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Abstract

The purpose of this study is to examine the two-way relationship between agricultural growth and the quality of the environment. Agriculture is considered a key sector and of great importance in the Cameroonian economy. But its sensitivity to climate fluctuations has created a great deal of concern about its ability to meet the food needs of the entire population as a result of climate change. Moreover, its contribution to the deterioration of the quality of the environment is far from being marginal. Thus, the analysis of the links between agricultural income and the quality of the environment was made in the framework of this study using the environmental curve of Kuznets and the Ricardian model. The results of the study show that there is a U-shaped relationship between agricultural growth and environmental quality (CO2). This shows that it is difficult to make agricultural production believe without having a negative effect on the quality of the environment. We finally show that rising temperatures have a U-shaped impact on farm income.

Key words: Agricultural Growth, Kuznets approach, Ricardian approach, Environmental quality, ARDL.

JEL : Q01; Q51; Q56

1. Introduction

Since the first United Nations Conference on the Environment, held in Stockholm in 1972, particular attention has been paid to the study of the quality of the environment and the overexploitation of natural resources. It is generally accepted in the literature that human activities are one of the main causes of accelerating climate change (environmental degradation) (IPCC, 2007). Based on the analysis of scientific literature evaluated by experts, the IPCC (2007) concluded that global warming was "unequivocal" and that it could be said with a probability of more than 90% that it was the average net effect of human activities at the global level. In sub-Saharan Africa in particular, environmental degradation is subject to a range of factors including: strong population growth, increased agricultural exploitation, desertification and deforestation.

In most of its history, agriculture has caused very little damage to the environment. Crop residues were incorporated into the soil or fed to livestock, and the manure returned to the land. The traditional mixed farm had few external effects. All this has changed since the Second World War in many parts of the world where farms have become highly mechanized and have become dependent on fertilizers and synthetic pesticides. These agrochemicals are the main source of agricultural contamination. Contamination extends to food, drinking water, soil, surface water and groundwater, the atmosphere, and in some cases reaches the stratosphere.

Yet agriculture is the main economic activity in Africa. It provides a means of survival and employment for a large number of people. In fact, agriculture provides about 40% of the region's GDP, employs more than 60% of the workforce and provides for the needs of 70% of the population (FAOSTAT, 2004). Similarly, in Cameroon, primary sector activities account for 21% of GDP. Land is therefore an essential resource and the survival base for most Africans.

However, large-scale deforestation for agricultural and other reasons is exacerbating climate change by contributing to greenhouse gas (GHG) emissions. The amount of CO2 stored in Africa's forests is estimated at 60 billion tons (Unmußig and Cramer, 2008). Relatively high deforestation rates in the 12 most heavily forested countries in the region (including Cameroon), accounted for about 1.1 billion tons of CO2 emitted into the atmosphere in 2005 (FAO 2007, UNDP 2007). .

Climate change is exacerbating the problem of undernutrition in Cameroon and will continue to undermine initiatives to reduce poverty and malnutrition. Undernutrition in turn undermines the resilience of vulnerable populations by reducing their ability to cope and adapt to the impacts of climate change, as well as their ability to grow economically. The drought in the Horn of Africa, which triggered famine in Somalia, for example, and fueled food crises in other countries, may be an indication of what might happen in the future, since such incidents become more common, and extreme weather events are more likely to occur due to climate change.

With respect to temperature rise, it is difficult to conclude that the effects on agricultural production are positive or negative because of the difficulty of separating physiological effects at the plant level from ecological effects (Nefzi A., 2012). As a result, there is still ambiguity about the nature of the links between the environment and agricultural production. Indeed, agricultural crops will be affected by changes in temperature and precipitation related to climate change, but also directly by increasing the concentration of carbon dioxide in the air. This increase is favorable to photosynthesis, stimulates the growth of plants and tends to increase the quantities produced. However, the magnitude of this effect depends on many factors, for example, rice production can increase by 30% for a doubling of the CO2 concentration, for moderate temperatures. However, this effect decreases rapidly for temperatures above 25 ° C and could even be reversed above 35 ° C (Nefzi A., 2012). Global warming will profoundly affect agricultural production. It will affect the world's agricultural sector in many ways. An example of this is an increase in the number of fires, changes in the rate and intensity of rainfall, and the smoothing of nutrients in the soil.

Thus, Cameroon will have to make more and more difficult choices in its development process, in particular, the arbitration between the development efforts of the agricultural sector and the maintenance of the quality of the environment. Indeed, despite the diversity and the diversity of its agroclimatic zones, the agricultural sector in Cameroon is not spared by the effects of climate change. Understanding the linkages between the agricultural system and climate change is the challenge this study proposes to address. As such, the purpose of our work is to capture the two-way nature of the links between environmental quality and agricultural growth in Cameroon.

The rest of this paper is organized as follows. Section 2 reviews the literature on environment and agricultural. Section 3 describes the data and the econometric model. Section 4 provides the empirical results. And we conclude in Section 5.

2. Environment and agriculture

Awareness of the imminence of climate change by the scientific community has given special attention to the agricultural sector. Indeed, the crucial role played by the agricultural sector in the daily survival of millions of people justifies such an interest. In addition, its high sensitivity and influence to climate fluctuations has created enormous concerns about its ability to meet the food needs of the world as a result of climate change. This is why the issue of agriculture has received the most attention to date (Adams, 1989, Adams et al., 1995, Adams et al., 1999, Adams et al., 1990 Deschênes and Greenstone, 2007). Moreover, the externalities of this sector of activity are far from being all positive or having a zero cost.

Indeed, Pretty (2005) has shown, for example, through studies on the costs of negative externalities of agriculture on the environment in Britain. He estimates that the annual external costs of British agriculture would be in the range of £ 1.5 to £ 2 billion. These costs come from damage to the atmosphere, water, biodiversity and landscapes, soils and human health. Using a similar framework of analysis, he finds that the annual external costs amount to nearly 13 billion pounds in the United States. It is therefore necessary to have an agricultural system that does not harm biodiversity and landscapes. Therefore, it is important to build an agricultural system that is sustainable. To achieve this, the direction given by Kuznet (1955) proves necessary in this case. This involves determining the relationship between agricultural growth and the environment in order to reconcile them.

From an economic point of view, the relationship between economic growth (of which agriculture is a major component for a country like Cameroon) and the quality of the environment constitutes a great debate and a wide literature has been (Georgescu-Roegen, 1971, Meadow et al., 1972, Cleveland et al., 1984). This debate focuses essentially on discussions and purely theoretical work until the early 1990s. Beginning in the 1990s, the availability of state of the environment data prompts researchers to empirically investigate the relationship between economic growth and environmental quality. In addition, empirical studies (Shafik and Bandyopadhyay, 1992, Grossman and Krueger, 1993, Panayotou, 1993) revealed important results, including the existence of a bell-shaped relationship between various pollution indices and the level of per capita income. The name of the 'Kuznets Environmental Curve' (CEK) has been attributed to this relationship. The CEK hypothesis postulates an inverted U-shaped relationship between environmental degradation and economic growth. This curve indicates that during the first phase of economic growth (increase in income), deterioration of the environment increases; but from a certain level of income (turning point), an improvement in the state of the environment occurs. However, one of the major criticisms of the CEK is that it only takes into account the effect of growth on the environment and ignores the effect of the environment on growth or production.

However, the sensitivity of agriculture to the climate is no longer to be demonstrated. This sensitivity originates in a set of interrelated physiological, climatic, geological and biological factors. These factors intermingle in the course of a growing season, culminating in a specific yield for the different plants and crops at the end of the growing season. Thus, fundamental factors such as the length of the growing season (freezing season), the timing of the frost, the accumulation of heat (temperature), the level of precipitation, evapotranspiration, hours of sunshine, Available moisture, the concentration of carbon dioxide, directly affect the yield of a crop. This is compounded by indirect factors such as a potential increase in insect and pathogen infestation, changes in soil characteristics and / or a change in water requirements for irrigation. These factors, which are for some positive and for other agricultural negatives, clash, canceling the effects of both, making the estimation of the net impact very difficult to predict (Brklacich et al ., 1998).

Climate change will therefore pose a major threat to agricultural development and food security in the coming decades, particularly in Africa, where economies are more climate-sensitive than any other continent (Pachauri and Reisinger, 2007). Some parts of Africa have dried up over the last century (eg the Sahel) and the continent is expected to experience a higher temperature rise than the world average (Boko et al., 2007). Africa has often been identified as one of the region's most vulnerable to climate variability and change due to multiple disruptions and low resilience resulting from endemic poverty, weak institutions and recurrent droughts, Emergencies and complex conflicts associated with it. Climate-related risks have fundamental repercussions on African populations and economies, and mobilize significant amounts for emergency resources.

Studies of the impact of climate change on economically-oriented agriculture are mainly based on three types of quantitative estimation : the simulation of agroeconomic models (Adams et al., 1988, Adams et al., 1990, Adams et al. (Fisher and Van Velthuizen, 1996), and the Ricardian method (Mendelsohn, Nordhaus and Shaw, 1995), the study of agro-ecological zones (Adams et al., 1999, Easterling et al 1993, Kaiser et al 1993, Rosenzweig and Parry 1994) 1994, 1996, 1999, Dinar et al., 1998).

Reilly (1996) shows that imposing climate change on crop models would provide an estimate of how "potential production" can change as a result of climate change. Therefore, an economic analysis of these estimates, which integrates more broadly the economic and technical characteristics of the study environment, would be preferable.

3. Methodology

In this work, two analytical tools will be used, namely the Kuznets model or the Kuznets environmental curve (CEK) and then the Ricardian model.

For this study, the Kuznets model examines the influence of agricultural growth on the quality of the environment. In this case, this model seeks to examine the evolution of CO2 emissions as a function of agricultural growth measured by agricultural income (PIBagr). The CEK is essentially an empirical phenomenon. The basic specification for examining the evolution of environmental degradation as a function of agricultural growth is presented by a polynomial function of degree two. In line with the objectives outlined above, we will first examine the direct relationship between the evolution of CO_2 emissions and PIBagr.

$$lnCO_{2t} = \gamma_0 + \gamma_1 \ln PIBagr_t + \gamma_2 (\ln PIBagr)_t^2 + \gamma_3 \ln Defor_t + \gamma_4 \ln OUV_t + \gamma_5 \ln VAind_t + \gamma_6 \ln ENERG_t + \gamma_7 \ln DPOP_t + v_t \quad (1)$$

Where t = 1971,…, 2013.

The second method was developed by Mendelsohn et al. in 1994. It examines the influence of climate on the net income or value of land. It is a matter of regressing the performance of the farm represented by the value of the land or the net income on a set of environmental factors, traditional inputs (land and labor) and support systems (infrastructure). This would make it possible to measure the contribution of each factor to the results and to detect the effects of long-term climate change on the agricultural value of the land. Contrary to the agro-economic approach, the Ricardian approach implicitly takes into account the adaptations of the farmer. In fact, profits and adaptation costs are automatically incorporated by the agricultural value of land or net income. This method relies on the assumption of market efficiency and therefore on the fact that the value of agricultural land reflects the present value of future income from the most productive exploitation of the land. In this study, we will replace the value of land or net income with farm income. This is justified by the fact that there is no information on the cost of agricultural production in Cameroon.

According to the work of Mendelsohn, Nordhaus and Shaw (1993), we assume that the climate variables take the quadratic form in the income function. The income function can thus be expressed in terms of climatic conditions and characteristics exogenous to the operator as follows:

$$PIBagr_t = \alpha_0 + \alpha_1 TEMP_t + \alpha_2 TEMP_t^2 + \alpha_3 Defor_t + \alpha_4 TRAV_t + \varepsilon_t \quad (2)$$

Where t = 1983,…, 2014.

The variable PIBagr is the agricultural income, it captures in model 1 the impact of the level of agricultural development on the environment. ENERG is fossil energy consumption in% of total energy consumption, VAind is the value added of the industrial sector as a % of gross domestic product and Defor and TRAV respectively represent the area of land used for agriculture and the number of workers in the agricultural sector. The term α_0 and γ_0 represent the unobserved specific effect; ε_t and v_t are the error terms; γ_1, γ_2, γ_3, γ_4, γ_5, γ_6, α_1, α_2, α_3 and α_4 are the coefficients to be estimated. OUV represents the commercial opening; it makes it possible to verify the hypothesis of «pollution haven" as developed by Birdsall and Wheeler (1992). Indeed, developing countries attract environmentally harmful activities through less stringent environmental regulations, which reduce production costs and can therefore encourage offshoring (Low and Yeats, 1992). These indicators are extracted from the World Development Indicators (2015). The NASA database provided us with the temperature change values (TEMP).

The descriptive statistics of the different quantitative variables are summarized in Table 1, while tables 2 and 3 list the different correlations between the variables. The correlation matrices of the variables of the two models suggest a strong correlation between certain variables.

Table 1: Descriptive Statistics of Variables

Variables	Obs	Mean	Median	Standard deviation	Min	Max	Skewness	Kurtosis
lnCO2	43	-8.354	-8.427	0.548	-9.364	-7.318	0.234	2.548
lnPIBagr	43	5.113	5.117	0.137	4.906	5.378	0.355	2.035
lnPIBagr2	43	26.157	26.188	1.409	24.069	28.922	0.391	2.07
lnDefor	43	0.853	0.969	0.508	-0.274	1.879	-0.511	2.905
lnENERG	43	2.836	2.813	0.315	2.198	3.482	-0.001	3.1
lnOUV	43	-1.053	-1.033	0.212	-1.49	-0.666	-0.381	2.257
lnDPOP	4 3	-1,295	-1,278	0,367	-1,917	-0,705	-0,079	1,772
lnVAind	43	3.323	3.397	0.226	2.769	3.623	-1.13	2.945
TEMP	32	23.65	23.85	0.652	22.3	24.6	-0.67234	2.200
TEMP2	32	559.735	568.825	30.585	497.29	605.16	-0.64145	2.173
PIBagr	32	83667.12	84481.99	11507.17	65247.62	101917.3	-0.121	1.697
Defor	32	9243688	9160000	194450.3	9060000	9750000	2.072	5.657
Trav	32	7792688	8085000	648964	6281000	8341000	-1.156	2.925

Table 2: Matrix of correlation between variables of the Kuznet model

	lnCO2	lnPIBagr	lnPIBagr2	lnDefor	lnENERG	lnOUV	lnVAind	lnDPOP
lnCO2	1.0000							
LnPIBagr	0.377	1.0000						
lnPIBagr2	0.373	0.9999	1.0000					
LnDefor	-0.171	0.215	0.218	1.0000				
lnENERG	0.559	0.742	0.744	0.0994	1.0000			
LnOUV	0.36	0.792	0.793	0.3211	0.671	1.0000		
lnVAind	0.675	0.544	0.539	0.0169	0.6235	0.7193	1.0000	
lnDPOP	0.6968	0.9881	0.9875	0.4773	0.7543	0.9084	0.6477	1.0000

Table 3: Matrix of correlation between variables of the Ricardian model

	PIBagr	TEMP	TEMP2	Defor	TRAV
PIBagr	1.0000				
TEMP	0.5595	1.0000			
TEMP2	0.5558	0.9999	1.0000		
Defor	0.6016	0.6741	0.6716	1.0000	
TRAV	0.4558	0.1396	0.1371	0.1919	1.0000

The Engel and Granger tests (1987) and the Johansen-Juselius test (1990) are most commonly used to identify a co-integration relationship (long-term relationship) between several variables. These methods require that all variables be stationary in the first difference. However, these methods present limits in the case of small samples. To overcome these limitations, Pesaran, Shin and Smith (1996) developed the coalescence test by staggered delays, in English Auto Regressive Distributed Lags (ADRL) approach to cointegration popularized by Pesaran et al. (2001). This method has the particularity that it does not require that all the variables be integrated of the same order, that is to say I (1). This method is valid for the variables I (0), I (1) or both (Pesaran and Pesaran, 1997).

It is on this basis that we will perform the cointegration test from the following equations:

$$\Delta \ln(CO2_t) = \alpha_0 + \sum_{t=0}^{q} \alpha_1 \Delta \ln(CO2_{t-i}) + \sum_{t=0}^{q} \alpha_2 \Delta \ln(PIBagr_{t-i}) + \sum_{t=0}^{q} \alpha_3 \Delta \ln(PIBagr^2_{t-i}) + \sum_{t=0}^{q} \alpha_4 \Delta \ln(ENERG_{t-i})$$
$$+ \sum_{t=0}^{q} \alpha_5 \Delta \ln(OUV_{t-i}) + \sum_{t=0}^{q} \alpha_6 \Delta \ln(VAIND_{t-i}) + \sum_{t=0}^{q} \alpha_7 \Delta \ln(DPOP_{t-i}) + \alpha_8 \Delta \ln(CO2_{t-1}) + \alpha_9 \Delta \ln(PIBagr_{t-1}) +$$
$$\alpha_{10} \Delta \ln(PIBagr^2_{t-1}) + \alpha_{11} \Delta \ln(ENERG_{t-1}) + \alpha_{12} \Delta \ln(OUV_{t-1}) + \alpha_{13} \Delta \ln(VAIND_{t-1}) + \alpha_{14} \Delta \ln(DPOP_{t-1}) + \varepsilon_t \quad (4)$$

$$\Delta PIBagr_t = \alpha_0 + \sum_{i=0}^{q} \alpha_1 \Delta PIBagr_{t-i} + \sum_{i=0}^{q} \alpha_2 \Delta TEMP_{t-i} + \sum_{i=0}^{q} \alpha_3 \Delta TEMP^2_{t-i} + \sum_{i=0}^{q} \alpha_4 \Delta Defor_{t-i}$$
$$+ \sum_{i=0}^{q} \alpha_5 \Delta TRAV_{t-i} + \alpha_6 PIBagr_{t-i} + \alpha_7 TEMP_{t-i} + \alpha_8 TEMP^2_{t-1} + \alpha_9 \Delta Defor_{t-1} + \alpha_{10} \Delta TRAV_{t-1} + \varepsilon_t \quad (5)$$

Implementation of the cointegration test by staggered delays requires a unit root test to ensure that the variables are not I (2), in which case this method is no longer valid. In order to determine the long-term relationship given by equations (4) and (5), we will perform a cointegration test in the sense of Pesaran et al (2001) using the value of the F statistic. Of this test, the optimal delay was selected through the AKAIKE (AIC) and SCHWARZ (SBC) information criteria. The ADRL method ends with the estimation of the short-term dynamics (ECM) given by the following equations (6) and (7):

$$\Delta \ln(CO2_t) = \alpha_0 + \sum_{t=0}^{q_1} \alpha_{1i} \Delta \ln(CO2_{t-i}) + \sum_{t=0}^{q_2} \alpha_{2i} \Delta \ln(PIBagr_{t-i}) + \sum_{t=0}^{q_3} \alpha_{3i} \Delta \ln(PIBagr^2_{t-i}) + \sum_{t=0}^{q_3} \alpha_{4i} \Delta \ln(ENERG_{t-i})$$
$$+ \sum_{t=0}^{q_5} \alpha_{5i} \Delta \ln(VAIND_{t-i}) + \sum_{t=0}^{q_6} \alpha_{6i} \Delta \ln(OUV_{t-i}) + \sum_{t=0}^{q_6} \alpha_{7i} \Delta \ln(DPOP_{t-i}) + \lambda ECT_{t-1} + U_t \quad (6)$$

Where q_i (i=1,2,…6) represents the optimal delays.

4. Results

4.1. Stationarity test

Dickey-Fuller Augmented (DFA) and Phillips-Perron (PP) stationarity tests were performed in order to reassure that no variable is integrated in an order greater than 1, under which the cointegration test by Delayed delays proposed by Pesaran et al (1999, 2001) ceases to be valid. These tests indicate that all variables meet the ARDL application standards, with the maximum integration order of the variables being 1 (Table 4). Similarly, this result is confirmed by the unit root test with a break (Table 5).

Table 4: Result of the stationarity tests of DFA, DF-GLS and PP

	ADF test			DF-GLS			PP test	
Variables	SIC retards	t-Stat	Valeur critique à 5%	SIC Retards	t-Stat	Valeur critique à 5%	t-Stat	Valeur critique à 5%
$lnCO_2$	0	-3,213	-2,94	0	-2,26	-1,95	-3,2	-2,94
lnPIBagr	1	-6,50	-2,94	1	-6,39	-1,95	-6,56	-2,94
$lnPIBagr^2$	1	-5,47	-2,94	1	-6,5	-1,95	-6,55	-2,94
lnENERG	1	-6,93	-2,94	1	-7,02	-1,95	-6,93	-2,94
lnDefor	1	-7,69	-2,94	1	-7,78	-1,95	-7,62	-2,94
lnDPOP	0	-7,046	-1,95	0	-5,26	-1,95	-12,8	-2,94
lnVAind	1	-5,39	-2,94	1	-5,34	-1,95	-5,37	-2,94
lnOUV	1	-6,14	-2,94	1	-6,17	-1,95	-8,97	-2,94
PIBagr	1	-3.683	-2,94	1	-6,03	-1,95	-4.47	-2,94
TEMP	0	-6.767	-2,94	0	-2,56	-1,95	-9.103	-2,94
$TEMP^2$	0	-6.797	-2,94	0	-2,6	-1,95	-9.177	-2,94
Defor	1	-4.235	-2,94	1	-4,27	-1,95	-4.228	-2,94
TRAV	0	-3.699	-2,94	0	-3,33	-1,95	-3.681	-2,94

Table 5: Results of the unit root test with ruptures (rupture)

	Perron (1997)(a) IO Model			Perron (1997) (a) AO Model			
Variable	t-stat	Critical values 5%	Break date	t-stat	Critical values 5%	Break date	Décisions
$lnCO_2$	-8,27	-4,44	1988	-7,65	-4,44	1993	Stationnaire
lnPIBagr	-6,51	-4,44	1988	-7,27	-4,44	1991	Stationnaire
lnPIBagr2	-6,51	-4,44	1988	-7,25	-4,44	1991	Stationnaire
lnDefor	-10,21	-4,44	1990	-10,33	-4,44	1990	Stationnaire
lnENERG	-10,008	-4,44	2007	-7,23	-4,44	1984	Stationnaire
lnDPOP	-6,5	-4,44	2008	-6,97	-4,44	2004	Stationnaire
lnVAind	-5,84	-4,44	1984	-5,9	-4,44	1986	Stationnaire
LnOUV	-7,11	-4,44	1984	-7,28	-4,44	1984	Stationnaire
PIBagr	-8,4	-4,44	1995	-5,23	-4,44	1995	Stationnaire
TEMP	-8,14	-4,44	2007	-8,19	-4,44	2007	Stationnaire
TEMP2	-8,04	-4,44	2007	-8,13	-4,44	2007	Stationnaire
Defor	-12,22	-4,44	2010	-21,85	-4,44	2003	Stationnaire
TRAV	-15,64	-4,44	2002	-20,92	-4,44	2002	Stationnaire

(A) Suppose that there is no break with the null hypothesis of unit root. In the Innovational Outlier Model (IO), the changes are assumed to occur gradually, allowing for both constant and slope breaks. In the AO (Additive Outlier) model, the changes occur rapidly, allowing the break only in the slope.

4.2. Cointegration test

Table 6 presents the results of the Pesaran cointegration test.

Table 6: Estimation of the optimal model and result of the cointegration test

	Optimal Lag		F-Statistics		Decision	
Model of kuznet	3		7,991990		Cointégration	
Critical values of Pesaran	10%		5%		1%	
	2,03	3,13	2,32	3,5	2,96	4,26
Ricardian model	4		9,786782		Cointégration	
Critical values of Pesaran	10%		5%		1%	
	2,45	3,52	2,86	4,01	3,74	5,06

Notes: The optimal delays of each model are obtained from the BIC information criteria. The upper bound of pesaran is read from the table CI (ii), Box II: restricted intercept and no trend, k = 7 and k = 4.

These results reject the hypothesis of no cointegration at the 5% threshold for all models. Ouattara (2004) and Akpan et al. (2011) argue that one of the conditions for applying the cointegration test by Pesaran et al. (2001) is that no series should be integrated in an order higher than 1.

4.3. Results of estimating the long-term model

Tables 7 and 8 present the results of the estimation of the effects of economic growth and its determinants on CO2 emissions (Kuznet model) as well as the effects of temperature on agricultural income (Ricardian model) in Cameroon. Several tests such as the serial correlation test (LM test), the error terms normality test (JB) and the heteroskedasticity test (ARCH test) were carried out on the long-term model. The results show that these tests are conclusive. Indeed, there is no serial correlation and the terms of errors are normally distributed. There is no evidence of traditional autoregressive heteroskedasticity. Therefore, the long-term model is well specified.

4.3.1. Results of estimating the impact of agriculture on the quality of the environment

By stimulating domestic consumption and production, the agricultural sector accelerates economic activity. It then affects negatively the quality of the environment by what is called the scale effect. On the contrary, a positive effect says technical effect can take place. It corresponds to the opportunities of the generally less polluting technologies acquired, and to the role of the agricultural sector in strengthening environmental regulations and deploying pollution reduction efforts through increased revenues. Thanks to agriculture, being economically richer allows, as well, to be ecologically cleaner. A third effect appears when agriculture causes a change in the economic structure in the country concerned: it is the compositional effect. It has a generally ambiguous sign. The net effect of agriculture on the quality of the environment depends on the balance of these three effects.

Table 7: Results of long-term relationships

Variables	Model of Kuznet
DLnPIBagr	-106,1816***
	(-4,152961)
D(LnPIBagr)^2	10,7775***
	(4,242255)
DLnDPOP	-0,9348**
	(-2,791094)
DLnDefor	0,2995**
	(2,219165)
DLnENERG	-0,309
	(-1,538597)
DLnOUV	-0,3424
	(-0,632519)
DLnVAIND	4,0183***
	(5,503721)
	237,1936***
C	(3,766951)
F	16,91491***
	(0,000001)[a]
R^2	0,910729
PIBagr of the turning point	$e^{(4,926077476)}$ = 137,8377786
Number of observations	40
Residue Normality Test	5,26
(Jarque Berra)	(0,072188)[a]
LM test	21,21784 (0,0000)[a]
ARCH test	4,431354 (0,2185)[a]
Stability test	The blue lines evolve inside the
(CUSUM ET CUSUMQ)	terminals

Notes: (.) Is the t of students, (.) A is the probability ***; **; * represent the significance at 1%, 5% and 10%, respectively.

The results of the estimate show that the sign of the linear term (PIBagr) is negative and significant whereas the sign of the quadratic term (PIBagr2) is positive and significant. This is a necessary condition for obtaining a U-shape of the CEK. CO2 emission levels decrease with agricultural growth to a certain level of per capita agricultural income (the turning point) from which there will be a deterioration in the state of the environment. The per capita agricultural income of the turning point is (in US $ 2005) 137.8377786.

Although the coefficient of the variables lnENERG and lnOUV is not significant, the Wald test rejects the hypothesis of their nullity at 1% (with Chi-square = 23.4 and Probability of 0.0000). Therefore, it can be said that these variables influence the evolution of the quality of the environment.

4.3.2. Results of estimating the impact of climate change on agriculture

The results of the regressions are given in Table 8. The Fisher-Snedecor test shows that the regressions are globally significant. The coefficient of determination (R^2) of the model is 0.984276, which means that the explanatory variables selected contribute to explaining 98, 4276% the evolution of agricultural income in Cameroon.

Table 8: Results of estimation of the impact of temperature changes on agricultural income in Cameroon

Variables	Ricardian model
DDefor	-0,2021**
	(-4,101331)
DTEMP	-1633942,9396**
	(-3,905361)
DTEMP2	35342,3627**
	(3,911004)
DTRAV	0,0152*
	(2,138478)
C	20674385,1575**
	(3,976179)
F	74,48517***
	(0,000384)[a]
R^2	0,984276
Temperature of the turning point	23,12°C
Number of observations	28
Residual Normality Test (Jarque Berra)	5,46 (0,065)[a]
LM test	19,40582 (0,0001)[a]
Test ARCH	4,302712 (0.0381)[a]
Stability test (CUSUM ET CUSUMQ)	The blue lines evolve inside the terminals

Notes: (.) Is the t of students; (.) A is the probability; ***, **, * represent the significance at 1%, 5% and 10%, respectively.

The Student test shows that the quadratic temperature term is significant at the 5% threshold. This means that the relationship between income and climate is non-linear. The signs of linear and quadratic terms are opposite. This means that temperature negatively affects income up to a certain level beyond which this variable becomes harmful to crops. The conquest of new soils for agriculture among others (Defor) negatively affects agricultural income in our model. This proves that the productivity of these soils is low in view of investments (fertilizers and many other agricultural inputs) made for their development.

The relationship between income and temperature for different potential earth activities is U-shaped. It shows the long-term equilibrium relationship between temperature and profit, that is, the most profitable use of the earth as a function of temperature.

In the first part of the graph, one realizes that an increase in temperature leads to a drop in agricultural income up to the point represented by the temperature level of 23.12 ° C. This fall in agricultural income is justified by the fall in agricultural production caused by the rise in temperature. This increase in temperature will therefore have the effect either of driving out certain farmers and their conversion to other sectors of activity or of adapting their land to other agricultural products which may develop under high temperature conditions.

The second part presents an increase in income as a function of the increase in temperature. This increase in income as a result of the increase in temperature does not necessarily reflect a good adaptation of farmers to the effects of climate change or an increase in agricultural production. It can be the result of rising agricultural prices due to the combined effects of foreclosure and falling agricultural production. In the long term, this increase in agricultural commodity prices will lead to an increase in agricultural production through the entry of new farmers.

4.3.3. Results of estimating the short-term model

Table 9 presents the results of the estimation of the short-term dynamics of the Kuznets and Ricardo models in Cameroon. From the error correction mechanism, it appears that the error correction term (ECT) has a negative and significant coefficient at 1%. This confirms the existence of a co-integration relationship. The coefficient of the ECT term in absolute value is 2.543350 and 1.074368 for the Kuznets and Ricardian models respectively. The existence of ECT implies variations in the dependent variable. These variations are a function of the levels of imbalance in the cointegration relation on the one hand and of the other explanatory variables on the other. These indicate the rate of deviation from the short-term dependent variable to its long-term trajectory.

It can be seen that in the Kuznets model, deforestation has a negative impact on CO2 emissions. The commercial opening positively affects these emissions of CO2 which confirms the hypothesis of the "haven of pollution". On the other hand, in the Ricardian model, all the variables selected have a significant influence on agricultural income. Stability tests are used to explore the stability of the parameters. For this we performed the CUSUM test and the CUSUMQ test (Figures 2 and 3).

The short term model establishes a relation in the form of a 'U' for the Kuznets model and " U " inverted for the Ricardian model.

Figure 2: stability test of the Kuznet model parameters

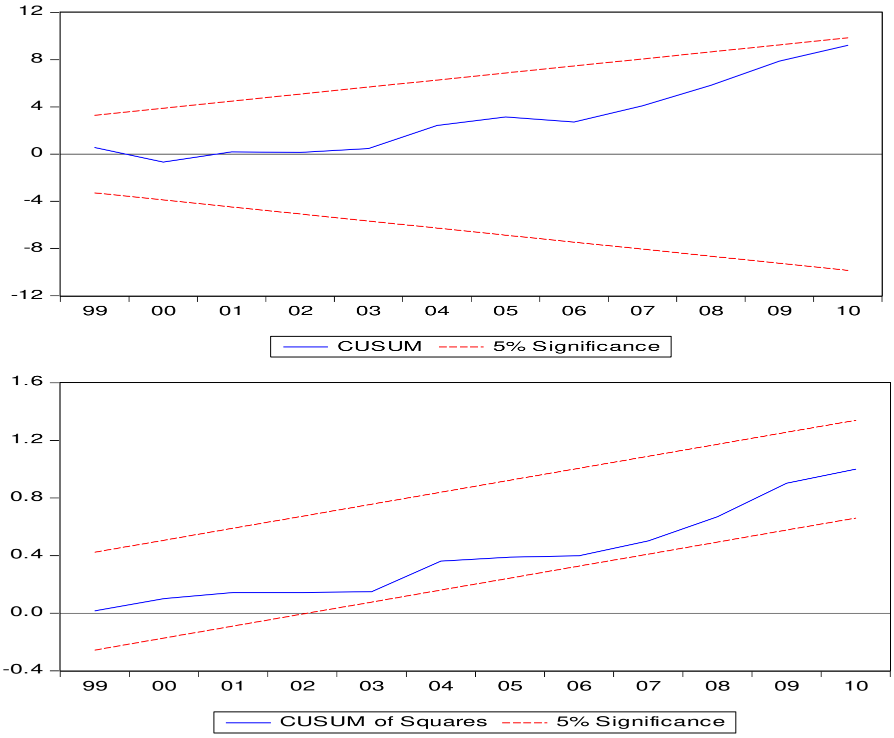

Figure 3: stability test of the Ricardian model parameters

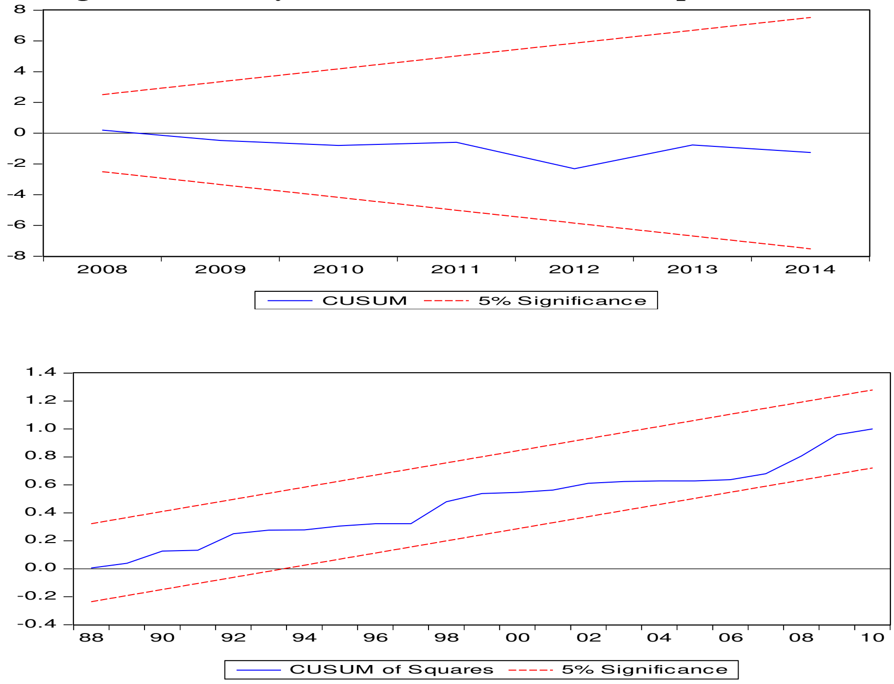

Table 9: Results of short-term model estimation

Variables	Kuznet model		Ricardian model	
	Lag	Estimations	Lag	Estimations
D(lnPIBagr)	2	-275,346882*** (-4,68945)		
D(lnPIBagr)2	0	27,411225*** (4,709121)		
D(lnDefor)	3	-0,408994* (-2,056864)		
D(lnENERG)	2	-0,787005* (-1,82733)		
D(lnDPOP)	3	8328,74997*** (4,3744)		
D(lnOUV)	2	1,432625** (2,840549)		
D(lnVAIND)	3	-2,3778*** (-3,863085)		
TEMP			3	1097097,728** (3,794269)
$TEMP^2$			3	-23135,578** (-3,806716)
Defor			3	0,399681** (4,481057)
Trav			3	-0,076129* (-2,205291)
ECT(-1)		-2,543350*** (-5,168087)		-1,074368*** (-5,376064)

5. Implications and agricultural policy.

As an implication of economic and agricultural policy, it is urgent for Cameroon to accelerate its agricultural transition process. This is possible thanks to a continuous flow of resources from agriculture to industry. We could speed up the mechanisms for the Cameroonian farmers to accompany the transitions, but this is not yet the case, although it is known that this is how one could access the creation of value And a vast potential for dynamic wealth production. In this transition, the progression of the real wage (and that of the land rent, but the hypothesis made in this reasoning is an unlimited supply of land) must be controlled.

Moreover, in Cameroon, agriculture has become increasingly a marginal activity. In order to avoid a relative decline in agriculture and to protect agricultural incomes, the State must put in place support policies, even if they are often distorting. However, the multifunctional nature of agricultural activity (production of non-market services) nevertheless justifies the allocation of support, but these must be decoupled from production in order not to interfere with the market.

The judicious management of existing resources will make it possible to transform sources of pollution and nuisance into positive factors that can enter the production cycle. It is therefore important to increase the agricultural transition in Cameroon in order to be on the chessboard where agricultural development is taking place, as well as the policies that will enable the Cameroonian peasants to exist, which will provide them with the food they need for their well-being.

6. Conclusion

The agricultural sector is one of the areas where climate impact research is most advanced and where quantification of impact is the most documented. This study goes along this line. In particular, it quantified the impact of climate change on agricultural incomes and agricultural income on the quality of the environment in Cameroon. It showed that climate has a non-linear effect on farm income and that there is an environmental Kuznets curve between per capita carbon dioxide level and per capita farm income.

Based on the results of the estimates made in this study, we can make the following recommendations.

Accelerate the agricultural transition in Cameroon, in the sense of Rybczynski (accumulation of capital). There is a need for policies to raise awareness and facilitate farmers to acquire less polluting technologies for their agricultural activities. This allows farmers to make better use of existing agricultural land and thus avoid cutting other trees to create new agricultural areas.

To develop the local processing sector of agricultural products and / or industry in order to facilitate the conversion of certain peasants who are victims of eviction (agricultural transition in the Lewis sense, ie transfer of labor) .

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