# Climate Change, Agricultural Productivity, and Food Prices in Ghana


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# Introduction

- The recent rise in global temperatures, erratic rainfalls, droughts, and frequent flooding as a result of carbon emissions and forest depletion has raised concerns among policymakers and researchers
- Among these concerns is the role of climate change and variability in economic activities. The dependence of agricultural (food) production on climatic features coupled with global rises in population raises concerns regarding food security, especially in the future (Kariuki et al., 2022).
- These concerns led to the World Summit on food security in 2009. It was declared during the summit that to catch up with global population growth, there is a need to increase crop production by about 70 percent by 2050 (Tester and Langridge, 2010).
- This expected increase in agricultural production will have to battle with a series of limitations and challenges caused by changes in the global environment

# Introduction

- climatic features continue to worsen as global temperatures are likely to rise further to 0.3 to 1.7 degree Celsius in moderate scenario and 2.6 to 4.8 degree Celsius in extreme case depending on greenhouse gases emissions and mitigation strategies (IPCC, 1990  2013). The rise in temperature has a dire consequence including global food insecurity, water scarcity, infectious diseases, economic losses, and displacements (WHO, 2015)
- The adverse effects of climate change on agricultural activities led to the inclusion of food security features in the Paris Agreement as a part of a global climate change accord (UNFCCC, 2015)

# Introduction

- Although the agricultural sector employs about 30 percent of the working force, its contribution to gross domestic product (GDP) has been declining overtime; 30.4% in 2006, 20.3% in 2015 and 18.3% in 2017. The service and industry sectors contribute 56.2% and 25.5% to gross domestic product.
- According to Kormawa and Jerome (2014), unlike the developed countries like Asia, Africa cannot grow or develop faster when it focuses more on the manufacturing and the service sectors
- Therefore, it is important for Africa to exploit growth opportunities outside manufacturing and service sectors in order to expedite the economic growth process.
- The only promising sector is the agricultural sector since it is the dominant employer with growing markets at both national and international levels.
- The world demand for food is fast growing as a result of the growth in population, rising income, rapid urbanization and more open inter-regional trade policies and it is projected to more than double by 2050 (Badiane and Ulimwengu, 2017).

# Stylized Facts about Ghana

- Number of dangerously hot days per year is projected to increase to 140 days by 2050s
- Manual labor productivity is projected to drop by 11% due to warmer temperatures
- Volatile rainfall patterns (flooding impacts 45,000 Ghanaians yearly and drought is estimated to affect 13% the population
- Drought ($15 million USD direct economic loss in 2022. Rainfall could decline by 12% by 2050, causing direct economic loss of $325 million USD per year
- Increased CO2 levels have been found to decrease nutrient density in staple food crops
- Cocoa (danger of floods, soil salinization, and coastal erosion
- Fishing (warmer water temperature causes migratory and reproductive patterns of fish species). Fisheries production has declined by 26%

# Stylized Facts

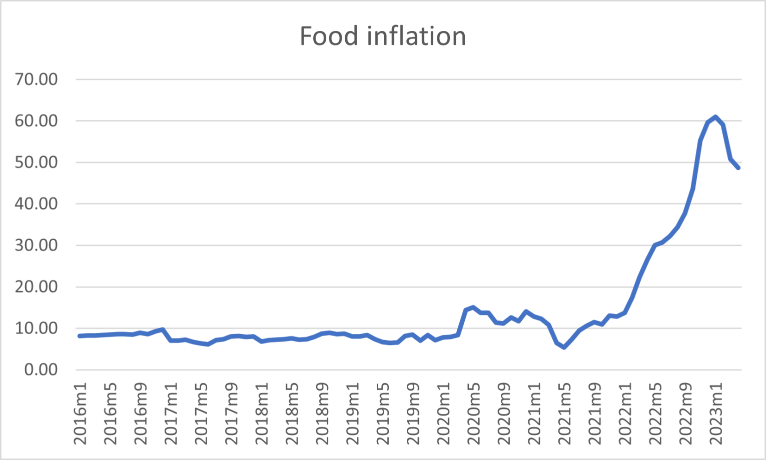


Figure: Monthly food inflation from 2016 to 2023

# Research Question

- Does **climate change and variability** have a significant effect on **agricultural productivity** in Ghana?
- Can the **worsening climatic conditions** explain the recent spikes in **food inflation**?
- What are the implications of weather-induced agricultural losses and food inflation on monetary policies?

# Literature Review

- Climate change and food productivity (Chemura et al. (2020); Barrios et al. (2018); Affoh et al (2022))

- Climate change and food inflation Kunawotor et al. (2022); Abril-Salcedo et al. (2020); Odongo et al. (2022), Moessner (2022)

- While there is growing literature on the effects of climate change on various sectors of the economy, there is little or no empirical studies on the nationwide effects of climate change on agricultural production and food inflation, and their implications on monetary policies in Ghana

# Methodology

- Theoretical model: Cobb-Douglas production model, where agricultural production is a function of labor (N), capital (K), land size (L), and climatic variables as specified below;

$$Y_t = F(K_t, N_t, L_t, C_t)$$

- Econometric model:

$$Y = \alpha + X`\beta + Z`\gamma + \epsilon$$

- Parameter of interest:

$$\beta \tag{1}$$

which is a vector of slopes of the climatic variables

# Methodology

- The model follows Svensson (1997). Central bank minimizes the following intertemporal loss function

$$\mathbb{E}(\sum_{t=0}^{T} \beta^t (L_t))$$

$$L_t = 1/2[(\pi - \pi^*)^2 + \lambda(x_t - x^*)^2]$$

Subject to

$$x_t = \mu x_{t-1} + \alpha(\pi - \pi^e) + z_t$$

$$\pi^e = \mathbb{E}\pi_t$$

# Methodology

- From the above optimization, we have our inflation rule as follows:

$$\pi_t = \pi^e + \alpha(X_t - X^*) + \beta(\pi_t - \pi^*) + Z_t \tag{2}$$

  Where $Z$ is the innovation term that captures the climatic variables in our model

- The central bank sets interest rates using the **Taylor rule** as follows:

$$i_t = r + \pi^e + \alpha(X_t - X^*) + \beta(\pi_t - \pi^*) \tag{3}$$

# Estimation framework

- We corroborate the relationships using the Autoregressive Distributed Lagged Model (ARDL)
- We proceeds to test the cointegration hypothesis, which involves testing the significance of the coefficients of the lagged independent variables in the following multivariate equilibrium correction framework:

$$\Delta Y_t = \gamma + \sum_{i=1}^{p} \alpha_g \Delta Y_{t-i} + \sum_{j=1}^{q} \beta_h \Delta X_{t-j} + \theta_1 Y_{t-1} + \theta_2 X_{t-1} + \epsilon_t \tag{4}$$

- The following error correction model (ecm) is specified to estimate the short-run parameters and to obtain the error correction term which measures the speed of adjustment.

$$\Delta Y_t = \gamma + \sum_{i=1}^{p} \alpha_g \Delta Y_{t-i} + \sum_{j=1}^{q} \beta_h \Delta X_{t-j} + \delta ect_{t-1} + \mu_t \tag{5}$$

# Results

| Model | F-statistics | Level of Significant | Lower Bound critical value | Upper bound critica |
|---|---|---|---|---|
| Model I | 4.679*** | 1% | 2.96 | 4.25 |
| Model II | 3.663*** | 5% | 2.32 | 3.50 |
| Model III | 5.218*** | | | |
| Model IV | 4.009*** | | | |
| Model V | 5.021*** | | | |
| Model VI | 4.289*** | | | |

Table: Bounds Test for Cointegration Results

# Results

**Table 3: Long Run Results**

| Variable | Model 1 | Model 2 |
|---|---|---|
| Carbon Emission | -1.289263*** | -0.4325177*** |
| | (0.3351062) | (0.1223331) |
| Arable Land Size | 1.645249** | 0.79075*** |
| | (0.7755266) | (0.1992028) |
| Agricultural Labour force | 7.699841*** | 0.7199484 |
| | (1.247881) | (0.4955528) |
| Fertilizer | 0.2073283** | 0.0102981*** |
| | (0.084401) | (0.0030047) |
| Rainfall | -0.4313103 | -0.379339** |
| | (0.2734801) | (0.1231102) |
| Temperature | -0.6120091*** | -0.1371711* |
| | (0.2090191) | (0.0753705) |
| Agricultural machinery | 0.5627943*** | 0.0671408** |
| | (0.1027131) | (0.0301162) |

Note: *, **, & *** denote significance at 10%, 5%, and 1% respectively. Coefficients in parentheses are standard errors. Source: Authors' construction from Stata 16

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Table 4. ARDL Short Run Results

| Variable | Model 1 | Model 2 |
|---|---|---|
| Agricultural output (-1) | 0.6659563***<br>(0.1387417) | |
| Cereal Production (-1) | | 0.345588***<br>(0.099612) |
| Carbon Emissions | -0.0384205<br>(0.1864724) | -0.5819876***<br>(0.1743484) |
| Carbon Emissions (-1) | -0.1685977<br>(0.2156911) | |
| Carbon Emissions (-2) | -0.5291182**<br>(0.1902502) | |
| Arable Land Size | 0.0150903<br>(0.6989366) | 1.379896***<br>(0.187254) |
| Arable Land Size (-1) | 0.9544857<br>(0.6896059) | 0.3158777<br>(0.2531594) |
| Agricultural labour force | 7.495409<br>(4.823838) | 9.797444*<br>(5.046996) |
| Agricultural Labour force (-1) | 11.89182**<br>(4.936609) | 10.76619**<br>(5.100204) |
| Fertilizer | 0.0367138<br>(0.0503338) | 0.013856***<br>(0.0045953) |
| Fertilizer (-1) | 0.0816653*<br>(0.0469025) | |
| Rainfall | -0.2462672<br>(0.1562275) | -0.1123189<br>(0.1593438) |
| Rainfall (-1) | | -0.3981055**<br>(0.1643375) |
| Temperature | 0.1897385**<br>(0.0733212) | 0.0737091<br>(0.0745336) |
| Temperature (-1) | 0.1597035*<br>(0.0794603) | 0.1108657<br>(0.078631) |
| Agricultural machinery | 0.158642**<br>(0.0620732) | 0.0351017<br>(0.0482786) |
| Agricultural machinery (-1) | -0.0255799<br>(0.0688637) | 0.1254451**<br>(0.048128) |
| Agricultural machinery (-2) | 0.1882791***<br>(0.058097) | |
| Constant | -68.20305***<br>(17.28589) | -23.49187**<br>(10.3311) |
| Error correction term | -0.5709745***<br>(0.0988617) | -0.345581***<br>(0.0199692) |

Note: *, ** and *** represent significance at 10%, 5% and 1% levels respectively; Standard errors are in parentheses.
Source: Authors' estimation from Stata 16

# Results

| Variable | Coefficient |
|---|---|
| Food Price Index (-1) | 0.2275*** |
| | (0.0826) |
| Temperature | 9.3027*** |
| | (3.0191) |
| Precipitation | -2.9065*** |
| | (0.9586) |
| Carbon Emission | -1.2783 |
| | (1.1195) |
| Food Production Index | -8.6009 |
| | (18.9442) |
| GDP growth rate | -0.0015 |
| | (0.0135) |
| GDP growth rate (-1) | 0.0395*** |
| | (0.0137) |
| Output gap | 2.5028*** |
| | (0.4252) |
| Money Supply | -0.1596 |
| | (0.3744) |
| Money supply (-1) | 2.6110*** |
| | (0.4426) |
| Exchange rate | -0.54*** |
| | (0.1232) |
| Ecm (-1) | -0.5407*** |
| | (0.1359) |

**Notes:** ***, **, * indicate significance at the 1%, 5% and 10% levels. Robust standard errors are in parenthesis.

# Results

| Variable | Coefficient |
|---|---|
| Temperature | 0.8141*** |
| | (0.2768) |
| Precipitation | -4.9491*** |
| | (2.8087) |
| Carbon Emission | -2.1073 |
| | (2.3082) |
| Food Production Index | -1.8782** |
| | (0.8965) |
| GDP growth rate | -0.0408*** |
| | (0.0167) |
| Output gap | -0.2867 |
| | (0.3741) |
| Money supply | 0.4647*** |
| | (0.1477) |
| Exchange rate | -0.4014*** |
| | (0.0702) |
| Constant | 7.5510*** |
| | (0.6167) |

**Notes:** ***, **, * indicate significance at the 1%, 5% and 10% levels. Robust standard errors are in parenthesis.

# Results

**Table 4.8: Diagnostic Test Results**

| | Model I | Model II | Model III | Model IV | Model V | Model VI |
|---|---|---|---|---|---|---|
| **Diagnostic test** | **Test statistic** | **Test statistic** | **Test statistic** | **Test statistic** | **Test statistic** | **Test statistic** |
| Normality | 0.2449 | 0.7235 | 0.0562 | 1.2810 | 2.5524 | 1.8457 |
| | (0.8848) | (0.6964) | (0.9723) | (0.5270) | (0.2791) | (0.3974) |
| Serial | 0.3275 | 1.7483 | 0.0180 | 0.1525 | 1.1030 | 3.0724 |
| correlation | (0.8489) | (0.4172) | (0.9910) | (0.9266) | (0.5761) | (0.2152) |
| Heteroscedasti | 1.4812 | 3.4845 | 0.8976 | 0.9610 | 0.8110 | 0.8189 |
| city | (0.2513) | (0.2724) | (0.5853) | (0.5265) | (0.6667) | (0.6591) |
| Functional | 3.7597 | 8.0237 | 2.6279 | 3.6164 | 2.4602 | 3.2884 |
| form | (0.6023) | (0.0660) | (0.1167) | (0.0710) | (0.1317) | (0.0948) |
| CUSUM | Stable | Stable | Stable | Stable | Stable | Stable |
| CUSUMSQ | Stable | Stable | Stable | Stable | Stable | Stable |

Notes: Probability values are in the parenthesis.

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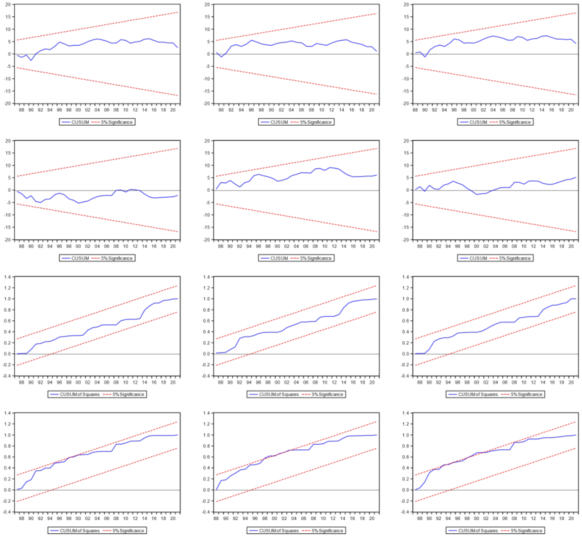
# Results



# Conclusion

- We found a significant negative impact of climate change (proxied by carbon emissions, precipitation, and changes in temperature) on overall agricultural performance and cereal production in Ghana
- On food inflation, temperature was found to increase food inflation both in the short- and long-run.
- We also found that increases in rainfall reduce food inflation. After introducing a quadratic term for rainfall, the results show that rainfall decreases food inflation up to some point after which any further increase in rainfall increases food inflation

# Conclusion

- We also extended the study to analyze how the monetary policy rate responds to fluctuations in agricultural productivity and food inflation. We found a **negative response** to a **positive productivity gap** and a **positive response** to a positive **food inflation gap**
- **Policy recommendations**
  - Education of Farmers
  - Research and Development

# Questions

**Thank You**