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Effect of Climate Change on Maize Productivity in Kenya: A Vector Error Correction Model

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Abstract:*As much as agriculture is the major catalyst for any nation's economy, it relies heavily on rainfall, which has changed in terms of rainfall patterns. SSA countries (97%) rely on rain fed agriculture. these countries' populations remain vulnerable to climate change. this study sought to analyze the effect of climate change of maize productivity VECM. A production function was used where the most commonly used weather indicators, which are precipitation; temperature averages and CO_2concentration were incorporated. Unit roots were done using the augmented Dickey-Fuller test and cointegration by Johansen cointegration test, where variables were found to be cointegrated. Temperature, temperature squared, CO_2 and CO_2 squared were found to be statistically significant. From the ECM results, rainfall squared, temperature and carbon dioxide squared had a positive (direct) and significant effect on maize output respectively (p-value 0.000, 0.011, 0,034< 0.05). Rainfall, temperature squared and carbon dioxide had a negative (indirect) significant effect on maize output respectively (p-value 0.000, 0.014, 0.002< 0.05). It is recommended that the government to seriously use the metrological departments to monitor the key indicators of the climate so as to advice the stakeholders accordingly.*

Keywords:*Error Correction Models (ECM, Cointegration)*

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I. Introduction

Agriculture has the potential to be the industrial and economic catalyst from which a nation's economic development can take off(Karshenas, 2001); (Hwa, 1989). The sector remains as one of the main source of livelihoods for the rural poor in Sub-saharan African countries. According to the works of Alvaro 2009, rain fed agriculture dominates agricultural production In SSA countries covering about 97% of the total cropland and exposes agricultural production to high rainfall variability. Africa must provide for an additional 3.5 billion people in the next 50 years(Mellor, 2014). This is made more difficult as climate change scenarios in the region show that agricultural production will largely be negatively affected and thus impeding the ability of the region in achieving the essential gains for future food security (Cassman, Grassini, & Van Wart, 2010)

Agriculture is the major sector of sustainable development in Africa given its contribution to the economic growth and employment. It employs over 70 % of the labor force in Africa (Palacios-Lopez, Christiaensen, &Kilic, 2017)and contributes significantly to GDP. An effective agricultural policy must take into account the effects of climate change in order to meet the commitments of Maputo in 2003 to make agriculture the engine of agricultural growth in Africa. the sector is one of the major economic sectors significantly affected by climate variability and change globally(Cassmanet al., 2010). (Brown, Gorski, &Lazaridis, 2014)note that climate change and climate variability are projected to contribute to increased drought episodes, food insecurity, irreversible decline in herd sizes, and deepening poverty. Climate change therefore presents a challenge for researchers attempting to quantify its local impact due to the universal scale in global scale of likely impacts and the multiplicity of agricultural systems.

The fifth assessment report of the united nations inter-governmental panel on climate change (IPCC – 2014) concluded that "beyond reasonable doubt, the earth's climate is warming" (IPCC, 2014). The report went on to note that climate change will have widespread impacts on the African society and Africans' interaction with the natural environment.Earlier on in 2007, the IPCC had alerted global policymakers that communities with the least resources have the lowest ability to adapt to climate-related consequences and are, therefore, often most vulnerable to climatic changes.

II. Literature Review

Theoretical Literature

The effects of climate change were evaluated by several scholars with consideration given only to the changes in the production of specific crops (principally maize, rice, cotton and soybean), using the so-called 'crop simulation models'. According to the works of (Josef, 2003) these models restrict the analysis to crop physiology, and simulate and compare crop productivity for different climatic conditions. Others scholars estimated the sensitivity of yields to climate using empirical yield models that apply the production–function approach ((Terjung, Hayes, O'Rourke, &Todhunter, 1984)). The basic idea of this approach is that the growth of agricultural production depends on soil-related and climatic variables that are implemented as explanatory variables in the model for estimating the production function. Changes in climate scenarios are usually simulated using the general circulation model (GCM) (Liang, Kunkel, Meehl, Jones, & Wang, 2008)(Colman &McAvaney, 1995).

In the production function approach, the economic dimension is of secondary importance and is considered in a partial and simplified manner(Alboghdady& El-Hendawy, 2016), even if these models produce important information for larger model frameworks that consider economy, later discussed. Some studies explicitly assess the economic impact of climate change through the estimation of the economic production function (Assunção&Chein, 2016). However, other research evaluates the economic effects of climate change by implementing the results of agronomic analyses or of empirical yields models in mathematical-programming models (Bernués, Rodríguez-Ortega, Ripoll-Bosch, &Alfnes, 2014).

The main weakness of the production–function model is that it is crop and site specific. It endorses the so-called 'dumb-farmer' hypothesis, which excludes from analysis the plausible adoption by farmers of strategies for coping with the effects of climate change, for example, strategies that replace crops that are most sensitive with others that are less so (Webb, Rosenzweig, & Levine, 1993).

Empirical Literature

Kumar Et Al (2014) Using Panel Regression Analysis For Thirteen States In India Examined The Effects Of Climatic And Non-Climatic Factors On Sustenance Grain Profitability In India. The Study Covered 1980-2009. Their Findings The Efficiency Of Rice And Maize Crops Are Adversely Impacted By Increment In Genuine Normal Most Extreme Temperature. On The Other Hand, Actual Minimum Temperature Has A Negative And Significant Influence On The Productivity Of Wheat, Barley And Grain.

The World Bank Identifies Five Main Factors Through Which Climate Change Affects The Efficiency Of Agricultural Yields: Changes In Precipitation, Temperature, Carbon Dioxide (CO2), Treatment, Atmosphere Fluctuation, And Surface Water Overflow. Expanded Atmosphere Changeability And Dry Spells Will Influence Animal Generation Also. Yield Creation Is Specifically Impacted By Precipitation And Temperature. Precipitation Decides The Accessibility Of Freshwater And The Level Of Soil Dampness, Which Are Basic Contributions For Edit Development. In View Of An Econometric Investigation, Reilly *Et Al*. (2003) Found That Higher Precipitation Prompts A Decrease In Yield Inconstancy. In This Way, Higher Precipitation Will Diminish The Yield Hole Between Rain Nourished And Watered Farming, Yet It Might Likewise Have A Negative Effect If Extraordinary Precipitation Causes Flooding (Falloon&Betts, 2010).

(Sonneveld, 2011), Found That Under Average Climate Change Conditions In The Ouémé River Basin In Benin, The Present Low Yields Are Not Decreased, Given That Trimming Designs Are Balanced, While Cost Increments Halfway Make Up For The Staying Unfavorable Impacts On Rancher Salary. Thus, With No Approach Mediation, Cultivate Earnings Remain Moderately Steady, However At Low Levels And With Expanded Event Of Yield Disappointments After Extraordinary Dry Seasons. Their Situation Reenactments Demonstrate That There Are Likewise Useful Perspectives That Can With Satisfactory Mediations Even Transform Misfortunes Into Picks Up.

Using The Production Function Approach (Awad, Griffiths, &Turpie, 2002)Analyse The Monetary Effect Of Environmental Change In South Africa. Their Examination Tends To Impacts On Characteristic, Agrarian, Man-Made And Human Capital. They Foresee That The Effect Of Environmental Change On Rangelands Will Be Sure, With The Treatment Effect Of CO2 Exceeding The Negative Impacts Of Diminished Precipitation. In Any Case, They Discover That The Effect Of Environmental Change On Maize Creation Will Be Negative Both 'With' And 'Without' CO2 Preparation. (Islam Et Al., 2016)Used The Same Approach To Analyse The Impact Of Climate In Sub Saharan Africa.She Related Respects Standard Climate Factors, For Example, Temperature And Precipitation, And Modern Climate Measures, For Example, Evapotranspiration And The Institutionalized Precipitation File. (Islam Et Al., 2016), Shows That Temperature And Precipitation Are Important Determinants Of The Crop Yields In Sub Saharan Africa.

(Seo, Mendelsohn, &Munasinghe, 2005)Additionally Utilized The RicardianWay To Deal With Measure The Effect Of Environmental Change On Sri Lankan Horticulture, Concentrating On Four Noteworthy

Products.The Creators Found That An Earth-Wide Temperature Boost Is Required To Be Hurtful To Sri Lanka Yet Increments In Precipitation Will Be Advantageous. They Additionally Find That With Warming, The Officially Dry Districts Are Required To Lose Huge Extents Of Their Present Horticulture, Yet The Cooler Areas Are Anticipated To Continue As Before Or Increment Their Yield. They Reasoned That Environmental Change Harms Could Be Broad In Tropical Creating Nations However Will Rely Upon Genuine Atmosphere Situations.

(Ngondjeb, 2013) In An Analysis Of The Impact Of Climate On Agriculture In Cameroon Found That Increased Precipitation Is Beneficial For Crop Production And That Farm Level Adaptations Are Associated With Increased Farm Returns.

III. Methodology

Data

The area under study is Kenya with the study using time series data spanning from 1961 to 2015. The Data were sourced from Food and Agriculture Organisation Database (FAOSTAT) and the African Climate Change portal.

Theoretical Model

In order to determine the effect of climate change on maize production in Kenya, we specify a production function approach (Awad et al., 2002). The model includes the most commonly used weather indicators, which are precipitation, temperature averages and CO2 Concentration. The production model can be specified as follows:

$Qt = \Sigma(z)$……………………. (1)

Where Z is a set of climatic variables: rainfall, temperature and precipitation. The standard production function equation relies on a quadratic formulation of climate:

$Ln(Q_t) = \alpha+\alpha_1 lnz + \alpha_2 lnz^2 + \mu$…………………. (2)

Where μ is the error term. Both the linear and quadratic terms for the climatic variables are introduced.

Climate change simulation

After estimating the impact of climate change on maize production, the study examines how future changes in climate will affect maize outputs. The study uses the Uniform Climate Change Scenarios. Under this scenario, the impact of climate change on maize production is analysed by using uniformly changing temperature and precipitation. The study assumed uniform change scenarios of an increase in temperature by 2^oC and 5^oC and a decrease in precipitation by 5% and 10%.

Cointegration and Unit root testing

The co-integration analysis involves unit roots test performed on both level and first difference to determine whether the individual input series are stationary and exhibit similar statistical properties. It must be noticed that relapsing non-stationary time arrangement information over non-stationary time arrangement information gives a deceptive or babble relapse. To amend for this, a unit root test is performed. Augmented Dickey Fuller (ADF) Test was utilized to test for the stationarity of the information while the Johansen methodology was utilized to test for the quantity of co-combination vectors in the model. Johansen procedure was utilized not just on the grounds that it is vector auto-backward based but since it performs better in multivariate model. In the event that Xt and Yt are then co-coordinated, their short-run flow can be depicted by Error Correction Model (ECM). The hypothesis expresses that if two factors Y and X is co-coordinated, at that point the connection between them can be communicated as ECM.

Results and Discussions

Unit Root Testing

The table 1 presents the ADF unit root tests for each of the variables. All the variables, except carbon dioxide are stationary at level. Carbon dioxide was however stationary after first differencing.

Augmented Dickey Fuller test

Tabl1 1: Stationarity results from the Augmented Dickey Fuller test

	Level 1(0)			***1st Difference 1(1)***		
Variable	**Test Statistic**	**P-value**	**Decision**	**Test Statistic**	**P-value**	**Decision**
Maize output (lny)	-4.645	0.0009*	Stationary	-	-	-
Rainfall (lnx1)	-6.449	0.0000*	Stationary	-	-	-
Rainfall Squared (lnx2)	-6.639	0.0000*	Stationary	-	-	-
Temperature (lnx3)	-6.067	0.0000*	Stationary	-	-	-
Temperature Squared (lnx4)	-6.012	0.0000*	Stationary	-	-	-
Carbon Dioxide (lnx5)	-2.061	0.5679	Unit root	-7.525	0.0000*	Stationary
Carbon Dioxide Squared (lnx6)	-1.380	0.8668	Unit root	-8.193	0.0000*	Stationary

Source: Authors' computation from STATA software, 2017
*, Denotes statistical significance at the 5 percent significance level. The critical values for the 52 observations: ADF statistics -4.146, -3.498 and -3.179

Table 2 presents the Johansen Co-integration result. The likelihood ratio shows that there are three co-integrating (CI) equations in the analysis. Only one of the CI equations was chosen. The CI equation chosen was based on the conformity of the coefficients with economic theory and its statistical significance. From the equation, all the independent variables considered are significantly having effect on Maize production in Kenya during the study period.

Table 2: Johansen Cointegration results

Eigen Value	**Log Likelihood ratio**	**5%**	**Hypothesized no of CE(s)**
0.68863	187.68	124.24	None
0.61440	127.00	94.15	None
0.49368	77.45	68.52	None
0.31996	42.06	47.21	At most 3
0.25125	22.01	29.68	None
0.12525	6.963	15.41	None
0.00009	0.005	3.76	None

Source: Authors' computation from STATA software, 2017
Log likelihood ratio indicates 3 cointegrating equations at 5% level of significance.
Since it has been ascertained that the variables exhibit unit root I (1) (non-stationary) at their levels but stationary after differencing and there exist a long run relationship between the variables, error correction model is thus formulated.

Longrun Relationship
Table3: longrun relationship

Maize output	coefficient	Std. Error	t-statistic	p-values
Temperature	.0444879	.021031	2.12	0.040
Temperature squared	-.0003586	.0001696	-2.11	0.040
Rainfall	-1.644069	6.088272	-0.27	0.788
Rainfall squared	.0339828	.1233011	0.28	0.784
CO2	.0002144	.0000535	4.00	0.000
CO2 squared	-9.79e-09	3.34e-09	-2.93	0.005
Constant	32.24394	75.15951	0.43	0.670

F(6, 46) = 13.32

Prob> F = 0.0000

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 R-squared     = 0.6347
Adj R-squared = 0.5870
 Root MSE      = 0.21054
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Source: Author, 2017

Within the period under study, temperature, temperature squared, CO2 and CO2 squared were found to be statistically significant. Long run relationships indicated that a unit increase in temperature and CO2 would result in a positive increase in maize output by .0444879 and .0002144 respectively. Conversely, despite temperature squared and CO2 squared being statistically significant, results indicated that a unit increase in their levels would result in a decrease in maize output by a value of.0003586 and 9.79e-09 respectively.
Rainfall and rainfall squared was found to be negatively and positively insignificant respectively in relation to maize production(p-value 0.788, 0.784 > 0.05)

Table 4: Results from the error correction model

Dependent variable: Maize Output

Variable	Coefficient	Standard error	P>/z/
Rainfall (lnx1)	-0.972	0.131	0.000
Rainfall Squared (lnx2)	0.008	0.001	0.000
Temperature (lnx3)	97.6	38.61	0.011
Temperature Squared (lnx4)	-1.91	0.782	0.014
Carbon Dioxide (lnx5)	-0.001	0.000	0.002
Carbon Dioxide Squared (lnx6)	4.73	2.23	0.034

Source: Authors' computation from STATA software, 2017

Table 3 presents the short run relationships after normalization between maize output and the various independent variables using equation 2. From the results, rainfall squared, temperature and carbon dioxide squared had a positive (direct) and significant effect on maize output respectively (P-Value 0.000, 0.011, 0,034< 0,05). Rainfall, temperature squared and carbon dioxide had a negative (indirect) significant effect on maize output respectively (P-Value 0.000, 0.014, 0.002< 0.05).

Table 3 also indicates that a unit increase in rainfall results in a decrease in maize output by 972. This is different for rainfall squared whose coefficient show that a unit increase in rainfall squared results in an increase in maize productivity by 0.008. This is in the same direction with temperature where a unit increase in temperature results in an increase in maize output by 97.6. Conversely, a unit change in temperature squared results in decrease in maize productivity by 1.91. This also applies to carbon dioxide whereby a unit change in the levels of carbon dioxide results in a decrease in maize productivity by 0.001. Carbon dioxide squared exhibited a positive coefficient whereby a unit change in carbon dioxide squared resulted in an increase in maize productivity by 4.73.

MODEL APPROPRIATENESS

Test for serial correlation

lags(p)	chi2	df	Prob> chi2
1	1.152	1	0.2831

H0: no serial correlation

Guided by the null hypothesis of no serial correlation, breusch-godfrey LM test for autocorrelation indicated a probability of 0.2831 which was greater than 0.05 hence accepting the null hypothesis of no serial correlation.

Test for Heteroskedasticity

Breusch- pagans, cook=Weisberg test for heteroscedasticity indicated a probability 0f of 0.0675 which was greater than the standard 0.05 hence leading to the acceptance of the null hypothesis of constant variance hence no heteroscedasticity

Lags(p)	Chi2	Df	Prob>chi2
1	3.34	1	0.0675

Ho: Constant variance

IV. CONCLUSION AND POLICY RECOMMENDATION

This study investigated the Effects of Climate Change on Maize Productivity in Kenya between 1961 and 2013. Results from the investigation revealed that for sure the rampant volatility in maize productivity is due to many factors related to temperature, carbon dioxide emissions, and rainfall among many factors relating to the above. It is therefore recommended that government should be in a position to monitor activities that may affect the listed factors to ensure that maize productivity is constant or improving.The government should seriously use the metrological departments to monitor the key indicators of the climate so as to advice the stakeholders in the maize subsector accordingly.

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