



COMESA Monetary Institute

Working Paper Series

No. 031/2025

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Daucilous Sadala, Marietta Mpingasa Kavalo and Austin Chiumia

October 2025

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Daucilous Sadala, Marietta Mpingasa Kavalo and Austin Chiumia
Reserve Bank of Malawi

Abstract

This study examined the macroeconomic impact of climate change on inflation in Malawi and the role that the central bank can play. Specifically, the study investigated the impact of climate change on headline, food and non-food inflation. This was accomplished by applying the Auto-regressive Distributed Lag model on annual time series data from 1980 to 2022. The study showed that adverse climate conditions increase both food and headline inflation. Based on the findings, the study recommends that the Reserve Bank of Malawi consider incorporating climate change variables in its quarterly projection model, the Bank's main analytical tool for inflation forecasts, to better capture the inflationary effect of climate change. On the policy front, there is need to scale up investment in climate-resilient infrastructure.

Keywords: Climate change, Inflation, ARDL

JEL Classification:

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For correspondences, dsadala@rbm.mw; mkavalo@rbm.mw and achiumia@rbm.mw. The authors are grateful to the COMESA Monetary Institute (CMI), the anonymous reviewers and the participants at the validation workshop organized by the CMI in Nairobi Kenya for the very valuable comments. The usual disclaimers apply.

For citations: Sadala, D., Kavalo, M.M., and Austin Chiumia, A., (2025) "The Impact of Climate Change on Inflation in Malawi", *CMI Working Paper No. 031/2025*, COMESA Monetary Institute.

I Introduction

Climate change, driven by human activity, alters the global atmosphere, exacerbating natural variability (UN, 1992). Key climate change indicators include rising temperatures and extreme weather events such as droughts, floods and heatwaves (World Bank, 2018). These changes harm agriculture, investment, and human health, increasing disease spread and harsh working conditions (Sandalli, 2021). Climate-related events also divert funds, strain fiscal positions, and undermine macroeconomic stability (Davis-Reddy & Vincent, 2017). Moreover, climate-related risks pose significant consequences for economic outlook, financial systems, and monetary policy (NGFS, 2021). Yet central banks have not fully enhanced their analytical tools to capture climate change's economic and financial impacts and adapt their monetary policy frameworks.

Empirically, there are diverse findings on the extent of climate change impact on macroeconomic variables particularly in African countries. For instance, various studies found that climatic events tend to raise inflation, reduce GDP growth as well as result in financial instability (MEFMI, 2023; Kahn, et al., 2021; Beckmann, et al., 2023; Faccia, et al., 2021; Hansen, 2022; Ciccarelli, et al., 2023).

Malawi's agri-based economy is highly vulnerable to climate change, with frequent droughts and floods disrupting food security and livelihoods, affecting 85 percent of the population reliant on small-scale rain-fed agriculture. Malawians spend a significant portion of their income on food, with an average of 57.3 percent nationwide, and an even higher proportion (58 percent) in rural areas compared to 45 percent in urban areas. This makes both rural and urban households vulnerable to climate-related shocks, which often drive inflation high and reduce output. Climate shocks create a policy dilemma with difficult trade-offs, especially when they increase inflation and reduce output. The absence of accurate estimates on the impact of climate shocks on inflation makes it difficult to have reliable inflation forecasts resulting in policy response uncertainty.

Additionally, the linkages between climate change and key macroeconomic variables is not clear in Malawi. This study attempts to address this gap by investigating the inflationary impact of climate change in Malawi. Specifically, the study seeks to:

- a) examine the impact of climate change on headline inflation in Malawi,
- b) examine the impact of climate change on food inflation in Malawi,
- c) examine the impact of climate change on non-food inflation in Malawi.

The rest of the paper is structured as follows: Section 2 presents stylized facts; Section 3 discusses literature while Section 4 describes the methodology. Section 5 reports and discusses results and Section 6 concludes with policy recommendations.

II Stylized Facts

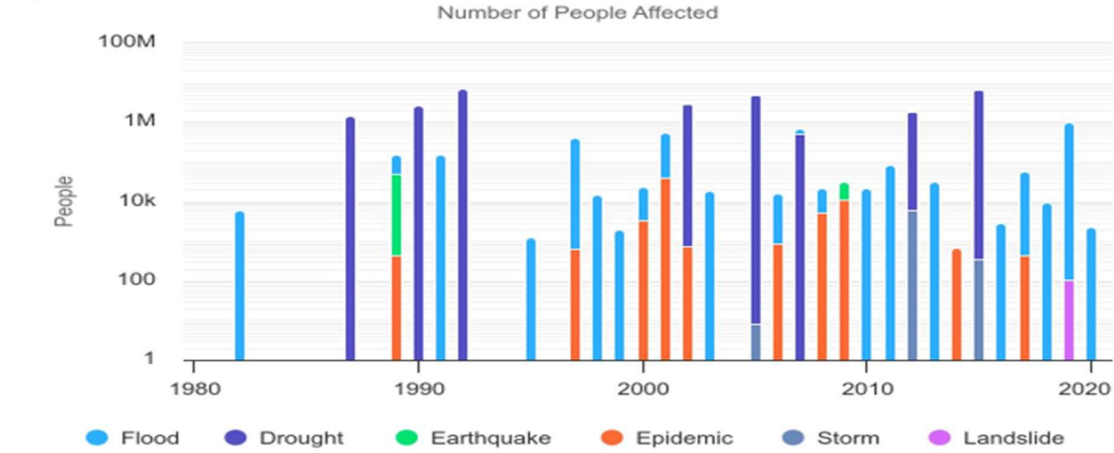
2.1 Malawi's Climate Profile

The climate in Malawi is subtropical, characterized by one rainfall season. Annual precipitation ranges between 700- and 2,500-mm. Mean temperatures vary from 17°C to 27 °C, with the lowest temperatures ranging between 4°C and 10°C. Weather and climate in Malawi are influenced by a combination of topography, effect of Lake Malawi, mean sea

level pressure, surface and upper-level winds, and sea surface temperatures in the tropical Pacific, Indian, and Atlantic Oceans (GoM, 2023).

According to the Climate Risk Index Report of 2025, Malawi is ranked 26 out of 171 countries, implying that it is among the highly vulnerable countries to the adverse effects of extreme weather events in terms of economic and human effects.¹ The recent ranking is a deterioration compared to the 1993-2022 ranking of 35. Cyclones, floods, and droughts have long been a constant occurrence. Malawi has experienced over 33 weather-related events between 1990 and 2023, compared to only 7 events, 20 years prior (Figure 1).

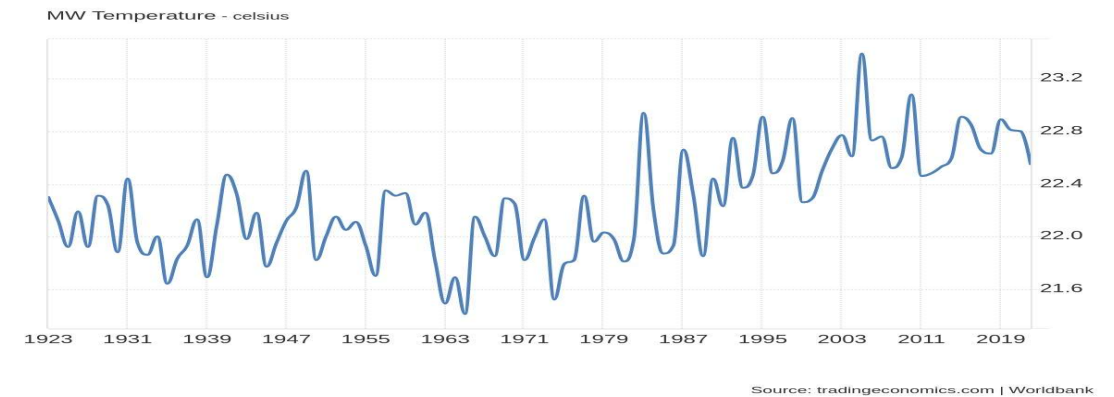
Figure 1: Key Natural Hazard Statistics



Source: World Bank

Malawi’s mean annual temperature has increased by 0.9°C between 1960 and 2006, an average rate of 0.21°C per decade (World Bank, 2011). Average annual temperatures have been on an upward trend since 1989 from 21.8°C to around 23.0°C in 2018 with 2005 being the hottest year with an average temperature of 23.4°C (Figure 2). Mean annual temperature is projected to increase by 1.1 to 3.0°C by the 2060’s, and by 1.5 to 5.0°C by the 2090s (World Bank, 2011)

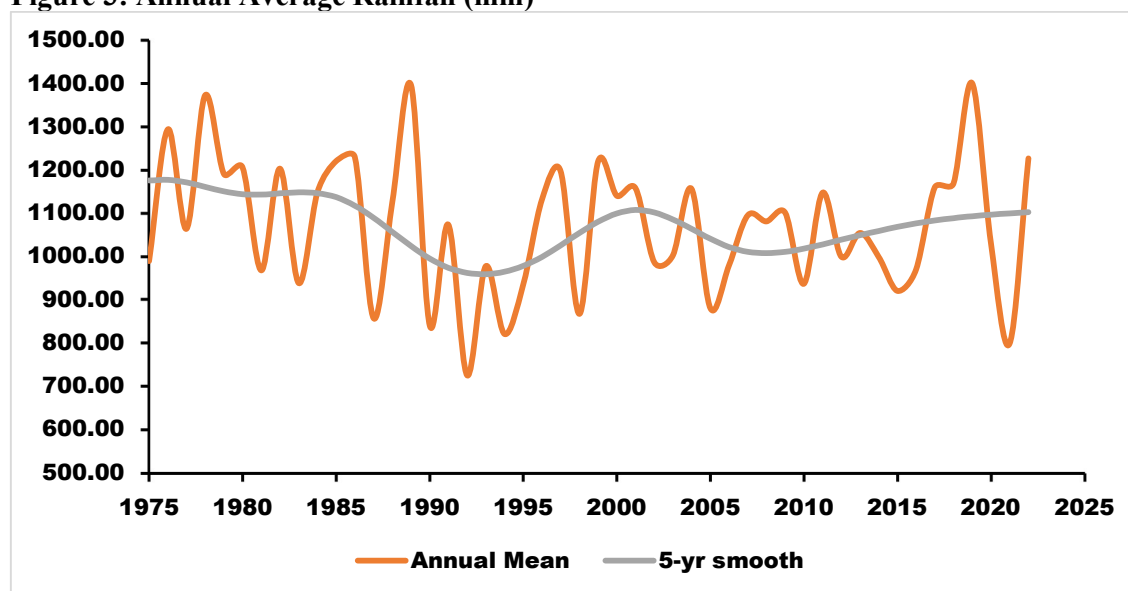
Figure 2: Annual Average Temperature



¹ A country that is ranked first is the most affected and vulnerable to extreme weather events

The rainy season in Malawi officially starts from October to April. The season characteristics have been changing in recent years in terms of experienced rainfall intensity, spatial and temporal distribution, as well as the extreme events that come with the rains (GoM, State of Malawi Climate , 2023b). Annual rainfall has decreased in recent years. Typical annual precipitation in Malawi is reasonably high (Figure 3) and can support cultivation of many crops, with local averages ranging between 800 and 1,500 millimeters (mm) per year. However, overall, precipitation has tended to trend downwards throughout the country.

Figure 3: Annual Average Rainfall (mm)



Source: World Bank

2.2 Inflation in Malawi

Headline inflation in Malawi is disaggregated into food and non-food, with the food component making up 53.7 percent of the total CPI basket (as of 2021). Since Malawi is an agro-based economy with considerable reliance on rain, adverse climatic conditions easily transmit into food prices and hence headline inflation. Figure 4 shows trends in climatic conditions and inflation over the sample period. The climatic condition is approximated by the Climate Change Index (CCI). The CCI measures the deviation in the observed values of rainfall and temperature from their historical norms. The index is computed as a weighted average of temperature and rainfall absolute deviations from their respective historical means. The higher the value of the CCI, the more adverse the climatic conditions are. Figure 4 shows that periods of high inflation have been preceded by or coincided with adverse weather shocks. For instance, the rise in inflation recorded in 1992 followed the drought in the same year (Schwarz, 1993) and the devastating flash floods in 1991 (UNDP, 1991); while the 2001 inflation resulted mostly from floods in that year (King, 2002). More recently (2021 and 2023), Malawi has been hit by back-to-back cyclones that damaged crops and property which contributed to high inflation.

Figure 4: Trends in Inflation in Malawi (RHS: CCI)

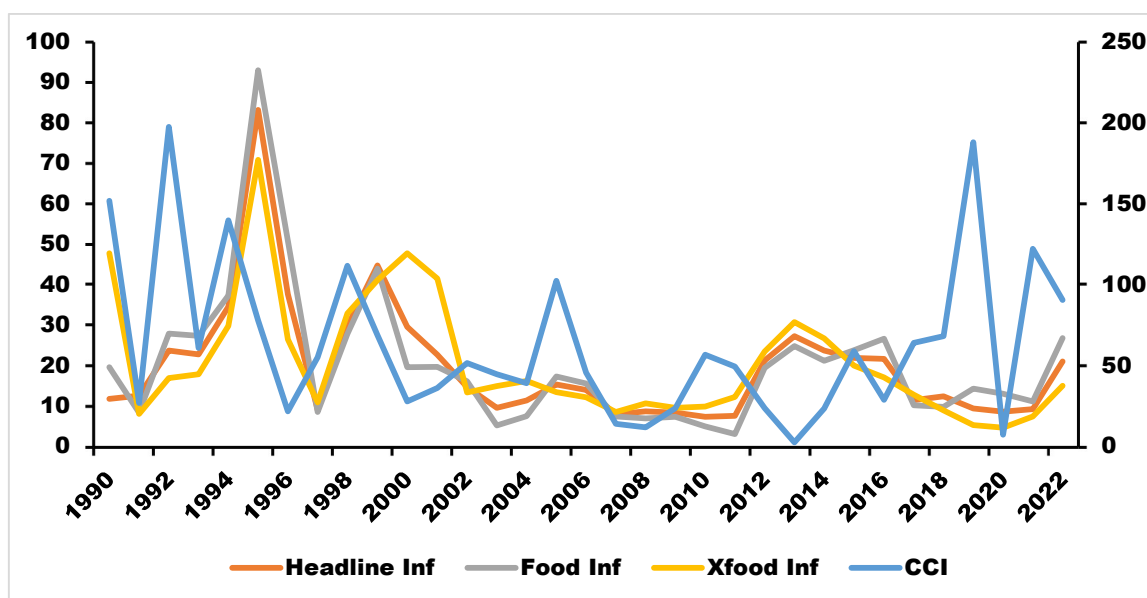
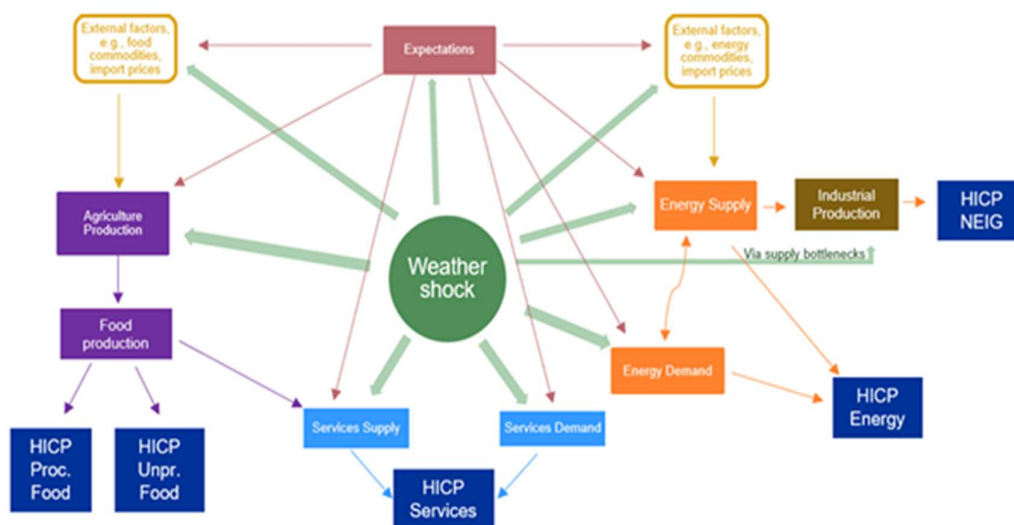


Figure 5: Channels Linking Weather and Prices



Source: *Ciccarelli, Kuik, & Hernandez (2023)*

Figure 5 demonstrates possible impact channels from extreme weather and climate to inflation in the context of the key risks. The channels illustrated in Figure 5 cover both the supply and demand side channels, in tandem with evidence provided by Ciccarelli & Marotta (2021) on the possible nature of climate-related shocks.

2.3 Monetary Policy in Malawi

The Reserve Bank of Malawi's monetary policy has evolved significantly since the Bank's establishment in 1964. However, throughout this period the Bank's primary mandate has been price stability. The Bank strives to achieve low and stable inflation. The evolution of monetary policy in Malawi can be categorized into three broad regimes: the repression period (1964-1986), the financial and liberalization reform period (1987-1994), and the post-financial reform period (1995-present). Over the review period, a considerable number of reforms have been implemented including a shift from a fixed exchange rate regime to a managed float, removal of direct controls on credit and deregulation of market interest rates, and a shift from direct to indirect tools of monetary policy. Additionally, the legal and regulatory framework of the banking system has been reviewed, and some restrictions on foreign flows have been removed, especially on current account transactions.

In 2016, the Bank started modernizing its monetary policy framework to an inflation targeting regime. This far, the Bank is still transitioning from the monetary targeting monetary policy framework and has attained significant milestones. One of the key milestones has been the adoption of the Forecasting and Policy Analysis System (FPAS), which provides a forward-looking, model-based analytical structure that facilitates projection of the paths of key variables such as inflation, interest rate, GDP growth, and exchange rate over a medium-term horizon. The core of the FPAS is the Quarterly Projection Model (QPM), which integrates supply, demand, and exchange rate dynamics to produce projections. In the recent past, climate change-related shocks, such as floods and droughts, have been prevalent in Malawi, resulting in large forecasting errors, hence rising uncertainties in monetary policy formulation. This has tended to complicate the conduct of monetary policy. It is, therefore, pertinent for the Reserve Bank of Malawi to adapt the Quarterly Projection Model to enable it to integrate the analysis of the impact of climate change on inflation and its transmission mechanism. This will adequately inform monetary policy discussions and decisions by the Bank's Monetary Policy Committee.

2.4 The State of Climate Finance in Malawi

The Malawi Government recognizes the risk that climate change poses to the country and has partnered with several development partners including the United Nations Development Fund and the Green Climate Fund (GCF) to mitigate the effects of climate change. This is aimed at supporting Malawi's national determined contribution to a combined unconditional and conditional contribution of a 51.0 percent reduction in green-house gas emissions by 2040 and ten strategic adaptation actions across three pillars: (i) institutional framework, (ii) knowledge, technology and financing and (iii) resilience of the most vulnerable (GCF, 2024).

Additionally, in 2016, the African Guarantee Fund (AGF) partnered with the Nordic Development Fund (NDF) to launch the Green Guarantee Facility in Malawi. The AGF provides for loan guarantee, equity guarantee and green fundraising guarantee and has been supporting SMEs in Malawi through local commercial banks since 2019. The AGF and NDF have played a significant role in reducing the risks assumed by the financial sector by offering financial guarantees to support green SMEs that are unable to provide acceptable collateral. The AGF also has a capacity development component that aims at building knowledge and capacity of banks in Africa to scale up lending for the green economy. This is expected to bring direct benefits in terms of climate change mitigation and adaptation as well as sustainable employment, poverty reduction and gender opportunity.

III Literature Review

3.1 Theoretical Literature

Climate change affects the macroeconomy through physical and transition risks (Bua et al., 2024). Physical risks include extreme weather events (floods, droughts, storms) causing productivity shocks, infrastructure losses, and supply chain disruptions. Transition risks are associated with the pace and extent at which an organization manages and adapts to reduce greenhouse gas emissions and transition to renewable energy. They would involve carbon pricing, shifting consumer preferences, and technological change (Beckmann, et al., 2023). These risks impact inflation, output, and financial markets, with physical risks affecting energy and food prices, and transition risks potentially leading to higher energy prices and stranded assets. Central banks must consider these persistent macroeconomic effects when maintaining price stability.

Climate change affects the economy through various channels, including agriculture, energy, and health. In agriculture, climate change can lead to reduced output, lower labor productivity, and supply chain disruptions. This can have a negative impact on food prices, leading to increased volatility and uncertainty. In the energy sector, climate change can have both positive and negative effects. On the one hand, high temperatures can reduce energy demand for heating, while on the other hand, rising temperatures can increase demand for cooling. This can lead to increased energy prices and volatility.

The impact of climate change on inflation is complex and subject to empirical confirmation. While extreme weather events and rising temperatures can increase food and energy prices, they can also reduce food prices in the short term. Overall, climate change can lead to increased price volatility and uncertainty in food and energy markets. Weather shocks can have both direct and indirect effects on various sectors, including energy, agriculture, manufacturing, and services. Direct effects can be seen through the impact on infrastructure, supply chains, and crops, while indirect effects can be seen through changes in input prices and expectations. The effects of weather shocks on consumer price inflation can materialize through several channels.

Firstly, extreme weather conditions can damage infrastructure, disrupt supply chains, and destroy crops, leading to higher food prices. This is particularly significant for developing economies where food consumption constitutes a large component of the consumer basket. Secondly, extreme heat events can lead to higher demand for cooling, resulting in increased energy prices. However, extreme cold events can decrease heating demand, potentially leading to lower energy prices. The overall impact on energy prices will vary depending on the geographic region. Lastly, weather shocks can also impact non-energy industrial goods through higher input prices. For example, energy disruptions can lead to firms using alternative, and more expensive power sources, resulting in higher prices for final products.

3.2 Empirical Literature

Several empirical studies have been conducted to examine the impact of climate change on macroeconomic variables. In general, these studies have established evidence supporting the undesirable impact that climate change has on macroeconomic variables, including inflation. For instance, Beckmann, et al., (2023) and Ciccarelli, et al., (2023) investigated the impact of climate change on inflation in the Euro area. Using NGFS climate scenarios, Beckmann, et

al., (2023) established that scenario-based analysis of transition and physical risks indicate that climate change can have persistent effects on inflation. However, the study results indicated that these effects were unlikely to raise inflation above the European Central Bank's target of 2.0 percent in the medium term.

The findings by Ciccarelli, et al (2023) revealed the presence of significant country asymmetries and seasonal responses of inflation to temperature shocks. The study found strong evidence that temperature variations affect inflation. These findings are similar to those found by Cevik & Jalles (2023) who examined how climate shocks, as measured by climate-induced natural disasters, influence inflation and economic growth in a large panel of countries between 1970 and 2020. The study found that inflation and growth respond significantly but also differently in terms of direction and magnitude to climate shocks. Specifically, the results showed that temperature shocks result in lower inflation, but droughts and storms lead to higher inflation, while all types of climate shocks have a negative impact on economic growth.

Faccia, et. Al., (2021) carried out a study to investigate how extreme temperatures affect medium-term inflation for advanced and emerging market economies. Using panel local projections, the study found that higher temperatures tend to be associated with increases in food inflation in the short run. The study also established that over the medium term, the impact across the various price indices tends to be either insignificant or negative.

Studies in African countries, found that climate change has a significant positive impact on inflation, (MEFMI, 2023 CBS, 2022; Kunawotor, et al., 2021). Specifically, Kunawotor et al (2021) found that significantly large weather-related events such as droughts and floods raise food inflation in a sample of 52 African countries. Likewise, CBS (2022) found that a 1.0 percentage point increase in the carbon emission variables leads to a 0.38 percent increases in year-on-year inflation among 16 SADC countries. MEFMI (2023) found that positive deviations in temperature have a negative impact on inflation while deviations in precipitation have insignificant effects on inflation among Eastern and Southern African countries.

The reviewed literature shows that most of the previous studies on the macroeconomic impact of climate change focused on a group of countries. Country specific studies on the implications of climate change on key macroeconomic variables, particularly based on data from African countries are scanty.

IV Methodology and Data

The study used the following econometric specification to examine the impact of climate change on inflation consistent with previous studies, notably, by Cevik & Jalles (2023).

$$Inf_t = \beta_0 + \beta_1 CCI_t + \delta_k \sum_{k=1}^Z X_{kt_k} + \mu_t \dots\dots\dots (1)$$

Where Inf_t represents the inflation variable, CCI is the climate change variable, X is a collection of control variables, while μ is the white noise error term, and t is the time variable.

The control variables used include the output gap, exchange rate, the FAO food price index and Brent crude oil prices- to capture the impact of imported inflation, and fiscal balance. In line with the study objectives, we estimate three versions of equation 1 with headline, food and non-food inflation as the dependent variables in each equation. The paper aims to estimate

climate change coefficients to be used in the Reserve Bank of Malawi's Quarterly Projection Model, which has different equations for food and non-food inflation. The choice of the control variables depends on the dependent variable used. For example, while exchange rate and CCI variables are used in all the three equations, the output gap and world food price index are only used in the headline and food inflation estimation, while fiscal deficit and crude oil price are only used in the non-food estimation. The foreign variables in both models capture the role of imported inflation on the relevant domestic CPI component.

Data for the climate variables is obtained from the World Bank's climate change knowledge portal. Data on inflation, exchange rate, and fiscal balance is sourced from the Reserve Bank of Malawi, while the output gap was computed using the Hodrick–Prescott filter. The world food index series is taken from the United Nations's Food and Agriculture Organization. Finally, data on crude oil prices is sourced from the U.S. Energy Information Administration.

4.1 The Climate Change Index (CCI)

In line with MEFMI (2023), Faccia et al., (2021) and Sandalli (2021), this study uses temperature and precipitation for climate change variables. Temperature and rainfall data is available on a monthly frequency. To get annual values, sum of the rainfall observations for the year has been used, while for temperature, the paper has computed annual averages from the monthly readings. MEFMI (2023) suggests computing a Climate Change Index, CCI. This is a weighted average of temperature (T) and rainfall (R) absolute deviations from their respective historical means. Following this approach, we use temperature and rainfall data to calculate annual averages for both temperature and rainfall for the period 1980-2022 before computing the deviations from the means. Thus, the CCI has been computed as follows:

$$CCI_t = w * |(T_t - T^*)| + (1 - w) * |(R_t - R^*)| \dots\dots\dots (2)$$

Where $w = 0.5$ and is the weight for the absolute deviation of temperature from their historical norm. The higher the CCI, the worse the climate conditions and vice versa. A CCI of zero implies that climate conditions are the same as the historical norms, no climate change.

The weighted composite index of temperature and rainfall variations as a measure of climate change is more representative and provides a more holistic picture of climate shifts than single indicators. Deviations of temperature from their normal patterns as well as rainfall deviations from their normal trend have implications on inflation. These variations are equally weighted in the computation of the index.

4.2 Estimation Technique

We used the Autoregressive Distributed Lag (ARDL) estimation technique, which was first introduced and developed by Pesaran & Shin (1995) and was refined by Pesaran *et al.* (2001). The ARDL model is considered the best econometric method compared to others in a case when there is a combination of stationary variables and variables integrated of first order, as is the case with the variables used in this study. The ARDL modeling procedure also enables the estimation of both long- and short-run coefficients within one equation and enables inclusion of the lagged variables to capture the data generating process.

In this analysis, three inflation variables were used as dependent variables: headline inflation and its two subcomponents of food and non-food inflation. As such, three separate equations were estimated. In this regard, the following equations were estimated.

$$\Delta HEADLINE_t = \beta_0 + \beta_1 HEADLINE_{t-1} + \beta_2 CCI_{t-1} + \beta_3 FAO_{t-1} + \beta_4 Exc_{t-1} + \beta_5 Outputgap_{t-1} + \sum_{i=1}^p \delta_1 \Delta CCI_{t-i} + \sum_{i=1}^p \delta_2 \Delta (FAO)_{t-i} + \sum_{i=1}^p \delta_3 \Delta (Exc)_{t-i} + \sum_{i=1}^p \delta_4 \Delta (Outputgap)_{t-i} + \mu_t \dots\dots\dots(3)$$

$$\Delta FOOD_t = \gamma_0 + \gamma_1 FOOD_{t-1} + \gamma_2 CCI_{t-1} + \gamma_3 FAO_{t-1} + \gamma_4 Exc_{t-1} + \gamma_5 Outputgap_{t-1} + \sum_{i=1}^p \sigma_1 \Delta CCI_{t-i} + \sum_{i=1}^p \sigma_2 \Delta (FAO)_{t-i} + \sum_{i=1}^p \sigma_3 \Delta (Exc)_{t-i} + \sum_{i=1}^p \sigma_4 \Delta (Outputgap)_{t-i} + \mu_t \dots\dots\dots(4)$$

$$\Delta XFOOD_t = \alpha_0 + \alpha_1 XFFOOD_{t-1} + \alpha_2 CCI_{t-1} + \alpha_3 Oil_{t-1} + \alpha_4 Exc_{t-1} + \alpha_5 Fiscal_{t-1} + \sum_{i=1}^p \varphi_1 \Delta CCI_{t-i} + \sum_{i=1}^p \varphi_2 \Delta (OIL)_{t-i} + \sum_{i=1}^p \varphi_3 \Delta (Exc)_{t-i} + \sum_{i=1}^p \varphi_4 \Delta (Fiscal)_{t-i} + \mu_t \dots\dots\dots(5)$$

Where $HEADLINE_t$, $FOOD_t$ and $XFOOD_t$ are the headline, food and non-food inflation rates, respectively, CCI is the Climate Change Index; FAO is the international food price index; Exc is the Malawi kwacha to the US dollar nominal exchange rate, Oil is the Brent crude oil price; Δ captures the first difference of the respective variables, δ_i and β_i are short-run and long-run parameters to be estimated, respectively; and μ_t is the white noise error term.

4.3 Motivation for the Choice of the Control Variables

In the estimation of headline inflation, three control variables have been used, including the FAO food index, the exchange rate and the output gap. The inclusion of the output gap follows the standard Phillips Curve to capture the impact of demand pressures on inflation. The output gap is estimated using an HP filter from annual GDP series. For Malawi, the apriori sign of β_5 is not definite as this largely depends on the source of the aggregate demand pressures. To the extent that the output gap is on account of a positive performance of the agriculture sector, the coefficient is likely to be negative, indicating that a food supply boost reduces inflation. However, if the increase in the output gap arises more from the non-agricultural sector, the coefficient is likely to be positive, portraying the impact from rising marginal cost of production. So, the apriori sign of β_5 is indeterminate.

The FAO food index has been included to capture the role of imported food inflation. It is a measure of the monthly change in international prices of a basket of food commodities. The index is compiled monthly by the Food and Agricultural Organisation. Rising international food prices are expected to directly elevate imported food prices for the domestic consumers. Accordingly, β_3 is expected to be positive.

The coefficient β_4 captures the impact of the exchange rate on inflation. The exchange rate variable is a log transformation of the annual average Malawi kwacha exchange rate per the US dollar. The inclusion of the exchange rate is meant to reflect the impact of real marginal cost. It is also directly capturing the impact of the exchange rate on imported prices. Consequently, β_4 is expected to be positive, consistent with the impact of depreciation on imported prices and on real marginal cost.

Lastly, it is expected that the CCI will be positively related with inflation. This is because a higher CCI represents worsening weather conditions, and thus, adverse supply-side shocks. The estimation of the other inflation components follows the same approach. For example, in the food inflation equation, the FAO food index has been included to capture the impact of imported food prices on food inflation, as argued before, imported inflation is expected to increase domestic inflation. As such, γ_3 is expected to be positive. Similarly, γ_4 is expected to be positive, while the apriori sign of γ_5 cannot be determined, as this largely depends on the nature of the output shock. In fact, it would have been more informative if an agricultural output gap had been used in the food inflation equation. This has not been possible due to data constraints.

For the equation of non-food inflation, the inclusion of oil prices is meant to gauge the impact of imported inflation on domestic non-food inflation, using a variable that would be more directly related to non-food inflation. For this reason, the FAO index was found to be more related to food inflation hence its exclusion, and use of oil prices. Annual oil prices are computed as an average of the monthly oil prices. The fiscal balance, expressed as a percentage of GDP is also used in the non-food inflation. This was chosen to represent domestic inflationary pressures as using the output gap was creating estimation problems, including unreasonable estimates and lack of a long-run relationship for the variables.

V Discussion of the Empirical Results

The study conducted unit root tests using the Augmented Dicky Fuller (ADF) test and the results are reported in Annex 1. The test results show that the variables are a combination of $I(0)$ and $I(1)$, thus validating the appropriateness of using an ARDL model. The paper adopted an automatic lag length selection based on the Akaike Information Criteria. The climate change index, as the main variable of interest was used in all the estimations. However, different control variables were used across the models.

The estimation results for the impact of climate change on inflation are presented in Table 1. The results indicate that climate change has adverse short-run and long-run impact on headline inflation. Particularly, in the long-run, a one-unit deviation of the index from the norm (zero) increases inflation by 0.1 percentage points. These findings are consistent with findings by Ciccarelli, Kuik, & Hernandez (2023) who established strong evidence that an increase in temperature variability has significant upward impact on inflation. The results also indicate that an exchange rate depreciation and an increase in international food prices result in a rise in headline inflation both in the short-run and the in the long-run, while no evidence of statistically significant impact has been found for the output gap.

Regarding food inflation, these results show that climate change has both short run and long run impact on food inflation. The results show that a one-unit deviation of the climate change index away from the norm raises food inflation by about 0.17 percentage points in the long-run. This corroborates findings by Faccia, Parker, & Stracca, (2021) who established that climate change tend to be associated with increases in food inflation. International food prices are also found to have both short-run and long-run impact on food inflation in Malawi suggesting the passthrough of international food price developments to domestic prices. The exchange rate is also found to have both short-run and long-run impact on food inflation.

The study findings highlight the role of climate change in the determination of inflation in Malawi. As a rain-fed agrarian economy, climate change has significant implications on food

production in the country. Higher values for the climate change index represent adverse climate conditions. In case of excessive precipitation, this would result in floods which negatively affect agricultural production hence directly affecting food inflation and consequently headline inflation. On the other hand, high temperatures can be related to droughts, which tend to negatively affect agricultural (food) production and hence raise inflation.

Meanwhile, climate change is found to have short-run and long-run significant impact on non-food inflation. Specifically, a one-unit increase in the climate change index reduces non-food inflation by 0.09 percentage points in the long-run. This outcome, however, is contrary to expectation. This long run negative impact of climate change on non-food inflation can be best understood by recognising that agriculture is the backbone of the Malawi economy. Performance of the agriculture sector determines the economy-wide wellbeing with the sector's backward and forward linkages with the rest of the sectors. As such, adverse weather conditions significantly weigh down agricultural production in the country, resulting in low income, and hence below-par economic activity and reduced consumption and investment. Therefore, the decline in disposable income lessens the pressure on demand for non-food items. So, in essence, it is this fall in disposable income (reflecting an underperformance of the non-agricultural sector) associated with adverse climatic shocks that accounts for the observed negative impact on non-food inflation. However, the results show that climate change has positive short-run impact on non-food inflation. The results also show that exchange rate has short-run impact on non-food inflation. The results also show that fiscal deficit significantly influences non-food inflation both in the short run and in the long run. Specifically, the results show that, in the long run, a one unit (1 percentage point of GDP) increase in the fiscal deficit raises non-food inflation by 1.8 percentage points in the long run.

The error correction terms in all the three equations are negative and statistically significant. Ideally, the value of an error correction term ranges between -1 and 0. Results presented in table 1, however, show that the estimated terms in the three models are less than -1. Such values do not necessarily imply instability in developing countries, which are buffeted by severe shocks and prone to structural instability. Thus, it would be possible that the long-run relationships are shifting rather than a stable equilibrium being disturbed. Such reactions should not be regarded as peculiar, especially for developing economies where policy responses and price adjustments, particularly in the food component, tend to be rapid and volatile following macroeconomic shocks. Narayan & Smyth (2005) and Pesaran, Shin, & Smith (2001) have documented similar findings in inflation and exchange rate models for developing economies.

Table 1: Estimation Results

Variable		Headline		Food		Non-Food	
Bounds Test							
Computed F-statistic		8.996		7.111		-	
F-Critical (5% significance level)		I(0)	I(1)	I(0)	I(1)	I(0) ²	I(1)
	F	3.203	4.704	3.183	4.775	-	-
	t	-2.869	-4.045	-2.845	-4.028	-	-
Speed of Adjustment							

² Too many coefficients for non-food equation, constraining the bounds test

ECM	-1.318*** (0.206)	-1.037*** (0.197)	- 1.191*** (0.275)
LONG-RUN RESULTS			
L1.CCI	0.102* ** (0.251)	0.17* (0. .041)	-0.09* (0.052)
L1. Outputgap	0.031 (0.083)	-0.319 (0.304)	-0.08 (0.144)
L1. Logxch	1.707*** (0.558)	2.804*** (0.896)	0.45 (0.827)
L1. FAO	0.145*** (0.049)	0.294*** (0.082)	-
Crude Oil	-	-	-0.29 (0.888)
Fiscal balance			1.776** (0.687)
SHORT-RUN RESULTS			
LD. H-Infl	0.329** (0.154)	-----	-----
LD. F-Infl	-----	0.229*** (0.172)	-----
LD. XF-Infl	-----	-----	0.49** (0.218)
L2D. XF-Infl			0.44** (0.177)
L3D. XF-Infl			0.36** (0.13)
D1.CCI	0.061*** (0.021)	0.077*** (0.3)	0.085*** (0.029)
LD.CCI	-	-	0.186*** (0.059)
L2D.CCI	-	-	0.073 (0.048)
L3D.CCI	-	-	0.054 (0.034)
D1.Outputgap	0.041 (0.107)	-.08 (0.144)	-0.034 (0.176)
D1. Logxch	30.23 (6.777)	29.232*** (10.503)	36.61*** (8.424)
LD. Logxch	47.784 (9.886)	53.229*** (12.383)	24.304* (12.644)
L2D. logxch	19.614 (11.875)	-1.103 (14.906)	-
L3D. logxch	29.275 (10.762)	37.35** (13.552)	-
D1. FAO	.191* (0.069)	-0.305* (0.091)	-
D1. Oil	-	-	-0.006 (0.108)
LD. Oil	-	-	0.18 (0.106)
D1. Fisc	-	-	-0.83 (0.338)
LD. Fisc			-2.01** (0.823)
L2D. fisc			-0.524 (0.503)
_cons	-11.488 (5.612)	-23.726 (7.291)	39.675** (15.55)

*, **, *** represent significance at 10%, 5% and 1% level of significance, respectively

Regarding the impact of international food prices, the results show that international food prices have both short-run and long-run impact on inflation. Specifically, according to these results, in the long run, a one-unit change in the FAO index raises food inflation by 0.29 percentage points, while headline inflation changes by 0.15 percentage points. This underscores the vulnerability of the Malawi economy to foreign price pressures, given its dependence on imported food items to supplement domestic food supplies. Fiscal deficit exerts no statistical significance on non-food inflation.

Generally, therefore, these findings emphasise the dilemma for monetary policy in the event of adverse climatic shocks which affect inflation as well as overall economic activity. Through their impact on economic performance and inflation. This worsens the trade-off for monetary policy in that while tight monetary policy would have to be invoked to address the inflationary pressures, an expansionary monetary policy would be desirable to stimulate the economy. It is, therefore, important for RBM to consider adapting its monetary policy framework to better reflect the challenge posed by climate change in monetary policy formulation and implementation.

All the three estimation equations pass the model diagnostics as shown in Annex 2. The parameters are stable, and the models do not suffer from autocorrelation nor heteroscedasticity, indicating that the estimates obtained are unbiased and consistent, hence reliable and can be used for inference.

5.1 Robustness Check

The findings from the Structural VAR analysis (results presented in the Appendix) do corroborate with findings from the ARDL methodology used in this study. According to these findings, there is a significant and permanent increase in headline inflation whenever the Malawian economy is subjected to a positive climatic shock. This supports the finding from the ARDL framework that largely shows a positive relationship between climate change and inflation.

The SVAR results also confirm results from the ARDL methodology in that they also established a negative relationship between climate change and non-food inflation. Regarding the impact of adverse weather conditions on real GDP, according to results of the headline equation estimation, adverse climatic conditions have a negative impact on output, depicted by the immediate decline in the output gap, following a positive climate shock. As indicated elsewhere in the study, the main channel through which adverse climatic shocks affect inflation in Malawi is through the negative impact it has on agricultural output. Agriculture constitutes a sizeable proportion of the real GDP in Malawi (estimated at about 23 percent as of 2024). The sector also has backward and forward linkages with other sectors, such as manufacturing and transportation. It is, therefore, not surprising that the SVAR clearly shows that adverse climatic conditions have a contractionary effect on the economy and hence the perverse sign between climate change and non-food inflation in the ARDL framework.

VI Conclusion and Policy Recommendations

This study set out to examine the impact of climate change on inflation in Malawi. The findings from the study suggest that adverse weather shocks are inflationary in Malawi. In

particular, the study established that climate change increases both food and headline inflation. The findings further highlight the need to acknowledge the significant role of climate change in inflation determination in Malawi and therefore incorporate its implications on monetary policy formulation and implementation.

One key policy implication from this study is that, considering the increasing intensity and frequency of extreme climate change events in Malawi in the recent past, and the negative impact that this is having on inflation, policy makers should begin to devise ways to capture this impact in the analytical tools, including the macroeconomic models designed to inform policy formulation. It is thus recommended that the Reserve Bank of Malawi be at the forefront in integrating climate matters in the Bank's operating frameworks as it delivers on its price stability mandate. It is therefore, crucial for the Bank to adapt its analytical framework to support the monetary policy decision making processes. Specifically, based on the current study's findings, the study proposes that the Reserve Bank of Malawi consider incorporating a climate change variable in its inflation equations in the Quarterly Projection Model. This can be integrated by directly inputting a climate change variable in the food inflation and non-food inflation equations.

This study mainly focused on one core mandate of the Reserve Bank of Malawi. However, as the literature suggests, climate change affects the economy through a variety of channels including non-performing loans, credit concentrations, liquidity levels, capital structure of the banking sector, among others. Further areas of research therefore include the analysis of the impact of climate change on macroprudential variables, analysis of climate change and key macroeconomic variables using different analytical tools such as DSGE technique, as well as consideration of analysis that splits the output gap into agriculture and non-agriculture output gaps subject to availability of data. This is because climate shocks are propagated directly through agriculture output to food prices and indirectly through the non-agriculture sectors. Analysis of demarcated agriculture and non-agriculture sectors was not possible in the current study due to data constraints.

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Annexes

Annex 1: Unit Root Test Results

Variable	In Levels		1 st Difference		Order of integration
	t-statistic	Critical Value	t-statistic	Critical Value	
Headline Inflation	-3.649***	-2.952	-----		I(0)
Food Inflation	-3.757***	-2.952	-----		I(0)
Non-Food Inflation	-3.981***	-2.952	-----		I(0)
RGDPG	-7.841***	-2.952	-----		I(0)
logxch	-0.925	-2.952	-4.193***	-2.955	I(1)
fisc	-5.371***	-2.952	-----		I(0)
Oil	-1.139	-2.952	-5.964***	-2.955	I(1)
FAO	-0.147	-2.952	-5.201***	-2.955	I(1)
CCI	-7.049 ***	-2.952	-----		I(0)

*, **, *** represent significance at 10%, 5% and 1% level of significance, respectively.

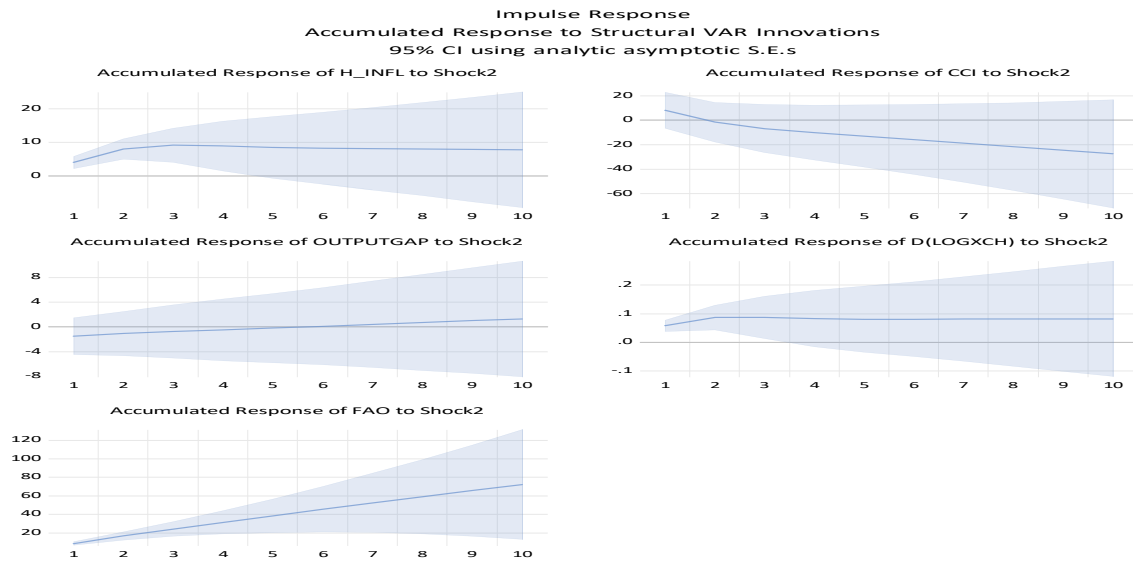
Annex 2: Diagnostic Test Results

	Headline		Food		Non-Food	
	t-statistic	t-critical (5%)	t-statistic	t-critical (5%)	t-statistic	t-critical (5%)
Model Stability (5%)	0.6397	0.9479	0.4146	0.9479	0.5624	0.9479
	chi2	Prob > chi2	chi2	Prob > chi2	chi2	Prob > chi2
Arch Effects	0.001	0.9799	0.082	0.7749	0.612	0.434
Breusch Godfrey	3.062	0.0802	1.835	0.1755	0.108	0.7426

Annex 3: Results of the SVAR Estimation

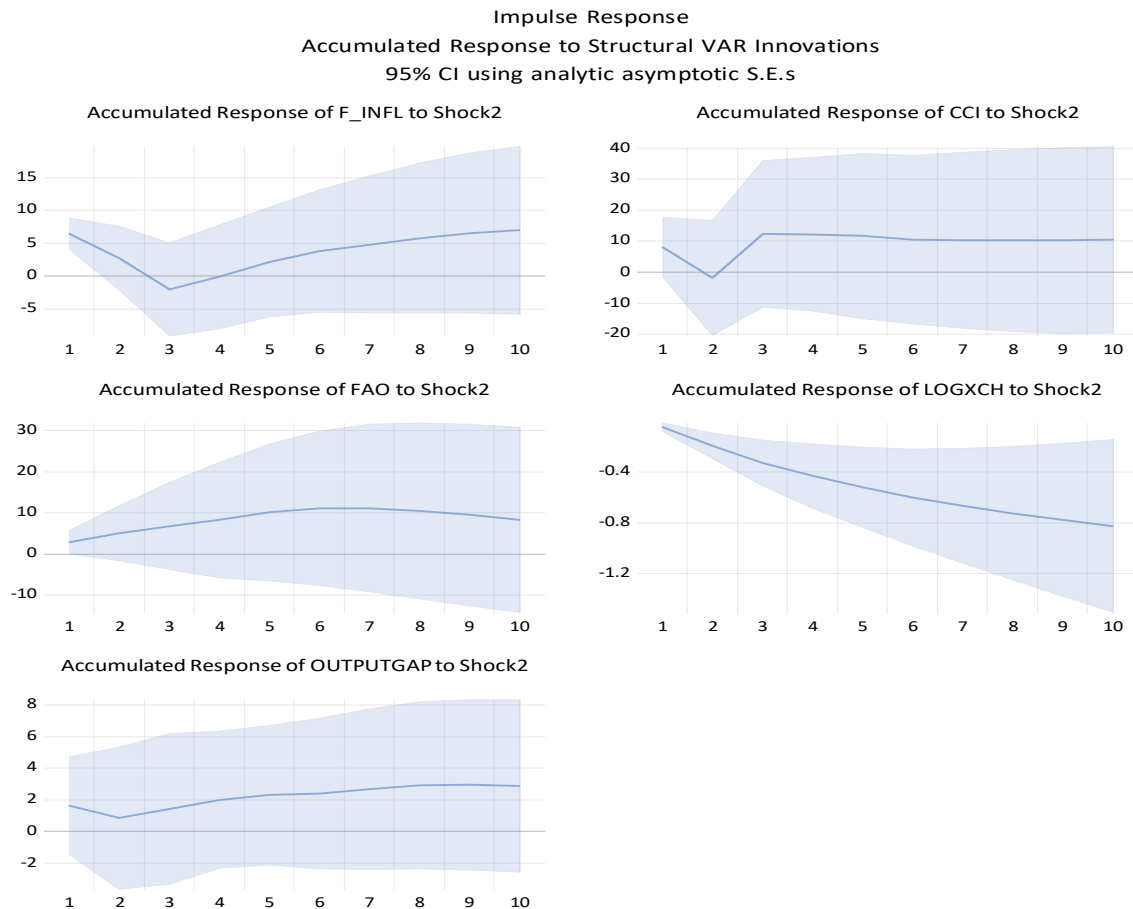
Headline Inflation Equation

There is a significant and permanent increase in headline inflation following a positive climatic shock. Meanwhile, output gap has been found to be negatively affected by climate change.



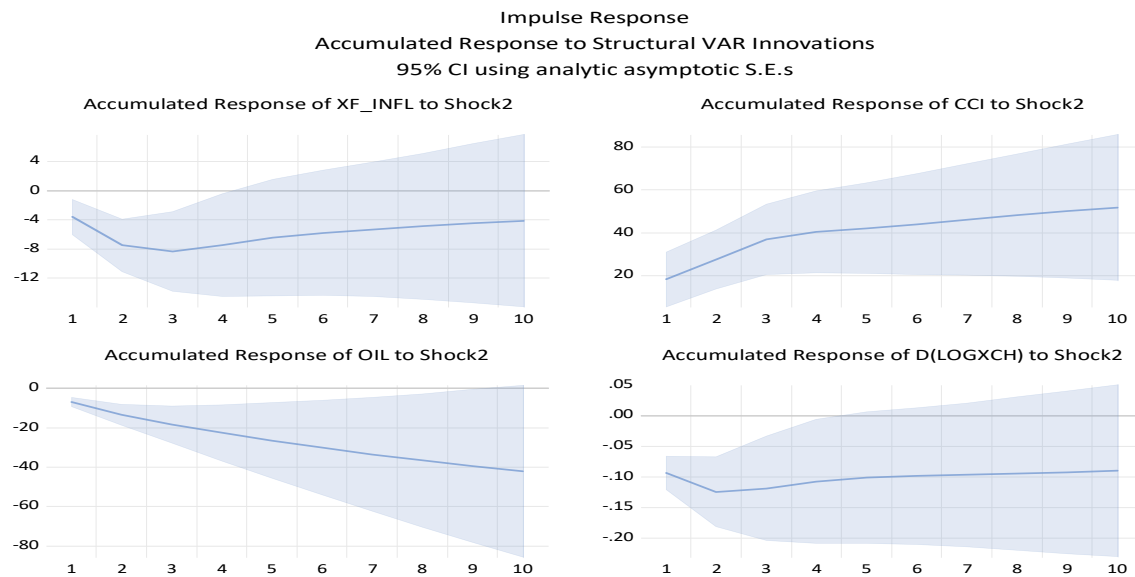
Food Inflation Equation

Initial immediate increase in food inflation from a climatic shock but food-inflation begins to decline in the net year before it begins to rise again.



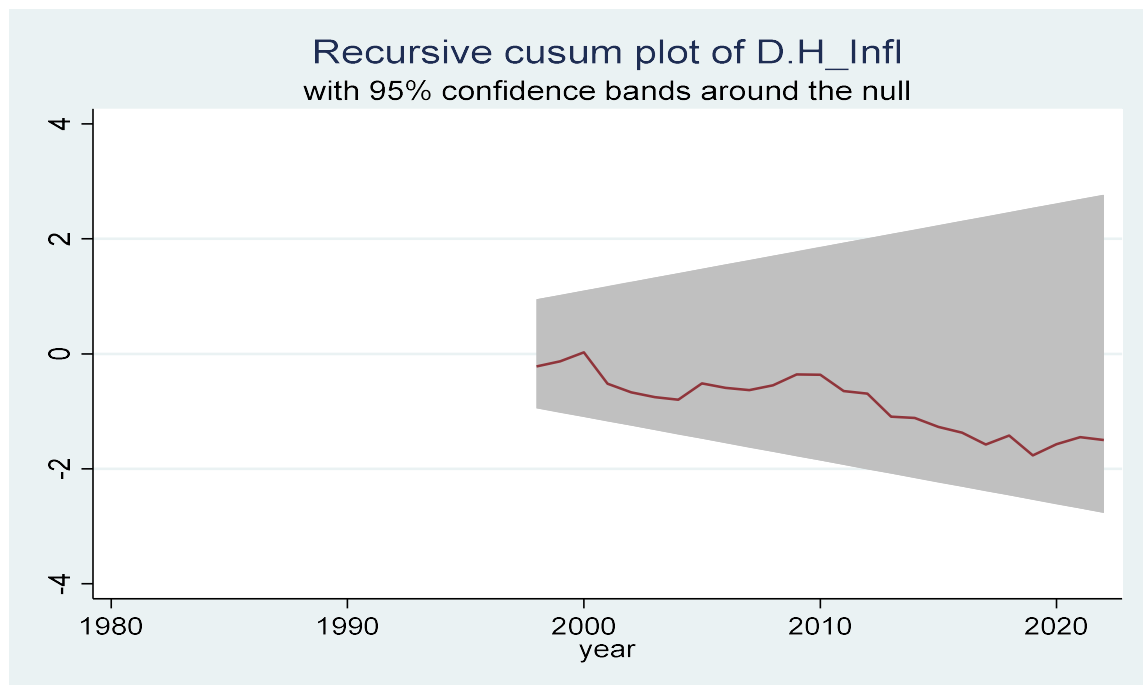
Non-food Inflation Equation

Just as in the ARDL estimation, the response of non-food inflation is negative.

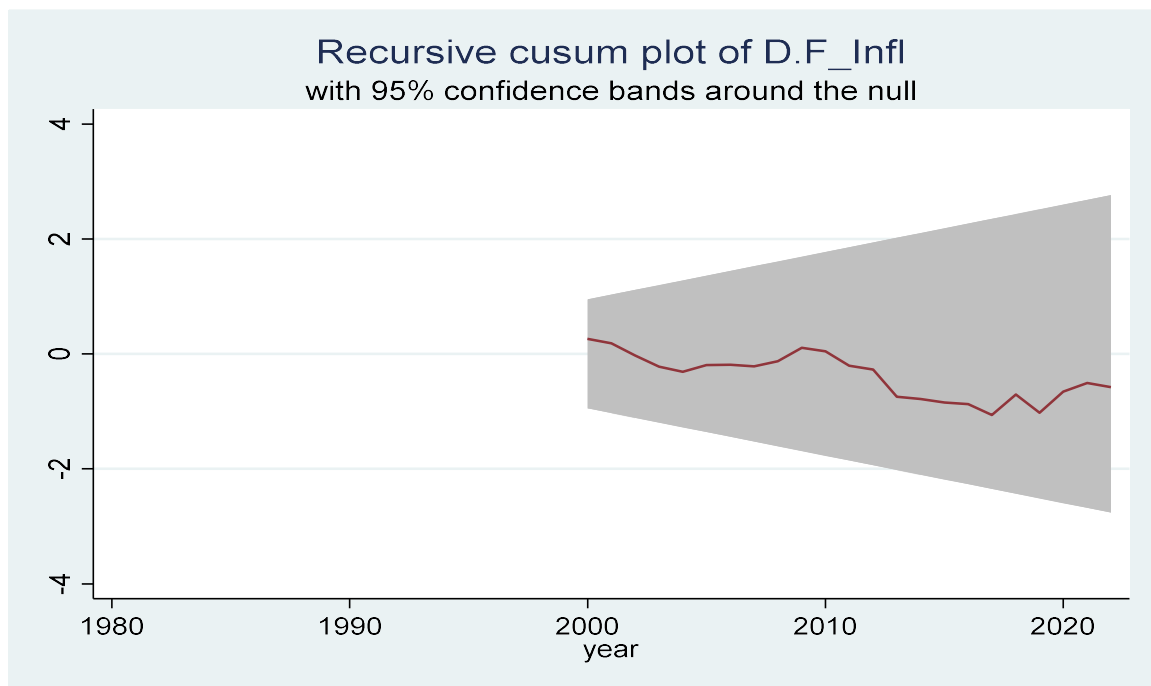


Annex 4: Model Stability Test Results

Headline Inflation



Food Inflation



Non-Food Inflation

