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Carbon Dioxide (CO_2) Emissions in Côte d'Ivoire: Should We Worry?

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Abstract
The objective of this paper is to contribute to a better understanding of the CO_2 emissions and growth nexus in Côte d'Ivoire. The data used range from 1960 to 2015. An ARDL model is used to assess the long run relationship between CO_2 emissions, per capita GDP and selected control variables. We found that there is a long run relationship between CO_2 emissions, per capita GDP, Investment; Openness, life expectancy and population. Thus, they are cointegrated. We also found long run causality running from CO_2 emissions to per capita GDP. The results indicated a nonlinear relationship between per capita GDP and CO_2 emissions. This enabled us determine a CO_2 emissions threshold beyond which any increment in CO_2 emissions negatively affect the country's economic performance. This tipping point stood at **7,755 kt**. The country's actual emissions is well above this threshold. There is therefore reasons to worry, and we call on government to take necessary actions to monitor CO_2 emissions in the country before it is too late.
Keywords: CO_2 emission, economic growth, ARDL

1. Introduction

Carbone Dioxide (CO_2) is define as a gas essential for life (animals exhale it and plants sequester it). It is also known as a greenhouse gas (GHG) i.e. a gas that absorbs and emits thermal radiation, creating the 'greenhouse effect' (Hannah and Max, 2018). Along with other greenhouse gases such as nitrous oxide and methane, CO_2 is important in sustaining a habitable temperature for the planet. Indeed, it is argued that if there were absolutely no GHGs, our planet would be too cold to be livable, as average surface temperature would be about -18 degree celsuis (Qiancheng, 1998). Thus, CO_2 is good for life. Unfortunately, its accumulation beyond a given level can disrupt the global carbon cycle thereby leading to a planetary warming impact. This can result in environmental problems such as change in seasons, flooding, severe storms, drought and heatwaves (see IPCC 2014 for details impacts)[1]. That is why CO_2 emissions are to be monitored closely and reduced drastically when and if we believe that its emissions have reached an unacceptable level.

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, 2018). It geographically propagates more easily than local air pollutants such as sulfur emissions (Aslanidis et al (2004). When we consider world and low middle income countries' CO_2 emissions (**Figure 1**) we observe that it has evolved over an upward sloping trend from 1960 to 2014. Côte d'Ivoire being among the low middle income countries, we looked at its CO_2 emissions over the same time period (**Figure 2**). We observe that although from 1980 to 2009 the country's CO_2 emissions registered some volatility, we can assert in general and considering that a polynomial of order 3 provides a good fit of the data (R^2 = 0.82), that the trend is upward sloping. In addition, the cumulative CO_2 emissions for the country stood at 288.1 million tons in 2014[2]. This is quite high if we consider that in 1960 when the country ascended to political independence the level of CO_2 emissions stood at 1.51 million tons. It is this "rapid" increase of CO_2 emissions over the years that called our attention to investigate how this development parallels the country's economic performance and whether we should worry or not. In addition, On December 2017, a Decree was passed by the Government to limit the age of used vehicles imported into the country (Côte d'Ivoire 2017). It is not clear whether this decision was informed by the sharp increase in CO_2 emissions in the country or not given that, used vehicles are not the only emitters of CO_2.

The dangers related to the excessive accumulation of CO_2 emissions has led several scholars (Beck and Joshi, 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. We would like to go beyond the simple relationship between economic growth and CO_2 emissions and investigate whether or not there is a tipping point at which CO_2 emissions is harmful to economic growth and where the country stands with respect to that tipping point.

[1] https://www.ipcc.ch/report/ar5/wg2/docs/WGIIAR5_SPM_Top_Level_Findings.pdf
[2] https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions#the-long-run-history-cumulative-co2

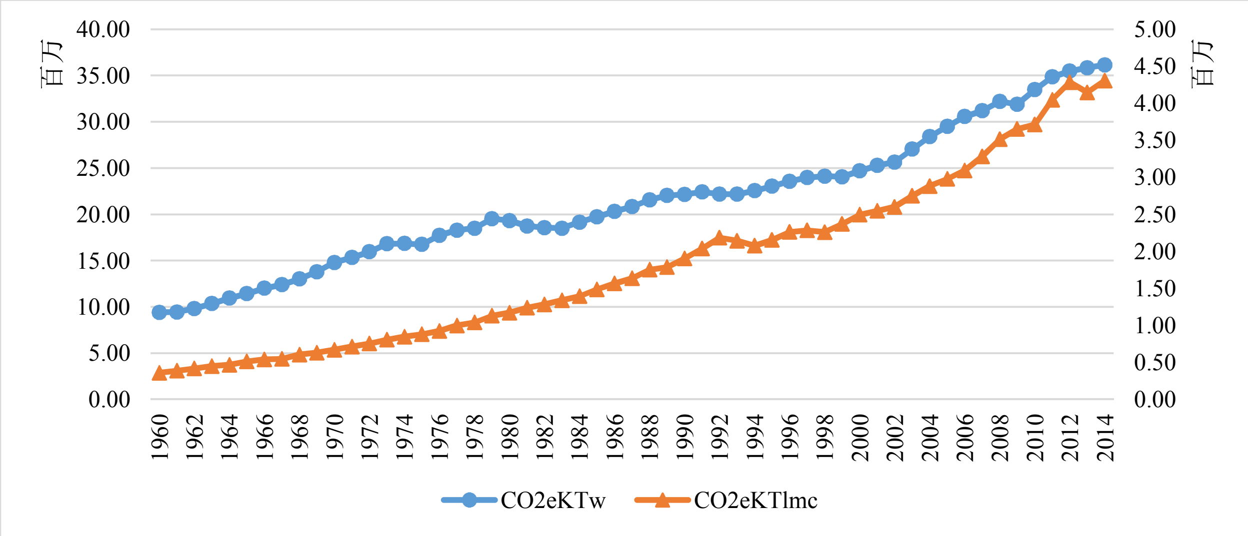

Figure 1. Trend of World (CO2ektw) and Low Middle Income (CO2ektlmc) countries' CO_2 emissions (in million tons) from 1960 to 2014.
Source: Carbon Dioxide Information Analysis Centre (CDIAC)

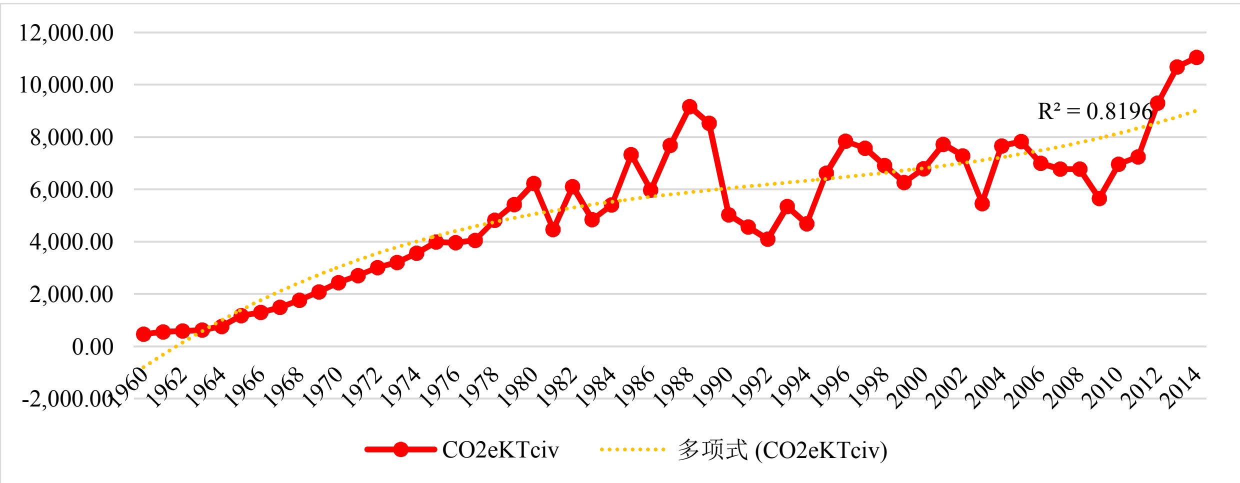

Figure 2. Trend of Cote d'Ivoire's CO_2 emissions (in Kt) from 1960 to 2014
Source: Carbon Dioxide Information Analysis Centre (CDIAC)

In line with the above and past studies the main objective of this paper is to contribute to a better understanding of the carbon dioxide emissions (CO_2) and economic growth nexus in Côte d'Ivoire. More specifically, the study seeks to determine the impact of CO_2 emissions, together with investment, openness, life expectancy and population size, on economic performance in Côte d'Ivoire. The rest of the paper is organized as follows: some stylized facts on how the country's CO_2 emissions compare to its economic performance over the years (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.

2. 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). How has it evolved over time in Côte d'Ivoire compared to the country's economic performance? Looking at **Figure 3** below, we observe that in Cote d'Ivoire CO_2 emissions trend is upward sloping although not smooth throughout the entire period of analysis. We can consider three (03) episodes. The first episode starts from 1960 to 1980. During that episode, both CO_2 emissions and per capita GDP were upward sloping. 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. During that same period per capita GDP grew from 1,234 US$ in 1960 to 2,397 US$ in 1978 representing 94% increase over the time period, before declining to 2,001 US$ in 1980. That period was tagged the "*Ivorian Miracle*" mainly due to rapid increase of per capita Gross Domestic Product (*GDPk*). Indeed, the country reached its all-time highest level of per capita GDP in 1978 at 2,397 US$. The miracle did not last and the country entered a severe economic recession for which it had to recourse to Bretton Woods' Structural Adjustment Programs. That is the second episode.

The second episode covers the period ranging from 1980 to 2009. The trend of CO_2 emissions was not smooth after the year 1980. Indeed, CO_2 emissions were volatile combining ups and downs till 2009. That period was a period of economic hardship for the country. Indeed, as indicated above, the country embarked on the Structural Adjustment Programs (SAP) spearheaded by the Bretton Woods institutions from 1981 onward. It was followed by a devaluation of the country's currency (CFA Francs) in January 1994, a military coup in 1999 and political unrest thereafter till 2011 which marked the end of the second episode. Despite all the Structural Adjustment Programs implemented, per capita GDP continued its decline with its corollary of hardship.

The third and last episode covered the period ranging from 2010 onward. After the year 2009, CO_2 resumed with continuous increase to reach its highest level in 2014 at 11,045kt (**Table 1**). Per capita GDP also resumed with an upward sloping trend from 2010 onward and stood at 1,496 US$ in 2014 well below the annual average over the period of analysis i:e: 1,560.75 US$. 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[1] 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.

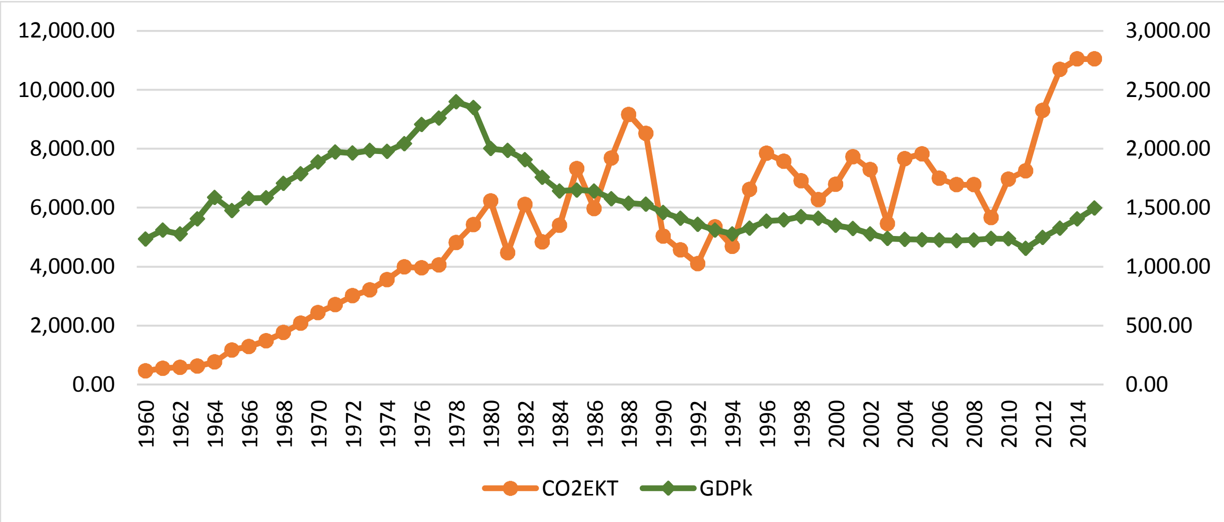

Figure 3. Trend of Carbon dioxide (CO_2) emissions and per capita GDP in Cote d'Ivoire from 1960 to 2015
Source: World Development Indicators (2017)

3. Related Literature review

Several scholars have investigated the CO_2 emission and economic growth nexus and found diverging results. These results ranged from linear (positive or negative) to nonlinear relationship between economic growth and CO_2 emissions. We will briefly review the works of these scholars.

3.1 Positive relationship between economic growth and CO_2 emissions

Lieb (2003) conducted a survey of the empirical evidence on the Environmental Kuznets Curve. He found that for CO_2 emissions the majority of studies found a monotonically rising pollution-income relationship. These studies included: Holtz-Eakin and Selen, 1992; Shafik and Bandyopadhyay, 1992; Cole et al. 1997; Lim, 1997; Roberts and Grimes 1997; Borghesi, 2000; Cavlovic et al 2000; Bengochea-Morancho et al 2001 and Heil and Selden, 2001.

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 which supported a nonlinear relationship. They highlighted weaknesses in the use of parametric models and hence moved for more "flexible ones" i.e. the Partially Linear Regression Model knowns as PLR and the Hamilton's model. When they assumed that only per capita GDP is nonlinearly related to per capita CO_2 emissions (in a non-parametric setting i.e. Hamilton's model), they found that the relationship between the two variables is monotonically increasing with slope changing over time. They, thus concluded that there is a

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

positive relationship between per capita CO_2 emissions and per capita GDP.

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 positive relationship between CO_2 emissions and income.

Lacheheb, et al. (2015) in their study on Economic Growth and Carbon Dioxide Emissions in Algeria, using data ranging from 1971-2009 with autoregressive distributed lag cointegration framework, found positive relationships between income and CO_2 from solid fuel consumption, electricity and heat production both in the long run and short run.

Ayeche et al (2016) investigated the causal linkage between economic growth, financial development, trade openness and CO_2 emissions in European countries. They used a panel of 40 countries over a time period ranging from 1985 to 2014. They found positive and significance impact of CO_2 emissions on growth.

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, they found positive relationship between per capita GDP and CO_2 Emissions.

Jamel and Derbali (2016) examined whether energy consumption and economic growth lead to environmental degradation? They used panel data for eight Asian countries (China, India, Thailand, Japan, Malaysia, Singapore, Indonesia and South Korea) for a period ranging from 1991 to 2013. They found positive relationship between economic growth and CO_2 emissions.

Mapapu and Phiri (2017) conducted a study on carbon emissions and economic growth in South Africa using quantile regression analysis. The data used ranged from 1970 to 2014, they also found positive relationship between carbon emissions and economic growth. However, the positive effect is magnified at extremely low or extremely high values of carbon emissions.

3.2 Negative relationship between economic growth and CO_2 emissions

Omri (2013) studied the CO_2 emissions, energy consumption and economic growth nexus in the MENA (Middle East and North Africa) countries. He used a panel of 14 countries with data ranging from 1990 to 2011. He found that for the individual country analysis, ten (10) out of the 14 countries exhibited significant negative relationship between CO_2 emissions and per capita GDP. For the remaining 4 countries, the relationship although negative, was not significant. The panel estimation results confirmed the negative relationship between CO_2 emissions and per capita GDP.

Azam et al (2016) investigated the impact of CO_2 emissions on economic growth from selected higher emissions economies i.e. China, USA, India and Japan. Using a Panel Fully Modified Ordinary Least Squares (FMOLS) method, on data ranging from 1971 to 2013, they found that CO_2 emissions have significantly negative impacts on economic growth although results vary for individual countries. For instance, for countries like China, USA and Japan they found positive relationships whereas for India they found negative relationship.

Nuryartono and Rifai (2017) examined the Causality between Economic Growth, Energy Consumption and Carbon Dioxide Emissions in 4 ASEAN Countries (Indonesia, Malaysia, Singapore and Thailand). They used data ranging from 1975 to 2013 and found that in the long run there is a negative relationship between economic growth and CO_2 emissions in two of the four countries i.e. Malaysia and Thailand.

3.3 Nonlinear relationship between economic growth and CO_2 emissions

Grossman and Krueger (1994) analyzed the relationship between economic growth and the environment. They used data assembled by the Global Environmental Monitoring System, they examined 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 environmental deterioration followed by a subsequent phase of improvement. Thus the relationship is not linear.

Ang (2007) in an article titled "CO_2 emissions, energy consumption and output in France", using data ranging from 1960 to 2000, found that CO_2 emissions and output variables have a quadratic relationship in the long run. Thus, the relationship is positive up to a threshold and then declines illustrating the nonlinear relationship between output and CO_2 emissions.

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, a clear indication of the nonlinear relationship.

Jayanthakumaran K., R. Verma and Y. Liu (2012) in a comparative study of China and India on CO_2 emissions, energy consumption, trade and income, using data ranging from 1971 to 2007 found a nonlinear relationship between CO_2 emissions and per capita GDP.

Balin et al. (2015), investigated the Environmental Kuznets Curve Hypothesis and the Effect of Innovation, for 27 developed countries. They used data ranging from 1997 to 2009 in a panel setting and found an N-shaped relationship between CO_2 emissions per capita and GDP per capita supporting the nonlinear relationship.

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 nonlinear relationship between the variables in the long run. The relationship is negative initially and then turns to positive after a threshold contrary to the EKC hypothesis.

Sinha and Shahbaz (2017), estimated an Environmental Kuznets Curve for CO_2 Emission in India. They found a nonlinear relationship between economic growth and CO_2 emissions. Their work used data ranging from 1971-2015 and an autoregressive distributed lag (ARDL) approach.

Sinha and Bhatt (2017) also found a nonlinear relationship between per capita GDP and CO_2 emissions in India. Their study used data ranging from 1960 to 2011.

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 nonlinear relationship between CO_2 and all income groups, except for the upper-middle-income countries where the relationship is not statistically significant.

Diputra and Baek (2018), analyzed the Growth and Environment nexus in Indonesia. Using annual data ranging from 1971 to 2013 and ARDL model, found similar nonlinear relationship between Economic Growth and CO_2 emissions. Thus, the relationship is initially positive up to a threshold and turn to negative onward.

3.4 Other results

Kasperowicz (2015) investigated economic growth and CO_2 emissions nexus for 18 European Union member countries from 1995 to 2012. He found that in the short run economic growth and CO_2 emissions are positively related due to the increasing need for intensive energy use by existing technology for increased production, whereas in the long run the relationship is negative given that new low-carbon technologies will enable reaching the same production level at lower CO_2 emissions.

It results from the above brief review of selected literature that there is no consensus regarding the relationship between economic growth and CO_2 emissions. This paper tries to contribute to the debate by providing evidence from a developing country in West Africa.

4. Method of analysis and data

Following past research work on the economic growth and CO_2 emissions nexus (Grossman and Krueger 1994; Balin and Akan 2015; Kasperowicz 2015;Azam et al. 2016; Ibrahiem 2016; Sinha and Bhatt 2017; Nuryartono and Rifai 2017; Diputra and Baek 2018 etc) we posit the following relationship between per capita GDP ($lngdpk_t$), CO_2 emissions ($lnCO2e_t$) and selected control variables i.e. Gross Fixed Capital Formation as a proxy for investment ($lninvt_t$), Life expectancy as a proxy for human capital development ($lnlife_t$), Imports as a proxy for openness (lnM_t) and economically active population (that is population aged 15 to 64 years) ($lnpop64_t$).

$$lngdpk_t = \alpha_0 + \alpha_1 lnCO2e_t + \alpha_2 (lnCO2e_t)^2 + \alpha_3 lninvt_t + \alpha_4 lnlife_t + \alpha_5 lnM_t + \alpha_6 lnpop64_t + \varepsilon_t \quad (1)$$

With $t = 1,2, \ldots, T$, $lnCO2e_t$ 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, $lninvt_t$ is natural logarithm of Gross Fixed Capital Formation as percentage of GDP at time t, $lnlife_t$ is natural logarithm of life expectancy at time t, lnM_t is natural logarithm of imports of goods and services as percentage of GDP at time t and $lnpop64_t$ is natural logarithm of population aged 15 to 64 years as percentage of total population.

Using the above specifications, we can determine the turning point level of CO_2 emissions by taking the first derivative with respect to the variable of interest and set it equal to zero. Thus, we obtain the following formulas:

$$\widehat{lnCO2e} = \frac{-\alpha_1}{2\alpha_2} \quad \Rightarrow \quad \widehat{CO2e} = exp^{(-\alpha_1/2\alpha_2)}\,; \quad (2)$$

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. The investigation of the existence of the long run relationship is done using the Bounds test (Pesaran et al., 1999). 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:

$$Y_t = \alpha \quad + \sum_{i=1}^{p} \delta_i \, Y_{t-i} + \sum_{i=0}^{q} \beta'_i \, X_{t-i} + \varepsilon_{jt} \tag{3}$$

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 (Pesaran et al. 2004 called it conditional ECM) or put differently, conditional ARDL(*p,q*) presented below:

$$\Delta lngdpk_t = \alpha \quad + \delta_1 lngdpk_{t-1} + \delta_2 lnCO2e_{t-1} + \delta_3 (lnCO2e_{t-1})^2 + \delta_4 lninvt_{t-1} + \delta_5 lnlife_{t-1} + \delta_6 lnM_{t-1} + \delta_7 lnpop64_{t-1} + \sum_{i=0}^{q} \beta_{1i} \Delta lngdpk_{t-i} + \sum_{i=0}^{q} \beta_{2i} \, \Delta lnCO2e_{t-i} + \sum_{i=0}^{q} \beta_{3i} \, \Delta (lnCO2e_{t-i})^2 + \sum_{i=0}^{q} \beta_{4i} \, \Delta lninvt_{t-i} + \sum_{i=0}^{q} \beta_{5i} \, \Delta lnlife_{t-i} + \sum_{i=0}^{q} \beta_{6i} \, \Delta lnM_{t-i} + \sum_{i=0}^{q} \beta_{7i} \, \Delta lnpop64_{t-i} + \varepsilon_t \tag{4}$$

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

$$\begin{cases} H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = 0 \\ H_1: \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq \delta_7 \neq 0 \end{cases} \tag{10}$$

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 (Pesaran 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 Pesaran et al (2001) is that the error terms in the above equation 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, Pesaran 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 (Pesaran 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:

$$\begin{cases} H_0: \delta_1 = 0 \\ H_1: \delta_1 < 0 \end{cases} \tag{12}$$

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 Pesaran 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.

5. Empirical results and discussions

In this section we present and discuss the empirical results. Let’s start with the descriptive statistics (**Tables 1 and 2**). We can observe that the country’s per capita *GDP* (*GDPk*) reached a maximum of US$ 2,397.090 (in 1978). Its lowest level over the period of analysis stood at US$ 1,154.75 (in 2011 period of the civil war). Investment as percentage of *GDP* stood on average at 15.9% below the regional threshold set at 20%. Imports of goods and services as percentage of *GDP* stood on average at 33% indicating low level of penetration of the local market by foreign companies. Life expectancy stood at an average of 47.7 years from birth which is very low compare to other countries in West Africa i.e. Ghana, The Gambia, Niger and Senegal.

Table 1. Descriptive Statistics of the variables of interest

Variables	**Num. Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
GDPk	56	1 560.76	328.24	1 154.75	2 397.09
CO2ekt	56	5 319.05	2 763.56	462.04	11 045.00
Inv	56	15.92	5.69	8.25	29.66
M	56	33.46	5.65	22.90	44.33
Life	56	47.78	4.41	36.87	52.92
Pop64	56	53.26	1.02	51.84	55.94

Table 2 presents pairwise correlation between the variables. Interpretation of these correlation coefficients need to be done with caution. We can infer from this table that the correlation between per capita GDP and CO_2 emissions is weak and not statistically significant. The investment variable is negatively correlated with CO_2 emissions. The correlation coefficient is below 0.5. However, the correlation between investment and per capita GDP is positive and statistically significant. We can also observe that life expectancy and CO_2 emissions are positively correlated with coefficient at 0.894 and statistically significant. Another variable that is positively correlated with carbon dioxide emissions is imports of goods and services. Another correlation that is important to consider is the one between population and per capita GDP. The coefficient is negative (-0.501) and statistically significant. This indicates that the size of the population could inhibit the country's economic performance. All these results will be investigated further in the *ARDL* setting.

Table 2: Pairwise correlation between the variables of interest.

Variables	*lnco2e*	*lnco2esq*	*lngdpk*	*lninvt*	*lnlife*	*lM*	*lnpop64*
lnco2e	1.000						
lnco2esq	**0.998***	1.000					
	(0.000)						
lngdpk	-0.101	-0.132	1.000				
	(0.457)	(0.334)					
lninvt	**-0.473***	**-0.479***	**0.717***	1.000			
	(0.000)	(0.000)	(0.000)				
lnlife	**0.894***	**0.886***	0.075	**-0.392***	1.000		
	(0.000)	(0.000)	(0.583)	(0.003)			
lM	**0.648***	**0.646***	0.020	-0.036	**0.505***	1.000	
	(0.000)	(0.000)	(0.882)	(0.789)	(0.000)		
lnpop64	**-0.621***	**-0.591***	**-0.501***	0.124	**-0.786***	**-0.414***	1.000
	(0.000)	(0.000)	(0.000)	(0.362)	(0.000)	(0.002)	

Author's calculation. Numbers in parenthesis are P-values. Asterisk (*) indicates significance at 1% probability level.

The time series characteristics of the data analyzed via the Unit Root test show that CO_2 emissions variable ($lnCO2e_t$) and life expectancy variable ($lnlife_t$) are stationary i.e. *I(0)* whereas the others remaining variables of interest i.e. per capita *GDP* ($lngdpk_t$), Investment ($lninvt_t$), Imports (lnM_t) and Population ($lnpop64_t$) are stationary after first differencing i.e. *I(1)*. The Unit Root tests results are presented in Table 3 below.

Table 3. Unit root tests results

Variables	*Levels*		*1st Difference*	
	ADF	**PPerron**	**ADF**	**PPerron**
lnco2e$_t$, lag(1)	**-2.963**^{**a}	**-3.041****		
	(0.038)^{b}	(0.031)		
Lnco2esq$_t$, lag(1)	-2.518	-2.537	**-5.213*****	**-8.053*****
	(0.111)	(0.107)	(0.000)	(0.000)
lngdpk$_t$, lag(2)	-1.656	-1.408	**-3.453*****	**-5.401*****
	(0.454)	(0.578)	(0.009)	(0.000)
lninvt$_t$, lag(1)	-1.691	-1.541	**-4.325*****	**-6.048*****
	(0.436)	(0.513)	(0.000)	(0.000)
lnlife$_t$, lag(4)	**-2.728***	**-2.991****		
	(0.069)	(0.036)		
LnM$_t$, lag(1)	-1.829	-2.522	**-5.519*****	**-8.271*****
	(0.366)	(0.110)	(0.000)	(0.000)
Lnpop64$_t$, lag(2)	-1.796	-2.426	**-1.973****	-1.773
	(0.382)	(0.134)	(0.027)	(0.394)

Schwartz-Bayesian Information Criterion (SBIC) was used to determine the optimal lag order;
[a] Asterisk indicate significance levels thus, * ➔10%; ** ➔ 5% and *** ➔ 1%. [b] Number in parenthesis are p-values

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 Pesaran, Shin and Smith (2001) to investigate any long run relationship.

Table 4 presents the results of the Bounds Test. Recall that we are testing 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, 0, 1, 0, 0**). The Bounds Test results give a F-statistics of **6.494** which is greater than the critical value for I(1) at the 5% probability level. The decision is therefore to reject the null hypothesis of ***No levels relationship***. That is, CO_2 emissions, per capita GDP and the control variables are cointegrated and thus move together in the long run..

Table 4. Bounds Test for cointegration among variables of interest
Bounds Test ARDL(1,0,0,0,1,0,0)

***H_0* ➔ No levels relationship**	
F-stat =	**F = 6.494**
Crit. val. at 5%	[I(0) I(1)]
k=6	[2.45 3.61]
Accept H_0 if F_{stat} < Critical Value for I(0) Regressors	
Reject H_0 if F_{stat} > Critical value for I(1) Regressors	
t-stat=	**t = -4.373**
Crit. val. at 5%	[I(0) I(1)]
k=6	[-2.86 -4.38]
Inconclusive	

Author's calculation.

In light of the above result we move to estimate both long and short run dynamics between CO_2 emissions, per capita GDP and the control variables. The results are presented in **Table 5** below. The speed of adjustment is negative and significant **(-0.444).** The coefficient associated with the linear term of CO_2 emissions ($lnCO2e_t$) is positive and significant at the 5% probability level. The coefficient associated with the quadratic term of CO_2 emissions ($lnCO2esq_t$) is negative and significant at the 5% probability level. Hence, there is a long run causality running from CO_2 emissions to per capita GDP in the country. Thus, there is a threshold level or a turning point of CO_2 emissions from which any additional CO_2 emissions will reduce GDP. Our results are in line with previous works that found nonlinear relationship between carbon dioxide emissions and economic growth.

Using the estimated coefficients we obtain the following turning point:

$$\widehat{CO2e} = exp^{(-1.021/(-2*0.057)} = \mathbf{7{,}755.37\ kt}$$

The above results is worrying given the country's CO_2 emissions have gone beyond this threshold. There is therefore need to be concerned. It is important to also consider the other results. The investment variable has the expected sign (positive) and it is significant indicating the critical role of investment for the country's long run economic performance. Thus, the authorities in the country are encouraged to invest into growth enhancing projects.

The next variable that we consider is life expectancy. It has no significant impact of the economic growth variable in the long run but in the short run it has a positive and significant impact. This calls for an improvement of human capital in the country. This is also of paramount importance. Indeed, in the short run, knowing that the health sector is well equipped with skilled/competent health personnel, one can focus on the daily work and be more productive thereby improving the economic performance. The other side of the coin is that when health sector lacks the minimum to attend to patient this negatively affect productivity and by the same token impacts negatively the economy.

The openness variable, measured by imports of goods and services has negative and significant coefficient. This indicates that the country's openness has had an adverse effect on economic performance. This calls for a closer look at the structure of the country's imports and see to what extent this negative impact could be mitigated.

The last variable of interest is the population variable. Its long run coefficient is negative and significant. This shows that the population size annihilates efforts to better the economy in the long run unless actions are taken to ensure that the capabilities of the population are developed. This can be done through lifelong skill development, lifelong civic education to ensure that the population has the common good at heart, improved security, strong institutions and good leadership that serves as role model as laid out in N'Zué (2010)[1].

Table 5. Results of the ARDL estimation of the impact of CO_2 emissions on economic growth in Cote d'Ivoire from 1961 to 2015

Dependent variable: Per capita Goss Domestic Product ($\Delta lngdpk_t$)	
Long run Dynamics	
Constant	9.436^{*b}
	$(0.088)^{a}$
ECT_{t-1}	$\mathbf{-0.444}^{***}$
	(0.000)
$lnco2e_t$	$\mathbf{1.021}^{**}$
	(0.021)
$lnco2esq_t$	$\mathbf{-0.057}^{**}$
	(0.038)
$lninvt_t$	$\mathbf{0.483}^{***}$
	(0.000)
$lnlife_t$	-0.430
	(0.277)
lnM_t	$\mathbf{-0.481}^{***}$
	(0.000)
$lnpop64_t$	$\mathbf{-4.126}^{**}$
	(0.026)
Short run dynamics	
$\Delta lnlife_t$	$\mathbf{1.705}^{**}$
	(0.030)
R-squared	0.534
Adj R-squared	0.453
$\mathbf{F_{(8, 46)}}$	6.590^{***}
	(0.000)
Breusch-Godfrey LM test for absence of autocorrelation (H_0: *no serial correlation*)	
$\chi^2_{(1)}$	0.021
	(0.884)
White's test for absence of heteroscedasticity (H_0: *homoscedasticity*)	
$\chi^2_{(43)}$	47.130
	(0.308)
See graph in Annex for stability test	

[a] Number in parenthesis are p-values. [b] Asterisk indicates significant levels * → 10%, ** → 5% & *** → 1%

6. Conclusion

This study has investigated the environment and growth nexus via an analysis of the long run relationship between CO_2 emissions, per capita *GDP* and a set of control variables. The data used ranged from 1960 to 2015. An *ARDL* model was used to assess the long run relationship between CO_2 emissions, per capita *GDP*,

[1] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1944768

investment, life expectancy, openness and population. The empirical results show the existence of a long run relationship between per capita *GDP*, CO_2 emission, investment, life expectancy, openness and population. Thus, they move together in the long run. The results also indicate that there is a tipping point beyond which increment of CO_2 emissions is detrimental to per capita *GDP*. The country has passed that tipping point. There is therefore an urgent need for the country's authorities to take actions towards curbing the accelerated accumulation of CO_2 emissions in the country to a reasonable level (below the identified threshold). In that route the recent Decree of the government to limit the age of imported used vehicles into the country is welcome. However, this will not be enough if serious regulations are not put in place to monitor CO_2 emissions not only from vehicles but also from all the manufacturing plants and refineries that emit on daily basis high quantity of CO_2. We therefore call for firm 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*.

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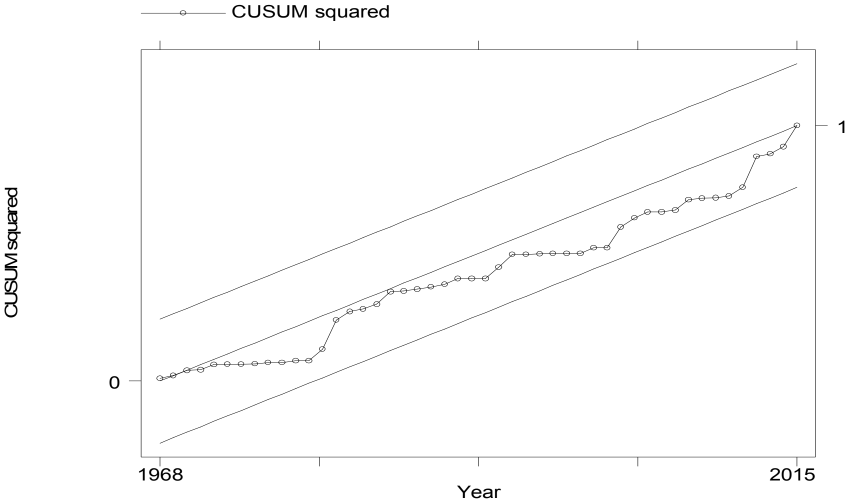
Annex

Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level