Impact of Extreme Climate Change on Inflationary expectations and its Influence on SARB Macroeconomic Policy in South Africa

Sithole, Mixo Sweetness

University of South Africa

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By

By Mixo Sweetness Sithole, University of South Africa

Mixosithole7@gmail.com

https://orcid.org/0000-0003-0543-656X

Abstract

This study investigated the impact of extreme climate change on inflationary expectations and its implications for macroeconomic policy in South Africa over the period 1970 to 2023. Using an Autoregressive Distributed Lag (ARDL) model, the analysis explores both the short run and long run relationships between inflation and key climate and macroeconomic indicators, including temperature anomalies, agricultural output, food production, broad money supply, real interest rates, and carbon dioxide (C02) emissions. The ARDL bounds test confirmed the existence of a long run cointegration relationship among the variables. Empirical findings revealed that rising temperatures and C02 emissions exert significant inflationary pressures in both the short run and long run. Conversely, increases in agricultural output and money supply are associated with disinflationary effects. The error correction term is negative and statistically significant, indicating a rapid adjustment towards equilibrium following short-term shocks. Diagnostic tests confirmed the stability and robustness of the model. These findings underscored the macroeconomic significance of climate change and highlighted the need for the South African Reserve Bank (SARB) to incorporate climate-related risks into its inflation-targeting framework and broader policy formulation.

Keywords: Climate change, inflation, temperature, central bank, microeconomic policy, South Africa

1. Introduction

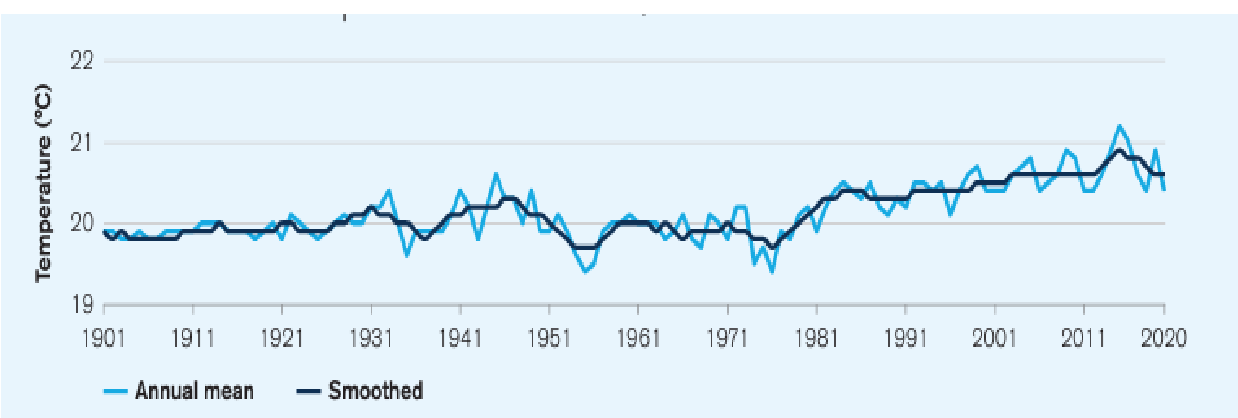
Climate change has a major impact on the world economy today. The consequences of climate change affect price stability and lead to inflation. According to Faccia et al. (2021), the fight against climate change is growing more and more essential because it is one of the major social and economic challenges of this century. Odongo et al. (2022), argue that the most vulnerable nations to the effects of climate change are developing countries, which mostly experience extreme weather events such as heat waves, floods, drought, storms, and variations in precipitation. Such devastating events have negative impacts on infrastructure, income, housing, agriculture, and food security. Furthermore, according to Ciccarelli et al. (2023), climate change has major implications on price stability, which also influences the policies of central banks. In comparison to the preindustrial normal, the global surface temperature increased by more than 1.1 degrees Celsius (˚C). according to Cevik and Jalles (2023), as the global temperatures rise to 4 ˚C in the next century, projections indicate that extreme climate change will increase the probability of drought, extreme heat, and severe storms. This will affect the environment, livelihoods and people.

According to Boneva and Ferrucci (2022) the goal, method and dissemination of monetary policy are all increasingly impacted by climate change. However, shocks and trends related to climate change are still missing from the standard models that central banks employ for forecasting and analysing their policies. Many central banks have agreed that it is important to comprehend how climate change will affect the macroeconomic environment and its impact on price stability (Ciccarelli et al. ,2023). More specifically, according to Faccia et al. (2021) the impact of climate change is attracting the attention of central banks, which have made explicit mention of them in their mandates. The Bank of England, for example, has included a climate action plan after reviewing its monetary policy strategy, and the Network for Greening the Financial System has expanded from its founding eight central banks and supervisors in December 2017 to over one hundred members and observers as of today.

In South Africa, according to the USAID (2023) report, climate adaption and mitigation are currently a major priority. Important climate initiatives have been authorized by the South Africa Cabinet, including the establishment of a carbon tax, a national climate change adaption strategy, a low-emissions development strategy, a presidential climate commission and a just transition framework. The South African Reserve Bank also recognizes the impact of extreme climate changes on inflationary expectations and the possible implications of climate change on macroeconomic policies of South Africa. The South African Reserve Bank is currently aiming to expand research on the effects of climate change on the centra banks of Southern Africa (SARB, 2024).

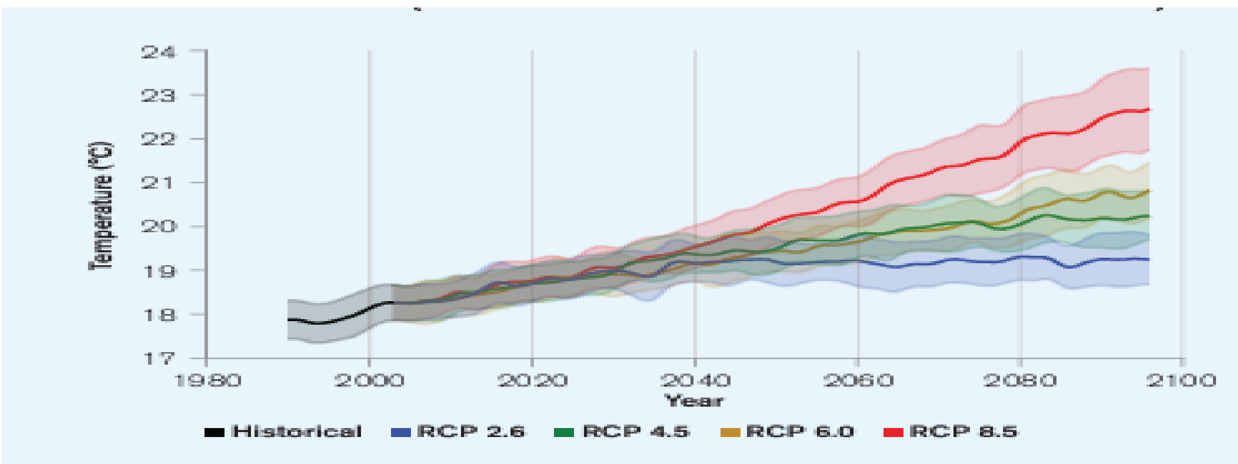
What is the impact of climate change in South Africa? According to USAID (2023), The ecosystem, economies and livelihoods of South Africa are already changing due to climate change. According to the report, the average temperature in the country has risen faster than the average temperature worldwide since 1990. There has been an increase in weather events such as a rise in heat waves, increased rainfall intensity, and water scarcity as a result of increased droughts. In addition, the shifts in temperature extremes have an impact on health systems, including emergency services, infrastructure, availability of medications and medical supplies.

Specifically, according to the World Bank (2020), climate change is anticipated to worsen the high risk of natural hazards and disasters that South Africa already faces, including droughts, floods, and storm-related occurrences like hail, strong winds, and coastal storm surges. The overflow of sewage and storm water systems during extreme rainfall events already leads to expensive repairs of infrastructure, traffic closures, restricted access to electricity, flooding, and pollution. Unusual temperatures are already having an impact on vital infrastructure, including railroads and roadways. The figure below shows the changes in temperature in South Africa between 1901 to 2020



(Source: World Bank, 2021)

According to the World bank report (2021), temperature in South Africa has been increasing since the 1960. As seen in the figure above, both maximum and minimum daily temperatures increase across all seasons. The changes in temperature fluctuated, with the highest rates seen during the mid-1970s and again in between the late 1990 to mid-2000. Furthermore, according to the World Bank report, rising temperatures are predicted to continue in South Africa, with mean monthly temperatures predicted to rise by 2.0°C by the 2050s and 4.2°C by the 2090s, respectively, under a high-emission scenario (RCP8.5). During the summer, from November to March, the greatest temperature increases are anticipated. Several factors pertaining to regional economic development and agricultural output will be impacted by rising temperatures, including more frequent and intense heat waves and increased rates of evapotranspiration. The figure below shows the predicted changes in temperature in South Africa.



(Source: World Bank, 2021)

The report further stated that temperatures will continue to rise in South Africa throughout the end of the century. As seen in the figure above, under a high-emission scenario (RCP 8.5), average temperatures are projected to increase rapidly by mid-century. In addition, severe rain keeps degrading lands, eroding soils, and endangering ecosystems and the services they offer. The study investigated the intricate relationship between extreme climate change events and their consequential impact on inflation rates in South Africa. As the frequency and intensity of extreme weather events continue to escalate globally, understanding how these phenomena contribute to inflationary pressures in the South African economy becomes imperative. By examining the interconnectedness of climate change and inflation in the context of South Africa, this research endeavours to provide valuable insights for policymakers, businesses, and stakeholders to formulate effective strategies for mitigating and adapting to the economic repercussions of extreme climate conditions.

Understanding how extreme climate change affects inflationary expectations among different groups is crucial for promoting economic resilience and social equity. This study contributed insights into potential disparities and vulnerabilities, allowing policymakers to develop targeted strategies that address the diverse needs of various segments of the population. The findings of this study can inform the formulation of effective and inclusive economic policies. By identifying how extreme climate events impact inflationary expectations differently across demographic, socioeconomic, and geographic groups, policymakers can design interventions that mitigate disparities and ensure more equitable outcomes.

2. Literature review

This section will provide the theoretical aspect on the relationship between climate change and inflation as well as the empirical analysis on previous studies conducted under the similar topic.

2.1.Theoretical Literature Review

The relationship between climate change and economic variables is increasingly gaining attention in recent years, particularly as the frequency and intensity of extreme weather events have increased globally. This section reviews the key theoretical frameworks that underpin the study on the impact of climate change on inflationary expectations and microeconomic policy in South Africa. The Environmental Kuznets Curves (EKC) theory posits an inverted-U relationship between environmental degradation and economic development and suggests that environmental impact increased with economic growth, to a certain extent, after which it begins to decrease as economies mature and adopt greener technologies (Kaika and Zervas, 2013). The theory was, however, critiqued for oversimplification of this relationship and failing to account for immediate and severe impacts of extreme climate events.

In the context of climate change the Behavioural Economics provides insight into how individuals form expectations in response to extreme climate events. This includes theories such as the Prospect Theory by Kahneman and Tversky (1979) which suggested that people may react to short-term, highly salient events such as flood, resulting in exaggerated inflationary expectations. This can lead to high inflationary pressures if not properly managed by policymakers. With regards to microeconomic policy, Climate-Economy Interactions Models including the work of Fiddaman (1997) are being used increasingly to analyse how central banks can incorporate climate-related risks into their monetary policy frameworks. These models suggest that central banks may need to adjust their traditional tools to account for the unpredicted effects of extreme climate events on inflation and economic stability.

2.2.Empirical review

Recent studies have increasingly explored the interaction between climate change and inflation and the impact on microeconomic policies by central banks. Batten et al. (2020) found that climate change and related mitigation policies could challenge central in achieving monetary stability, as climate change impacts macroeconomy through gradual warming, changes in rainfall, sea level rise and more frequent extreme weather events which can create inflationary pressures. Boneva and Ferrucci (2022) argue that central banks should intergrade climate-related factors into their models, emphasizing a 'suite-of-model' approach to better analyse financial sector vulnerabilities and the role of the energy sector in the economy. Furthermore, Boneva et al. (2022) found that Climate change impacts the central bank's ability to maintain price stability and reviewed potential central bank responses, ranging from protective actions to proactive actions like supporting green finance and sustainable growth.

Economides and Xepapadeas (2018) examined whether monetary policy should consider the expected impact of climate change and concluded that climate change has significant implications for the conduct of monetary policy. Drudi et al. (2021) showed that climate change, along with financial and fiscal vulnerabilities, could significantly limit the effectiveness of monetary policy in addressing business cycle fluctuations. Mukherjee and Ouattara (2021) found that temperature shocks lead to persistent inflationary pressures, especially in developing countries, and stated that temperature shocks pose a significant challenge to monetary policy.

Cevik and Jalles (2023) highlight that climate shocks impact inflation and GDP growth differently across nations, with the effects varying based on income levels, economic conditions, and institutional capabilities. Rudebusch (2019) reported that climate change impacts the economy directly through environmental changes like hotter temperatures, rising sea levels, and more frequent extreme weather events such as storms. The indirect effects stem from adaptation efforts and the transition to a low-carbon economy aimed at mitigating climate change. Ciccarwlli et al. (2023) found that rising temperatures in European countries could exert sustained upward pressure on inflation, suggesting greater volatility and heterogeneity in inflation due to more frequent extreme weather events.

Kousar et al. (2022) investigated how energy inflation is caused by a twin deficit, urbanization, climate change, the production of energy from oil and gas, and currency rates and identified a strong positive correlation between energy inflation and the twin deficit and exchange rates, particularly noting that the twin deficit has a more pronounced effect on oil prices than electricity costs. Li et al. (2023) reported a strong correlation between temperature changes and inflation, emphasizing the role of energy demand in driving inflationary pressures and revealing a nonlinear relationship moderated by GDP per capita. Wahidah and Antriyandarti (2021) showed that COVID-19 and climate change had mixed effects on general inflation and food inflation in Indonesia, using temperature as a proxy for climate change, with temperature showing a negative influence on food inflation. Moessner (2022), found that higher carbon dioxide emissions are linked to higher inflation at the country level.

Yusifzada (2024) found that climate change has a significant impact on agricultural prices globally. Zhang (2023) demonstrated that climate change risks significantly affect inflation in BRICS nations, with Russia experiencing more structural breakpoints due to climate change, and India and South Africa showing greater sensitivity to short-term climate risks. Kunawotor et al. (2021) examined the impact of extreme weather in headline and food price inflation in Africa, suggesting that these effects are significant and should be considered in monetary policy, particularly due to the influence on agricultural production. Ichoku et al. (2023) found a significant correlation between climate shocks and food price inflation in Nigeria, recommending a shift towards Climate-Smart Agriculture to mitigate future risks.

Ayinde et al. (2011) noted that while changes in rainfall positively affect agricultural productivity in Nigeria, temperature changes had a negative effect, underscoring the need for climate-sensitive agricultural technologies. Odongo et al. (2022) highlighted that in Eastern and Southern African countries, supply shocks due to climate change, alongside factors like oil prices and imported food inflation, are key drivers of food inflation, recommending sector-specific climate change policies. Iliyasu and Mamman (2023) found that climate change reduces real output and increases food and general consumer prices in Egypt, Nigeria and South Africa, indicating broad economic impacts across these regions.

3. Methodology

This section outlined methodological framework employed to examine the impact of extreme climate change on inflationary expectations and its influence on macroeconomic policy by the South African Reserve Bank (SARB). The study employed an Autoregressive Distributed Lag (ARDL) approach to model both the short-run and long-run relationships between inflation and selected climate change macroeconomic indicators. The table below displays the variables used in the study and the sources of data as follows:

Table 3.1: Data Sources and description of variables

Variable Symbol	Description	Dependent/ independent	Data source
Inf	the inflation, consumer prices annual percentage (annual %)	Dependent	World Bank (WDI)
Temp	Average Air Surface temperature measure in ◦C	Independent	World Bank climate change knowledge portal
AGRO	agriculture, forestry, and fishing value added (annual % growth)	Independent	World Bank (WDI)
F_Pro	Food production index	Independent	World Bank (WDI)
M2	Broad definition of money M2 growth (annual %)	Control	World Bank (WDI)
RiR	Real interest rates (%)	Control	World Bank (WDI)

C02_Emissions	Carbon dioxide emissions (total)	Control	World Bank climate change knowledge portal

Source: Author’s compilation

The study used secondary annual data collected from the World bank development Indicators as well as the World Bank climate change knowledge portal. The data collected covers periods between 1970-2023. The year 2023 is the latest period for climate change data.

3.1.Model Estimation

This study employed a quantitative approach, using secondary time series data to examine the impact of climate change on inflationary expectations in South Africa and its influence on macroeconomic policy by the central bank of South Africa. Inflation rate was used as the dependent variable and the temperature was used as proxy for climate change and acts as the independent variable. Other variables include agriculture output, food production, Real interest rates and broad money and C02 emissions as independent and control variables. The study therefore utilized an econometric model, specified as follows:

$$Infla_t = \beta_0 + \beta_1 Temp + \beta_2 AGRO + \beta_3 F\_Pro + \beta_4 M2 + \beta_5 RiR + \beta_6 C02 + \varepsilon_t \qquad 3.1$$

Whereby,

Infla is the inflation, consumer prices annual percentage;

Temp is the Average Air Surface temperature measure in ◦C;

Agro is the agricultural output of agriculture, forestry, and fishing value added

F_Pro is the food production index

M2 is the M2 growth annual growth rate;

RiR is the real interest rate; and

C02 is carbon dioxide emissions (total)

β0 is the coefficient slope, β1------β6 represents the slope coefficient of regressors and ξt is the error term.

3.2.Empirical model

The study employed the Autoregressive Distributed Lag Model (ARDL) as introduced by Pesaran, Shin, and Smith (2001). The ARDL model is suitable for analysing relationships when variables are integrated into different orders, i.e., order I (0) or order I (1), but not order I (2). This flexibility makes it ideal for the current study. In addition, the model is used to test cointegration in the variables of the study using the bounds test, after which, the long run and short run ARDL is estimated if cointegration is evident among the variables (Pesaran et.al, 2001). To estimate the model, the null and the alternative hypothesis are specified as follows:

The Null hypothesis argues that there is no cointegration and is given as follows:

Ho: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7$

The null hypothesis was tested against the alternative hypothesis that argues that there is cointegration, given as:

H1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7$

From the stated hypothesis above, the ARDL bounds test model was estimated as follows:

$$\Delta InInfl = \alpha_{01} + \sum_{i=1}^{p} \alpha_{11} \Delta\, InInfl_{t-i} + \sum_{i=1}^{q} \alpha_{21} \Delta\, InTemp_{t-i} + \sum_{i=1}^{q} \alpha_{31} \Delta\, InAgro_{t-i} + \sum_{i=1}^{q} \alpha_{41}\, \Delta InF\_pro_{t-i} + \sum_{i=1}^{q} \alpha_{51} \Delta InM2_{t-i} + \sum_{i=1}^{q} \alpha_{61} \Delta InRiR_{t-i} + \sum_{i=1}^{q} \alpha_{71} \Delta\, InC02_{t-i} + \beta_{11} InInfl_{t-1} + \beta_{21} InTemp_{t-1} + \beta_{31} InAgro_{t-1} + \beta_{41} InF\_pro_{t-1} + \beta_{51} InM2_{t-1} + \beta_{61} InRiR_{t-1} + \beta_{71} InCO2_{t-1} + \mu_{t1} \quad (3.2)$$

Since this is a long-run relationship, all variables were expected to be cointegrated. If cointegration exists among the variables, the Error correction model was used to capture both the long run and short run dynamics, specified as follows:

$$\Delta InInfl = \alpha_{01} + \sum_{i=1}^{p} \alpha_1 \Delta\, InInfl_{t-i} + \sum_{i=1}^{q} \alpha_2 \Delta\, InTemp_{t-i} + \sum_{i=1}^{q} \alpha_3\, \Delta InAgro_{t-i} + \sum_{i=1}^{q} \alpha_4 \Delta InF\_pro_{t-i} + \sum_{i=1}^{q} \alpha_5 \Delta InM2_{t-i} + \sum_{i=1}^{q} \alpha_6 \Delta InRiR_{t-i} + \sum_{i=1}^{q} \alpha_7 \Delta InC02_{t-i} + \lambda ECT_{t-1} + e_{1t} \quad (3.3)$$

Where; Δ represents the first differences, γ is the error correction term that represents the speed of adjustment toward the long-run equilibrium, ECT_{t-1} is the lagged residual from the cointegration equation, which corrects the short-term deviation from the long-run equilibrium. From the estimated ECM model the diagnostic tests, such as the LM autocorrelation test by Breusch Godfrey LM, the test for heteroskedasticity by Breusch-Pegan-Godfrey the normality test by Jarque-Bera, Ramsey RESET test for model specification and the CUSUM and CUSUMSQ tests for parameter stability. These were used to ensure that the model is valid and robust.

4. Study Results and Analysis

This section presented and interpreted the empirical results obtained from the Autoregressive Distributed Lag (ARDL) model estimated to assess the impact of extreme climate change on inflationary dynamics in South Africa over the period 1970-2023. The analysis began with the unit root test, followed by the lag length selection criteria. The next section presented the cointegration test using the bounds testing approach to determine the existence of a long-run relationship among the variables. This was followed by a detailed discussion of the existence of long run relationships among the variables. Furthermore, the error correction model was examined to evaluate the speed at which the system returns to equilibrium following short-run disturbances. Lastly, diagnostics and stability tests were performed to ensure the reliability and robustness of the estimated model.

4.1. Unit root tests

At Levels I(0)							
Test	**Infl**	**Temp**	**Agro**	**F_pro**	**M2_money**	**RiR**	**C02**
ADF test	0.1030	0.0001***	0.0000***	0.9822	0.7713	0.0154*	0.9894
P-P test	0.1280	0.0001***	0.0000***	0.3983	0.7353	0.0126*	0.9894
At first dif I(1)							
Test	**Infl**	**Temp**	**Agro**	**F_pro**	**M2_money**	**RiR**	**C02**

ADF test	0.0001***	0.0001***	0.0000****	0.0000****	0.0000****	0.0000****	0.0000***
P-P test	0.0000****	0.0000****	0.0001***	0.0000****	0.0000****	0.0000****	0.0001***

Source: Author's compilation

The table above showed the results of the unit root tests applied in the study, namely, the Augmented Dicky- Fuller (ADF) and the Phillip-Perron tests. From the tests it is seen that most of the variables are stationary after the first difference I (1) except for temperature, real interest and agricultural output. The three variables are stationary at levels I (0). This means we reject the Null hypothesis of non-stationarity among the variables. Moreover, all the variables are stationary at first difference I (1) as represented by the probabilities <5%. This makes it possible for the study to proceed with the ARDL bounds test.

4.2. Lag length selection criteria

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	-1213.799	NA	2.97e+15	55.49086	55.77471	55.59612
1	-988.9228	397.9790*	1.03e+12*	47.49649	49.76728*	48.33861*
2	-951.2439	49.66771	2.04e+12	48.01109	52.26881	49.69006
3	-889.3313	61.91257	1.86e+12	47.42415	53.66881	49.73997
4	-814.6888	50.89259	1.84e+12	46.25858*	54.49019	49.31126

Source: Author's compilation

From the unit root test results in table 4.1 above, it is seen that the inflation, food production, M2 money growth and C02 emissions are stationary at first difference, while, temperature, agriculture output and real interest rates are stationary at levels. The study performed the optimal lag length selection criteria presented in table 4.2. The results of the Sequential Modified Likelihood Ratio Test Statistic (LR), Final Prediction Error (FPE), Shwarz Information Criteria (SC) and Hannan-Quin Information Criteria (HQ) tests selected 1 lag to be used on the model. The Akaike Information Criteria (AIC) on the other hand revealed that 4 lags can be used on the model, with the lowest value of 46.2585, making it the most appropriate lag selection for the study. The study, therefore, used the AIC selection criteria, with 4 lags selected for the ARDL model. The study continued to perform the ARDL bounds test for cointegration with the results presented below.

4.3. ARDL Bounds test results

NULL HYPOTHESIS: NO LEVELS RELATIONSHIP

TEST STATISTICS	Value	Significance.	I(0)	I(1)
F-STATISTICS	5.293964	10%	2.53	3.59
K	6	5%	2.87	4
		2.5%	3.19	4.38
		1%	3.6	4.9
TEST STATISTICS	Value	Significance.	I(0)	I(1)
T-STATISTICS	-7.858938	10%	-3.13	-4.37
		5%	-3.41	-4.69
		2.5%	-3.19	-4.96
		1%	-3.96	-5.31

Source: Author's compilation

After the optimal lag was selected, the study employed the ARDL bounds test approach to test for cointegration in the model, using both the f-statistics and t-statistics test. The results of the ARDL bounds test above confirmed the existence of cointegration within the model. With the F-statistical value of 5.293964. The value is higher than the bound values at I(0) and I(1) at significant levels 10%, 5%, 2.5%, and 1% respectively. This means that the null hypothesis (H0) of no cointegration can therefore be, be rejected and we can therefore proceed with the long-run ARDL model. In addition, the t-statistical value, -7.858938 is lower than the I(0) and I(1) values at 10%, 5%, 2.5%, and 1% respectively, further confirming the presence of cointegration among the variables on the model. With the presence of cointegration confirmed, the study was able to proceed testing the presence of the long-run and the short-run models. The long run model results are given as below.

4.4. ARDL Long-run Results

Variables	Coefficients	Std.Error	t-statistics	Prob
Temp	0.017121	0.00739	2.316698	0.0457
Agro	-0.767672	0.280661	-2.833600	0.0251
F_Pro	0.731653	0.278592	2.626253	0.0275
M2	-1.177702	0.205156	-5.740522	0.0003
RiR	-0.245319	0.320120	-0.766333	0.4631
C02	0.275299	0.051629	5.332216	0.0005

Source: Author's compilation

From the ARDL bounds test results above, the long-run ARDL model was estimated to establish the long run relationship among the variables. The results of the ARDL model confirm the existence of a long run cointegration between inflation and the following variables: temperature, agricultural output, food production, money supply, real interest rate and carbon dioxide emissions. In addition, temperature (Temp) showed a positive and significant effect on inflation (p=0.0457), suggesting that rising temperatures drive inflationary pressures, likely through food and energy prices. These results are consistent with the study by Li et al. (2023) which also confirmed a positive association between temperature change and inflation. In addition, food production (F_pro) also showed a positive long-run effect on inflation (p=0.0275). This may reflect that rising temperatures drive inflationary pressures, likely through food and energy prices.

Furthermore, agricultural output (Agro) shows a significant negative effect (p=0.0251) on inflation, indicating that increases in agricultural output helps reduce inflation, possibly by easing food supply constraints. These findings align with the study by Iliyasu et al. (2023) which shows that climate change tends to reduce real output from its potential level and increase food and general consumer prices across countries. The observed dynamics in the South African context confirm that climate change variability impacts on only output but also transmit inflationary effects through disruptions in food and resource availability.

Broad money supply (M2) is strongly negatively significant (p=0.0003), suggesting that money supply growth suppresses inflation in the long run, which may reflect financial deepening or other structural effects in the South Africa context. C02 emissions have a strong positive long run effect on inflation (p=0.0005), highlighting the potential inflationary costs of environmental degradation and carbon-intensive industries. Lastly, the real interest rate (RiR) is not significant in the long run, (p=0,4631), showing a statistically insignificant negative impact on inflation.

4.5. ARDL Short-run model

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Cointeq(-1)	-0.760415	0.096758	-7.858938	0.0000
D (Infl (-3))	0.252961	0.092081	2.747160	0.0226
D (Temp (-1))	-0.015132	0.001587	-9.533892	0.0000
D (Temp (-2))	-0.016486	0.001944	-8.482449	0.0000
D (Temp (-3))	-0.009652	0.001660	-5.813263	0.0000
D (Agro (-1))	0.570123	0.051853	10.99420	0.0000
D (Agro(-2))	0.434041	0.042379	10.24178	0.0000
D (Agro (-3))	0.126291	0.021970	5.748460	0.0000
D (F_pr(-1))	-0.309513	0.087868	-3.522460	0.0065
D (F_pro (-3))	0.287876	0.093127	3.091223	0.0129
D (M2 (-1))	0.557882	0.102890	5.422103	0.0004
D (M2 (-2))	0.571551	0.114494	4.991991	0.0007
D (RiR)	-0.188974	0.065352	-2.891625	0.0178
D (C02)	-0.037567	0.013690	-2744119	0.0227
D (C02 (-1)	-0.253712	0.032166	-7.887706	0.0000
D (C02 (-2)	-0.176779	0.023988	-7.369516	0.0000

D (C02 (-3))	-0.132706	0.019519	-6.797852	0.0001

Source: Author's compilation

The table above summarizes the short-run dynamics, and the error correction results from the ARDL model examining the impact of climate change on inflation and macroeconomic policy of the central bank in South Africa. The error correction term (ECT) coefficient is -0,760415 (p=0,0000), indicating a strong and statistically significant adjustment mechanism. About 76 per cent of inflationary disequilibrium is corrected annually, confirming a stable and long-run relationship. In addition, lagged inflation (D (INFL (-3)) = 0,252961 shows mild persistence. The past temperature anomalies (lags 1-3) all reduce inflation significantly in the short run for example, (D (TEMP (-1)) =-0,015132, P=0,0000, possibly due to delayed demand or supply responses. The results align with the study by Qi et al. (2025), which also supports the short-run inflationary impact of climate change, noting that climate variability can significantly increase the inflation rate in the short-run.

The agricultural output lag 1-3 have a significant positive impact on inflation, for example, (D (AGRO (-1)) = 0,570123, p=0,0000, indicating short-run inflationary impacts, potentially from cyclical production. Aligning with the study by Yusifzada (2024), which highlighted that climate change significantly impacts agricultural production. Food production effects were mixed, lag 1 is negative (-0,309513, p=0,0065) and lag 3 is positive (0.287876, p=0.00129), reflecting time-varying food supply dynamics. Real money supply lags 1-2 increases inflation, consistent with monetary expansion. Furthermore, real interest rate showed a significantly negative effect (D(RiR) = -0.188974, p=0.0178), suggesting that tightening policy helps reduce inflation. Lastly, the C02 emissions of carbon dioxide showed a negative effect on inflation in all lags, possibly due to deflationary effects of environmental damage. Overall, inflation in South Africa responds significantly to both climate and macroeconomic shocks in the short run.

4.6. Diagnostic Test

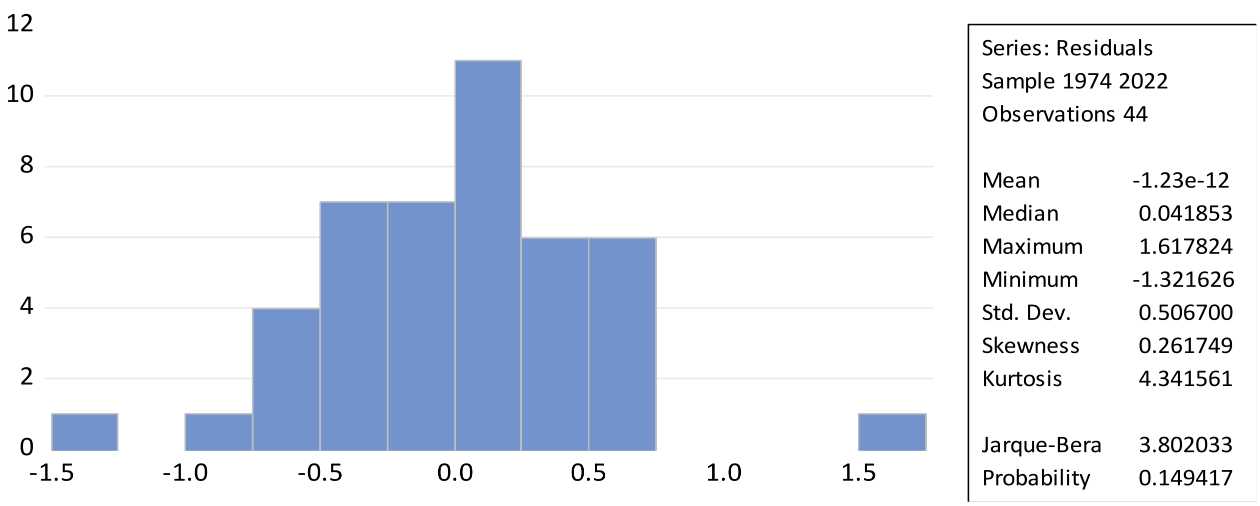
Test	**Prob (lag 1)**
Serial Correlation LM test	0.2658
Heteroscedasticity White Test	0.7017

Ramsey Reset test stability	0.6304

Source: Author's compilation

The table above shows the results for the diagnostic tests conducted in the study, including the test for serial correlation, the test for heteroscedasticity and the test for stability. The LM test for serial correlation has a probability value of 0,2658, above 0,05, which means that we fail to reject the null hypothesis of no serial correlation and conclude that there is no serial correlation in the model. The White test for heteroscedasticity showed a probability of 0,7017 confirming that no heteroscedasticity exists in the model and the null hypothesis of no heteroscedasticity is therefore accepted. The Ramsey reset test for stability also confirmed that the model was correctly specified to test the relationship between climate change and inflationary expectations and the null hypothesis was, therefore, accepted.

Figure 4.1: Jarque-Bera Normality test Histogram



Source: Author's compilation

The histogram above shows the results of the Jarque-Bera test for normality. The test showed a p-value of 0.149417, which is above 0,05 or 5 per cent. These results meant that the null hypothesis that the model residuals are normally distributed cannot be rejected. This therefore meant that the residuals of the model were indeed normally distributed and consistent with the linear model. The study preceded with the CUSUM and the CUSUMSQ tests as presented below.

Figure 4.2: CUSUM TEST

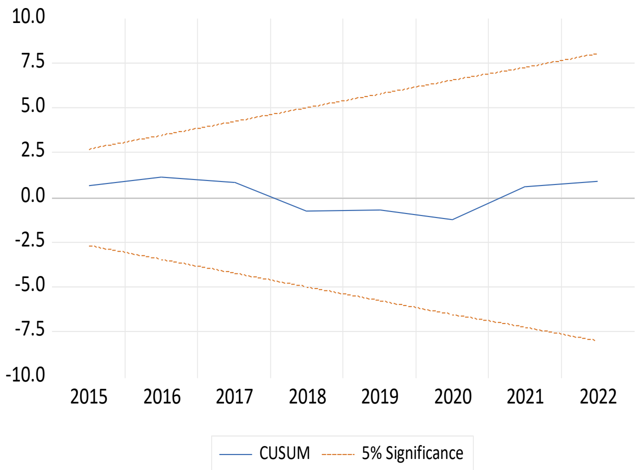
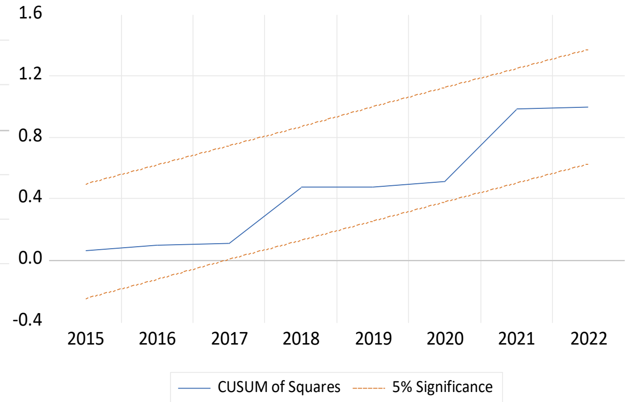


Figure 4.3: CUSUMSQ TEST



The CUSUM and the CUSUMSQ tests were conducted to assess the structural stability of the ARDL model over the sample period. The results from the plots showed that the recursive residuals, as represented by the blue line, lie within the 5 per cent significance bounds for both tests. The blue trend line in both tests drifts upwards and downwards without overshooting the 5 percent (red lines) meaning the residuals are stable for the period under study. This therefore indicates that the model is structurally stable and there are no significant parameter instabilities over time.

5. Conclusions and recommendations

The study examined the impact of climate change on inflation in South Africa and its potential influence on macroeconomic policy by the central bank. The ADF and P-P unit root tests are conducted to verify stationarity among the variables and all the variables are found to be stationary at first difference I (1). From the confirmed lack of unit root among the variables, the study proceeded with the optimal lag length criterion selection and found the AIC criteria to be suitable with four lags selected. The ARDL bounds test was conducted to detect the existence of cointegration among the variables and confirmed cointegration within the model. Moreover, from the confirmed cointegration, study conducted the ARDL long run test and found a positive long run relationship between temperature and inflation rate in South Africa. The positive relationship is also detected among the other variables, including food production showing an increase in food production results in inflationary pressures. In addition, a positive correlation was detected between inflation and C02 emissions, which shows that C02 emissions of carbon dioxide increase inflation in South Africa, highlighting the potential inflationary costs of environmental degradation.

The relationship between agricultural output and inflation is negative, confirming that the increase in agricultural production reduces inflation in the country. In addition, the study confirmed a negative relationship between inflation and broad money supply, indicating that money growth suppresses inflation in the long run. However, a less significant negative long-term relationship was detected between inflation and real interest rates. In the short run, inflation dynamics are shaped by both macroeconomic factors and climate-related variables. The significant and negative error correction model confirms that the system adjusts rapid to the long run equilibrium after short-term shocks. However, the mixed sometimes counterintuitive short run effects, such as the C02 emissions reducing inflation, highlight the need for deeper understanding of environmental disruptions and their economic consequences.

From the empirical evidence above, the following recommendations are suggested to the policy makers. Firstly, given that both temperature increases and C02 emissions are inflationary, climate change policy should be treated as a macroeconomic stability tool. In other words, South Africa could benefit from strengthening green industrial policy and investing in climate-resilient infrastructure and promoting carbon tax frameworks that manage emissions without exacerbating inflationary pressures. In addition, transitioning to a low-carbon economy may assist in reducing inflationary pressures in the long-run by promoting more sustainable production methods. This may involve encouraging the development of green finance and support of investments in renewable energy, climate friendly infrastructure and sustainable agriculture. The central bank should consider incorporating climate-related risks into the monetary policy framework. This may include adjusting the interest rates in response to weather-related supply shocks.

Second, the model finds that agricultural output reduces inflation, while food production increases it. This may reflect the need to improve efficiency and accessibility of agricultural output. In addition, investing in storage, logistics, and food value chains to convert increased production into lower consumer prices. The central bank can also collaborate with the government to strengthen the resilience in the agricultural sector. This may include investment in climate-resilient farming practices, promoting agricultural innovation or encouraging financial support for farmers to adopt technologies that reduce vulnerability to climate change. Lastly, the Broad money supply (M2) has a consistent disinflationary effect in both the short run and the long run, suggesting that monetary policy should remain proactive, possibly through measures that enhance financial inclusion and credit market efficiency. In addition, monetary policy should also consider interaction with climate shocks, especially in setting inflation targets and adjusting rates. In other words, managing money supply more effectively can help curb excess inflationary pressures that come during climate-related supply chain disruptions

In conclusion, the study aimed to examine the impact of climate change on inflation in South Africa and its influence on monetary policy frameworks and found a long run positive relationship between inflation and climate change. Overall, the study contributes to the growing body of literature linking climate change to macroeconomic performance, emphasizing the need for integrated climate-economic policymaking. The study acknowledges some limitations to the study, including the use of variables such as real interest rates instead of nominal interest rates and the methodologies adopted. Future research should consider the use of other variables such as the role of repo rate, world food prices and other methodologies to further examine this relationship.

References

Ayinde, O.E., Muchie, M. and Olatunji, G.B., 2011. Effect of climate change on agricultural productivity in Nigeria: A co-integration model approach. Journal of Human Ecology, 35(3), pp.189-194.

Bast, J.L., 2010. Seven theories of climate change. Chicago: Heartland Institute.

Batten, S., Sowerbutts, R. and Tanaka, M., 2020. Climate change: Macroeconomic impact and implications for monetary policy. Ecological, societal, and technological risks and the financial sector, pp.13-38.

Boneva, L. and Ferrucci, G., 2022. Inflation and climate change: the role of climate variables in inflation forecasting and macro modelling.

Boneva, L., Ferrucci, G. and Mongelli, F.P., 2022. Climate change and central banks: what role for monetary policy?. Climate Policy, 22(6), pp.770-787.

Cevik, M.S. and Jalles, J.T., 2023. Eye of the storm: the impact of climate shocks on inflation and growth. International Monetary Fund.

Ciccarelli, M., Kuik, F. and Martínez Hernández, C., 2023. The outlook is mixed: the asymmetric effects of weather shocks on inflation. Research Bulletin, 111.

Dafermos, Y., Nikolaidi, M. and Galanis, G., 2018. Climate change, financial stability and monetary policy. Ecological Economics, 152, pp.219-234.

Drudi, F., Moench, E., Holthausen, C., Weber, P.F., Ferrucci, G., Setzer, R., Nino, V.D., Barbiero, F., Faccia, D., Breitenfellner, A. and Faiella, I., 2021. Climate change and monetary policy in the euro area.

Economides, G. and Xepapadeas, A., 2018. Monetary policy under climate change (No. 7021). CESifo Working Paper.

Faccia, D., Parker, M. and Stracca, L., 2021. Feeling the heat: extreme temperatures and price stability.

Fiddaman, T.S., 1997. Feedback complexity in integrated climate-economy models (Doctoral dissertation, Massachusetts Institute of Technology).

Iliyasu, J., Mamman, S.O. and Ahmed, U.A., 2023. Impact of climate change on output and inflation in Africa's largest economies. Climate and Development, 15(10), pp.864-875.

Ichoku, H., Anthony, I., Olushola, T. and Martins, A., 2023. Modelling Dynamic Linkage between Climate Change and Food Inflation in Nigeria. International Journal of Environment and Climate Change, 13(11), pp.1200-1217.

Kahneman, D. and Tversky, A., 2013. Prospect theory: An analysis of decision under risk. In Handbook of the fundamentals of financial decision making: Part I (pp. 99-127).

Kaika, D. and Zervas, E., 2013. The Environmental Kuznets Curve (EKC) theory—Part A: Concept, causes and the CO2 emissions case. Energy policy, 62, pp.1392-1402.

Kousar, S., Sabir, S.A., Ahmed, F. and Bojnec, Š., 2022. Climate Change, Exchange Rate, Twin Deficit, and Energy Inflation: Application of VAR Model. Energies, 15(20), p.7663.

Kunawotor, M.E., Bokpin, G.A., Asuming, P.O. and Amoateng, K.A., 2022. The impacts of extreme weather events on inflation and the implications for monetary policy in Africa. Progress in Development Studies, 22(2), pp.130-148.

Li, C., Zhang, X. and He, J., 2023. Impact of Climate Change on Inflation in 26 Selected Countries. Sustainability, 15(17), p.13108.

Moessner, R., 2022. Evidence on climate policy, carbon dioxide emissions and inflation. International Journal of Global Warming, 28(2), pp.136-151.

Mukherjee, K. and Ouattara, B., 2021. Climate and monetary policy: do temperature shocks lead to inflationary pressures?. Climatic change, 167(3), p.32.

Odongo, M.T., Misati, R.N., Kamau, A.W. and Kisingu, K.N., 2022. Climate change and inflation in Eastern and Southern Africa. Sustainability, 14(22), p.14764.

Qi, C., Ma, Y., Du, M., Ma, X., Xu, Y. and Zhou, X., 2025. Impacts of climate change on inflation: An analysis based on long- and short-term effects and pass-through mechanisms. International Review of Economics & Finance, 98, p.103846.

Rudebusch, G.D., 2019. Climate change and the Federal Reserve. FRBSF Economic Letter, 9(March 2019).

USAID. 2023. South Africa climate change country profile. Available from https://www.usaid.gov/climate/country-profiles/south-africa.

Wahidah, N.L. and Antriyandarti, E., 2021, April. Impact of climate change and Coronavirus Disease (COVID-19) on inflation in Indonesia. In IOP Conference Series: Earth and Environmental Science (Vol. 724, No. 1, p. 012105). IOP Publishing.

World Bank, 2021., Climate Risk Country Profile: South Africa. Available from https://climateknowledgeportal.worldbank.org/sites/default/files/country-profiles/15932-WB_South%20Africa%20Country%20Profile-WEB.pdf

Yusifzada, T., 2024. Evaluating the global impact of climate change on agricultural inflation: An innovative climate condition index approach. Environment, Development and Sustainability, 26(7), pp.18411-18438.

Zhang, Z., 2023. Are climate risks helpful for understanding inflation in BRICS countries?. Finance Research Letters, 58, p.104441.