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Threshold effect between environment and economic growth in Côte d'Ivoire

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Abstract: The objective of this paper is to empirically assess the impact of economic growth on carbon dioxide (CO2) emissions in Côte d'Ivoire. To do so, we adopted an empirical methodology based on a threshold effect regression, in this case the quadratic model. The data used in this study cover the period from 1990 to 2021. The results obtained from the estimations reveal that economic growth would be detrimental to the environment in the early stages of development; then, above a certain threshold of per capita income, economic growth would lead to an improvement in environmental quality. In other words, the relationship between growth and environmental degradation would be inverted U-shaped. The environmental Kuznets curve is confirmed for Côte d'Ivoire economy and the optimal threshold of GDP per capita is 1881.30 US Dollars.

Keywords: Carbon dioxide (CO2) emissions; Gross Domestic Product (GDP); Côte d'Ivoire; Environmental Kuznets curve.

JEL: C23, O1, Q43, Q56

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1. Introduction

Since the beginning of the 20th century, the world has been confronted with technical, demographic and economic changes caused by human activities. The relentless pursuit of national wealth and the over-consumption of natural resources, especially energy, has led to a change in the global climate balance and has placed industry at the heart of economic activity. However, the development of this sector affects the environment.

In this respect, debates on environmental economics emphasise the relationship between environmental degradation and economic growth. Kuznets (1951) shows that as economic growth increases, environmental pollution increases, to a point where further growth leads to less pollution. This theory is illustrated by means of an inverted U-shaped curve. The Kuznets Environmental Curve (KEC) states that there is a threshold of pollution beyond which economic activity becomes harmful to the environment. Most of the work has aimed at verifying the environmental Kuznets curve (EKC) for the main pollutants (Bensbahou and Seyagh, 2020; Domguia and Ndieupa, 2017; Balsalobre-Lorente et al, 2021).

Carbon dioxide emissions are the main cause of climate change and global warming, and are therefore among the most widely used indicators of environmental degradation (Shahbaz et al., 2013; Khan et al., 2019; Cosmas et al., 2019). However, according to the CO2 emission-economic growth relationship improves if health is used as a transmission channel (Constant and Raffin, 2016).

Other economists reject the idea of a possible threshold effect in the relationship between environmental degradation and economic growth. For them, environmental degradation can only improve national production. This is the case of Kapnang (2012) who shows that despite the existence of a unidirectional causal relationship between growth and pollution, the idea of an environmental Kuznets curve does not apply to China. In other words, there is a positive long-term relationship between economic growth and air pollution.

In view of these contradictory positions, this paper is situated in the literature on the non-linearity between economic growth and pollution. We attempt to reconcile the different strands of the economic literature on the link between the market and these two variables. Thus, if this relationship is a fact, its impact seems more than uncertain in the case of Côte d'Ivoire. In this situation, where many concerns are raised about the future of the national and global environment, the objective of this study is to highlight the relationship between CO2 emissions and economic growth, and the presence of a possible effect in this link.

This article is organised as follows: the first part presents the estimation technique to be adopted; the second part will be devoted to the presentation and analysis of the results obtained.

2. Methodology

2.1. Study model

We have opted for an approach that consists of determining the optimal level of GDP per capita through the method that consists of regressing the logarithm of CO2 emissions on the variable of interest as well as on its square (quadratic model). This method is based on the principle of the Kuznets environmental curve and models an inverted U-shaped relationship between the threshold variable and the endogenous variable. The estimation of the quadratic equation model shows whether there is a reversal effect of the proxy variable of economic growth development on environmental degradation.

Thus, the model is written:

$$LOGCO2_t = \alpha_0 + \alpha_1 LOGGDPC_t + \alpha_2 LOGGDPC_t^2 + \varepsilon_t \quad (1)$$

$LOGCO2_t$ denotes the logarithm of CO2 emissions; $LOGGDPC_t$ denotes the logarithm of GDP per capita, α_0, α_1 and α_2 denotes the model parameters to be estimated and ε_t denotes the specification error term.

We will insert a control variable in our basic model. The choice of this variable is urbanisation (*URB*). Thus, the model retained in the framework of this study is formulated as follows:

$$LOGCO2_t = \alpha_0 + \alpha_1 LOGGDPC_t + \alpha_2 LOGGDPC_t^2 + \alpha_3 URB_t + \varepsilon_t \quad (2)$$

This study seeks to determine the level of economic growth that maximises environmental degradation. Mathematically, the following operation will be performed:

$$\frac{d(LOGCO2_t)}{d(LOGGDPC_t)} = 0 \Leftrightarrow \alpha_1 + 2\alpha_2 LOGGDPC_t = 0 \quad (3)$$

The optimal tax rate that maximises economic growth is obtained by the following relationship:

$$LOGGDP_t^* = -\frac{\alpha_1}{2\alpha_2} \quad (4)$$

Or $\tau^* \in \mathbb{R}^+ \Leftrightarrow \alpha_1 > 0$ and $\alpha_2 < 0$.

Therefore, the optimal level of GDP per capita is given by the following equation:

$$GDPC^* = e^{\log GDPC_t^*} = e^{-\frac{\alpha_1}{2\alpha_2}} \quad (5)$$

Thus, at the level of this model, the coefficient of the threshold variable and that of its square must be of opposite sign before one can speak of a reversal or the existence of a threshold (A. WADE, 2014). These thresholds, if they exist, are obtained by deriving the proxy variable for CO2 emissions with respect to the threshold variable.

The variables that will be included in this model are presented in the following table:

Table 1: Description of variables used in the model

Variables	Definition	Data source	Expected sign
LOGCO2	The logarithm of CO2 emissions	WDI, 2022	-
LOGGDPC	The logarithm of GDP per capita	WDI, 2022	Positive
$LOGGDPC^2$	The logarithm of GDP per capita squared	WDI, 2022	Negative
URB	Urbanization	WDI, 2022	Positive

Source : Author's construction

The data collected for this study are annual and come from secondary sources and are quantitative in nature. They were extracted from the World Bank's World Development Indicators (WDI, 2022) database. Indeed, this data source has been used for many scientific works that have been conclusive at national, regional and international levels. Thus, we assume the reliability of the various data sources as a fact. This study covers the period from 1990 to 2021.

2.2. Evolution of series

Before any empirical analysis, it is important to have a visual view of the evolution of the series over the entire study period. This visual observation would make it possible to detect the presence of possible components of a time series on the one hand, and on the other hand to identify the order of integration of the series studied. In the second case, this analysis of the order of integration of the series will be confirmed by stationarity tests which will be carried out in the following section.

The figure 1 below shows the evolution of environmental degradation following the evolution of economic activity.

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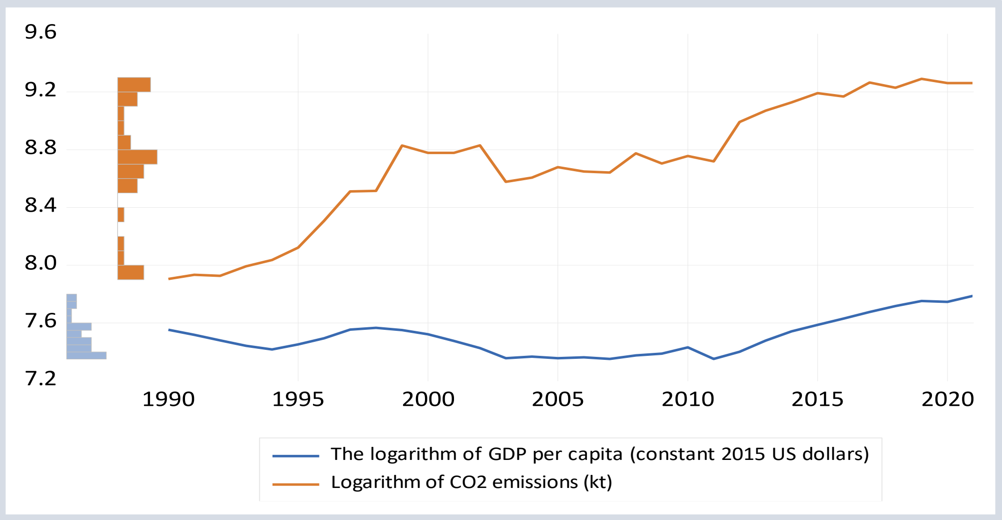

Figure 1: Comparative evolution between the logarithm of CO_2 emissions and the logarithm of GDP per capita.

The visual analysis in Figure 1 reveals that between 2002 and 2011, Côte d'Ivoire experienced a major period of economic recession due to the great period of socio-political instability; however, it has experienced a good recovery since the aftermath of this decade of disruption. Today, the Ivorian economy is the most dynamic in the WAEMU and the second most dynamic in the ECOWAS zone. As regards the deterioration of the environment, the curve shows an upward trend over the period under consideration. Indeed, since the beginning of the year 2000, the Ivorian economy has been trying to move from a primary economy to an industrial economy.

In sum, a remarkable observation of this curve is that the two series do not flutter around their averages, which justifies that a priori, the series are not stationary. However, this is only a presumption that will be confirmed or refuted by a stationarity test in the last chapter of our study.

3. Empirical results

In this section, the results of the estimation of the quadratic model are interpreted: the effect of economic growth on environmental degradation. These results allow us to confirm or refute our initial hypotheses.

3.1. Preliminary tests

Before any estimation procedure, it is essential to assess the quality of our data. To do this, we will use descriptive statistics and the correlation matrix of the variables.

Table 2 *:* Descriptive statistics of variables

	LOGCO2	LOGDPC	LOGGDPC_SQ	URB
Mean	8.700883	7.503574	56.31959	45.53075
Median	8.737764	7.479014	55.93565	45.44300
Maximum	9.290075	7.789223	60.67199	52.18000
Minimum	7.904704	7.351099	54.03866	39.34500
Std. Dev.	0.434188	0.128406	1.938631	3.883826
Skewness	-0.431964	0.711970	0.738157	0.070478
Kurtosis	2.206053	2.548797	2.590246	1.796587
Jarque-Bera	1.835633	2.974922	3.129873	1.957427
Probability	0.399390	0.225946	0.209101	0.375794
Sum	278.4282	240.1144	1802.227	1456.984
Sum Sq. Dev.	5.844093	0.511130	116.5070	467.6073
Observations	32	32	32	32

Source**:** Author, based on WDI data (2022)

Table 2 shows that the average logarithm of CO2 emissions for the sample over the study period is 8.73, with a minimum value of 7.90 and a maximum value of 9.29. For the economic growth indicator, Côte d'Ivoire records an average value of 7.47 as the logarithm of GDP per capita. The average level of urbanisation is 45.44% of the total population. Furthermore, the results of this table reveal that the averages and medians are very close, which implies that the data do not suffer from any "outlier" problem. A remarkable observation in this table is that all series follow a normal distribution. Indeed, the p-values associated with the Jarque-Bera statistics are all above 5%.

The table below shows the result for the correlation between the variables.

Table 3 : Correlation matrix of variables

Correlation Probability	LOGCO2	LOGGDPC	LOGGDPC_SQ	URB
LOGCO2	1.0000			
LOGGDPC	0.4870	1.0000		
LOGGDPC_SQ	0.4900	0.9999	1.0000	
URB	0.9276	0.4678	0.4724	1.0000

Source**:** Author, based on WDI data (2022)

With regard to the correlation between the variables (Table 2), one remark deserves to be highlighted. Indeed, the remark is based on a positive and significant correlation at the 5% threshold between all the exogenous variables (logarithm of GDP per capita, its square, urbanisation and urbanisation) and logarithm of CO2 emissions. All in all, the reading of the correlation matrix proves the existence of a weak correlation between the variables (the correlation coefficients are generally lower than 0.75). This leads to the conclusion that there is no problem of multi-collinearity. Consequently, all the variables can be taken into account in the model.

The rest of the analysis is devoted to the empirical evaluation of the impact of economic growth on environmental degradation. For this purpose, an analysis of the stationarity test on the series seems indispensable in order to be objective with regard to the choice of the estimation method.

3.2. Stationarity tests

The analysis of the stationarity of the series is a priori necessary in order to avoid any spurious regression. To do this, we opted for the Augmented Dickey-Fuller (ADF) and Phillips-perron (PP) tests. The results are recorded in the table 5 below:

Table 4: Results of the stationarity tests on the variables

Variables	Model	In level		1st difference		Conclusion
		ADF	PP	ADF	PP	
Logarithm of CO2 emissions	Constant	0.8981	0.7601	0.0003	0.0000	I (1)
	Cst and trend	0.2249	0.1984	0.0001	0.0001	
	Without	0.7604	0.6791	0.0000	0.0001	
Logarithm of GDP per capita	Constant	0.2952	0.2913	0.1927	0.0038	I (1)
	Cst and trend	0.9539	0.6609	0.1905	0.0153	
	Without	0.3804	0.5489	0.0239	0.0002	
Logarithm of GDP per capita squared	Constant	0.3278	0,5734	0.0000	0.0000	I (1)
	Cst and trend	0.3204	0.4739	0.0000	0.0000	
	Without	0.0733	0.2280	0.0000	0.0000	
Urbanization	Constant	0.8951	0.5626	0.1827	0.0049	I (1)
	Cst and trend	0.7343	0.6127	0.2382	0.0080	
	Without	0.8829	0.7655	0.0044	0.0003	

Source**:** Author, based on WDI data (2022)

According to the results of the ADF and PP tests, all variables are unit order stationary i.e. I (1). Thus, according to Keho (2011), the estimation of series with different integration orders is very complex. At a glance, the ordinary least squares (OLS) method does not seem to be adequate, as there is a presumed long-run relationship between the series. This leads us to determine the cointegration rank of the variables. However, before determining the cointegration rank, it is necessary to know the optimal number of lags.

3.3. Optimal number of lags and cointegration test of variables

Cointegration analysis makes it possible to clearly identify the true relationship between two variables, by looking for the existence of a cointegrating vector and eliminating its effect if necessary. The approach used in this study is the Johansen (1988) cointegration test. The application of this test requires the prior determination of the optimum number of delays to be considered.

Table 5: Determination of the optimal delay

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-82.7573	NA	1.50e-05	5.9171	6.1973	6.0068
1	212.1247	452.1525	5.04e-13	-11.3416	-9.3799*	-10.7140
2	271.8491	67.6875*	1.42e-13*	-12.9232*	-9.2801	-11.7578*

Source: Author, based on WDI data (2022)

Table 6 *:* Johansen cointegration test

Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob. **
None *	0.9402	187.4950	95.7536	0.0000
At most 1 *	0.7243	105.8035	69.8188	0.0000
At most 2 *	0.6071	68.4322	47.8561	0.0002
At most 3 *	0.5626	41.3369	29.7970	0.0015
At most 4 *	0.4279	17.3561	15.4947	0.0259
At most 5	0.0391	1.1579	3.84146	0.2819

Source: Author, based on WDI data (2022)

The results of the Johansen cointegration test reported in this table show that there are four (4) cointegrating relationships as the probability is greater than 5% that from more than 4 cointegrating relationships.

The estimation of a long-run relationship involving integrated variables has been the subject of much recent literature (Montalvo, 1995; Keho, 2011). According to the previous results, it is then possible to estimate the Vector Error Correction Model (VECM). This model allows us to analyse the detailed results of the long-term relationship, as well as the dynamics of the variables in the short-term. However, the objective of our analysis is to determine the level of economic growth that maximises pollution. This optimum can only be determined from the long-term dynamics. To do this, we opt for the FMOLS (Full Modified Ordinary Least Square) technique proposed by Phillips and Hansen (1990), the DOLS (Dynamic Ordinary Least Square) technique proposed by Stock and Watson (1994) to overcome some of the limitations of the OLS method and also the Canonical cointegrating regression (CCR) technique. Indeed, when the presence of a long-term relationship has been confirmed, these three methods can then be applied to analyse the long-term relationship between the cointegrated variables.

3.4. Long-run estimation

As mentioned above, we estimate the equations of the quadratic model by the DOLS, FMOLS and CCR methods. At the end of our estimations, we will retain the estimator that offers us the highest explanatory power of the model. In practice, several specifications were carried out. However, dummy variables that were not significant were ejected from the model. The results are shown in the table below:

Table 7: Long-term estimation results

Variable	FMOLS		DOLS		CCR	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
LOGGDPC : α_1	95,8330*	0.0615	322.6253***	0.0001	100.2033*	0.0794
LOGGDPC_SQ : α_2	-6.3545*	0.0619	-21.4128**	0.0001	-6.6452*	0.0802
URB	0.1224***	0.0000	-0.0731**	0.0199	0.1213***	0.0000
C	-358.0850*	0.0639	-1214.306***	0.0001	-374.4603*	0.0816
Adjusted R-squared	$\bar{R}^2 = 86.37\%$		$\bar{R}^2 = 96.50\%$		$\bar{R}^2 = 86.39\%$	
Threshold : $LOGGDPC_t^* = -\frac{\alpha_1}{2\alpha_2}$ $GDPC^* = e^{LOGGDPC_t^*} = e^{-\frac{\alpha_1}{2\alpha_2}}$	$LOGGDPC^* = -\frac{95.8330}{2(-6.3545)}$ $GDPC^* = 1881.83\ US\ dollars$		$LOGGDPC^* = -\frac{322.6253}{2(-21.4128)}$ $GDPC^* = 1863.10\ US\ dollars$		$LOGGDPC^* = -\frac{100,2033}{2(-6.6452)}$ $GDPC^* = 1881.83\ US\ dollars$	
Jarque-Bera normality test on residual	Normally distributed		Not normally distributed		Normally distributed	
Note : *** significant at 1% level; ** significant at 5% level; * significant at 10% level						

Source**:** Author, based on WDI data (2022)

A remarkable observation of these results is that regardless of the estimation technique (FMOLS, DOLS or CCR), the parameter estimate $\alpha_1 > 0$ and $\alpha_2 < 0$. Therefore, an inverted U-shaped or bell-shaped curve is evident between economic growth and environmental degradation in Côte d'Ivoire. However, the Jarque-Bera normality test leads us to eliminate the results of the DOLS estimator because the residual from the model estimated by this technique is not normally distributed. On the other hand, the FMOLS technique gives us a good explanatory power of the model. Thus, we retain the results from the CCR model to the detriment of the results from the FMOLS technique. The equation of the estimated model becomes:

$$LOGCO2_t = -374.4603 + 100.2033 LOGGDPC_t - 6.6452 LOGGDPC_t^2 + 0.1213 URB_t + e_t \quad (6)$$

The results of the econometric estimations highlight the existence of a non-linear relationship between economic activity and CO2 emissions supported by Balsalobre-Lorente et al (2021). Thus, there would be an optimal threshold of GDP per capita that maximizes environmental degradation. Thus, when the GDP per capita is lower than 1881.83 US dollars, economic growth positively affects environmental degradation with a high elasticity of 95.83.30 However, when the GDP per capita exceeds this value, economic activity becomes detrimental to carbon dioxide emissions.

As for urbanisation, our results reveal that it has a positive and significant influence on environmental degradation. Thus, if we consider all other things being equal, a 1% increase in the urban population induces a 0.12% increase in the logarithm of CO2 emissions. however, the elasticity remains very low.

4. Conclusion

The main objective of this study is to determine the effect of economic growth on environmental degradation in Côte d'Ivoire. To achieve this general objective, we used a threshold effect model, namely a quadratic model. Indeed, our study covers the period from 1990 to 2021 due to the availability of data on carbon dioxide emissions used as a proxy for environmental degradation.

The results of the econometric estimations highlight the existence of a non-linear relationship between economic activity and CO2 emissions supported by Balsalobre-Lorente et al (2021). Thus, the optimal threshold of GDP per capital is 1881.83 US dollars. However, below this threshold, economic activity positively affects environmental degradation in Côte d'Ivoire, while above this threshold, economic activity has perverse effects on CO2 emissions. However, since 2014, GDP per capita has been above the threshold of US$1881.83. These results reveal that, in the quest for national well-being, Ivorian economic agents tend to demand a healthier environment. This leads to a strengthening of standards and an improvement in the quality of the environment in the city of Abidjan. The hypothesis of the Kuznets environmental curve for the Ivorian economy is therefore verified.

This study contributes to the debate on the link between income and environment. In terms of policy implications, it would be important for policy makers to adopt economic development linked to environmental protection, investment in cleaner infrastructure, advancement in the promotion of cleaner buildings, in order to decrease the direct pollution link between increasing urbanization and the process of environmental degradation.

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