technologies that could boost sectoral productivity and increase its contribution to GDP. One of the shortcomings of this paper is that it used a reduced form specification (omission variable biais). A full structural model will be investigated in another endeavor to see if results are different.

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