Journal of Social and Economic Statistics

Vol. 8, No. 1, Summer 2019

QUANTIFYING THE EFFECTS OF CLIMATE CHANGE ON CROP PRODUCTION

Mbu Daniel TAMBI[a]

Abstract

This study attempts to analyze the impact of climate change on crop production using household consumption survey collected by the national institute of statistics and data imported from the department of statistics of ministry of agriculture and rural development. The main research question is: what is the relationship between climate change and crop production? Methodologically, used is made of instrumental variable and control function models to compute for the data. We realized that to a lesser extent climate change has an effect on agricultural production and more of a fishing phenomenon. In terms of policy, mainstreaming climate change adaptation into national development strategy and budgets could promote proactive engagement on the formulation and implementation of climate change adaptation strategy; this is a wise step towards increasing crop production and malnutrition reduction.

Keywords: Quantifying, Effects, Climate Change, Crop Production, Cameroon
JEL Classification: T12, D23, T34

Author's Affiliation

[a] - University of Dschang, Department of Agricultural Economics, Cameroon, tambi2015@yahoo.co.uk

1. Introduction

Climate change and agricultural production issues are in the heart of policy in almost all countries, international organizations and civil society organizations today. The world needs people who are strong, elegant and intelligent, those that can contribute positively in the labour market, solve the devastating problem of poverty and ameliorate living standards; these kinds of people can be seen if they are well nourish. However, for these things to happen, those factors that might tempered with the system need to be given a deeper look so as to devised ways in managing the system. The main objective of this study is to assess the impact of climate change on agricultural production in Cameroon. Critically, climate change can affect humanity directly or indirectly through basic food production, health and consequently economic activities in many ways. Higher temperatures may lead to heat stress for plants and human, increasing sterility and lowering overall productivity. It also increases evaporation from plants and soils, increasing water requirements while lowering water availability.

Generally, the world body has unanimously accepted that the global climate is changing and that this change has serious repercussion on human life, though there is yet to be a convergence on the magnitude of its impact on economic growth both at the regional and country specific levels (Akachi et al., 2009). In fact there is limited empirical analysis on the damaging effects of climate change on the African economy both collectively and at individual country levels (Odusola and Abidoye, 2012). More research is therefore needed to quantify the climate change effects especially in Cameroon where no major attempt has been made in relation to economic analyses vis-a-vis crop production. Adams et al (1998) noted that climate is the primary determinant of agricultural productivity. Given the fundamental role of agriculture in human welfare, concern has been expressed by federal agencies and others regarding the potential effects of climate change on agricultural productivity. Interest in this issue has motivated a substantial body of research on climate change and agriculture over the past decade. Climate change is expected to influence crop and livestock production, hydrologic balances, input supplies and other components of agricultural systems.

Following Fisher et al (2005) and Jönsson (2011) there is a large concern regarding the impacts of climate change and its variability upon agricultural practices worldwide. Thus, Jönsson (2011) explained that the global distress of food insecurity is but one consequential factor where each country and state is alarmed by the outcomes of the impacts of climate change that might arise over the coming decades. Following UN (2017), a large number of studies have analyzed the potential impacts of climate variability and instability upon agricultural production in developed and countries in transition. The studies in question revealed that an increased variable climate could have potential positive impacts on agriculture

(Mendelshon et al., 1994; Fisher et al, 2005). In developing countries, the impact has not yet provided a unified picture (Fisher et al, 2005).

Some studies have attempted to estimate the impact of climate change on food production at the country, regional, or global scale (Pearce et al., 1996; McCarthy et al., 2001; Parry et al., 2004; Stern, 2007). Insights from these studies are crucial to appreciate the extent of the problem and to designing appropriate mitigation strategies at the global or regional level. However, most of these attempts failed to provide critical insights in terms of effective use of secondary data in handling the endogeneity and simultaneous bias at the micro or household level. Studies on the impact of climatic change (in particular rainfall and temperature) and climate-related adaptation measures on crop yield are very scanty. In the real sense, most of the literature in climate change has looked into the determinants of farm technology adoption decisions (particularly, soil and water conservation, fertilizer, improved seed varieties, and biodiversity) and their impacts on farm productivity (Yesuf et al., 2008).

To the best of our knowledge most of the studies directly dealing relating climate change to agricultural productivity are outside Cameroon and most of those existing studies have applied the Ricardian approach, wherein the cost of climate change is imputed from farm net revenue as a proxy for capitalized land value (Deressa, 2007; Yesuf et al., 2008). Over the years many authors have criticized the use of Ricardian model; Mendelsohn et al (1994) points out the fact that the production function approach has a tendency to “overestimate the damages from climate change because it does not, and indeed cannot, take into account the infinite variety of substitutions, adaptations, and old and new activities that may displace no longer-advantageous activities as climate changes (UN, 2017). Gbetibouo and Hassan (2004) noted that the approach assumes that the way farmers respond to alternative climates over space is the same way that farmers will respond in the long run to those same climates over time. However, this assumption may not be accurate since important variables are likely to be correlated when climate have been excluded. Hertel and Rosch (2010) noted that another limiting factor of Ricardian model is that the model assumes that the only limiting factor to agriculture is the climate, not for example water availability and supply constraints. An additional criticism is the fact that the model treats prices as a constant and is therefore underestimating damage and overestimating benefits. Finally the approach is criticized for presumptuous implicit zero adjustment costs and therefore give way to a lower-bound estimate concerning the costs of climate change.

Considering all these critics on the Ricardian model, our study will use a control function approach to determine the effects of climate change on crop production? The research questions are: what is the relationship between climate change and crop production in Cameroon? What effect can climate change have on rural and urban crop production? And what policies can be suggested on the basis of our analysis?

2. Brief Literature Review

The literature on Climate change and its effect on different systems have actually gain grounds in the policy menu since last decade; Odusola and Abidoye (2012) in analyzing the relationship between climate change and economic growth in Africa, cited Gornall et al (2010) who observed that higher growing temperature can significantly affect agricultural productivity, farm income and food security, however, they noted that the effect differs across temperate and tropical areas. In mid and high latitudes, the suitability and productivity of crops are projected to increase and extend northwards while the opposite holds for most countries in tropical regions. Gornall et al (2010) found that a 2 degree Celsius rise in temperature in mid and high latitudes could increase wheat production by about 10 percent while in low latitude regions, it could reduce by the same amount. Taking the effect of technology into account, they found that rising temperature in Russia Federation could increase wheat yield by between 37 and 101 percent by 2050s (Odusola and Abidoye, 2012).

In the same way, Salvador et al (2004) found the effect of rising temperature on agriculture to be more severe in Sub-Saharan Africa (SSA) than other developing countries. Their observation from simulation exercises indicated that if the rainfall and temperatures had remained at their pre 1960s level, the gap of agricultural production between SSA and other developing countries at the end of the 20th century would have been only 32 percent of the current deficit (Salvador et al., 2004). Using econometric analysis on Nigeria between 1980 and 2005, Ayinde et al (2011) reveals that while rainfall change exerted positive effect on agricultural productivity, temperature change instead generated negative effects. Yesuf et al (2008) presents an empirical analysis of the impact of climate change on food production in a typical low-income developing country based on primary data from 1,000 farms producing cereal crops in the Nile Basin of Ethiopia and found that climate change and climate change adaptations have significant impact on farm productivity. They also noted that, extension services and access to credit and information on future climate changes affect adaptation positively and significantly while farm households with larger access to social capital are more likely to adopt yield-related adaptation strategies.

CEEPA (2006) in proposing environmental policies in Zambia, noticed that marginal net revenue per hectare of land for an increase of 1°C in the mean temperature of November and December is US$322.628, indicating that if the temperature rises at the beginning of the cropping season, when plants are germinating, this may have a negative effect on the crop. The marginal net revenue per hectare for an increase of 1°C in the mean temperature of January and February is US$315.70, indicating that if the temperature rises during the growing stage of the plant, this may have a positive effect on the crop. Kabubo-Mariara and Karanja (2006) estimated a seasonal Ricardian model to assess the impact of climate change on net crop revenue per acre in Kenya and observed that climate affects crop productivity. They also notice a non-linear relationship between temperature and revenue on one hand and between precipitation and revenue on the other, estimated marginal impacts suggested that global warming is harmful for crop productivity. In the same way their predictions from global circulation models confirm that global warming will have a substantial impact on net crop revenue in Kenya.

Stern (2006) intimated that "with a predicted temperature increase of 1-5°C by 2100 the impacts on African agricultural land with a tropical climate are likely to experience a decline in yields of 5 percent to 20 percent". A number of studies have also proven that tomato is positively or negatively correlated to rainfall, temperature and sunshine hours depending on different production phases (Wada et al, 2006; Weerakkody et al, 1997). According to a study made in Sri Lanka by Weerakkody et al (1997) the variation in yields, fruit number, fruit size and fruit weight emphasized the need of rain almost up to the maturity stage, whilst late flowering and fruit ripening could be heavily damaged by heavy rainfall and increased temperatures. Yesuf et al (2008) in examining issues around climate change underscore that, there is an urgent need to avert the trend which climate change is plugging in the whole of SSA through adoption of robust adaptation strategies as a means of mitigating severe food insecurity across the entire region. Hence, a call for the respective regional government to embark on policies and investments that support sustainable agricultural practices and technologically driven development. There has been a good deal of literature on agricultural innovations in developing countries (UN, 2017).

Climate change may result to water scarcity, which causes declines in agricultural productivity, leading to regional tensions and even open conflict between states struggling with inadequate water supplies due to rising populations and over-pumping of groundwater. As stated in the literature, climate change causes a rise in sea level making communities more vulnerable to storm surges (UN, 2017). It may also cause changing patterns in seasons; shift in ecological niches, unpredictable and unreliable rainfall both in timing and volume, leading to greater uncertainty and heightened risks for farmers and so potentially eroding the value of traditional agricultural knowledge. In Cameroon, the rainy season begins from mid-March to mid-November and the dry season starts from mid-November to mid-March. This has been the normal phenomenon over the years, however, from the 2000s a new phenomenon is observed to set in. Rain has become irregular with serious variations in seasons. This alteration in seasons has weakened the effort of farmers. For instance in the year 2010, rain started falling in early February however, by April after most farmers have planted crops, suddenly there was dryness that prolonged until early June. The crops that started growing were interrupted with dryness, farmers were discouraged, productivity reduced and hence increasing poverty among people in the agricultural sector.

3. Methodology of the study

Rainfall variation is an appropriate framework for analyzing crop production as condition by climate change (UN, 2017). In our model, climate change (CC) and crop production (CP) are jointly determined, thus, considering the problem of variable omission in our data due to bias in the time of collection or treatment, the problem of endogeneity bias may arise. To resolve this problem of endogeneity bias, we sort for an instrument that will consistently estimate the effect of climate change on crop production (Mendelsohn et al., 1994; Deschenes and Greenstone, 2004). As noted in the literature, the instrument, otherwise known as treatment variable, is that variable that can affect climate change without directly influencing crop production. Here, we are interested in using cluster mean of household altitude in meters and the exploitation of forest resources) (Adams et al., 1998).

In fact the crop production generating functions may take the following structural form:

$$CP_i = \alpha_1 d_{CP} + m_1 CC_i + \mu_1 \quad (1)$$

$$CC_i = \alpha_2 d_{CP} + m_2 CP + \mu_2 \quad (2)$$

$$CC_i = \alpha_2 d_{CP} + m_2 (\alpha_1 d_{CP} + m_1 CC_i + \mu_1) + \mu_2 \quad (3)$$

Whereby CP_i refers to crop production as collected by the Ministry of Agriculture and Rural Development (MINADER) respectively; for the purpose of this study, CC_i is climate change as captured by variation in rainfall. Rainfall is expressed in percentage changes, showing the percentage changes in yields as a result of a percentage change in precipitation, also the variables impacting upon yields might not only be caused by climatic factors, this could be explained by changes in demand, consumption patterns and farmer behaviour. From the equations above α_1; is a vector of exogenous variables that determine CP, while α_2 is a vector of exogenous variables that determine climate change and d, m re parameters to be estimated, while μ_1 and μ_2 are error terms since they appear in the structural equation.

From equation (1) we observed that climate change is determined simultaneously with CP. Factors such as farm size, agricultural occupation, household size, wind and location of household seem to be principal factors affecting climate change; hence we observed that climate change can positively or negatively influence CP if these factors are taken care of. Climate change in this case is hypothesized to correlate with omitted inputs that enhance CP it means CC_i is correlated with μ_1 which leads to bias and inconsistency in OLS estimates and in the same way CC_i is correlated with μ_2. Our interest here is to estimate equation (3), if the right-hand side of equation (1) is plugged in for CP in equation (2) we obtain equation (3) of climate change as shown above.

Considering equation (3), to solve for CC_i, we assume that $m_2 m_1 \neq 1$ however, irrespective of our assumption this is practically an empirical issue. This equation (3) will result to equation (4) and (5) as:

$$(1-m_2 m_1)CC_i = m_2 \alpha_1 d_{CP} + \alpha_2 d_m + m_2 \mu_1 + \mu_2 \quad (4)$$

$$CC_i = \alpha_1 X_{CP} + \alpha_2 X_{cc} + \mu_3 \quad (5)$$

Given that:

$$X_{CP} = (m_2 d_{CP})/(1-m_2 m_1)$$

$$X_{cc} = (d_{cc})/(1-m_2 m_1)$$

$$\mu_3 = (m_2 \mu_1 + \mu_2)/(1-m_2 m_1)$$

Equation (5) expresses climate change in terms of the vector of exogenous variables X_{CP} and X_{cc} and the error terms, is the reduced form equation for climate change also the vectors of parameters α_1 and α_2 are reduced form parameters they are nonlinear functions of the structural parameters in equation (1) and equation (2). The reduced form error, μ_3 is a linear function of the structural error terms; μ_1 and μ_2. Since μ_1 and μ_2 are each uncorrelated with α_1 and α_2. μ_3 is also uncorrelated with α_1 and α_2. Thus, the vectors of parameters X_{CP} and X_{cc} can be consistently estimated by the OLS this is input in to 2SLS estimation.

Following Wooldridge (1997) to account for potential endogeneity and heterogeneity of responses of unobservable that are complementary with climate change, equation (1) can be augmented to equation (6) which is the control function model:

$$CP = \lambda_0 + \alpha_1 d + \gamma_1 CC_i + \lambda_1 \hat{\mu}_3 + \ell \qquad (6)$$

Here $\hat{\mu}_3$ is fitted residual of climate change derived from equation (5) while ℓ is the error term, γ_1, λ_1 are parameters to be estimated. In addition, the IV estimates of equation (6) are unbiased and consistent only when: (a) the expected value of the interaction between climate change and its residual is zero or the interaction between climate change and its fitted residual is linear and (b) there is no sample selection problem. If the correlation is non-linear, the control function approach is required to purge the estimated coefficients of the effects of unobservable variables.

Data Presentation

Our analysis is based on the 2007 Cameroon Household Consumption Survey (CHCS) collected by the National Institute of Statistics. We are interested at 11391 individuals, of which we have imported climate change variable capture in this study as rainfall variability from the department of statistics of the Ministry of Agriculture and Rural Development (MINADER) to complement our survey data. Considering the CHCS, crop production is captured by household agricultural production (such as the production of food crops e.g. maize, plantains, rice…). Potential endogenous instruments are cluster altitude in meters and the cluster mean of exploitation of the Forest resources such as timber and non timber products, while the exogenous variables to be used in the study include: household size, agricultural occupation, parent socio-economic status, parent education, gender of household, size of production farm and location of household. Generally, the variables use in this study will be captured at community level (cluster level) to avoid individual effects given that climate change is a global issue.

4. Empirical Results

Weighted Sample Statistics of Selected Variables

The statistics table below shows that 63.7 percent of households in Cameroon are engaged in different aspect of agricultural production (food crop, cash crop). This figure is not surprising because until 2018, agriculture is the mainstay in Cameroon and contributes to about 75 percent of national Gross Domestic Product (GDP). This value corresponds to the number of household heads having agriculture as their main occupational activity. Among the households involved in agricultural production, 33.6 percent are primary school leavers, 52.6 percent are female agriculture producers involved in all manner of agricultural activities.

The average annual rainfall variation for 2003-2007 precipitation for the different regions of Cameroon range from 216.3562 to 941.0812 millimeters with the highest rainfall experience around the coastal and highlands of Cameroon, however, the mean annual rainfall is 470.2544 millimeters. The rainfall equally varies according to the altitude of the geographical location of the household. From our statistical table, 4.8 percent of households live in mountainous regions while 55 percent of the households were strongly involved in forest exploitation.

Despite the struggle of the government to increase agricultural productivity, only 5.5 percent of households have access to credit. This may probably due to the massive population living in rural areas where these services are absent and the farmers are completely excluded from financial services such as the existence of micro financial institutions, mobile financial services, etc. With this only 37 percent of households live in urban community, among which 60 percent are non poor. About 60 percent use agricultural equipments in their farms, this is a major contributing factor to agricultural output in Cameroon, this is complemented by the large existing households the offers labour in this sector. Some of the households have up to 43 persons within their family; this can be translated in to sufficient labour manpower coupled with the age of the household heads that ranges from 11 to 95 years. Ceteris paribus, a 95 years old farmer has a great pole of knowledge and experience for many to draw from and this has great repercussion on the production of agricultural products. Our weighted descriptive statistics results are presented in table one.

Table 1: Weighted Sample Statistics of Selected Variables

Variables	N	Mean	Min	Max
Outcome Variable of Interest				
Agricultural production (tons of production)	11391	0.6371	0	99.988
Endogenous Variable				

Cluster mean of average annual rainfall variation in millimeters, for 2001 - 2007 precipitation for the different regions	11391	470.2544	216.3562	941.0812
Household Head Characteristics				
Level of education (1= primary, 0 otherwise)	11391	0.3361	0	1
Gender (1= female, 0 otherwise)	11391	0.5262	0	1
Social status (1= nonpoor, 0 otherwise)	11391	0.6091	0	1
Occupation (1= agricultural worker, 0 otherwise)	11391	0.6302	0	1
Age of household head in complete years of living	11391	42.0387	11	95
Household size	11391	4.3930	1	43
Household size Square	11391	28.4505	1	1849
Place of residence (1= urban, 0 otherwise)	11391	0.3702	0	1
Farming Characteristics				
Agricultural financing (1= access to credit, 0 otherwise)	11391	0.0550	0	1
Acquisition of farming equipments (1= modern and traditional agricultural equipments, 0 otherwise)	11391	0.5993	0	1
Endogenous Instruments				
Environmental Relief Feature of Household (1= mountainous region, 0 otherwise)	11391	0.0485	0	1
Exploitation of resources (1= forest resources, 0 otherwise)	11391	0.5587	0	1
Control Variables				
Predicted climate change Residual	11391	-1.69e-08	-491.5806	669.6198
Predicted interaction term (climate change * Climate Residual)	11391	48539.93	-164830.1	630166.6

Source: Computed by the author

Determinants of Climate Change (Average Annual Rainfall Variation)

The reduced form column of table 2 presents the result of the determinants of climate change captured as the average annual rainfall variation in Cameroon. The result reveals that the factors fuelling climate change in Cameroon are: altitude of the geographical location of the household, exploitation of forest resources, the use of farming equipments, access to credit, primary level of education, female headed households, non-poor households, agricultural household, family size and urban residence. These factors are all strongly influencing environmental characteristics at different magnitudes as shown in Table 2.

It’s geographically proven that the higher the height, the cooler it becomes meaning that there is a strong variation in precipitation in both low and highlands. The mountainous regions generally have higher rate of precipitation as compared to the low regions, this explains why there is a correlation between the relief feature and climate change, meaning that the type of relief feature will determine the variation of precipitation. Forest exploitation is significantly and negatively affecting climate change. As noted in climatology, deforestation or destruction of the ecosystem may result to the destruction of the ozone layer and so practically increasing immensely the rate of sun rays reaching the earth given that the existence of trees may generate nitrite and igneous gases that act as coverage between the hemisphere and the earth. Therefore, the greater deforestation the more dryness will prevail and vice versa.

We observed that most of the factors that favor deforestation such as large household size that provokes pressure on land cultivation, female primary level of education and agricultural household which is consistent with agricultural occupation, access to agricultural credit and equipments are correlating with agricultural exploitation. All these factors reveal that all activities that result to reducing the ozone layer through increase emission of nitrogen in the atmosphere as it’s the case of deforestation and unfavourable agricultural activities.

The non-poor households and urban residence are more prone or in other words have a higher probability to activities that may affect the ozone layer than poor households and rural inhabitance.

Table 2: Determinant of Average Annual Rainfall Variation and Production Effects

Variables	Reduced Form	2SLS	CF Without Interaction	CF With Interaction
Average annual rainfall variation in millimeters_MPU	n/a	0.000* (1.78)	0.000** (2.17)	0.002** (2.15)
Primary Level of education_MPU	-78.25**2***** (17.55)	0.025** (2.17)	0.025*** (2.65)	0.025*** (2.66)
Female HH_MPU	0.550*** (-7.90)	0.010* (1.73)	0.010** (2.10)	0.010** (2.11)
Non-poor HH_MPU	-108.188*** (20.21)	0.032** (2.04)	0.032** (2.49)	0.032** (2.49)
HH agricultural worker_MPU	-23.807* (1.90)	0.909*** (139.85)	0.909*** (170.34)	0.910*** (170.10)
Age of HH_MPU	-0.206 (1.42)	0.000*** (2.76)	0.000*** (3.37)	0.000*** (3.36)
HH size_MPU	3.124** (2.19)	0.001 (1.17)	0.001 (1.43)	0.001 (1.40)
HH size Square_MPU	0.091 (1.12)	-0.000*** (2.21)	-0.000*** (2.69)	-0.000*** (2.67)
HH urban residence_MPU	-59.932*** (9.49)	0.000 (0.02)	0.000 (0.03)	0.000 (0.07)
HH access to credit_MPU	30.198*** (3.31)	-0.007 (1.14)	-0.007 (1.39)	-0.007 (1.38)
HH farming equipments_MPU	77.987*** (6.79)	0.028** (2.25)	0.028*** (2.74)	0.027*** (2.71)
Constant	586.326*** (58.81)	-0.138 (1.64)	-0.138** (2.00)	-0.138** (1.99)
Predicted Residual	n/a	n/a	-0.000** (2.16)	-0.000** (2.22)
Predicted interaction term	n/a	n/a	n/a	-0.000* (1.65)
Environmental Relief Feature_MPU	0.016*** (3.11)	n/a	n/a	n/a
forest exploitation_MPU	-41.435*** (6.13)	n/a	n/a	n/a
R^2 /Pseudo- R^2 / Pseudo R2	0.1265	0.9584	0.9720	0.9720
F-Stat [df; p-val]	126.74	20456.07	28215.51	26333.15

	[13, 11377; 0.0000]	[13, 11377; 0.0000]	[14, 11376; 0.0000]	[15, 11375; 0.0000]
F test of excluded instruments/ Joint F / χ^2 (p-value) test for Ho	n/a	9.65 [1, 11377; 0.0019]	n/a	n/a
Angrist-Pischke multivariate F test	n/a	9.655 [0.0019]	n/a	n/a
Cragg-Donald F-Stat [10% maximal IV relative bias]	n/a	9.652 [16.38]	n/a	n/a
Sargan statistic: (Chi-sq(2) P-val)	n/a	26.690 [12.348]	n/a	n/a
Durbin-Wu-Hausman χ^2 test	n/a	4.686 [0.0003]	n/a	n/a
Observations	**11,391**	**11,391**	**11,391**	**11,391**

Source: Author. N/B: CF= Control Function. ***, ** and * indicate 1%, 5% and 10% levels of significance respectively; absolute value of robust t-statistics in parentheses beneath estimates

Average Annual Rainfall Variation and Agricultural Production Effect

The two stage least square, control function with interaction and control function without interaction presents the result of climate change effects on agricultural production. The three results presented in table 2 based on the complementary hypothesis shows that on a low percentage value, climate change significantly affects agricultural production in Cameroon. This result seem correct in the sense that the instruments use are valid, the first-stage *F*-statistic on excluded instruments in table 2 varies from about 126.74 to 28215.51 (*p*-value = 0.0000), while the Sargan statistic (26.690, p-value = 12.348) suggests that the instruments are valid, however, looking at the Cragg-Donald F-statistic we realized that though the instruments are relevant, they are marginally weak (9.652 [16.38]). Further, since there are two instruments, there is need to check whether over-identification restrictions hold; so it is necessary to test the assumption that the extra instruments are uncorrelated with the structural error term. Diagnostic tests indicate that the inputs into agricultural production function are endogenous, since the Durbin-Wu-Hausman Chi-square Statistic is 4.686, *p*-value = 0.0003, which indicates that the OLS estimates are not reliable for inference. Not-with-standing the χ^2 statistic is sufficiently high, indicating that our instruments are strongly identify while the *F*-statistics on excluded instruments for the input equations are low, suggesting that the excluded instruments are weak though relevant.

Comparing the three results we realized that the result of control function with interaction is having a stronger magnitude compared to others. Secondly the result of the interaction term [-0.000(1.65)] is significant showing that the control function estimates of the last column of Table 2 preferred to other columns. The result of this column shows that climate change affects agricultural production on a significant rate of 0.2 percent. This percentage point means that favourable constant rainfall considering the complementary hypothesis will increase agricultural productivity by 0.2 percent while irregular rainfall will engender decrease agricultural productivity to about 0.2 percent. Climate change therefore corroborates with agricultural productivity.

Other factors susceptible to increasing agricultural productivity in association to climate change includes: primary level of education, female headed households, non-poor households, agricultural households, experience in working in the agricultural sector, acquisition of agricultural equipments and access to credit. In Cameroon most educated individuals are embedded with the spirit of white collar jobs and tend to reject agricultural jobs. That is why agricultural is more concentrated in rural communities where a majority of the people are not educated. Female education is still under look, most families will send their male children to school while neglecting the female counter part. On this basis most of them tend to resolve in working in the agricultural sector. Farmers always take agricultural credit to booster their productivity while farming equipments on personal supply, or donated by family, friends, Nongovernmental organization or governmental institution is mostly use to increase agricultural productivity. In Cameroon, the often use equipments are: trucks, hoes, cutlasses, showers, wheel barrows, diggers, spade and tractors. All these factors are complementing climate change to improve agricultural productivity in Cameroon.

Agricultural Production Effects by Type of Agricultural Activity

Applying the control function estimate with interaction, we observed that on a global scale, climate change has not actually affected aquaculture which is simply the cultivation of aquatic produce such as aquatic plants, fish and other aquatic animals. As of now in Cameroon only about 0.2 percent of households are involve in the aquaculture activity, this is relatively insignificant considering our entire sampling population of 11,391 individuals.

Apiculture which is the keeping and maintenance of bees for commercial reasons is not significantly correlating climate change, meaning that as of now variation in rainfall is not in any way affecting the productivity of honey. However, the production of honey following our result may be affected by the number of agricultural workers involve in Apiculture. The type of farming equipment use in the apiculture farm also significantly affects the production of honey. This discussion can be presented in table three.

Hunting which is the activity of chasing and killing of animals to get food and for commercial reasons. Hunting is a restricted activity and about 3.51 percent of households are effectively involved in this domain. Climate change according to our observation is insignificantly correlating with hunting meaning that no major relationship exists between climate change and the chasing of animals. Factors contributing to increase the hunting of animals are the number of persons in the field and the quality of equipments to be use in chasing the animals.

Table 3: Agricultural Production Effects by Type of Agricultural Activity

Variables	**Estimation Method:** Control Function With Interaction			
	Aquaculture	**Apiculture**	**Hunting**	**Fishing**
Annual Rainfall Variation	-0.004 (0.48)	-0.000 (0.62)	-0.000 (0.43)	0.012* (1.67)
HH Level of education	0.093 (0.16)	-0.034 (0.58)	-0.020 (0.39)	-0.007 (0.12)
Female HH	0.023 (0.06)	0.009 (0.09)	-0.035 (1.12)	0.005 (0.16)
Non-poor HH	-0.263 (0.30)	-0.034 (0.43)	-0.027 (0.39)	-0.008 (0.11)
HH agricultural worker	0.535 (1.31)	0.531*** (10.63)	0.639*** (19.66)	0.839*** (27.71)
Age of HH	0.000 (0.15)	0.000 (0.05)	0.001* (1.67)	0.001* (1.97)
HH size	-0.077 (0.52)	-0.000 (0.04)	0.004 (0.79)	0.006 (1.26)
HH size Square	0.006 (0.48)	0.000 (0.31)	-0.000 (0.56)	-0.000 (1.03)
HH urban residence	0.324 (0.67)	-0.050 (0.90)	-0.051 (1.06)	-0.032 (0.68)
HH access to credit	0.050 (0.19)	-0.001 (0.04)	0.007 (0.17)	-0.010 (0.31)
HH farming equipments	0.263 (0.41)	0.388*** (5.62)	0.155*** (2.84)	0.019 (0.32)
Constant	1.437 (0.32)	0.341 (0.80)	0.380 (1.02)	0.134 (0.32)
Predicted Residual	0.002 (0.30)	0.001 (0.80)	0.000 (0.56)	0.000 (0.28)
Predicted interaction term	-0.000 (0.67)	-0.000 (1.25)	-0.000 (1.32)	-0.000 (0.26)
R^2/Pseudo-R^2 / Pseudo R2	0.9741	0.9085	0.7836	0.8940
F-Stat [df; p-val]	17.54 [15, 7; 0.0004]	72.80 [15, 110; 0.0000]	92.70 [15, 384; 0.0000]	297.44 [15, 529; 0.0000]
Observations	**23**	**126**	**400**	**545**

Source: Author; N/B: CF= Control Function, HH= Household. ***, ** and * indicate 1%, 5% and 10% levels of significance respectively; absolute value of robust t-statistics in parentheses beneath estimates.

Fishing which is the activity or business of catching fish from a body of water to meet present household consumption or commercial reasons, about 4.78 percent of agricultural households are involve in this domain of activity. Climate change correlates with fishing at 10 percent significant level and at 1.2 percent rate. By virtue of irregular rainfall and intense sun rays hitting the earth by virtue of the burning of fossils acids, most rivers have gone dry, the volume of most streams is now very low and so most of the fishes have swam downstream to bigger streams, rivers, seas and oceans where the volume is heavy for better living. This has greatly affected the smaller local fishermen who left only with fewer small fishes to meet their needs.

5. Conclusion

Understanding the intricacies underlining the effects of climate change on crop production as well as factors determining climate change in Cameroon as underscored above is critical for public policy and debate that highlights food security in Cameroon. The main research question is: what is the relationship between climate change and crop production in Cameroon? Methodologically, we have used the 2007 household consumption survey and data imported from the Ministry of Agriculture and Rural Development. In analyzing the data, used is made of instrumental variable and control function models.

The reduced form results presented the determinants of climate change captured as the average annual rainfall variation in Cameroon. This result revealed that the factors fuelling climate change in Cameroon are: altitude of the geographical location of the household, exploitation of forest resources, the use of farming equipments, access to credit, primary level of education, female headed households, non-poor households, agricultural household, family size and urban residence. These factors are all strongly influencing environmental characteristics at different magnitudes and levels as shown in Table 2.

In estimating the control function we realized that to a lesser extent climate change has an effect on agricultural production in Cameroon, while result by type of agricultural activity shows that climate change corroborates with fishing activity more as to hunting, apiculture and aquaculture.

In terms of policy, mainstreaming climate change adaptation into national development strategy and budgets could promote proactive engagement on the formulation and implementation of climate change adaptation strategy; this is a wise step towards increasing crop production and malnutrition reduction.

References

Adams, R., Hurd, B., Lenhart, S., Leary, N. and Ayinde, O. (1998). Effects of global climate change on agriculture: an interpretative review. *Research Climate*, **11**, pp. 19–30.

Akachi, Y., Goodman, D., Parker, D. (2009). Global Climate Change and Child Health: A review of pathways impacts and measures to improve the evidence base. *Innocenti Research Centre,* UNICEF, Discussion Paper - IDP No. 2009-03.

Ayinde, E., Ajewole, O., Ogunlade, I. and Adewumi, M. (2011). Empirical Analysis of Agricultural Production and Climate Change: A Case Study of Nigeria. *Journal of Sustainable Development in Africa*, **12**(6), pp. 275-283.

CEEPA (2006). An empirical economic assessment of impacts of climate change on agriculture in Zambia, CEEPA Discussion Paper No. 27, CEEPA.

Deressa, T. (2008). Analysis of perception and adaptation to climate change in the Nile Basin of Ethiopia. *Centre for Environmental Economics and Policy for Africa (CEEPA), University of Pretoria, 2008.*

Deschenes, O. and Greenstone, M. (2004). The Economic Impacts of Climate Change: Evidence from Agricultural Profits and Random Fluctuations in Weather. Massachusetts Institute of Technology, Department of Economics, Working Paper Series, 2004.

Fisher, G., Shah, M., Tubiello, F. and Velhuizen, H., (2005). Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990-2080. *Philosophical Transactions of the Royal Society B Biological Sciences,* **360**(1463), pp. 2067- 2083.

Gbetiobouo, G. and Hassan, R. (2004). Measuring the economic impact of climate change on major South African field crops: a Ricardian approach. *Global and planetary change 2004,* **47**, pp. 143-152.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K. and Wiltshire, A. (2010). Implications of climate change for agricultural productivity in the early twenty-first century. *Philosophical Transactions of the Royal Society B Biological Sciences,* **365**(1554), pp. 2973-2989.

Hertel, W., Rosch, S., (2010). Climate Change, Agriculture and Poverty. *Applied Economic Perspectives and Policy, 2010*, **32**(3), pp. 355-385.

Kabubo-Mariara, J. and Karanja, K. (2006). The Economic Impact of Climate Change on Kenyan Crop Agriculture: A Ricardian Approach. Paper prepared for the Third World Congress of Environmental and Resource Economics: Kyoto Japan, July 3-7, 2006.

McCarthy, J., Canziani, F., Leary, A., Dokken, D. and White, C. (2001). Climate change 2001: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press.

Mendelsohn, R., Nordhaus, W., Shaw, D. (1994). The impact of global warming on Agriculture: a Ricardian Analysis. *The American Economic Review*, **84**(4), pp. 753-771.

Odusola, G. and Abidoye, I, (2012). Climate Change and Economic Growth in Africa: An Econometric Analysis, University of Pretoria; Working Paper.

Parry, M., Rosenzweig, C., Livermore, M. (2004). Climate change, global food supply and risk of hunger. *Philosophical Transactions of the Royal Society B 2005,* **360**, pp. 2125-2138.

Pearce, D., Cline, W., AAchanta, S., Fankhauser, R., Pachauri, R. and Vellinga, P. (1996). *The social costs of climate change: Greenhouse damage and benefits of control. In Climate change 1995: Economic and social dimensions of climate change*. Cambridge: Cambridge University Press.

Salvador, B., Bazoumanna, O. and Strobl, E. (2004). The Impact of Climatic Change on Agricultural Production: Is it different for Africa? MPRA Paper No 6240.

Stern, N. (2006). Stern Review: The Economics of Climate Change, Part II.1/3/4/5. Government Equalities Office.

UN (2017). United Nation Climate Change annual report 2017. The artificial islands of Lau Lagoon Islands.

Wada, T., Ikeda, H., Matsushita, K., Kambara, A., Hirai, H., Abe, K. (2006). Effects of Shading in Summer on Yields and Quality of Tomatoes grown in a Single-truss System, *Journal of Japan Socio-Horticultural Science*, **75**(1), pp. 51-58.

Weerakkody, P., Peiris, N., Jayasekara, A., (1997). Yield and Quality of Tomato as Affected by Rainfall During Different Growth Stages, *Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka.*

Wooldridge, J. (1997). On Two Stage Least Squares Estimation of the Average Treatment Effect in a Random Coefficient Model. *Economics Letters*, **56**, pp. 129-133.

Yesuf, M, Salvatore, D., Deressa, T, Ringler, C. and Kohlin, G. (2008). The Impact of Climate Change and Adaptation on Food Production in Low-Income Countries: Evidence from the Nile Basin, Ethiopia; IFPRI Discussion Paper 00828.