Non-linear impact of climate change on crop yields: Evidence from African countries

Dr. Piyali Kumar
Researcher, Department of Economics, The University of Burdwan, West Bengal, India

Abstract: Climate change may have detrimental effects on crop farming in Global economy and according to the IPCC, 2014 (Intergovernmental Panel on Climate Change), the impacts of climate change will be more vigorous in the coming years. Research substantiated that poor economies are more vulnerable to climate hazards (e.g. temperature and precipitation) compared to rich economies. This study aims to investigate non-linear climatic effect on crop yields involving a panel of 8 African countries groups covering the period 1990-2021. The result of the empirical non-linear model is estimated by using the panel regression estimation methods (Pooled Ordinary Least Square, Fixed Effect and Random Effect), detects the negative role of temperature in crop production. Precipitation is initially beneficial for crop production activities, beyond a threshold point it reduces the output of crop.

Key Words: Climate Change, Crop Production, Nonlinearity, Precipitation, Temperature

1. INTRODUCTION

The climate and weather play a major role in crop productivity. The complex relationship between increasing temperature and crop production is a serious debatable issue among researchers. Variability in day-to-day temperature harms the natural resources, predominantly land and water which are fundamental base to agricultural sector. Most of the research outcome have quantified the variability in estimated damage of agricultural growth as the ramifications of temperature change (Dell et al., 2014; Burke et al., 2015). The effects different climate change indicators as flood, drought, rain variability on crop yield have been explored by a wide array of approaches- national data from different income countries, different region specific data etc. In most of the empirical studies (Mensah et al., 2019; Li et al., 2019) it is observed that surplus precipitation rate stimulates crop production growth, specially in poor and arid countries, whereas reduction in rainfall has an adverse impact on crop growth.

The consequence of change in weather pattern i.e. heavy and very frequent precipitation pattern along with too much cold and heat may not be symmetrically distributed. The adverse impact of parameters of climate indices such as temperature and rainfall is mostly faced and suffered by the poorest countries. In low income economies, majority of the populace is dependent on climate-sensitive sectors and lack of infrastructure make a burden of huge cost to promote and adopt different mitigation strategies. Sometimes the advanced economies have experienced the loss in agricultural output. Additionally, surface temperature and excessive precipitation rate might impose significant and unstained economic cost by an additional independent channel (Sudarshan and Tewari, 2014). So anthropogenic climate change issues provide a compelling motivation to recognize the association between the weather parameters-temperature and precipitation and crop yield and why this association exist.

Apart from the abundant natural resources, agrarian development is fabricated and managed by two other factors namely, human resource and fixed capital. Human capital which indicates social abilities, programming skills and knowledge, ideals, and health of people, constitutes an active factor to develop the productivity of crops (Gruzina et al., 2021). Besides human capital, the performance and distribution of agricultural growth is impossible without the fundamental factor like fixed capital which includes machines, equipment, devices, roads, telephones, transport, power grids and so on. There is a group of research paper that emphasized on the role of fixed capital on agriculture output- maximizing process. (Abbas et al., 2020; Lach, 2010) reported that increase in investment in fixed capital is positively associated with crop production development.

2. OBJECTIVE

So, based on the scholastic evidence of previous researches on climate variation issues, this study has been carried out to examine the change in climate condition together with human and physical capital in African economies and its impact on crop yield.

3. MODEL SPECIFICATION AND METHODOLOGY

This study uses a panel framework and the relevant data span over 31 years from 1990 to 2021, for the required variables corresponding to eight African countries such as Malawi, Central African Republic, Tanzania, Madagascar, Ethiopia, Uganda, Senegal and Gambia. Data on total production of primary crops have been obtained from Food and Agriculture Organization whereas Human Capital Index data have taken from Penn World Table 10.0. For rest of the variables, we have used the database of World Bank Development Indicator.

Here the proposed non-linear model is the investigation of the relation between crop production and the climate change along with other economic factors. Using the general form, this relation can be expressed as follows:

$$TCROP/TP = f(TEMP, PREC, PREC^2, HC, FC) \quad (1)$$

$$PCCROP = f(TEMP, PREC, PREC^2, HC, FC) \quad (2)$$

Here, this expression states that per capita crop yield (PCCROP) is a function temperature (TEMP), precipitation (PREC), human capital (HC) and gross fixed capital (FC). The proposed model is the investigation of the relation between crop yield and the climate change along with the other economic factors. In specific forms the models are

$$PCCROP_{i,t} = \alpha_1 + \alpha_2 TEMP_{i,t} + \alpha_3 PREC_{i,t} + \alpha_4 PREC_{i,t}^2 + \alpha_5 HCI_{i,t} + \alpha_6 FC_{i,t} + \varepsilon 1_{i,t} \quad (3)$$

Where, PCCROP= TCROP/ POP; TCROP is the total amount of crop yield and POP is the total number of population of the economy.

The proposed non-linear models have been measured by panel regression model. and we have estimated pooled ordinary least square (Pooled OLS), fixed effect (FE) and random effect (RE) model. Then, we have applied three specifications tests- the Wald test, Breusch–Pagan and Lagrange Multiplier (LM) tests, Hausman test to determine the appropriate model among pooled OLS, FE and RE model.

4. RESULT AND DISCUSSION

Table 1: Specification Test for Panel Regression Model

Tests	Statistics
Wald	1397.65***
Breusch–Pagan LM	793.41***
Hausman	1.48
Model	RE

The results of the Wald test and Breusch–Pagan LM test (Table 1) show that all statistics are significant which indicates that the fixed-effects model is preferred to the pooled-OLS model. Additionally, the LM test implies that the random-effects model is more applicable compared to the pooled-OLS model. The result of the Hausman speciation tests show the acceptance of RE model.

Table 2: Regression Result of Equation 3

Variables	Statistics
Temp	-1.152***
PREC	.007***
$PREC^2$	-2.06e-05**
HCI	36.204***
FC	3.95e-09***
Constant	96.094***
Model	Random Effect
R^2 within	0.450
R^2 between	0.383
R^2 overall	0.369

Note: ***, **and* indicate Significance level at 1%, 5% and 10 % respectively

This Table 2. provides the evidence of significant negative effect of temperature change on agriculture sector. Agriculture is highly dependent on the climate. Decrease in temperature may enhance the crop yield and plant growth in the selected countries. In fact, due to increase in temperature and inability of acclimatizing the change in heat in human body lead hampering of farmer's productivities. Most of the tropical temperature zone countries specially in Africa have low income and technological resources to devote to mitigating the effects of temperature (Herold et al., 2017). It is also noted that there is a significant non-linear relationship of crop yields with average precipitation level i.e. having an inverted 'U' shaped relationship between PREC and the per capita crop

yield. An adequate amount of rainfall for some specific types of crops specially, the seasonal and rainwater dependent crops. Rainfall is found to increase crop production output first, after a certain point of time excessive rainfall reduce the productivity of crops. On the other side, dealing with draught is a challenging matter in areas where rising summer temperature cause soil to become drier. So precipitation is necessary to supply sufficient water for cultivation. But when temperature and precipitation exceed a crop's optimum level, crops are prevented from growing and reduce yield. The adverse impact of climate change on agriculture productivity can be to some extent reversed by the application of skilled human capital having an innovative outlook. Having knowledge about improved farming practices, the skilled human capital enlarges the agriculture productivity. They employ more machine and equipment for agricultural purpose. Gross fixed capital is an important factor which has a significant positive contribution to crop production growth.

5. CONCLUSION

The present study has carried out temperature and non-linear precipitation effect along with human capital and physical capital on crop production for eight selected economies in Africa. By using temperature and rainfall variation, we can better identify different effects of climate change on crop production. Among all the factors of climate, temperature is very sensitive to crop productivity because extreme heat has a large and statistically negative significant effect on crop yield in long run. Initially, a generally positive relationship is observed between precipitation and crop production specially in poor African countries meaning that higher rainfall mostly stimulates crop cultivation, but when it becomes extreme and crosses up to a threshold level, it would be destructive for its production activities. Fixed capital is always beneficial in crop farming for the poor African countries.

REFERENCE

[1] Abbas Q, Nurunnabi M, Alfakhri Y, Khan W (2020) The Role of Fixed Capital Formation, Renewable and Non-Renewable Energy in Economic Growth and Carbon Emission: A Case Study of Belt and Road Initiative Project. *Environment Science and Pollution Research* 27 (36): 45476–45486

[2] Burke M, Hsiang SM, Miguel E (2015) Global Non–linear Effect of Temperature on Economic Production. *Nature* 527 (7577): 235–239

[3] Dell M, Jones BF, Olken BA (2014) What do We Learn from the Weather? the New Climate–economy Literature. *Journal of Economic Literature* 52 (3): 740–798

[4] Gruzina Y, Firsova I, Strielkowski W (2021) Dynamics of Human Capital Development in Economic Development Cycles. *Economies* 9 (2): 67

[5] Herold N, Alexander L, Green D, Donat M (2017) Greater Increases in Temperature Extremes in Low Versus High Income Countries. *Environmental Research Letters* 12(3): 034007

[6] Lach L (2010) Fixed Capital and Long Run Economic Growth: Evidence from Poland. *Systems Science* 36(4): 33-50

[7] Li Y, Guan K, Schnitkey GD, DeLucia E, Peng B (2019) Excessive Rainfall Leads to Maize Yield Loss of a Comparable Magnitude to Extreme Drought in the United State. *Global Change Biology.* 25(2)

[8] Mensah CK, Kyerematen R, Acheampong SA (2019) Impact of Rainfall Variability on Crop Production within the Worobong Ecological Area of Fanteakwa District, Ghana. *Advances in Agriculture* 123: 1-7

[9] PWT (2021) Penn World Table 10.0. https://www.rug.nl/ggdc/productivity/pwt/

[10] Sudarshan A, Tewari M (2014) The Economic Impacts of Temperature on Industrial Productivity: Evidence from Indian Manufacturing

[11] FAO (2003) Food and Agriculture Organization. https://www.fao.org/home/en

[12] WDI (2023) World Development Indicators, World Bank. (2021) https://databank.worldbank.org/indicator