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Estimating the effects of climate change on Agricultural production in Eastern and Middle African Countries: An Econometric Analysis

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Abstract: *The level of agricultural production in eastern and middle African countries has been in the downfall in the recent past years. This has been theoretically attributed to many factors including climate change. Consequently, a study was conducted to estimate the effects of climate change on Agricultural production in Eastern and Middle African Countries. The study employed longitudinal research design using panel data from various sources including International Fertilizer Industry Association, UNCTAD and FAO. The study covered 24 countries over the period 1970 to 2013 having estimated a production function. The study established that livestock production and labor force involved in agriculture had a positive effect on agricultural production whereas, the use of modern agricultural inputs (agricultural machinery and fertilizer) had a negative effect on agricultural production in the countries under study. Climatic variables showed that rise in temperatures had a positive effect on agricultural production while precipitation increase had a negative effect on agricultural production.*

Key words: *Climate change, panel data and precipitation*

I. Introduction

The Intergovernmental Panel on Climate Change (IPCC, 2014) reported that the African continent is one of the regions of the world most susceptible to the effects of climate change. Rain fed agriculture accounts to over 96% of the overall crop production in Eastern and Central Africa where in most parts of the regions, agricultural production is mainly vulnerable to the effects of climate change (World Bank, 2015a). According to the World Bank report of 2013, the Agricultural sector employs more than 65% of Africa's labor force with the sector's output increasing since 2000, largely due to an expansion of the agricultural area. The yield potential is still higher than the actual with water and nutrients inadequacy being the major inhibiting factors (Mueller et al. 2012). O' Loughlin et.al, 2014 noted that devastating impacts of climate change variability presents are wide ranging from alleged trigger of conflict to production constriction among smallholder farmers in SSA and thus have become critical to expound. Production and outlays related with climate change are equally increasing. A resolute analysis of these outlays and risks is fundamental in prioritizing effective investments that will assist adaptation to the advocated changes. According to Schlenker and Lobell (2010) changes in SSA's mean aggregate production for cassava, maize, millet and sorghum are likely to be -8%, -22%, -18% and -17% respectively.

II. Theoretical Literature

2.1 Production function

This was the pioneering method used to analyse the impact of climate change on agricultural production. It is based on empirical production functions where economic and climatic variables such as precipitation and temperature are inputs. Mendelsohn et al (1994) explains that the environmental variables in the production function are varied to estimate the impacts of climate change on agricultural output. The outputs are then incorporated in economic models to predict the changes in benefits resulting from climate change.

This approach however, suffers from various limitations. This technique does not integrate the adaptation measures farmers adopt in the wake of climate change that is unlikely, as farmers will respond to the changing climatic conditions by either introducing new crops or replacing livestock production with crops. According to Mendelsohn et al., 1994, the lack of integration of adaptation mechanisms, results in the overestimation of damages resulting from climate change. Deressa (2007) also notes that the approach is very costly due the controlled experimentation required.

2.2 Empirical literature

Accordingly, the production function has mainly been used to estimate the effects of climate change on agricultural production. Previous studies include Makhado (1996), Onyeji and Fischer (1994), Mati (2002), Chang (2002), and Downing (1992) among others. Makadho (1996) analysed the prospective effects of climate change on Zimbabwean corn production. Results from the study indicated that corn production is expected to decline due the rise in temperature since an increase in temperature will result in the shortening of the growth period of corn. The study by Onyeji and Fischer (1994) on the prospective impact of climate change on the Egyptian maize and wheat, applied the IBSNAT crop model to replicate the changes in crop output related with the different climatic change scenarios. The authors found out that climate change will lead to a decrease in agricultural production and other negative implications to the general economy. Downing (1992) investigated the susceptibility of Kenyan agriculture to climate change by adopting a land use model. An increase in temperature will increase agricultural production in the highlands and vice versa in the arid and semi arid lands (Downing, 1992). The author further noted that an increase in temperature, accompanied by an increase in precipitation would increase the Country's food production potential.

III. Methodology

3.1 The Econometric model and methodology

The study applied a cob Douglass production function (following Eberhardt and Taal, 2012) to analyze the effects of climate change on agricultural production. The study considered the following linear panel regression model:

$Y_{it} = \gamma_i + \beta_i X_{it} + \mu_{it}$.......................... (1)

Where:

Y_{it} is the annual value of agricultural production for country *i* at time *t*, *Xit* is a combination of both economic and climatic variables and is the error term. $X_{it} = [v_{it}, am_{it}, la_{it}, fe_{it}, pe_{it}, te_{it}]$. This includes economic and climatic variables. The economic variables are land under agricultural production *(al)* and labor force involved in agricultural production *(la)* while the climatic variables are precipitation *(pe)* and temperature *(te)*. The model for regression analysis then becomes:

$Y_{it} = \gamma_i + \beta_1 v_{it} + \beta_2 am_{it} + \beta_3 la_{it} + \beta_4 te_i + \beta_5 pe_{it} + \beta_6 te_{it} + \mu_{it}$........................ (2)

All the variables in equation (2) are expressed in natural logarithms except temperature and precipitation.

3.2 Data

The data set used to estimate equation (2) is derived from two data sources. The main variables of interests, precipitation and temperature are taken from FAOClim-NET: Agroclimatic database management system that covers monthly data for 28100 stations, for up to 14 observed and computed agro climatic parameters. It includes both long-term averages and time series for rainfall and temperatures. Agricultural data and agricultural machinery data was obtained from FAO online database. For agricultural output value, we used the FAO net production index. FAO's measure of agricultural land area is used as a proxy for land inputs. Fertilizer data was obtained from International Fertilizer Industry Association online database. Data on labor force was obtained from UNCTAD online database.

3.3 Description of the variables

Table 3.1: Description of variables

Variable	Unit	Description	Source
Annual Agricultural production (y)	1,000 $ US	Net Agricultural production index(2004-2006=100)	FAO Statistics
Agricultural Machinery (am)	Number	All types of Agricultural tractors used in Agriculture	FAO Statistics
Livestock production (v)	1,000 $ US	Net Livestock production index(2004-2006=100)	FAO Statistics
Labor (la)	Thousands	Total Agricultural labor force in Agriculture	UNCTAD
Fertilizer (fe)	Tonnes	Annual Fertilizer Consumption	International Fertilizer Industry Association
Temperatures (te)	Celsius	Mean annual temperatures	FAOClim-NET: Agroclimatic database management system
Precipitation (pe)	Millimetre	Mean annual precipitation	FAOClim-NET: Agroclimatic database management system

IV. Results and Discussions

4.1 Univariate Characteristics of the Variables

This study applied the standard unit root tests provided by Im, Pesaran and Shin (2003). IPS (2003) developed a set of tests that relaxes the hypothesis of a universal autoregressive parameter. The IPS test is suitable for the study, as it does not need balanced datasets. The results of the study conventionally rejected the null hypothesis of a unit root in favour of the alternative hypothesis that at least some panels represent a stationary process.

4.2 Hausman test regression results

The study adopted the Husman statistic to distinguish between fixed effects and random effects regressions. The Hausman test (Hausman, 1978) is based on the idea that the difference between two consistent estimators tends to zero. The hausman statistic was significantly large with a value of 76.4 at the 0.05 significance level. From the hausman specification results, the study conservatively rejected the null hypothesis in favour of the alternative hypothesis. The study therefore uses fixed effect regression results to report and explain the results.

4.3 Fixed effects regression results

Table 5.0 shows fixed effects regression results in which the study estimated the effect of agricultural inputs and climatic variables on agricultural production in Eastern and middle African countries.

Table 5.0: Fixed effects regression results

variable	Coefficient	Standard error	T	p>/t/
v	.279**	.014	20.02	0.000
am	-.036**	.002	-19.69	0.000
la	.019**	.001	13.71	0.000
fe	-.009**	.002	-6.00	0.000
Te	.001*	.001	1.87	0.062
Pe	-.001 **	.000	-12.73	0.000
Constant	10.18	.062	163.58	0.000
R^2 within	0.8866			
R^2 between	0.3318			
R^2 overall	0.7644			
F_ test	1063.40			
F_ui=0	25.54***			
Number of observations	1012			

$Y = 10.2 + 0.28v - 0.36am + 0.02la – 0.09fe - 0.01pe + 0.01te$

Overall, the regression results explain more than 70% of the dependable variable variance (76.44%). The regression results show that the economic variables showed positive and significant relationship with agricultural production except for fertilizer and agricultural machinery. Agricultural production and inputs were presented in logarithmic form meaning the regression coefficients represent the elasticity of production of each input. Ceteris paribus, a one-unit increase in livestock and labor, leads to an increase of 0.3% and 0.02% respectively in agricultural production. The negative sign of agricultural machinery and fertilizer parameter estimates infers an overuse of both modern inputs of fertilizer and machinery. The results conform to those of Alboghdady, Mohamed et al. 2016 who argue that the overuse of modern inputs such as fertilizers and agricultural tractors had a negative effect on agricultural production in the Middle East and North African Countries.

The estimated parameter of temperature was positive and significant at the 0.1 significance level while precipitation coefficient is negative and significant at the 0.01 level of significance. This means that a 1% increase in temperature will increase the agricultural output by an average of 1% and vice versa for precipitation. This consistent with Downing (1992) found out that an increase in temperature might increase agricultural food production mainly in the highlands if accompanied by an increase in precipitation. Precipitation may have detrimental effects to Agriculture if it leads to flooding. Looking at the Eastern and Middle African countries, they are located in the Arid and equatorial climatic zones dominated by low adoption technology rates with rain fed agriculture. In these regions of SSA, labor is a significant input in agricultural production as opposed to modern inputs.

V. Conclusion

This paper estimates the relationship between agricultural production, conventional input factors and climatic variables (temperature and precipitation) for 24 countries over the period 1970 to 2013. Based on the results of the estimated production function model, livestock production and labor force involved in agriculture had a positive effect on agricultural production. Conversely, the use of modern agricultural inputs (agricultural machinery and fertilizer) had a negative effect on agricultural production in the countries under study. Climatic variables showed that rise in temperatures had a positive effect on agricultural production while precipitation increase had a negative effect on agricultural production. Finally, the research considers other areas for future study. The present study results found a positive correlation between agricultural production and traditional agricultural inputs but negative correlation with modern agricultural inputs. Overall, climate change is already negatively affecting agricultural production especially in sub Saharan African countries and thus affecting the livelihoods of millions of people. In order to reduce the negative and adverse effects of inevitable climate change, it is appropriate to apply adaptation measures that are applicable to agricultural sector. These findings therefore underpin the significance of adaptation approaches taking into account the explicit characteristics in Agriculture.

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