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The Impact of Deforestation on CO2 Emissions: Evidence from WAEMU

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Abstract:
The objective of this research is to study the determinants and effects of deforestation in the WAEMU countries. On the basis of panel data covering the 8 WAEMU countries from 2000 to 2014 and with a fixed-effect regression with correction for heteroskedasticity, we come to the conclusion that the gross domestic product per capita contributes in the short term to the increase. deforestation but a long-term decrease in deforestation is possible because there is an inverted U-shaped relationship between these two variables. Population density and respect for the rule of law are determinants of deforestation in the WAEMU zone. In addition, deforestation contributes positively to CO2 emissions in WAEMU. In view of these results, in terms of energy use, the State must favor energies based on renewable energies more than fossil energies which are more polluting; encourage reforestation initiatives. Improving the quality of institutions through the establishment of a framework promoting respect for the rule of law will be an asset in the fight against deforestation in WAEMU.

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Introduction

Humanity faces two major challenges, namely economic development and environmental preservation (Aye and Edoja, 2017). Raising by Meadows et al. (1972), on the possibility of limiting economic growth due to the depletion of production factors, mainly natural capital, has sparked a debate around the weak and strong sustainability of sustainable development. The weak law of sustainable development supported by Hartwick (1977), postulates a levy of rents as resources are depleted, which are equal to the difference between the price and the marginal cost of resources and must be reinvested to produce capital, a substitute for depleted resources. In contrast, in strong sustainability, the maintenance of the natural resource stock is on the contrary sought without resorting to substitutability (Daly, 1990).

Forests essentially play three functions, namely ecological; economic and social and cultural. Ecologically, they are reserves of biodiversity, of genetic and plant protection resources, of carbon sinks and of erosion and desertification control (Rautner, Leggett, and Davis, 2013). Economically, they provide a variety of wood products including extraction of firewood, industrial wood and lumber and non-wood products including food, fibers used in construction, furniture, clothing or utensils, resins, gums and plant and animal products used for medicinal, cosmetic purposes (Tom and Lynne, 2015). On the social and cultural level, they constitute sources of heritage and common goods because they are privileged places of leisure, relaxation, tourism, discovery of fauna and flora and landscapes. Beyond these advantages, it is clear that forest resources are subject to increased exploitation, the consequences of which are disastrous for the forest ecosystem itself and the threat to the survival of the human population.

Deforestation is the transformation from a permanent form of forest land to other uses such as agriculture, grazing or urban development (Zambrano-Monserrate et al., 2018). Although the expansion of agriculture and animal husbandry, and the use of wood as a raw material for fuel, have been necessary for the economic growth of countries, they have also caused the disappearance of half of the world's forests. This has resulted in the loss of biodiversity (plants, animals) in different regions of the planet (Watson, Noble, and Bolin, 2000). Partly responsible for climatic disturbances, deforestation leads to the liberalization of CO_2. In fact, deforestation is the second largest anthropogenic source of carbon dioxide emissions into the atmosphere, after the combustion of fossil fuels (Van Der Werf et al., 2009). This is because the trees and soils in tropical forests store large amounts of carbon. When trees are burned to clear agricultural land, this carbon turns into carbon dioxide, which is actually one of the greenhouse gases that accelerate climate change, thus increasing environmental degradation (FAO and UNEP, 2020). In addition, the destruction of forests reduces the planet's ability to absorb CO_2 from the atmosphere (Van Der Werf et al., 2009).

The reduction of emissions from deforestation and forest degradation (REDD) in developing countries is a program that was initiated following the negotiations of the Thirteenth Conference of the Parties (COP13) of the United Nations Framework Convention United Nations on Climate Change (UNFCCC) in 2007 in Bali, Indonesia. It is a program that has been officially recognized as an important and achievable global climate change mitigation strategy. In 2009, during COP 15 in Copenhagen, the role of forest conservation, sustainable forest management and enhancement of forest carbon stocks was added to the initial concept, expanding the role of this mitigation tool by REDD + (Guadalupe et al., 2018). In the implementation of REDD + and related payments from the Green Climate Fund and other similar financing mechanisms, interested countries must go through three phases which are closely related to each other namely (i) the preparation phase which requires the development of national strategies or action plans for REDD + mitigation and capacity building; (ii) the phase of implementation of national strategies and results-related demonstration activities, (iii) results-related activities, which should be fully measured, reported and verified. There are five activities including (i) reducing emissions from deforestation; (ii) increase in forest carbon stocks; (iii) role of forest conservation: (iv) sustainable forest management (FAO, 2020). With developing countries being the target of the program, it is in these countries that everything is played out in terms of forest conservation.

Beyond these studies, few have taken an interest in sub-Saharan Africa, especially the West African Economic and Monetary Union (WAEMU). To quote a few, we have Lokonon and Mounirou, (2019) who, through the techniques of stationing and co-integrating panel data, verified the pollution haven hypothesis through the effect of direct foreign investment on the deforestation in sub-Saharan Africa. It emerges from their analysis that the pollution haven hypothesis is verified only for a few countries and suggests that other countries can continue to attract foreign direct investment while putting a control on deforestation linked to foreign direct investment flows. In the analysis of CO_2 emissions due to deforestation in the middle Sota basin (northern Benin) on the basis of remote sensing data (SPOT5 and SPOT 7), Issifou Moumouni and Toko Imorou, (2019) arrive at the conclusion that net deforestation is estimated at 465.46 ha / year (i.e. 1.01%) in protected areas, while it amounts to 2,204.74 ha / year (i.e. 2.59% / year) in the terroirs. Overall, the basin has a total emission factor of 11,080.45 Mt. CO2-eq / ha, while historical emissions due to deforestation amount to approximately 295.87 Mt. CO_2-eq / ha, i.e. 29.58 Mt. CO_2-eq / ha / year. By seeking to understand the mode of energy consumption and the role of forests as a source of energy and income for rural villagers and urban poor, Temudo, Cabral, and Talhinhas, (2020) on the basis of surveys and analyzes by remote sensing explain to us that a low price of oil which is the main source of energy for lighting and cooking in towns and villages in the province of Zaire and northern Angola could help reduce deforestation.

From these studies, may have been interested in analyzing the relationship between income, deforestation and CO_2 emissions in WAEMU. The main issue of our work is formulated in the following question: what is the link between income, deforestation and CO_2 emissions in WAEMU? This study seeks to fill the research gap on the link between income, deforestation and CO_2 emissions on the one hand and on the other hand to highlight the EKC by taking as an indicator of the quality of the environment deforestation and CO_2 emissions in the WAEMU.

2- Literature review

The relationship between deforestation and CO_2 emissions has long interested some researchers who measured it through the link between economic growth and indicators of environmental quality including deforestation and greenhouse gas emissions. on the one hand and on the other hand, some researchers have focused on the determinants of deforestation. This section will theoretically and empirically address the notion around the concept of deforestation and CO_2 emissions which tends to be of interest to economists, geographers, ecologists, environmentalists, etc.

Theoretical review: Economic growth and environmental degradation have been an area of theoretical and empirical research since the early 1990s, when environmental deterioration and its consequences intensified around the world (Nasir and Ur Rehman, 2011). In the field of environmental economics, the idea of the Environmental Kuznets Curve (EKC) has received considerable attention from researchers. It was highlighted by Grossman and Krueger, (1991). This curve goes back since the work of Kuznets, (1955) who asserts a correlation between economic growth and income inequality resembling an inverted U-curve.

Since pollution is a negative externality, it is a cost to society if nothing is done. Externality or external effect refers to the fact that the production or consumption activity of an economic agent creates an advantage or a disadvantage for others, without any financial compensation. In order to limit these externalities which are created by a market failure, two authors have marked economic theory, namely Pigou, (1920) and Coase, (1960). Indeed, Pigou proposes the intervention of the State in order to internalize the costs of pollution, by imposing on the producers of activities generating negative externalities to force them to produce less and, by subsidizing the producers of generating activities. positive externalities to increase their production. Unlike Pigou, Coase draws attention to the possibility of solving the problem of externalities by organizing direct transactions between the parties involved. For Coase, the state must be satisfied with allocating clearly defined property rights for the resources affected by the externalities, these rights then becoming commodities like any other.

Referring to the definition of deforestation which is a long-term or permanent conversion of forest land for non-forest use (Nasi et al, 2012) or the UNFCCC (decision 11 / CP.7) defines it as: "... the direct anthropogenic conversion of forest land into non-forest land" and the work of Barbier, (2013) we retain that the immediate causes of deforestation are linked to human activity. Fundamental explanations, taken from the literature on deforestation presented by Barbier, (2013) group the factors of deforestation into 5 categories. These are demographic factors (human population dynamics, sometimes referred to as demographic "pressure"), economic factors (commercialization, development, growth or economic change), technological factors (technological change or progress), political factors and institutional (change or impact of politico-economic institutions, institutional change) and a set of socio-political or cultural factors (values, public attitudes, beliefs and behavior of individuals or households).

The empirical review

Although the forest ecosystem is a source of economic wealth and preservation of the environment and being under increased exploitation, given its disappearance in the medium and long term and its determining role in climate change, researchers have volunteered to focus on the phenomenon of deforestation by analyzing the existing relationships between deforestation and human actions. While some have focused on highlighting the Kuznets curve, others have looked at the causes that influence deforestation. This concept has interested many researchers from different fields who have focused their research more on Latin America, Asia, Europe and Africa. To our knowledge, almost no authors are not particularly interested in the WAEMU zone, which is made up of countries which in particular have abundant forest resources.

In analyzing the causes of deforestation, Benedek and Fertő, (2020) sought to analyze whether economic growth influences the forest trend. Using panel data composed of 63 countries that experienced an increase in their forest cover over the period 1990-2015, based on a parametric and non-parametric model to which they applied the instrumental variables and concluded that 'There is a positive relationship between forest regeneration and the income level of these middle-income countries. They also found the presence of an environmental N-shaped Kuznets curve which suggests long-term optimism but caution is required at the first turning point (a decrease in forest regeneration), unlike at the second, could be quite easy to reach. This N-shaped Kuznets curve between deforestation and income level has been found for Latin America and Africa unlike Asia which simply shows the inverted U shape in Bhattarai and Hammig's research, (2001).

These authors analyzed the role of the quality of institutions in the deforestation process in 66 countries of Latin America, Africa and Asia over the period 1972-1991. Using Generalized Least Squares (GLS) as an estimation method, they find a positive relationship between per capita income and deforestation in the three continents on the one hand and on the other hand that institutions help reduce pressure on forest resources in Latin America and Africa unlike Asia which presents a different cultural context. By going in the same direction of analysis concerning the role of institutions in deforestation at the level of the three regions, Culas, (2007) takes as an institutional variable "the applicability of contracts" which measures the relative degree of contractual provisions which are respected, rated from 0 to 4, with a higher score for better applicability. He used panel data to constitute 14 tropical countries from three zones over the period 1972-1994 on which he made a regression based on panel techniques. It emerges from his work that the expected signs for EKC is verified for the three regions which confirms the results of Bhattarai and Hammig, (2001) but only for Latin America is statically significant as is the effect of the variable institutional on the EKC unlike Africa and Asia. The author asserts that the insignificance of the institutional variable as well as the EKC of Africa could be due to the size of the sample unlike the samples used by Bhattarai and Hammig, (2001).

Through an ARDL model where Ahmed et al. (2015) studied the link between deforestation, energy consumption and economic growth in Pakistan over the period 1980-2013 confirmed the presence of EKC for this country. Economic growth and energy consumption have been identified as the causes of deforestation based on the Granger causality test. In the analysis of CO_2 emissions due to economic growth that drains environmental resources through forestry and mining, researchers have looked at the relationship between the increase in per capita income, energy consumption of fossil and biomass type, of which firewood is the main one as the elements responsible for the emission of CO_2. Moreover, the demonstration of EKC was an object of study. Thus, Danish et al., (2019) analyzed the relationship between natural resources, renewable energies, economic growth and CO_2 emissions in BRICS countries. Their studies covered the year 1990-2015. On the basis of the AMG (Augmented Mean Group) estimator they conclude that the hypothesis of the EKC between economic growth and CO_2 emission is verified in the BRICS countries, except India, where it cannot be verified. Natural resources have an insignificant impact on CO_2 emissions in Brazil, China and India. The abundant availability of resources in Russia contributes to the reduction of CO_2 emissions, unlike South Africa where it contributes more to its emission.

From this review of the literature which plunged us into the transmission channels of deforestation, we can retain that deforestation and CO_2 emissions are mainly due to human actions or this quest for perpetual search for growth in is the cause and the solution respectively in the short and long term of the state of the environment. Several econometric methods with their limitations have been revealed in this literature as well as the study areas. To our surprise, studies are lacking for the WAEMU zone.

3- Materials and Methods

3-1 Theoretical framework

The Kuznets Environmental Curve theorized and demonstrated for the first time by Grossman and Krueger, (1991, 1995) was carried out on the basis of a model relating economic growth and pollution in their study of environmental impact of the North American

Free Trade Agreement. The reduced form equation that relates the pollution level of a place (air or water) is a flexible function of the current and lagged income per capita in the country; Other co-variables were also used to study the relationship between pollution and growth. Specially they estimated this equation:

$$Y_{it} = G_{it}\beta_1 + G_{it}^2\beta_2 + G_{it}^3\beta_3 + \bar{G}_{it}\ \beta_4 + \bar{G}_{it}^2\ \beta_5 + \bar{G}_{it}^3\ \beta_6 + X_{it}'\beta_7 + \epsilon_{it} \qquad (1)$$

Where $\boldsymbol{Y_{it}}$ it is a measure of water or air pollution in station $\boldsymbol{i}$ in year $\boldsymbol{t}$, $\boldsymbol{G_{it}}$ it is the average GDP per capita, $\boldsymbol{\bar{G}_{it}}$ is the average GDP per capita over the three previous years, $\boldsymbol{X_{it}'}$ is a vector of other co-variables, $\boldsymbol{\epsilon_{it}}$ is an error term and $\boldsymbol{\beta_i}$ parameters to be estimated.

The shape of the curve is determined by the parameters $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_2}$. For the relationship between a measurement of water or air pollution and wealth per capita to have an inverted U shape, $\boldsymbol{\beta_1} > 0$ and $\boldsymbol{\beta_2} < 0$ must. We can then determine the turning point, the level of income for which a measurement of water or air pollution reaches their maximum, from the formula: $\mathbf{G_{it}} = -\frac{\beta_1}{2\beta_2}$.

This basic model was the reference model for future researchers (Ang, 2007; Cole, Rayner, and Bates, 1997; Cropper and Griffiths, 1994; Lucas, Wheeler, and Hettige, 1992; Panayotou, 1993; Suri and Chapman, 1998) which highlighted the Environmental Kuznets Curve with the inclusion of other control variables.

3-2 Model specialization

Generally, most studies (Ang, 2007; Cole, Rayner, & Bates, 1997; Cropper & Griffiths, 1994; Lucas, Wheeler, & Hettige, 1992; Suri & Chapman, 1998) have looked at the taking of the show. CO_2 as the variable that measures the quality of the environment. As part of our study we will constitute two models where in the first, the CO_2 emission which will be our variable will measure the quality of the environment and in the second model, we will take deforestation as a variable for measuring the quality of the environment. environment as developed by (Barbier, Delacote, and Wolfersberger, 2017; Bhattarai and Hammig, 2001; Culas, 2012; Waheed et al., 2018; Zambrano-Monserrate et al., 2018) augmented by our control variables which more accelerate deforestation.

Model I is as follows:

$$E_{it} = f(TDFR_{it}, Y_{it}, Y_{it}^2, Z_{it}) \qquad (2)$$

$$E_{it} = a_i + \beta_{1it}TDFR_{it} + \beta_{2it}lY_{it} + \beta_{3it}lY^2{}_{it} + \gamma_{it}Z_{it} + \mu_{it} \qquad (3)$$

Where $\boldsymbol{E_{it}}$ represents the emission value of carbon dioxide, $\boldsymbol{TDFR_{it}}$ the annual deforestation rate, $\boldsymbol{lY_{it}}$ and $\boldsymbol{lY_{it}^2}$ respectively the logarithm of the gross domestic product per linear and quadratic head, , $\boldsymbol{Z_{it}}$ the vector control variables composed of the consumption of renewable energy as a percentage of the total energy consumed, the growth rate of the urban population, the control of corruption and trade openness, $\boldsymbol{\beta_{it}}$ the coefficients of the variables $\boldsymbol{TDFR_{it}}$, $\boldsymbol{Y_{it}}$ and $\boldsymbol{Y^2{}_{it}}$, γ_{it} the vector of parameters to be estimated, $\boldsymbol{a_i}$ are unobserved individual country effects and $\boldsymbol{\mu_{it}}$ is a notion of idiosyncratic error.

Model II is as follows:

$$TDFE_{it} = f(Y_{it}, Y_{it}^2, TCP_{it}, DP_{it}, RPG_{it}, IDE_{it}, RL_{it}) \qquad (3)$$

$$TDEF_{it} = a_i + \beta_{1it}lY_{it} + \beta_{2it}lY^2{}_{it} + \beta_{3it}TCP_{it} + \beta_{4it}DP_{it} + \beta_{5it}RPG_{it} + \beta_{6it}IDE_{it} + \beta_{7it}RL_{it} + \mu_{it} \qquad (4)$$

Where $\boldsymbol{DEF_{it}}$ represents the annual deforestation rate, $\boldsymbol{lY_{it}}$ and $\boldsymbol{lY^2_{it}}$ the logarithm of the linear and quadratic gross domestic product per capita, , $\boldsymbol{TCP_{it}}$ the permanent cultivable land, $\boldsymbol{DP_{it}}$ the density of the population, $\boldsymbol{RPG_{it}}$ the growth rate of the rural population, $\boldsymbol{FDI_{it}}$ Foreign Direct Investment, $\boldsymbol{RL_{it}}$ respect for the rule of law; $\boldsymbol{\beta_{it}}$ are the parameters to be estimated, $\boldsymbol{a_i}$ are unobserved individual country effects and $\boldsymbol{\mu_{it}}$ is a notion of idiosyncratic error.

3.3- Estimation procedures

To achieve our two objectives, we will use econometric estimates based on panel data as used by (Suri and Chapman, 1998; Culas, 2007; Koop and Tole, 1999). The first step will be to estimate the coefficients from the Ordinary Least Squares (OLS) estimator with country specific effects. The latter makes it possible to control for the heterogeneity of countries and for structural and stable variables over time which may have been omitted in the specification but which may explain the dependent variable. In this regard, two tests will be associated, namely (i) the Hausman test which will make it possible to decide on the fixed effects and random effects model and (ii) the F-test which accounts for the overall significance of the specific effects introduced. Hausman's test presents a statistic distributed asymptotically according to the chi-square law. Since the associated probability is less than 10%, the fixed-effect model is the most appropriate. If this is not the case, Kpodar, (2007) offers a choice based on a number of arguments. Thus, the use of intra-individual variation (Between) and of inter-individual variation (Within) can also make it possible to discriminate between the two models. When the intra-individual variation is greater than the inter-individual variation, then the fixed-effect model is more appropriate and vice versa.

3-4 The data

In this brief, the data used come from the World Bank database (WDI 2020) covering the period 2000-2014. They cover the 8 WAEMU countries including Benin, Burkina-Faso, Côte d'Ivoire, Guinea Bissau, Niger, Mali, Senegal and Togo. The selected variables are as follows:

- **For the first model**

E: Carbon dioxide emissions (metric tons per capita)
TDFR: The annual deforestation rate (in square kilometers)
lY: The logarithm of gross domestic product per capita (constant 2010 US $)
$\boldsymbol{lY^2}$: The logarithm of gross domestic product per capita squared (constant 2010 US $)
REC: Renewable energy consumption (in% of total energy consumed)
UPG: Growth rate of the urban population (in annual%)
CC: Control of corruption
OV: Trade openness (trade in% of GDP)

- **For the second model**

TDFR: The annual deforestation rate (in square kilometers)
lY: The logarithm of gross domestic product per capita (constant 2010 US $)
$\boldsymbol{lY^2}$: The logarithm of the gross domestic product per capita quadratic (constant 2010 US $)
$\boldsymbol{TCP_{it}}$: Permanent cultivated land (% of area)
$\boldsymbol{DP_{it}}$: Population density (people per square kilometer of land surface)
$\boldsymbol{RPG_{it}}$: The growth rate of the rural population (annual%)
$\boldsymbol{IDE_{it}}$**:** Foreign direct investments (net inflow in% of GDP)
$\boldsymbol{RL_{it}}$: Respect for the Rule of Law

Table 1: Descriptive statistics of model I

Variable	Definition	Obs.	Average	Stand. dev	Min	Max
E	Carbon dioxide emissions (metric tons per capita)	120	.258	.171	.049	.661
TDFR	The annual deforestation rate (in square kilometers)	120	1.43	1.803	-.149	8.7
lY	Gross domestic product per capita (constant 2010 US $)	120	6.601	.379	6.056	7.229
lY^2	Gross domestic product per capita (constant 2010 US $) quadratic	120	43.712	5.047	36.676	52.262
UPG	Rural population growth rate (annual%)	120	4.166	.985	2.72	6.716
REC	Renewable energy consumption (% of total energy consumed)	120	72.518	14.587	40.467	91.238
CC	Control of corruption	112	-.707	.352	-1.538	.176
OV	Trade Openness (Trade as% of GDP)	120	58.936	19.212	30.368	112.761

Table 2: Descriptive statistics for model II

Variable	Definition	Obs.	Average	Stand. dev.	Min	Max
TDFR	The annual deforestation rate (in square kilometers)	120	1.43	1.803	-.149	8.7
lY	The logarithm of gross domestic product per capita (constant 2010 US $)	120	6.601	.379	6.056	7.229
lY^2	The logarithm of gross domestic product per capita (constant 2010 US $) quadratic	120	43.712	5.047	36.676	52.262
RPG	Rural population growth rate (annual%)	120	2.143	.657	1.331	3.912
DP	Population density (in population per Km^2)	120	54.182	31.134	8.946	131.237
TCP	Permanent cropland (% of area)	120	3.631	4.657	.02	14.151
FDI	Foreign direct investments (net inflow in% GDP)	120	2.255	2.598	-.66	18.818
RL	Respect for the rule of law	112	-.695	.421	-1.586	.066

4- results and discussions

4.1- Model validity test (I and II)

In the analysis of panel data, the Hausman test allows us to decide which model to use between a fixed or a random effect model. The test is based on this assumption:

- H0: presence of random effect (GLS),
- H1: presence of fixed effect (WITHIN).

The results are recorded in the table below

Table 3: Hausman test

	Model I	Model II
Chi2(7)	30,41	15, 46
Prob>chi2	0,0001	0,0305

The probabilities associated with the Hausman test for model I and II respectively are less than 10% therefore the fixed-effect model is more appropriate for our two models.

4.2- Estimation of the fixed-effect model I with correction for heteroscedasticity.

Although the Hausman test allows us to decide on a fixed effect model, we will also present the estimation of the random effect model but the interpretation will be based on the fixed effect model with correction for heteroskedasticity.

Table 4: Results of the estimation of model I

Estimation method	(Fixed effect)	(Fixed effect with Robust option)	(Random effect)
Variable	E_{it}	E_{it}	E_{it}
$TDFR_{it}$	0.013	0.013**	0.036***
	(0.009)	(0.006)	(0.007)
lY_{it}	-7.301***	-7.301***	-2.009*
	(1.715)	(1.498)	(1.082)
lY^2_{it}	0.579***	0.579***	0.176**
	(0.130)	(0.116)	(0.082)
RCE_{it}	-0.004***	-0.004***	-0.004***
	(0.001)	(0.001)	(0.001)
UPG_{it}	0.001	0.001	-0.026**
	(0.019)	(0.013)	(0.011)
CC_{it}	0.011	0.011	-0.036
	(0.030)	(0.040)	(0.029)
OV_{it}	0.001	0.001	-0.001*
	(0.001)	(0.001)	(0.001)
CONS	23.366***	23.366***	6.207*
	(5.643)	(4.854)	(3.558)
Obs.	112	112	112
Pseudo R^2	0,501	0,930	0,964

Standard errors are in parenthesis
**** p<0.01, ** p<0.05, * p<0.1*

According to the results of the fixed-effect regression with the Robust option, our variable of interest, which is deforestation, shows a positive and significant sign at 5%. A sign that is consistent with the literature, because deforestation increases the level of CO_2 (Waheed et al., 2018 Solarin et al., 2017). Thus, we can say that an increase in the annual deforestation rate of 1 km ^{2} in the WAEMU zone leads to an increase in CO_2 emissions of 0.013 metric tons per capita. The coefficients of the linear and quadratic gross domestic product are respectively significant at 1% but present a simple U-shaped relationship. This testifies to an absence of the environmental Kuznets Curve between GDP per capita and CO_2 emissions in WAEMU. Our results allow us to say that the environment in the short term will be better than in the long term. An explanation that can be linked to our current income level which does not allow us to pollute the environment more.

The sign and significance of the consumption of renewable energy does not surprise us. A result in line with the result of Waheed et al. (2018) where the consumption of renewable energies reduces CO_2 emissions. It is significant at 1%. We can affirm in the WAEMU zone that an increase in renewable energies of 1% of total energy consumed decreases CO_2 emissions by 0.004 metric tons per capita. The growth of the urban population rate, corruption and trade openness have positive effects on CO_2 emissions but are not significant.

4.3- Estimation of the fixed-effect model II with correction for heteroscedasticity

In this part, only the results of the fixed effect with the Robust option will be commented on.

Table 5: Result of the estimation of Model II

Estimation method	(Fixed effect)	Fixed effect with Robust option)	(Random effect)
Variable	$TDFR_{it}$	$TDFR_{it}$	$TDFR_{it}$
lY_{it}	34.052**	34.052*	-11.708
	(14.872)	(20.002)	(18.538)
lY^2_{it}	-2.902**	-2.902*	0.678
	(1.142)	(1.543)	(1.382)
RPG_{it}	-1.251***	-1.251***	-0.439
	(0.368)	(0.459)	(0.271)
DP_{it}	0.090***	0.090***	0.042***
	(0.012)	(0.015)	(0.004)
TCP_{it}	-0.554***	-0.554***	-0.110**
	(0.144)	(0.160)	(0.052)
FDI_{it}	-0.014	-0.014	0.119***
	(0.021)	(0.028)	(0.039)
RL_{it}	0.952***	0.952***	0.170
	(0.340)	(0.257)	(0.568)
cons	-95.990**	-95.990	48.009
	(48.362)	(64.936)	(62.485)
Obs.	112	112	112
Pseudo R^2	0,467	0,944	0,793

Standard errors are in parenthesis
**** p<0.01, ** p<0.05, * p<0.1*

By examining the results of Model II, we can admit that our variable of interest which is the linear gross domestic product positively influences deforestation at a significance level of 10%. Likewise, at a significance level of 10%, the quadratic gross domestic product has a negative influence on deforestation. A result which allows us to affirm that there is a non-linear relationship between deforestation and the variables of gross domestic product. The observation of an increase in deforestation initially with the increase in gross domestic product up to a threshold effect where there is a decrease in deforestation which is accompanied by an improvement of the environment confirms an inverted U relationship between our two variables. A result which allows us to confirm the presence of the Environmental Kuznets Curve between deforestation and gross domestic product in WAEMU. A result which is consistent with the literature of Bhattarai and Hammig, (2001) on a presence of EKC for Africa. But referring to the work of Lokonon and Mounirou, (2019) they do not find this evidence for all of Sub-Saharan Africa but only in a few countries and support it with the work of Copeland and Taylor (2004) who stated that the estimation of the EKC is very sensitive to the sample (period, country or group of countries, type of pollutants, etc.).

In addition, there is a positive and significant effect of the population density and the institutional variable of compliance with the 1% rule of law on the annual deforestation rate in the WAEMU. A result which confirms the determining role of urbanization measured by population density in deforestation (Leblois, Damette, and Wolfersberger, 2017). Likewise, we can see that the rule of law is not respected in WAEMU. A result that does not surprise us given the poor score obtained by most of the WAEMU countries. Unlike Bhattarai and Hammig, (2001); Culas, (2007) who found, respectively, that political rights and indices of civil liberty for one and the efficiency of contracts and the efficiency of bureaucracy for the other reduce deforestation in Africa; Cuneyt Koyuncu and Rasim Yilmaz, (2008) confirm that corruption accelerates deforestation in their study where a group of countries in Africa, Asia and America are represented. We can retain that the result resulting from the taking into account of various variables which measure the quality of the institutions gives us divergent results.

The growth rate of the rural population and permanent cultivated land (% of area) have a negative influence on deforestation respectively and are all significant at 1%. These two variables present us with an unexpected sign of the latest model 7B (7th multivariate model) estimated by Cuneyt Koyuncu and Rasim Yilmaz, (2008) where they present a positive sign unlike model 1B (1st multivariate model) where the signs are negative and not significant. By referring to the explanations of Leblois, Damette, and Wolfersberger, (2016) where they find the same sign for cultivated land we can argue that in the case where the higher the agricultural area, the lower the deforestation can be explained by the fact that when the amount of agricultural land is high, the residual forest cover is therefore low. Therefore, the marginal value of the forest is high and countries are likely to reduce their deforestation activity. Foreign Direct Investment shows a negative sign and is not significant. A result that presents the same signs found by Lokonon and Mounirou, (2019) in their study “Does foreign direct investment hamper forest area in sub-Saharan Africa? ".

Conclusion and recommendation

On the basis of panel data covering the period 2000-2014 and using a regression on two fixed-effect models with correction for heteroskedasticity after specialization of the models through the Hausman test, we were able to achieve the objectives defined in this memory. The results of model I allowed us to conclude that deforestation has a positive influence on CO_2 emissions in WAEMU and that in terms of CO_2 emissions, the quality of the environment in the short term will be better than that of the long term. term. A result that was possible thanks to the sign presented by the linear and quadratic GDP which leads us to refute the presence of the Environmental Kuznets Curve between the CO2 emission and the level of income. On the other hand, the results confirm an important role of the consumption of renewable energies in the reduction of CO2 emissions in WAEMU.

The results of the second model revealed the crucial role of income level in deforestation in WAEMU. We can retain that the level of the current gross domestic product in WAEMU is one of the determining factors of deforestation in the area. On the other hand, the results show a decrease in deforestation with the quadratic term of gross domestic product. A fact that leads us to admit the presence of the Environmental Kuznets Curve between deforestation and gross domestic product. The results also show that population density which represents the level of urbanization is one of the determinants of deforestation in WAEMU. A fact that can be explained by the growing demand for construction timber and energy for individuals and on the other hand exploitation for the establishment of infrastructure. However, we notice that respect for the rule of law is violated because the latter is also identified as a factor of deforestation in the area.

In the search for the determinants of deforestation in the WAEMU zone, some socio-cultural aspects were not taken into account, such as the level of education developed in the study by Nguyen Van and Azomahou, (2007) as well as estimation technique, data, period and country may constitute a limitation in themselves for our work. For future research, "The Green Solow Model" can be explored in the CKE evidence.

As an economic policy measure we can suggest the implementation of measures boosting inclusive and sustainable development promoting sober consumption through the use of improved stoves and gas for cooking as fuelwood. In terms of energy use, the State must give priority to energies based on renewable energies rather than fossil energies which are more polluting; encourage reforestation initiatives. Improving the quality of institutions through the establishment of a framework promoting respect for the rule of law will be an asset in the fight against deforestation in WAEMU.

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