COMESA

# THE NEW FRONTIERS OF ECONOMIC STABILITY

**Climate Impacts,**
**Sovereign Exposure,**
**and Policy Responses**
**in COMESA Countries**




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# Foreword

Climate change and the sovereign-bank nexus have emerged as central concerns for the economic and financial stability of COMESA countries. Extreme weather events such as droughts, floods, and cyclones increasingly disrupt agriculture, energy production, and trade, creating persistent inflationary pressures and volatility in economic output. These climate-induced shocks not only affect households and businesses but also challenge the conduct of monetary and fiscal policy, highlighting the vulnerability of economies with shallow financial markets and high reliance on agriculture.

At the same time, banks in the region hold significant amounts of government debt, directly linking fiscal health to the stability of the financial sector. This interconnection can propagate and amplify shocks to the sovereign, the banking sector and the financial system. Climate change has further heightened these sovereign- financial system risks. Understanding these dynamics is critical, as the combined effects of climate shocks and sovereign-bank linkages influence inflation, output, credit availability, financial system stability and overall economic resilience.

This book brings together evidence from selected COMESA member countries examining how climate change affects inflation and output, while simultaneously exploring the sovereign-bank nexus and its implications for financial stability. For policymakers, researchers, and practitioners, the insights presented underscore the urgency of rethinking policy mandates and instruments to respond effectively to climate-related shocks, as well as the need to confront climate change not only as an environmental threat but as a central determinant of economic stability, long-term growth, and financial resilience. The findings also highlight opportunities for policy and institutional innovation, ranging from climate-sensitive monetary policy frameworks and sovereign risk stress testing to the integration of climate metrics into macroprudential regulation.

The analysis presented herein contributes to the evolving discourse and is expected to play an important role in informing policies that shape economic decision-making. It is my hope that readers will gain insights required to address the unprecedented fiscal, financial sector and climate change challenges to the economy.

**Lucas Njoroge (PhD)**
Director
COMESA Monetary Institute

# Executive Summary

Climate change is no longer viewed as a distant ecological concern but a core macro-financial issue shaping inflation dynamics, fiscal sustainability, asset valuations, and the stability of financial systems. In the COMESA region, climate risk has emerged as a critical determinant of economic stability and development. Countries in the region are increasingly exposed to extreme weather events such as droughts, floods, and cyclones, which disrupt agricultural production, energy supply, and trade flows, with significant implications for inflation and the conduct of monetary policy.

To assess the impact of climate change in COMESA countries, an analysis of its implications on inflation and output was conducted using diverse approaches across five countries in the region. Evidence from the studies on Malawi, Uganda, and the Democratic Republic of Congo (DRC) consistently indicates that climate change and climate-related shocks have significant macroeconomic effects, although the effects vary across sectors and countries. In Malawi, adverse climate conditions increase both food and headline inflation, highlighting the sensitivity of prices to weather variability. In Uganda, climate shocks lead to persistent increases in inflation alongside temporarily reductions in GDP, suggesting prolonged price pressures but short-lived output losses. In the DRC, extreme weather events adversely affect agriculture and mining, amplifying financial sector vulnerabilities through higher non-performing loans, while elevated $CO_2$ levels may enhance agricultural production for certain crops.

In the Middle East and North Africa (MENA) region including Egypt, climate shocks significantly affect inflation, while their impact on economic growth is largely insignificant. This underscores the need for central banks to integrate climate considerations into monetary policy and macroprudential frameworks to better manage climate-induced inflationary pressures. In Mauritius, rainfall and temperature shocks have notable effects on output and prices: rainfall shocks reduce both output and inflation, while temperature shocks lead to a temporary increase in the output gap followed by a persistent decline, alongside lower inflation.

Together, these findings highlight the structural vulnerability of COMESA economies to climate risks and emphasize the need to integrate climate considerations into central banks' policy frameworks. Incorporating climate-related variables into inflation forecasting tools would allow central banks to better capture climate-induced inflationary pressures and improve policy calibration. Beyond monetary policy, coordinated macroeconomic and structural responses are essential, including scaling up investments in climate-resilient infrastructure and promoting agricultural practices that mitigate the economic impacts of climate variability.

Climate-related shocks not only influence inflation and growth dynamics but also place additional strain on public finances and balance sheets, highlighting the importance of understanding the sovereign–bank nexus as a key channel of systemic risk in COMESA economies.

In these countries, banks often hold substantial amounts of government debt, directly linking fiscal health to financial stability. Many COMESA economies are characterized by shallow financial markets, high public debt levels, and vulnerability to external shocks, making the sovereign-bank relationship particularly important. Stress in either the banking sector or sovereign finances can therefore propagate rapidly, amplifying systemic risks. Examining this nexus provides policymakers with critical insights to design appropriate exposure limits, strengthen regulatory frameworks, and safeguard both fiscal and financial stability. Accordingly, empirical studies based on data from four COMESA countries were undertaken to shed light on the dynamics of the sovereign-bank nexus in the region.

The findings from these studies reveal heterogenous effects of banks' holdings of government securities on financial stability across countries. In Eswatini, government securities strengthen capital adequacy and profitability but reduce liquidity, with inflation and exchange rate volatility adversely affecting bank profits. In Rwanda, banks' exposure to sovereign debt is relatively limited, resulting in negligible effects of government securities on loan loss provisions; however, higher government bond yields are associated with lower provisions, whereas higher lending rates increase them. In Uganda, banks, particularly primary dealers, show sensitivity to short-term market volatility and interest rates movements, with significant crowding-out effects on private sector credit, highlighting the need for exposure limits and enhanced stress testing frameworks. In Zambia, a bi-directional relationship exists between banking sector stress and sovereign stress, with each reinforcing the other over time. Overall, the evidence underscores the importance of regulating sovereign exposures, promoting portfolio diversification, strengthening capital buffers, and maintaining fiscal discipline to safeguard financial stability.

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# Introduction

# 1. Introduction

## 1.1 Background

Sub-Saharan Africa (SSA), and the COMESA region in particular, faces an increasingly complex policy environment shaped by intensifying climate shocks, rising fiscal pressures, and heightened financial vulnerabilities. Economies remain heavily dependent on climate-sensitive sectors, while public balance sheets and financial systems are under growing strain. In this context, understanding the interactions between climate risks, macroeconomic stability, and sovereign vulnerabilities has become critical for informed and effective policymaking.

The chapters in this book convey a clear message: climate risks and sovereign vulnerabilities are mutually reinforcing and managing them requires integrated and coordinated policy responses. The first part of the book examines the impact of climate change on monetary policy, illustrating how climate-related shocks are reshaping traditional macroeconomic relationships. In the COMESA region, where agriculture constitutes a significant share of output and employment, extreme weather events frequently disrupt food supply, trigger price spikes, and destabilize inflation expectations. These shocks complicate the task of central banks, which must balance inflation control with the need to support economic growth and maintain financial stability. The analysis shows that climate risk is no longer a peripheral concern; it directly affects output, inflation volatility, and the transmission of monetary policy. As a result, central banks in the region increasingly require tools that incorporate climate considerations into forecasting models, risk assessments, and policy communication.
The second part of the book focuses on sovereign risk exposure and macroprudential policy, highlighting the growing interconnectedness between public debt dynamics and financial-sector stability. Many COMESA countries have experienced a rapid accumulation of public debt, with commercial banks holding a substantial share of government securities. While this provides governments with a readily accessible source of domestic financing, it also heightens the exposure of banking systems to sovereign stress. Deteriorating fiscal conditions can quickly spill over into credit markets, liquidity conditions, and broader financial stability. The analysis underscores the need for more comprehensive macroprudential frameworks that explicitly account for sovereign exposures, strengthen stress-testing capabilities, and enhance coordination among central banks, ministries of finance, and financial regulators.

"The chapters in this book convey a clear message: climate risks and sovereign vulnerabilities are mutually reinforcing and managing them requires integrated and coordinated policy responses.

## 1.2 Chapters in the Outline

### 1.2.1. The Impact of Climate Change on Inflation in Malawi

This study examined the macroeconomic impact of climate change on inflation and the role of the central bank in Malawi. 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. The study recommends scaling up investment in climate-resilient infrastructure.

### 1.2.2. The Macroeconomic Impact of Climate Change and the Role of the Central Bank of Congo

This study investigated the impact of climate change on the economy of the DRC by applying descriptive and a non-linear autoregressive distributed lag model to monthly data from 1990 to 2021. Specifically, the study analyzed the trends between indicators of climate change and financial stability and estimated the impact of carbon dioxide emissions on agricultural production. The descriptive analysis showed that climate shocks, particularly extreme weather events, adversely affect the agricultural and mining sectors and increase non-performing loans, which is a threat to financial systemic stability. However, the econometric results show a positive relationship between $CO_2$ and agricultural production both in the short run and in the long run, implying that elevated $CO_2$ levels enhance agricultural production. Thus, calling for proactive monetary and prudential measures by the Central Bank of Congo to mitigate climate-related financial risks and ensure balanced monetary policy actions, given the non-uniform effects of climate change on the agriculture sector. Additionally, the DRC authorities should integrate climate stress tests, adjust macroprudential measures, and regularly update their models to enhance the financial sector's resilience to these climate risks. Increased regulation of climate risk disclosures is also necessary, and regulators should mandate financial institutions to publish reports detailing their exposure to climate risks.


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### 1.2.3. Impact of Climate Shocks on Inflation and GDP: Evidence from Uganda

This study examined the impact of climate shocks on headline inflation and real GDP in Uganda. The study used quarterly data for 2000–2022 and applied vector autoregression frameworks on macroeconomic and climate change indicators. The results showed that climate shocks significantly affect both inflation and output. Headline inflation responds persistently, indicating prolonged price instability after climate disturbances. In contrast, the effect on GDP is transitory, reflecting a temporary decline in economic activity. These patterns highlight Uganda's structural vulnerability to climate risks. The findings underscore the need for the Bank of Uganda to incorporate climate risk factors into its modelling and policy frameworks to improve the effectiveness of monetary policy. Beyond macroeconomic policies, this study emphasizes the importance of building resilience through targeted investments in irrigation systems and drought-resistant crop varieties. Such measures are essential for mitigating the economic costs of climate variability and safeguarding long-term stability.

### 1.2.4. The Impact of Climate Change on Macroeconomic Situation of the MENA Region and its Implications on Monetary and Macroprudential Policies

This paper investigated the impact of climate change on key macroeconomic variables in the MENA countries. A vector autoregressive approach was employed to assess the effect of climate disasters on growth and inflation in the MENA countries using panel data from 1990 to 2022. The econometric analysis was separately conducted on the entire sample of countries and sub-samples of data split into high and low-income countries. The findings show that climate shocks have a significant effect on inflation, particularly in low-income countries, while their impact on growth is insignificant. Based on the findings of the paper, central banks must incorporate the climate aspect into their monetary policy and macroprudential frameworks to better address inflationary pressures.

### 1.2.5. Macroeconomic Impact of Climate Change and the Role of Central Bank in Mauritius

Climate change is increasingly viewed as a complex and dynamic issue that has a wide-ranging macroeconomic impact. This study applies the Structural Vector Autoregression methodology to investigate the consequences of climate change on key macroeconomic variables in Mauritius using time series data extending from 2005Q1 to 2022Q4. Rainfall and temperature are identified as climate indicators. Empirical results point to an adverse impact of rainfall on output and prices. Results for temperature slightly differ but are still aligned with empirical findings. Output gap rises initially but declines thereafter and remains persistently negative while inflation declines. The underlying results emphasize the urgency for monetary policy reactions to maintain price stability. The macroeconomic repercussions of climate change stress the need for a faster transition to a green economy by designing adequate climate policies in order to strengthen the economy's resilience and achieve sustainable economic growth.

## 1.2.6. Assessing the Sovereign-Bank Nexus: The Case of Eswatini

This study explored the sovereign-bank nexus in Eswatini and assessed how the interaction between sovereign debt and the domestic banking sector influences financial stability. The nexus, characterized by banks' significant holdings of government securities, creates potential vulnerabilities by linking sovereign and banking risks. Although widely analyzed in advanced economies, evidence from smaller developing countries like Eswatini remains scarce, despite their unique challenges of shallow financial markets, high refinancing risks, and exposure to external shocks. Using quarterly data from 2014–2023 and an Autoregressive Distributed Lag model, the study estimated the effects of sovereign debt exposure on banks' capital adequacy, liquidity, and profitability. The findings show that government securities bolster capital adequacy and profitability but weaken liquidity in the long term. Inflation and exchange rate volatility reduce profitability, while interest rates improve the capital adequacy ratio. The results highlight liquidity risks as public debt rises, recommending diversification, stricter exposure limits, stronger credit infrastructure, and fiscal discipline to protect stability.

## 1.2.7. Sovereign Exposure Risk and Macroprudential Policy in Uganda

The study analyzed the sovereign-bank nexus in Uganda using an approach that decomposed the aggregate impact of market heterogeneity, particularly the distinction between primary and non-primary dealers in the government securities market. The results showed that primary dealers exhibit higher sovereign exposure and are more elastic in response to changes in short-term yields. The study also provides evidence of the crowding-out effect, in which banks' preference for government securities can limit credit availability to the private sector. The study thus proposes that regulators set limits on sovereign debt held by banks, beyond which surcharges should be applied to encourage diversification of bank balance sheets and hence minimize sovereign exposure risk. The study also proposes regular stress testing to assess the resilience of banks to plausible scenarios of sovereign exposure. Finally, introducing dynamic risk ratings for securities, rather than classifying sovereigns as risk-free, will enable regulators to control the direction of sovereign exposure and achieve sound and resilient financial systems.

> "Although widely analyzed in advanced economies, evidence from smaller developing countries like Eswatini remains scarce, despite their unique challenges of shallow financial markets, high refinancing risks, and exposure to external shocks.

### 1.2.8. The Impact of the Sovereign-Bank Nexus on Financial System Stability in Rwanda

This study examines the sovereign-bank nexus on financial system stability in Rwanda, using panel data from nine commercial banks over the period 2014Q3 to 2024Q1. Applying a bias-corrected fixed effects model, the study investigated the impact of banks' holdings of government securities and bond yields as indicators of banks' exposure and preference in government securities, respectively, on financial stability. The main findings reveal that the holding of government securities by banks does not have a statistically significant impact on loan loss provisions, suggesting that the government securities held by banks minimally influence provisions for potential loan losses. In contrast, bond yields have a significantly negative effect on loan loss provisions, as banks perceive government securities as default-risk-free, resulting in lower provisions. Furthermore, lending rates significantly increase loan loss provisions due to higher borrowing costs and perceived risks, while return on assets shows a negative relationship with loan loss provisions, indicating that more profitable banks allocate fewer resources to provisions. Robustness checks suggest an absence of sovereign–bank exposure in the Rwandan banking sector. Nevertheless, to mitigate against such exposures occurring in the future, it would be beneficial for the National Bank of Rwanda to continue implementing prudential policies that optimize the level of sovereign securities held by banks and establish exposure limits to prevent excessive concentrations on their balance sheets, strengthen banking sector stability, and enhance financial market efficiency.

### 1.2.9. Can the sovereign-bank nexus cause financial system distress? Evidence from Zambia

The study examined the sovereign-bank nexus in Zambia using monthly time series data from January 2010 to June 2024 and applied the Granger causality and structural vector autoregression (SVAR) methods. The Granger causality tests indicated that banking sector stress predicts sovereign stress and vice versa. The SVAR results showed that banking sector stress initially worsens sovereign stress for the first four months before easing, while sovereign stress increases banking sector stress from the second to fifth months before subsiding. SVAR results further reveal that sovereign stress is largely driven by its own shocks in the short term, but over time, the contribution of banking sector stress to variations in sovereign stress increases. The findings highlight the close interdependence between the sovereign and banking sectors. Policy recommendations include strengthening capital buffers, revising the regulatory treatment of government securities, and limiting the use of implicit and explicit government guarantees.

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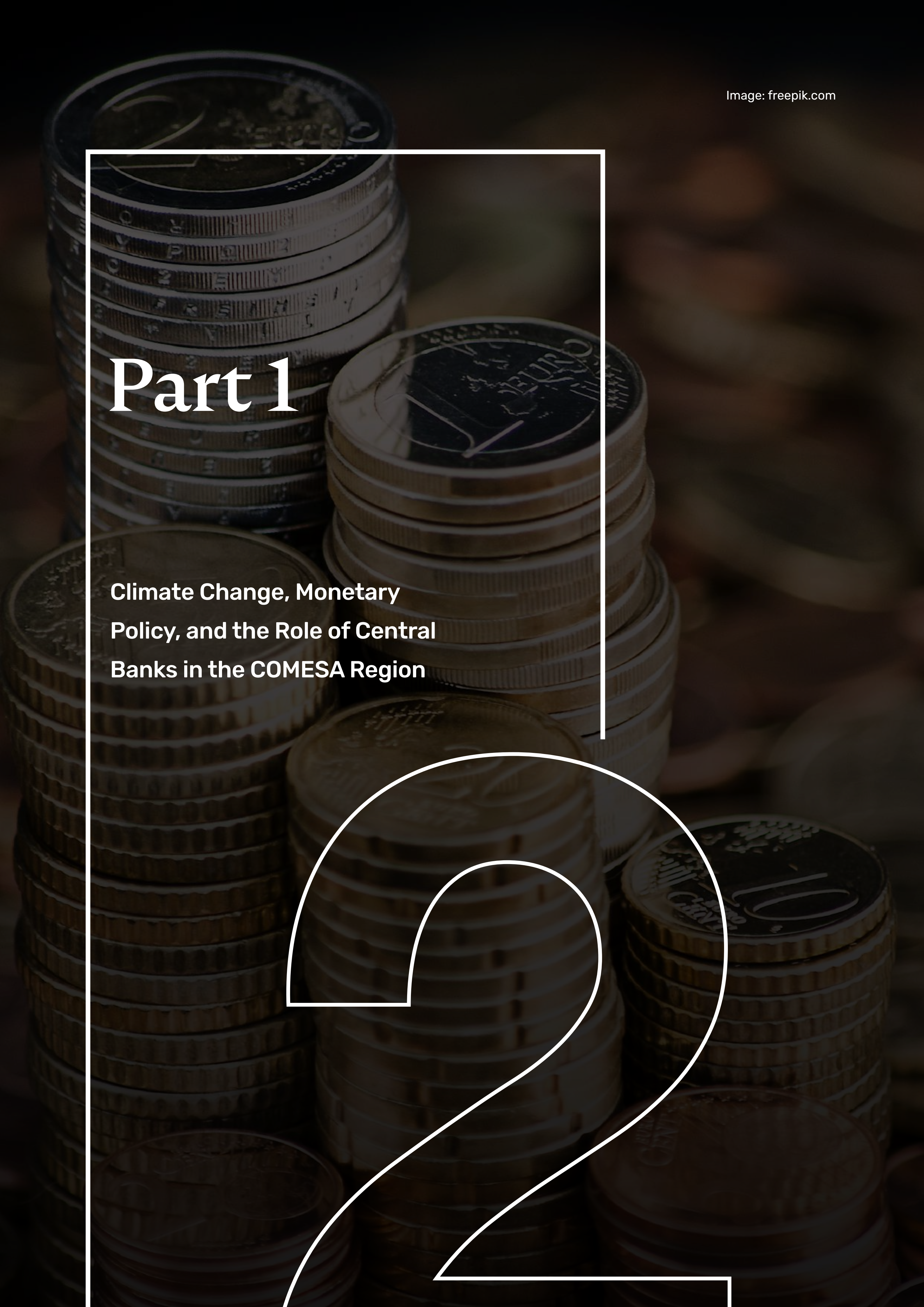

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# Part 1

## Climate Change, Monetary Policy, and the Role of Central Banks in the COMESA Region

## 2.1 The Impact of Climate Change on Inflation in Malawi

*Daucilous Sadala, Marietta Mpingasa Kavalo, and Austin Chiumia*

### 2.1.1 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 the literature, while Section 4 describes the methodology. Section 5 reports and discusses results, and Section 6 concludes with policy recommendations.

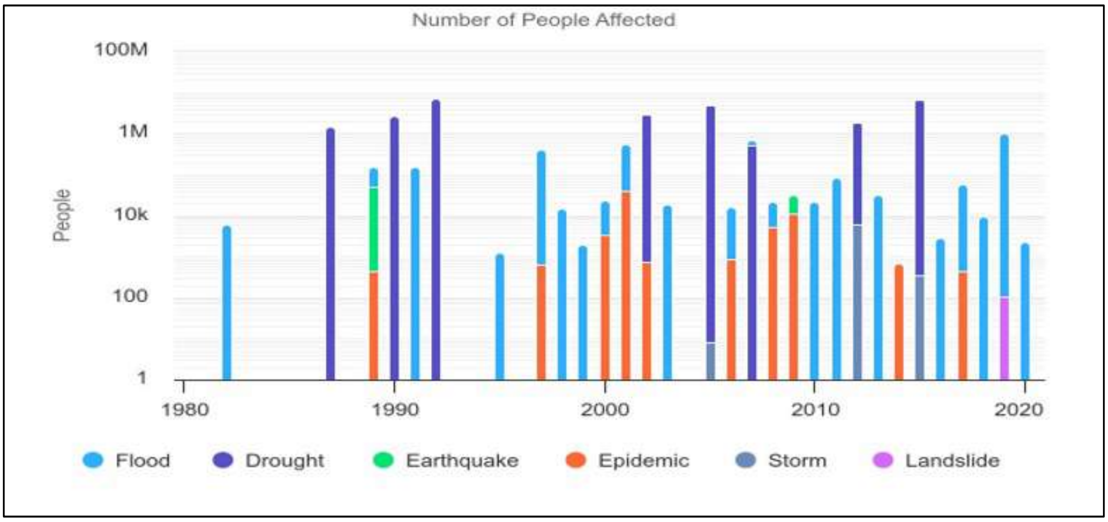
## 2.1.2 Stylized Facts

### 2.1.2.1 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, the 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**

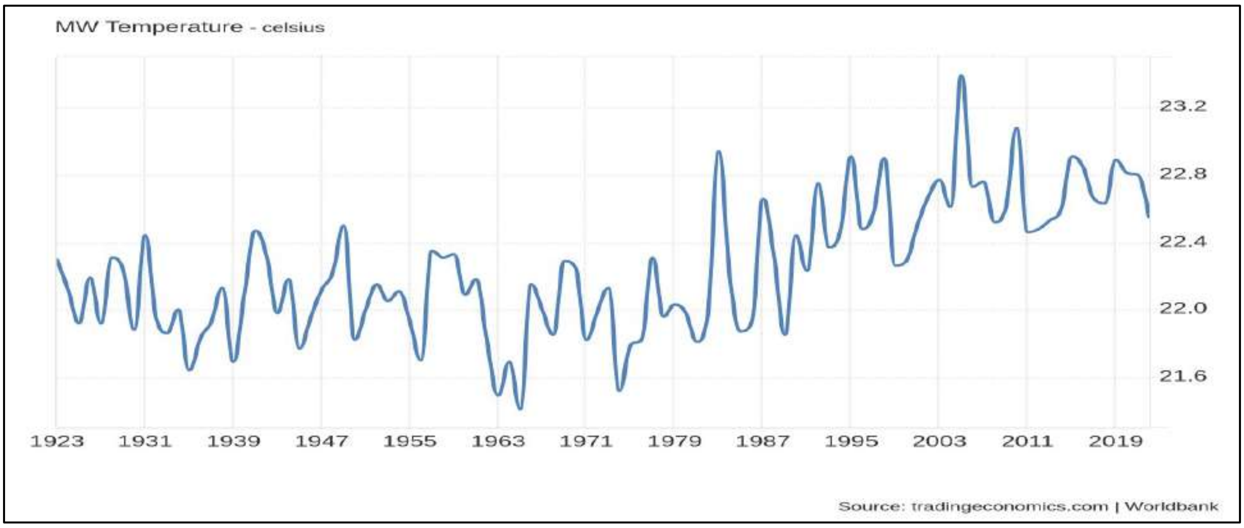



Source: World Bank

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 2060s, and by 1.5 to 5.0°C by the 2090s (World Bank, 2011)

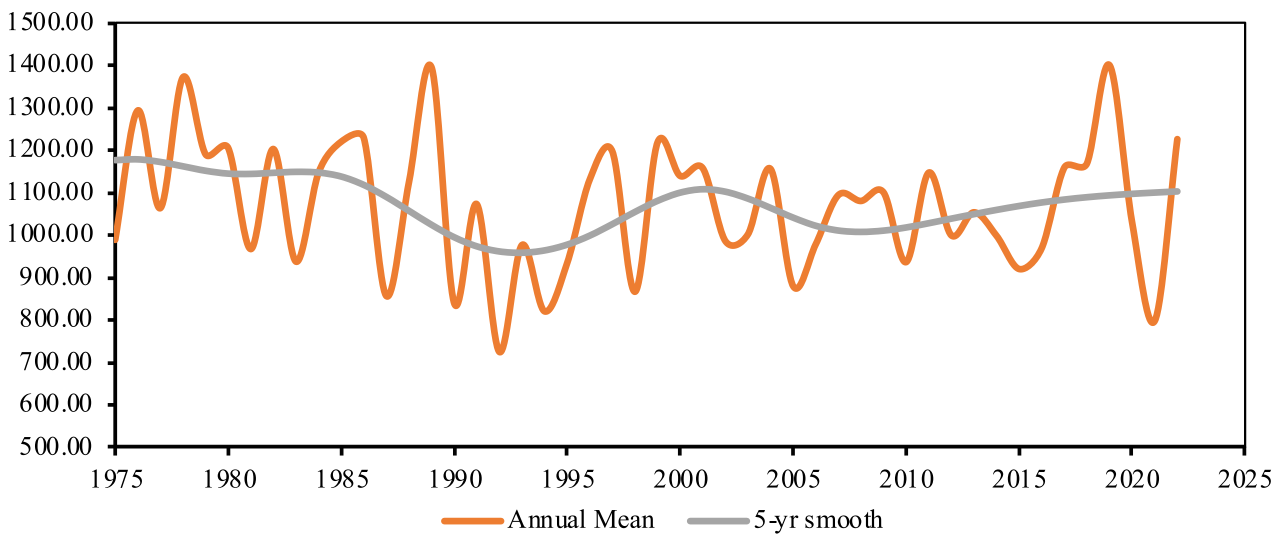
1 A country that is ranked first is the most affected and vulnerable to extreme weather events

**Figure 2: Annual Average Temperature**




The rainy season in Malawi officially starts from October to April. The seasonal 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 the 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

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 translate 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)**

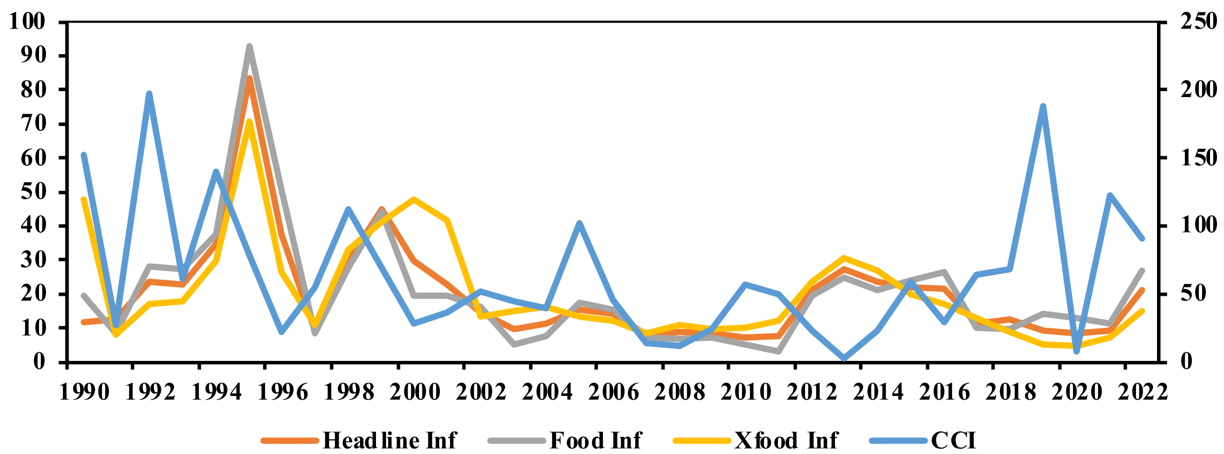
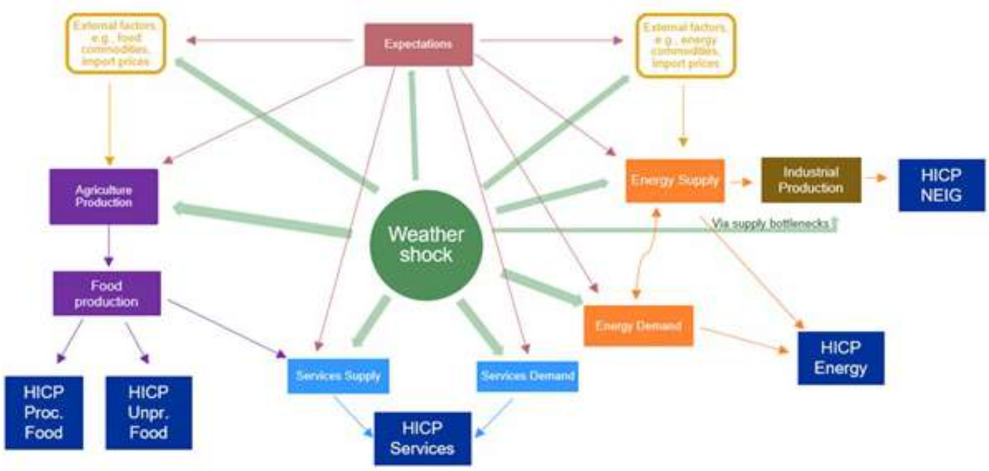



Figure 5 demonstrates possible impact channels from extreme weather and climate to inflation in the context of the key risks. The channels illustrated in Figure 5 cover both the supply and demand side channels, in tandem with evidence provided by Ciccarelli & Marotta (2021) on the possible nature of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

**Figure 5: Channels Linking Weather and Prices**




## 2.1.2.3 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 the 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 QPM 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.

## 2.1.2.4 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 nationally determined contribution to a combined unconditional and conditional contribution of a 51.0 percent reduction in greenhouse 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 the 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.

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## 2.1.3 Literature Review

### 2.1.3.1 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.

### 2.1.3.2 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 Southern African Development Community (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.

## 2.1.4 Methodology and Data

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

$$Inf_t = \beta_0 + \beta_1 CCI_t + \delta_k \sum_{k=1}^{z} X_{kt_k} + \mu_t \text{ ……….. (1)}$$

Where Inf 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' Food and Agriculture Organization. Finally, data on crude oil prices is sourced from the U.S. Energy Information Administration.


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### 2.1.4.1 The Climate Change Index

In line with MEFMI (2023), Faccia et al. (2021), and Sandalli (2021), this study uses temperature and precipitation as climate change variables. Temperature and rainfall data is available on a monthly frequency. To get annual values, the 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:

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

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.

### 2.1.4.2 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.

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

$$\Delta FOOD_t = \gamma_0 + \gamma_1 FOOD_{t-1} + \gamma_2 CCI_{t-1} + \gamma_3 FAO_{t-1} + \gamma_4 Exc_{t-1} + \gamma_5 Outputgap_{t-1} + \sum_{i=1}^{p} \sigma_1 \Delta CCI_{t-i} + \sum_{i=1}^{p} \sigma_2 \Delta(FAO)_{t-i} + \sum_{i=1}^{p} \sigma_3 \Delta(Exc)_{t-i} + \sum_{i=1}^{p} \delta_4 \Delta(Outputgap)_{t-i} + \mu_t \quad \ldots\ldots\ldots..(4)$$

$$\Delta XFOOD_t = \alpha_0 + \alpha_1 XFFOOD_{t-1} + \alpha_2 CCI_{t-1} + \alpha_3 Oil_{t-1} + \alpha_4 Exc_{t-1} + \alpha_5 Fiscal_{t-1} + \sum_{i=1}^{p} {}^{\varphi}{}_1 \Delta CCI_{t-i} + \sum_{i=1}^{p} {}^{\varphi}{}_2 \Delta(OIL)_{t-i} + \sum_{i=1}^{p} {}^{\varphi}{}_3 \Delta(Exc)_{t-i} + \sum_{i=1}^{p} {}^{\varphi}{}_4 \Delta(Fiscal)_{t-i} + \mu_t \quad \ldots\ldots(5)$$

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, $\delta_i$ and $\beta_i$ are short-run and long-run parameters to be estimated, respectively; and $\mu_t$ is the white noise error term.

## 2.1.4.3 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 the annual GDP series. For Malawi, the a priori sign of β5 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 the rising marginal cost of production. So, the a priori sign of β5is 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 Agriculture Organisation. Rising international food prices are expected to directly elevate imported food prices for domestic consumers. Accordingly, β3 is expected to be positive.

The coefficient $\beta 4$ 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, $\beta 4$ 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, $\gamma 3$ is expected to be positive. Similarly, $\gamma 4$ is expected to be positive, while the apriori sign of $\gamma 5$ 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.

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### 2.1.4.4 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 Alkaike 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, & and Stracca, (2021) who established that climate change tends 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.

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Regarding food inflation, these results show that climate change has both short run and long run impact on food 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.

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**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** | | | | | | | |
| **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.Output gap** | | 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 (0.762) | | 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 impacts 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 that 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 and 4. The parameters are stable, and the models do not suffer from autocorrelation or heteroscedasticity, indicating that the estimates obtained are unbiased and consistent, hence reliable and can be used for inference.


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### 2.1.4.5 Robustness Check

The findings from the Structural VAR analysis (results presented in Annex 3) 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.


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### 2.1.5 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, policymakers 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, and 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 the DSGE technique, as well as consideration of analysis that splits the output gap into agriculture and non-agriculture output gaps, subject to the availability of data. This is because climate shocks are propagated directly through agricultural 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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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.

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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.

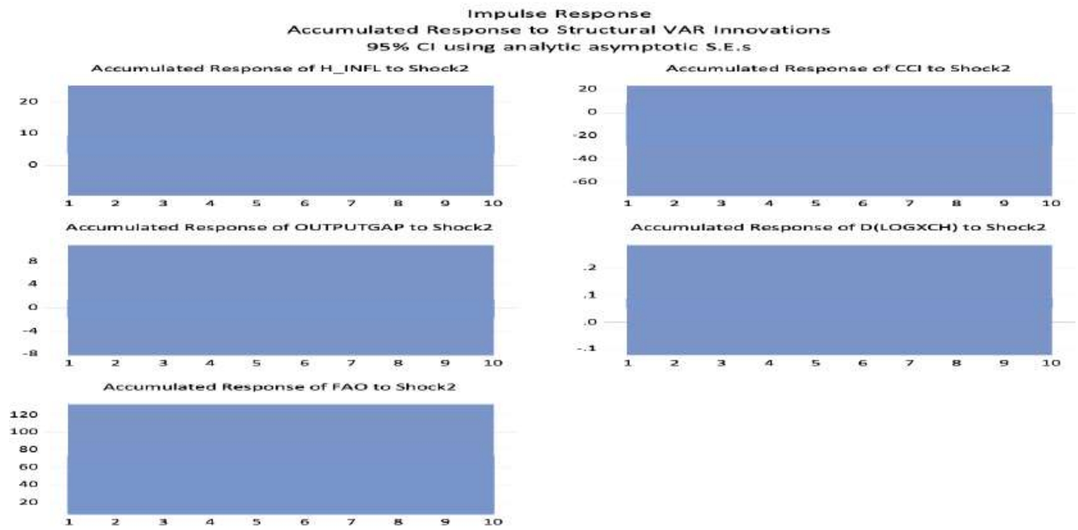
### Annex 2: Diagnostic Test Results

| | 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**

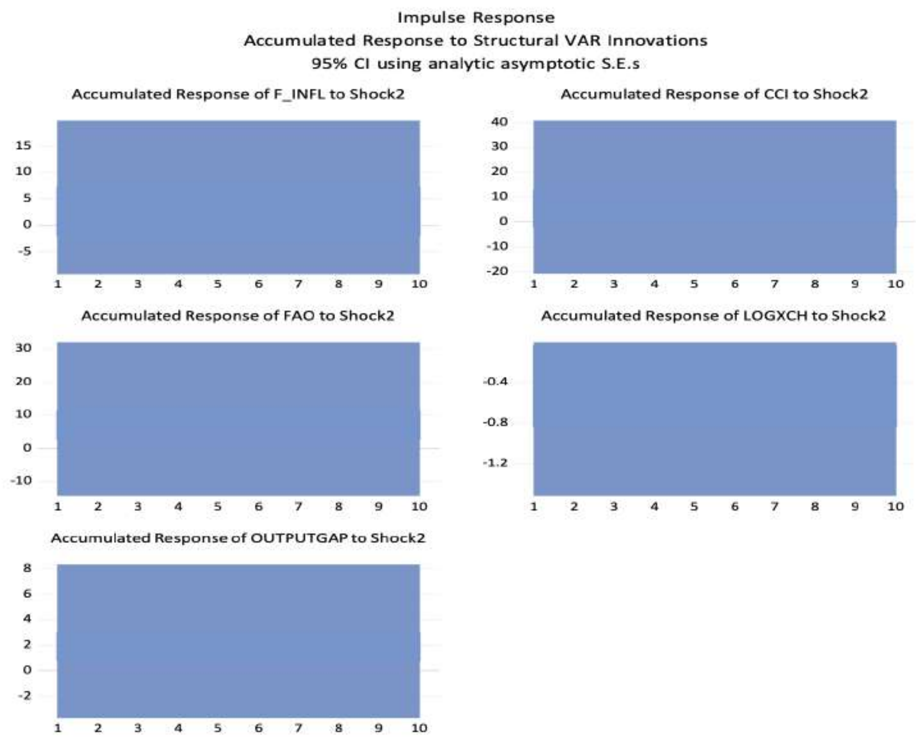
**Headline Inflation Equation**

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



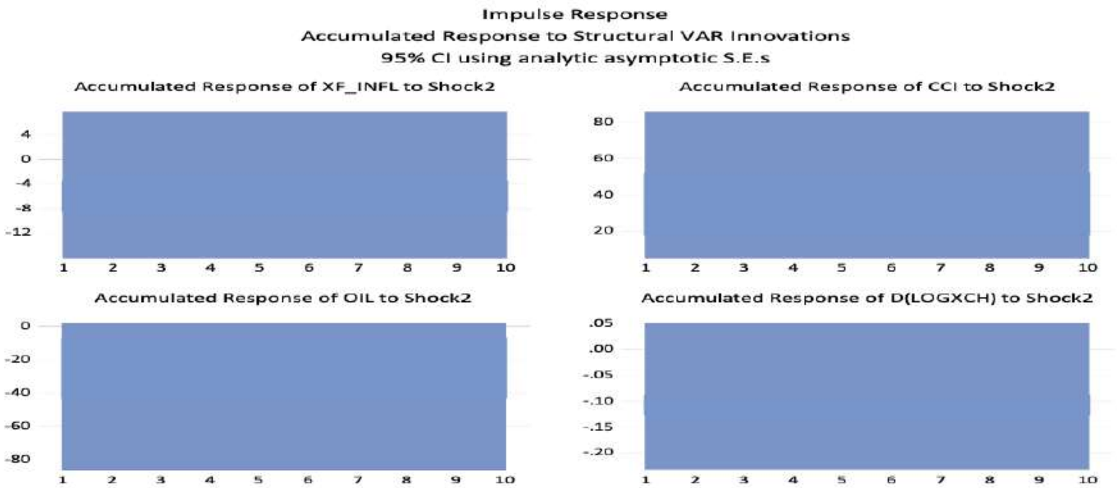

**Food Inflation Equation**

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.



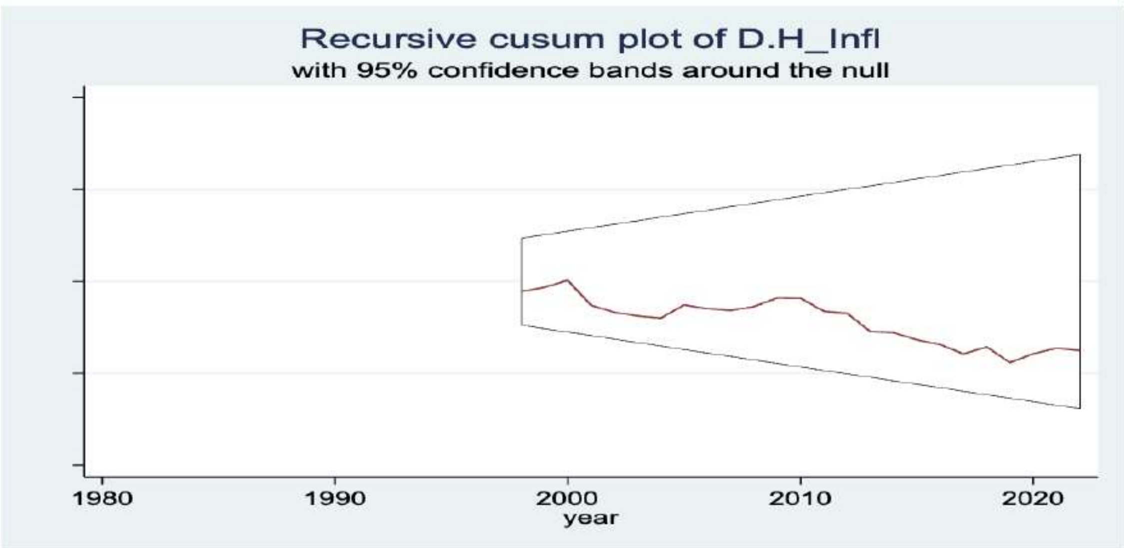
**Non-food Inflation Equation**

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

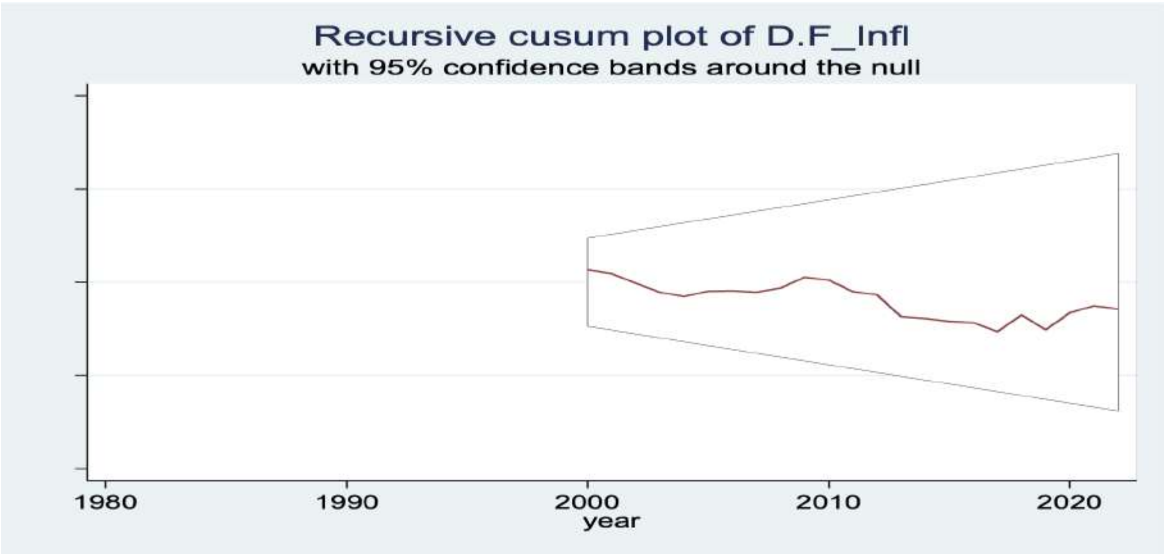



**Annex 4: Model Stability Test Results**

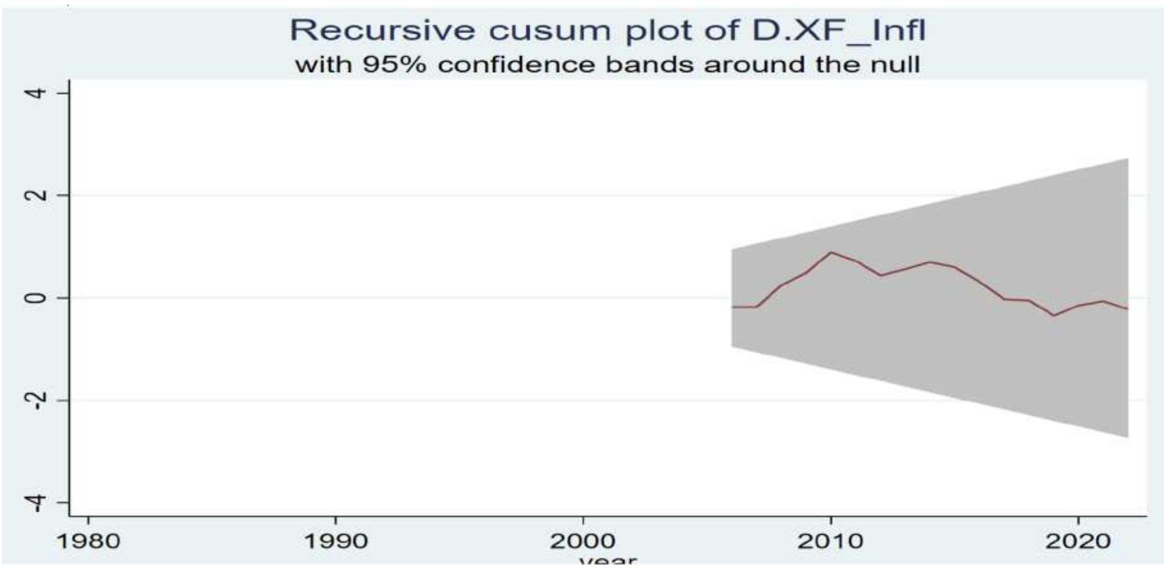
**Headline Inflation**



**Food Inflation**




**Non-Food Inflation**



## 2.2 The Macroeconomic Impact of Climate Change and the Role of the Central Bank of Congo

*Jules Nsunda Ngindu*

### 2.2.1 Introduction

Climate change theories posit that greenhouse gas emissions have led to a rise in global temperatures and extreme weather events over the past fifty years (Hansen, 1981; Hulme, 1996; Adams et al., 1998). These emissions have also impacted the economy by reducing crop yields, productivity, consumption, investment, and output (Dell et al., 2012; Ericksen, 2009). Global temperatures have increased by over 1.1°C relative to pre-industrial averages and could rise up to 4°C in the coming century (IPCC, 2021). This increase is expected to heighten the frequency and severity of weather-related disasters.

In this context, global landscapes are increasingly vulnerable to climate change risks and the associated long-term impact on the global economy, with a disproportionate effect on developing countries. In these countries, mitigation and adaptation strategies remain limited, and they are affected by the variability of their climate risk profiles, geographical heterogeneity, and sector-specific characteristics (BIS, 2021; Koetter et al., 2020; Odongo et al., 2022). The banking sector in these economies is thus exposed to climate risks, regardless of the bank's size, complexity, or economic model. This exposure can be direct, through household balances and climate-sensitive sectors, or indirect, through the effects of climate change on the economy and the financial system at large.

It is crucial to emphasize that the scale of impacts from climate events varies significantly based on the level of economic development of states. Low-income and middle-income countries, including the Democratic Republic of Congo (DRC), despite being less polluting, are generally more susceptible to climate risks. Despite its vast forest potential, representing two-thirds of the Congo Basin's forests, the DRC is ranked as the 5th most vulnerable country to climate change globally, according to the ND-GAIN vulnerability index (2021)[3] . Due to its low level of economic development, the DRC is also among the 10 most exposed countries to major climate risks such as flooding, localized droughts, coastal erosion, and extreme temperatures. Climate change affects the Congolese economy from both the supply and demand sides.

On the supply side, climate events severely disrupt economic activity, particularly in the agricultural sector. Reduced agricultural production leads to higher food prices, which affects the cost of living and deteriorates the trade balance in the case of food imports. Additionally, damage to infrastructure necessitates redirecting expenditures towards reconstruction and replacement, impacting productivity, accelerating capital depreciation, and increasing repair costs.

3 https://gain.nd.eu/.

On the demand side, repair and replacement expenditures for damaged goods and infrastructure increase, while investment and consumption for other goods decrease. This situation weakens households and businesses, with ripple effects throughout the economy. These supply and demand shocks result in opposing trends in production and inflation, creating a trade-off for the Central Bank of Congo (BCC) between stabilizing inflation and stabilizing output fluctuations.

According to various development scenarios as per the World Bank Report for DRC, (World Bank, 2023), if the DRC continues its current growth trajectory, climate change could lead to GDP losses of between 4.7% and 12.9% by 2050, in the absence of adaptation and mitigation policies. In monetary terms, public investments needed to partially offset climate-related risks are estimated at around $2.3 billion by 2030 and $8.5 billion for 2030–2050, totaling at least $10.9 billion by 2050, primarily for building improved infrastructure (new and upgraded roads and bridges), creating cooling options to positively impact health and labor productivity, and reducing flood risks for urban infrastructure and livelihoods.[4] The most significant economic impacts of climate change are expected to stem from thermal stress on rural workers experiencing extreme heat waves, with losses amounting to 4.8% of GDP and potentially reaching 8%, according to the most pessimistic climate scenario. The results of the analysis further highlight the significant impact of adaptation measures in reducing economic damage. By the year 2050, these measures could reduce the impact of climate change on GDP in the most pessimistic climate scenario. Conversely, the absence of such measures would lead to increased budgetary costs.

In response to these challenges, the BCC must integrate climate aspects into its traditional approach to monetary and financial policy. Indeed, the traditional role of the BCC, which includes regulating the money supply, controlling inflation, and preserving financial stability, is now closely linked to managing environmental and climate risks. The central question to examine is: How does climate change influence macroeconomic and financial aggregates in the DRC, and what monetary and prudential policies can the BCC implement? To date, only a few empirical studies have examined the relationship between climate change, macroeconomic aggregates, and monetary policy in the DRC, which makes this study pioneering and unprecedented within the national context. To this end, the objective of this study is to assess the macroeconomic and financial impact of climate change in the DRC, with particular attention to key sectors such as agriculture and mining.

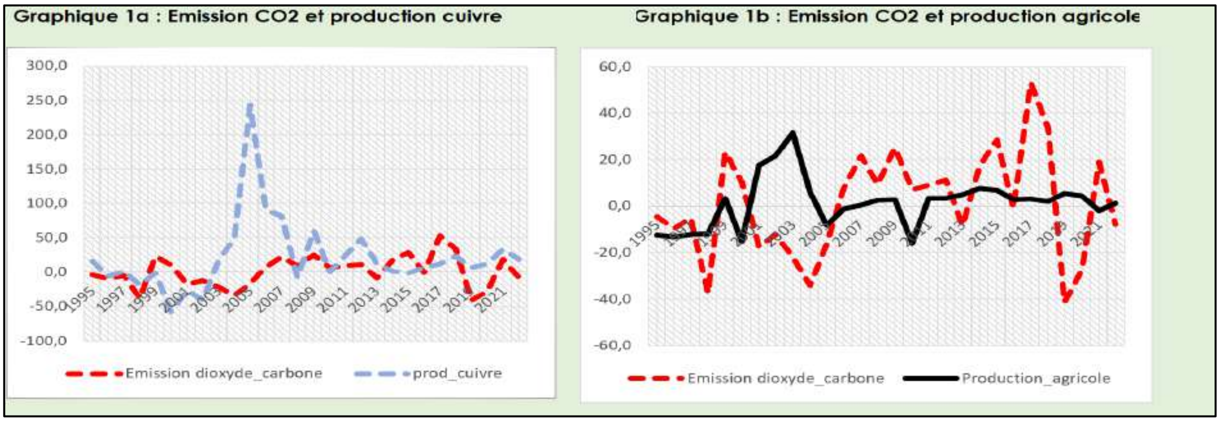
The rest of the study is organized as follows: the next section provides stylized facts on climate change indicators in the DRC, while section 3 presents the literature review. The fourth section focuses on methodology, while the fifth section reports the results and provides policy recommendations.

4 The details are available in the Country Climate and Development Report for the DRC (World Bank, 2023). As per the Report, the macroe-conomic consequences of climate change are evaluated under four distinct scenarios. These scenarios combine two growth trajectories a baseline scenario of maintaining the status quo and an ambitious scenario reflecting accelerated growth with two adaptation options, namely with and without adaptation measures. This approach allows for a comprehensive assessment of the potential impacts of climate change the role of adaptative strategies in mitigating adverse macroeconomic effects

## 2.2.2 Stylized Facts: Climate Change and the Macroeconomy in the DRC

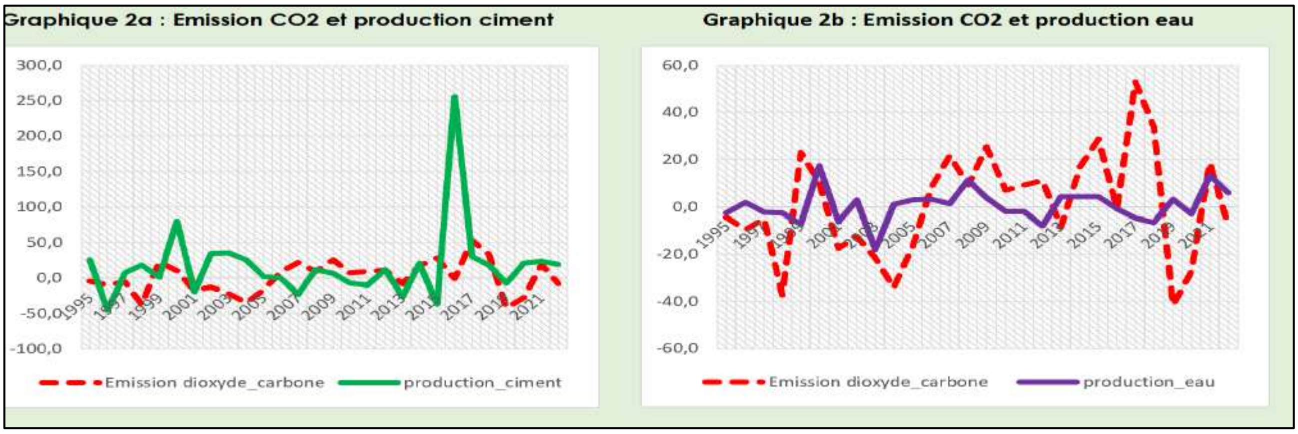
The analysis in Figure 6 shows a mixed pattern of the evolution of the relationship between shocks (CO2) and copper production, but with a bias towards a positive relationship between copper production and CO2 emissions. Similarly, the analysis of stylized facts highlights an inverse relationship between CO2 emissions and agricultural production: as emissions rise, agricultural output tends to decline in the DRC (Figure 6). This decline, by reducing local food supply, exerts upward pressure on food prices. The resulting price increases spill over into overall inflation and weigh on households' purchasing power. They also lead to greater reliance on food imports to cover the production shortfall, thereby worsening trade balance deficits and slowing economic growth. Finally, this situation heightens social vulnerability and the risk of food insecurity, particularly among already fragile rural populations.

**Figure 6: Evolution of CO2 Emissions, Mining Production, and Agricultural Production**




Cement production in the DRC follows a similar trend to CO2 emissions, indicating that the increase in these emissions is closely related to cement production. In contrast, CO2 emissions lead to variability in water production with periods of positive co-movement and negative patterns, particularly in the last decade, indicating the impact of global warming on weather patterns (Figure 7). This link suggests that CO2 emissions may contribute to the scarcity of water resources, affecting both potable water supply and agricultural activities.

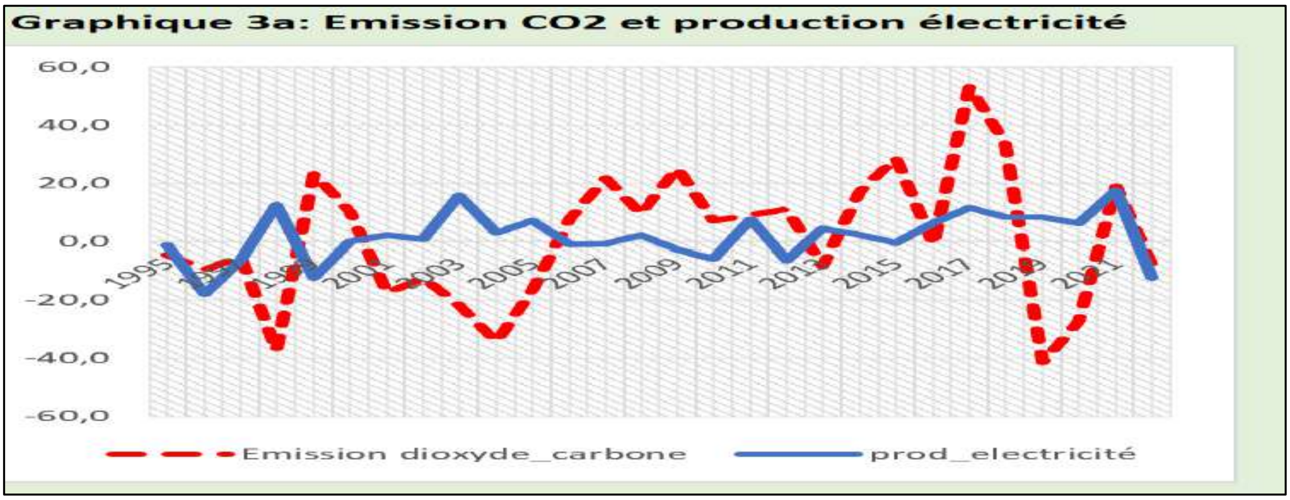
**Figure 7: Evolution of CO2 Emissions, Cement Production, and Water Production**




Source: Author

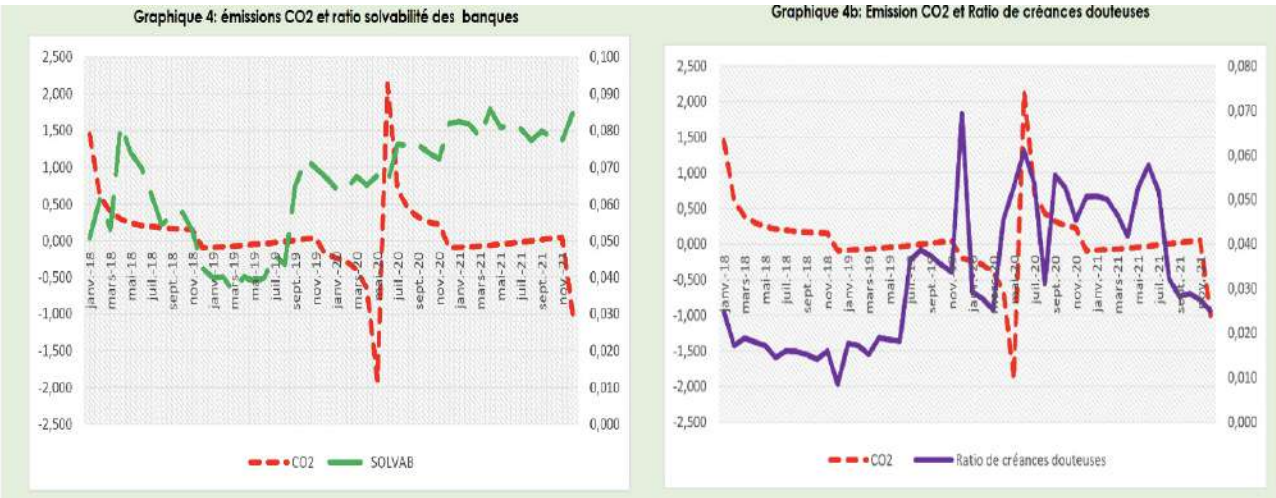
Figure 8 shows a nearly divergent trend between CO2 emissions and electricity production in the DRC, suggesting that climate effects related to CO2 impact electricity production. Fluctuations in water levels caused by droughts or floods reduce the efficiency of hydroelectric dams, thereby disrupting the electricity supply. These disruptions affect not only the electricity sector but also the economic, agricultural, and banking sectors.

**Figure 8: Evolution of CO2 emissions and electricity production**



The trend analysis of indicators of financial stability shows that extreme climatic events have a significant negative impact on key indicators in the banking sector, including the non-performing loan (NPL) ratio (Figure 9 and 10). In this case, events such as droughts, floods, or heatwaves directly affect the agricultural and mining sectors. As a result, household and corporate income decline, leading to a reduction in purchasing power. In turn, lower incomes reduce the ability of businesses and households to service their loans, leading to rising defaults and an increase in the NPL ratio. Consequently, the deterioration of bank balance sheets weakens lending capacity, creating liquidity stress and lowering profitability. Credit contraction slows investment and economic growth, while systemic risks threaten the stability of the financial system.

**Figure 9: Financial Stability Arguments of Climate Change in the DRC**

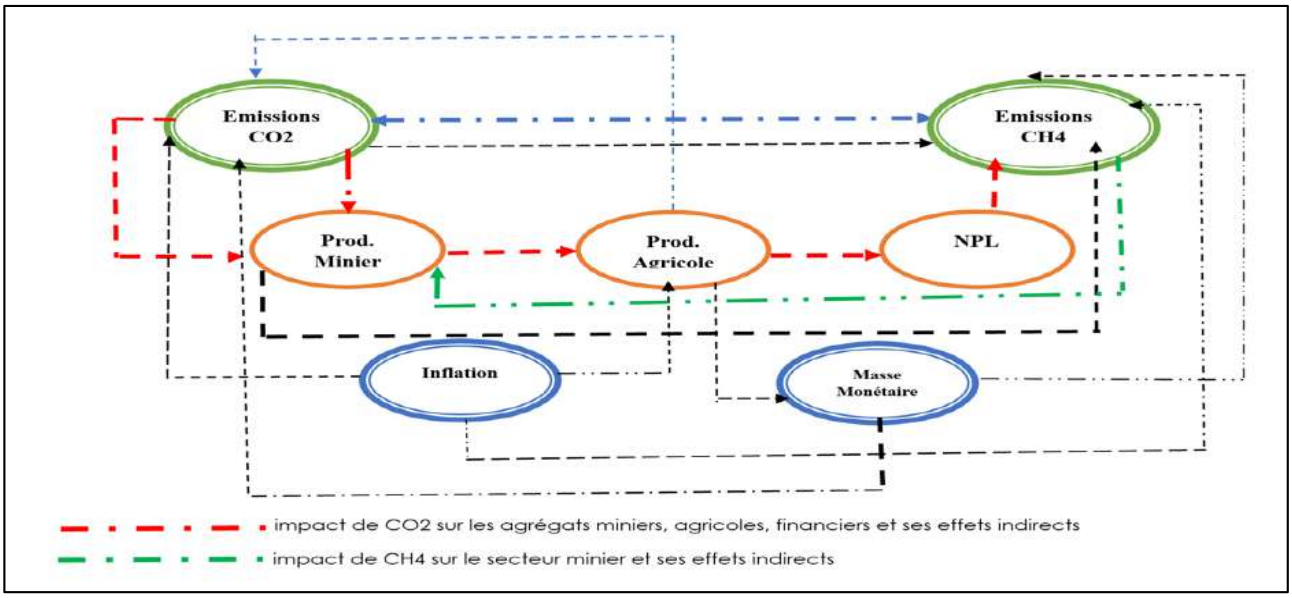



Source: Author

The mechanism of transmission of climate shocks to economic and financial aggregates in the DRC is complex, with interconnected direct and indirect effects across different sectors. CO2 and CH4 emissions interact, mutually amplifying their impact on critical sectors such as agriculture, mining, and banking.

Image: unsplash.com

**Figure 10: Transmission of Climate Shocks to the Agricultural and Banking Sectors**




Source: Author

Figure 11 illustrates how climate shocks affect the real economy and the financial sector, highlighting the transmission mechanisms through physical and transition risks. In DRC, climate shocks like extreme rainfall and floods can damage agricultural production and mining infrastructure. For example, floods in 2022 caused crop losses (maize and cassava) and disrupted mining operations (copper and cobalt exports), leading to higher food prices and reduced export revenues. These disruptions increase inflation, strain household incomes, and raise non-performing loans (NPLs) in local banks, affecting overall economic stability. The interplay of CO2 and CH4 emissions from deforestation and mining exacerbates these challenges, further amplifying the economic and financial risks.

**1. Physical Risks in the DRC:** Direct damage to property, infrastructure, and land leads to significant economic disruptions.

a) In 2019, floods in South Kivu caused agricultural losses estimated at USD 1.2 million, affecting food production and household incomes.[5]

b) In 2020, crop production declined with a reduction of maize yields by 15%. This leads to increased food costs and decreased farmers' incomes in Tanganyika.

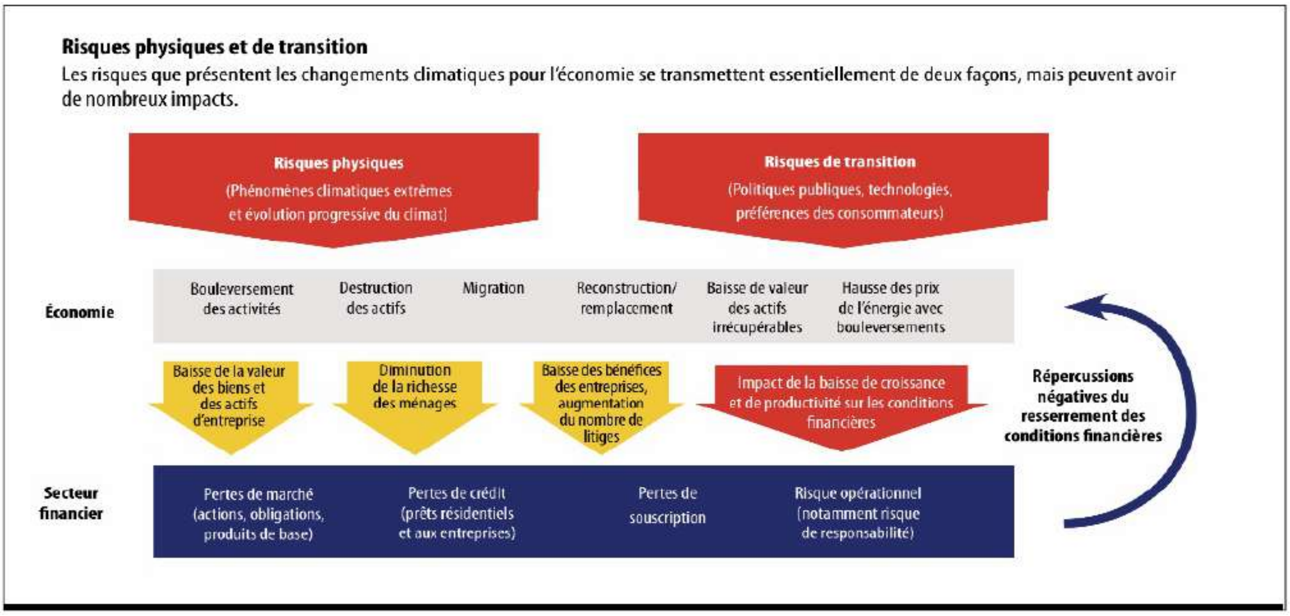
**2. Transition Risks in the DRC:** Changes in climate policies and technologies pose risks to financial assets and the economy:

• Asset Valuation: The transition to greener technologies has negatively impacted the value of investments in the mining sector in the DRC, which represents about 2% of the nation-al GDP.

• In summary, climate shocks in the DRC trigger cascading effects on the real economy and the banking sector, from asset depreciation and reduced household wealth to in-creased non-performing loans and losses on public securities. Proactive management and adaptation of financial policies are crucial to mitigate these impacts.

5 OCHA, Office for the Coordination of Humanitarian Affairs: Analysis of Food Crises in the DRC, 2020.

**Figure 11: Climate Shocks**

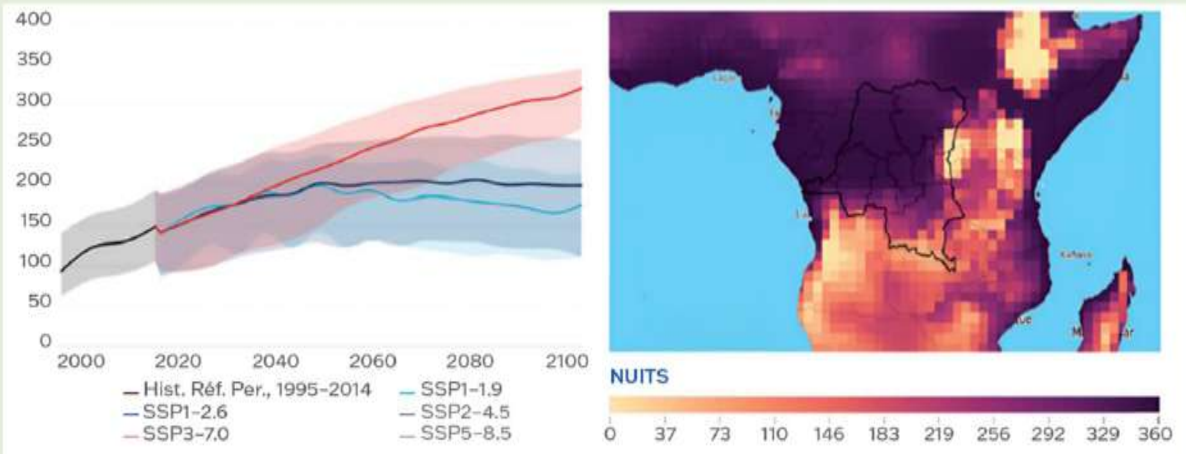



Source: IMF, 2019.

## 2.2.3 Climate Change Challenges in DRC

The DRC is highly vulnerable to climate change and its effects but is poorly prepared to cope with them. Ranked 182nd out of 185, the DRC is the 5th most vulnerable country in the ND-GAIN Index 2021 (ND-GAIN Index, 2021) and one of the least prepared to face the effects of climate change (185th out of 192 countries, ND-GAIN Index, 2021). Located in the Congo River Basin, the country is highly exposed to riverine flooding, particularly during episodes of heavy equatorial rainfall. Yet, despite its many water sources, the risk of forest fires has increased with temperature variations, particularly in regions already prone to drought (IMF, 2023), exacerbating the economic vulnerabilities of the DRC. According to the World Bank (2022), climate disruptions could reduce GDP per capita by 2% to 3% per year by 2050. Extreme phenomena like droughts and floods damage infrastructure, disrupt supply chains, and increase production costs. This economic instability contributes to weaker economic growth and increased vulnerability to global financial crises.

**Figure 12: Forecast and Spatial Distribution of Tropical Nights**




Source : Portail de connaissances sur les changements climatiques — Profil de la RDC, Banque mondiale, 2022

Climate change is affecting agriculture, as well as flooding and the subsequent damage to settlements, roads, communications, and infrastructure. The agricultural sector is likely to face the negative consequences of climate change throughout its entire value chain and workforce, including production, processing, storage, and transportation of crops. Specific details of GHG emissions by sector and the economic and financial impact of climate change are detailed in Tables 2 and 3.

**Table 2: Contribution to GHG Emissions by Sector in the DRC**

| Sector | Contribution to GHG Emissions | Details |
|---|---|---|
| **Land Use Change and Forestry** | Over 90% | This sector is the main contributor to greenhouse gas (GHG) emissions. |
| **Agriculture** | 2.9% to 4.5% | GHG emissions mainly come from bushfires and the burning of agricultural residues. |
| **Energy** | 2.6% to 4.4% | $CO_2$ and $CH_4$ emissions have been increasing since 2004, especially after data from the eastern provinces became available. Other greenhouse gases remain stable. |
| **Waste** | Less than 1% | Minor contribution to GHG emissions. |
| **Industrial Processes** | Negligible (0.1%) | Industrial emissions were 125 Gg $CO_2$-eq in 2000 and reached 264 Gg $CO_2$-eq in 2008. Cement production is the main source of $CO_2$ emissions. Other processes contribute minimally. |
| **Source:** Ministry of Environment and Sustainable Development | | |

This table, based on IPCC data, shows that:

**1. Land Use change and forestry:** Contributes to over 90% of greenhouse gas (GHG) emissions, highlighting the significant impact of deforestation and land-use changes.

**2. Agricultural sector:** Accounts for between 2.9% and 4.5% of emissions, mainly due to bush-fires and the burning of agricultural residues. Although less significant than the forestry sector, it remains an important source of GHGs.

**3. Energy sector:** Contributes between 2.6% and 4.4% of emissions, with an upward trend due to new data from the eastern provinces. An energy transition is crucial to reducing this share.

**4. Waste and industrial processes:** Have a marginal contribution, representing less than 1% and 0.1% of total GHG emissions, respectively.

In summary, the agricultural sector is the main source of CO2 and CH4 emissions, with significant contributions from bushfires and the burning of residues.

**Table 3: Economic and Financial Impacts of Climate Change by Province in the DRC**

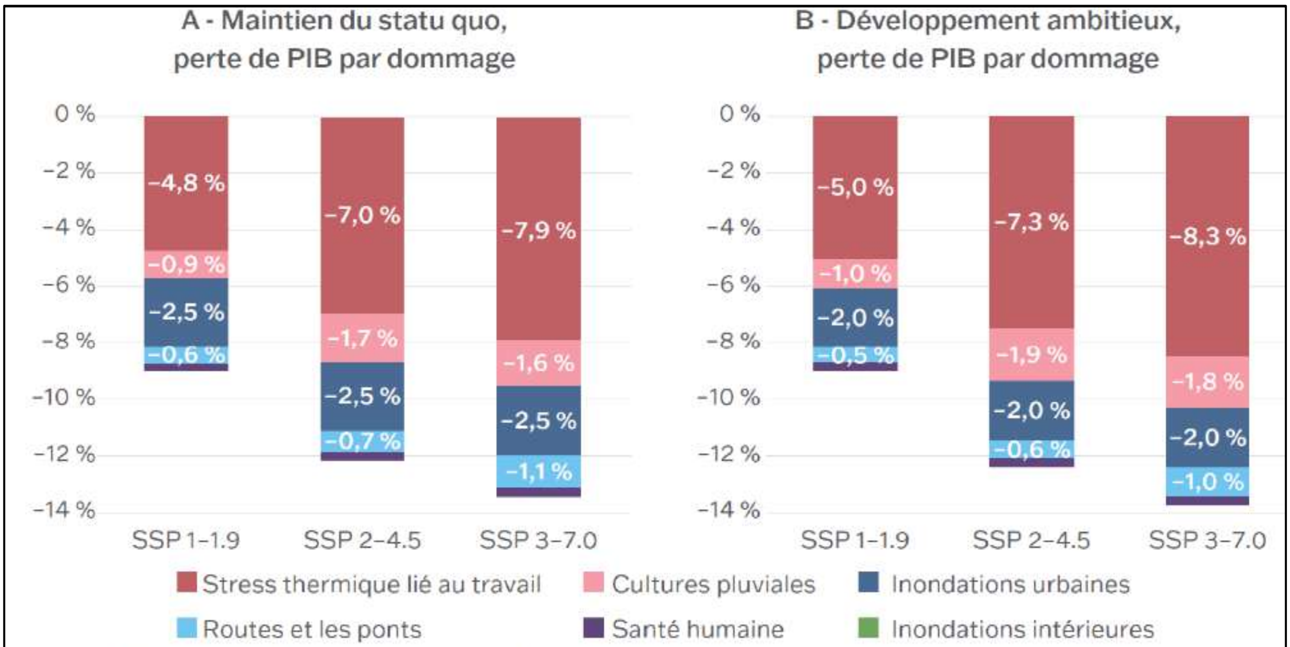
| Region | Impact | Data (Year) | Economic Losses | Sources |
|---|---|---|---|---|
| Bas-Congo | Floods | 2020 | Approximately 100 million USD | Report from the National Observatory of Natural Disasters (ONC), 2021 |
| Coastal Erosion | Projections for 2030 | Potential loss of 15 km² of agricultural land per year | National Institute for Environmental Studies and Research (INERE), 2020 | |
| Ituri and Haut-Uele | Drought | 2019 | Approximately 50 million USD | Ministry of Agriculture of the DRC, 2020 |
| Water Shortages | 2021 | Increased costs for agricultural activities | Report from the Food and Agriculture Organization (FAO), 2021 | |
| Haut-Lomami and Tanganyika | Rainfall Variability | 2021 | Approximately 70 million USD | Report from the National Institute of Statistics (INS), 2022 |
| Impact on Agriculture | Reduction in cassava and maize production | Reduced dependence on food imports | FAO, 2021 | |
| Maniema and South Kivu | Deforestation | 2015-2020 | Approximately 200 million USD in ecosystem services | United Nations Environment Programme (UNEP), 2021 |
| Soil Erosion | 2021 | Loss of 100,000 hectares of forest per year | Institute for Nature Conservation (ICCN), 2021 | |
| Katanga | Changes in Water Resources | 2020 | Approximately 250 million USD | Katanga Chamber of Mines, 2021 |
| Impact on Economic Activities | 2021 | Increased operational costs for extractive companies | Report from the Central Bank of Congo (BCC), 2022 | |
| Savanna (Kasai, Tshopo) | Soil Degradation | 2010-2020 | Approximately 60 million USD per year | INS, 2021 |

## 2.2.4 Cumulative Effect of Climate Risks and Development

The primary consequence of climate change will likely come from hydrological changes that reduce agricultural productivity, access to freshwater resources, and ecosystem degradation. According to various development scenarios, climate change, without adaptation, could result in up to a 13% loss in GDP. The macroeconomic consequences of climate change have been estimated with and without adaptation, under a baseline scenario of maintaining the status quo and an ambitious, faster growth development scenario. The results highlight the significant impact of adaptation measures on reducing economic damage.

Specifically, some adaptation measures could reduce climate change-related economic damage by more than 40%, not only under the status quo scenario but also within a "resilient development" scenario combining adaptation with ambitious development reforms. If not addressed, climate change will impose high costs on the economy and exacerbate household vulnerability. The DRC's economic development and growth will contribute to strengthening overall resilience but will not be sufficient on their own. If the DRC continues its current growth trajectory, climate change could result in GDP losses ranging from 4.7% to 12.9% by 2050, depending on various climate scenarios.

**Figure 13: Losses to GDP under Different Climate Scenarios**

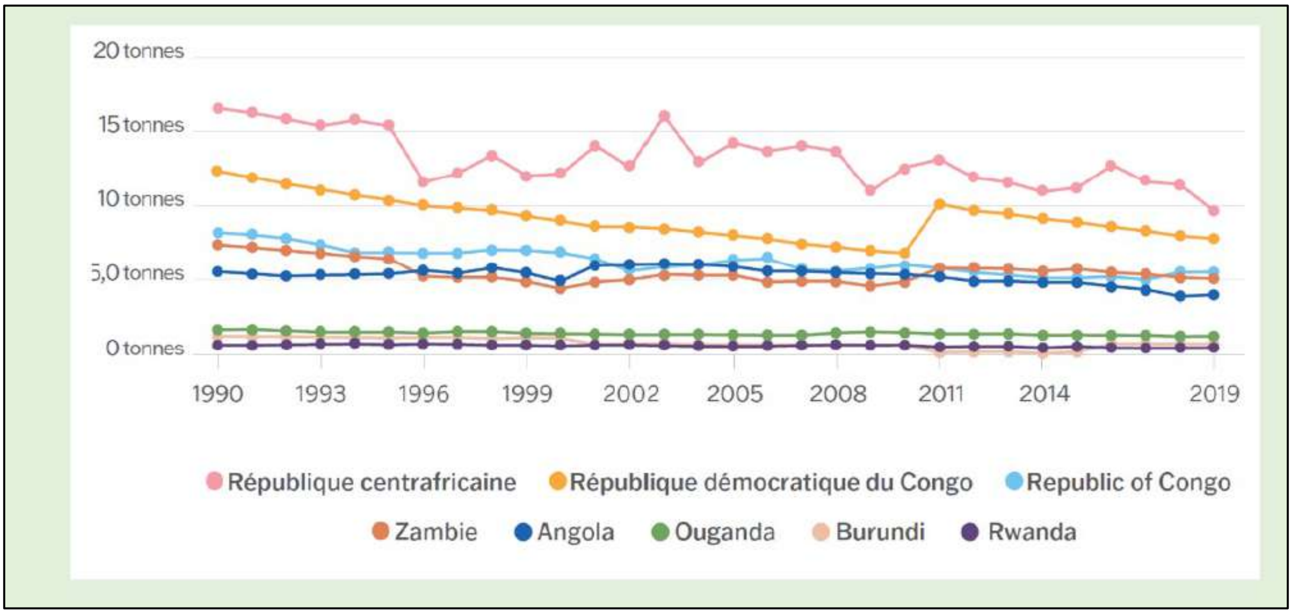



Source : Résultats de la modélisation de la Banque mondiale

The most significant economic consequences of climate change are expected to come from thermal stress on rural workers experiencing extreme heatwaves, with losses amounting to 4.8% of GDP and potentially reaching 8% under the most pessimistic climate scenario (SSP3–7.0). Another important factor is the extent of urban damage caused by flooding, with losses amounting to 2.5% of GDP.

Figure 14 shows that the main challenge in the DRC is to alter the current emissions curve and avoid locking into a high-carbon development model, which is inefficient and costly to reverse. The DRC has reiterated its intention to position itself as a "solution country" to reduce global GHG emissions, with high carbon sequestration potential due to its vast forest resources, significant hydropower production essential to meet the expected increase in energy demand, and to become a low-carbon supplier of transition minerals for clean energy (primarily copper and cobalt).

**Figure 14: GHG Emissions Per Capita in the DRC and Neighboring Countries, CO2 Per Capita**




Source: World Bank

To achieve these aspirations, it will be necessary to leverage sectors with high growth potential (mining, energy) and allocate the resulting revenues to investments that strengthen the resilience of sectors with high employment and medium-term growth potential (namely agroforestry, commercial agriculture, agro-industry, clean cooking, and services). Clean cooking is a key climate change mitigation measure in the DRC's 2021 Nationally Determined Contributions (NDC), aligned with the United Nations Sustainable Development Goals (SDGs), as well as SDGs 1, 3, and 13.

## 2.2.5 Literature Review

Economic literature has extensively examined the macroeconomic implications of climate change and the role of central banks. Analyses show that climate shocks can have major repercussions on production, inflation, employment, and financial stability through various transmission channels (Stern, 2008; IPCC, 2021).

### 2.2.5.1 Theoretical Review

Theoretically, some authors argue that central banks have not always prioritized climate-related aspects in their action plans (Carney, 2015). This choice can be justified by the fact that, in many countries, price stability objectives remain the primary focus of central banks, relegating climate risk integration in monetary policy (IMF, 2016). However, recent theoretical analyses highlight a direct and indirect link between climate shocks and economic and financial stability.

From a theoretical perspective, several potential action channels for central banks have been identified (Dikau & Volz, 2021; Monasterolo & Raberto, 2017). Nevertheless, the concrete implementation of these levels remains complex, especially in developing countries where data and institutional capacities may be more limited. In this context, the literature emphasizes the importance for central banks to develop a progressive and context-specific approach (Dikau & Volz, 2021).

Central banks are expected to integrate these emerging climate-related risks into their monetary and prudential policies to preserve macroeconomic stability (Batten et al., 2016; Villeroy de Galhau, 2015). However, the precise action mechanisms are still debated in the literature, especially concerning developing countries that are heavily dependent on climate-sensitive sectors such as agriculture and mining (Volz et al., 2020; Campiglio et al., 2018).


Image: unsplash.com

### 2.2.5.2 Empirical Review

Nabila et al. (2022) used non-linear autoregressive distributional lag approaches to estimate the asymmetric effect of climate change on the economic growth of Pakistan based on annual data covering the years 1980–2021. The results indicate that $CO_2$ emissions and mean temperature have asymmetrical effects on economic growth, both in the long run and short run. On the other hand, precipitation had a positive impact on economic growth. Carney (2015) has advocated for central banks to incorporate the impact of climate change on financial stability into their annual action plans. The author identifies three main channels through which climate can affect financial markets: (i) physical risks, (ii) transition risks, and (iii) liability risks. However, this study does not address liability risks.

Yang et al. (2022) used panel data models to analyze the effect of economic growth on $CO_2$ and $CH_4$ emissions, controlling for variables such as energy consumption and other economic factors. Their research confirms the Environmental Kuznets Curve for $CO_2$ and $CH_4$ emissions using panel data. They found evidence of an inverted U-shaped relationship between economic growth and emissions, suggesting that while emissions increase with economic growth in the early stages, they tend to decrease after a certain income level. Similarly, Burke et al. (2015) used nonlinear analysis to demonstrate that extreme temperatures significantly reduce economic production. They recommend that central banks consider climate projections when formulating their macroeconomic policies.

## 2.2.6 Data and Methodology

### 2.2.6.1 Data

This study integrates financial indicators, data on the real economy, and climate variables. Data related to financial stability and the monetary aggregate (M2) are available monthly. To harmonize all the data, we used the Chow-Lin (1976) method to convert annual aggregates into specific monthly series.

The climate variables selected for this study are carbon dioxide ($CO_2$) and methane ($CH_4$). $CO_2$, a major greenhouse gas, primarily originates from the combustion of fossil fuels such as coal, oil, and natural gas, used for energy and transportation, as well as from agricultural activities. $CH_4$, also an important greenhouse gas, mainly arises from agriculture (livestock, rice cultivation), organic waste, and the extraction of fossil fuels. The macroeconomic variables analyzed include inflation and Gross Domestic Product (GDP), distinguished by the agricultural and mining sectors. Regarding financial stability, the chosen indicator is the Non-Performing Loans (NPL) ratio, which measures the risk of loss for the financial sector due to loan defaults that have been outstanding for at least 90 days. In this study, the ratio of non-performing loans to total gross loans (NPL) is used as an indicator of credit risk.

Data on climate variables and GDP are sourced from the World Bank indicators (WDI), while data related to financial stability are sourced from the Central Bank of Congo. The study covers the period from the fourth quarter of 1990 to the fourth quarter of 2023. The study conducted unit root tests using the Augmented Dickey-Fuller (ADF) tests. The ADF stationarity test results indicate that the selected macroeconomic variable, that is, log (GDP) and the emissions of log(CO2) and log(CH4) are non-stationary but become stationary after differencing (first difference).

The ADF results are provided in Annex 1.

## 2.2.6.2 Empirical Model

To assess the macroeconomic impact of climate change, a Nonlinear Autoregressive Distributed Lag (NARDL) model was employed (Shin et al., 2014). This model, which extends the ARDL approach, not only captures the asymmetric effects of climate variables on economic activity but also identifies critical thresholds where a sign change between the variables may occur. However, it is important to note that, while the model highlights past statistical tendencies, it assumes that these trends will be repetitive in the future. The study aims to model the asymmetric effects of both increases and decreases in carbon dioxide (CO2) and methane (CH4) on key macroeconomic variables such as agricultural GDP, mining GDP, and inflation. Additionally, the impact on financial stability is also analyzed, particularly focusing on non-performing loans (NPL) and the money supply in the DRC.

In this study, the NARDL model is specified as follows:

$$\mathrm{GDP}_t = \alpha + \sum_{i=1}^{p} \emptyset_i \, GDP_{t-i} + \sum_{j=0}^{q} (\beta_j^+ CO2_{t-j}^+ + \beta_j^- CO2_{t-j}^- + \beta_j^+ INFL_{t-j}^+ + \beta_j^- INFL_{t-j}^-) + \varepsilon_t$$

…………(1)

To capture the asymmetric effects, the explanatory variables CO2 emissions and inflation are decomposed into two series: $C02_t^+ \; et \; C02_t^-$, $\beta_j^+ INFL_t^+ \; et \; \beta_j^- INFL_t^-$, representing the increases and decreases, respectively in CO2 and inflation.

The use of a nonlinear NARDL model is justified by the nonlinear nature of the effects of climate change on economic activity. The underlying theory is that of tipping points in the climate system. According to this theory, beyond a certain level of greenhouse gas concentration in the atmosphere, the climate may undergo abrupt and irreversible changes that would lead to significant economic and social impacts. These nonlinear and asymmetric effects of climate change have been highlighted in scientific literature since the mid-2000s. Studies such as Lenton et al. (2008) have identified several potential tipping points in the climate system, such as accelerated ice sheet melting, disruption of ocean currents, and the disintegration of tropical forests.

Thus, the use of a NARDL model allows capturing these nonlinear and asymmetric dynamics, where the impacts of increases and decreases in CO2 emissions on economic activity may differ. This provides a more nuanced understanding of the transmission mechanisms between climate change and growth, which is essential for informing economic and environmental policy decisions. By integrating these components into the model, we obtain:

$$\mathrm{GDP}_t = \alpha + \sum_{i=1}^{p} \emptyset_i\, GDP_{t-i} + \sum_{j=0}^{q} \beta_j^{+}$$

$$+ \sum_{k=1}^{t-j} \max\,(\Delta CO2_{k,} + \sum_{j=0}^{q} \beta_j^{-} \sum_{k=1}^{t-j} \min\,(\Delta CO2_{k,} + \sum_{k=1}^{t-j} \max\,(\Delta INFL_{k,} + \sum_{j=0}^{q} \beta_j^{-} \sum_{k=1}^{t-j} \min\,(\Delta INFL_{k,}) + \varepsilon_t$$

$$CO2_t^{+} = \sum_{k=1}^{t-j} \max\,(\Delta C02_{k,}\, 0)$$

$$CO2_t^{-} = \sum_{k=1}^{t-j} \min\,(\Delta C02_{k,}\, 0)$$

$$INFL_t^{+} = \sum_{k=1}^{t-j} \max\,(\Delta infl_{k,}\, 0)$$

$$INFL_t^{-} = \sum_{k=1}^{t-j} \min\,(\Delta linfl_{k,}\, 0)$$

- $\alpha$ is the constant term of the model;
- $\emptyset_i$ represents the autoregressive coefficients measuring the effects of past values of GDP on its current value;
- $\beta_j^{+}\ et\ \beta_j^{-}$ coefficients measuring the respective effects of increases and decreases in CO2 levels as well as inflation (INFL) on economic activity;
- $\varepsilon_t$ is the residual error term.

The decomposed coefficients of the NARDL model and its lagged terms provide a better understanding of the asymmetric dynamics between variations in CO2, inflation, and GDP. The coefficients show how increases and decreases in CO2 differently affect economic activity, thus capturing the differential impact of positive and negative shocks on the economy. Taking into account both short-term and long-term effects, the dynamic equation of model (1) can be written as follows:

**Short-term and long-term equations**

$$\Delta\mathrm{GDP}_t = \alpha + \textstyle\sum_{i=1}^{p} \emptyset_i\, \Delta GDP_{t-i} + \sum_{j=0}^{q}(\beta_j^{+} \Delta CO2_{t-j}^{+} + \beta_j^{-} \Delta CO2_{t-j}^{-} + (\beta_j^{+} \Delta INFL_{t-j}^{+} + (\beta_j^{+} \Delta INFL_{t-j}^{+}) + \sum_{j=0}^{q}(\beta_j^{+} CO2_{t-j}^{+} + \beta_j^{-} CO2_{t-j}^{-} + \beta_j^{+} INFL_{t-j}^{+} + \beta_j^{-} INFL_{t-j}^{-}) + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The use of the NARDL model allows for capturing short-term and long-term asymmetries in climatic variables, specifically carbon dioxide (CO2) and inflation.

## 2.2.7 Discussion of Findings

The cointegration test results are presented in Table 4, and the statistical test shows an F-statistic of 4.10, which is well above the upper bound value of 3.15, indicating the presence of cointegration among the variables in the NARDL model.

**Table 4: Cointegration Tests Results**

| Test Statistic | Value | Significance | I(0) | I(1) |
|---|---|---|---|---|
| | Asymptotic: n=1000 | | | |
| F-statistic | 4.10 | 10% | 1.85 | 2.85 |
| K | 8 | 5% | 2.11 | 3.15 |
| | | 2.5% | 2.33 | 3.42 |
| | | 1% | 2.62 | 3.77 |

The error correction term reflects the speed of adjustment of the model towards the long-term relationship after short-term shocks. This coefficient is negative and statistically significant at the 1percent level, indicating the existence of a long-term relationship between the variables.

In the short term, the asymmetric effects of CO2 emissions on agricultural GDP are significant. A 1 percent increase and a CO2 reduction seem to increase agricultural growth by 0.92 percent and 3.8 percent, respectively, contrary to expectations, implying that in this case, elevated CO2 levels enhance agricultural production, especially in C3 plants such as wheat, rice, and potatoes. In addition, given the level of economic development of DRC, it is possible that emissions can contribute to increased economic expansion through increased energy use in agricultural production and other sectors, such as transport, that are linked to agricultural production. For inflation, a 1 percent increase measured three periods ago raises agricultural production by 1.18 percent, suggesting that past inflation may stimulate certain agricultural activities due to better price prospects for the agricultural produce.

**Table 5: Short-Term Results of CO2 Emissions on Agricultural GDP**

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(PROD_AGR(-1)) | -0.200911 | 0.112728 | -1.782255 | 0.0885 |
| D(PROD_AGR(-2)) | 0.607810 | 0.081684 | 7.441028 | 0.0000 |
| D(C022_POS) | 0.922805 | 0.135870 | 6.791814 | 0.0000 |
| D(C022_NEG(-2)) | -3.805911 | 1.022277 | -3.722973 | 0.0012 |
| D(INFL_POS(-3)) | 1.185493 | 0.389739 | 3.041762 | 0.0060 |
| D(INFL_NEG) | -1.027838 | 0.266599 | -3.855374 | 0.0009 |
| CointEq(-1)* | -0.006844 | 0.000739 | -9.265607 | 0.0000 |

Source: Author

Long-term results show that an increase in CO2 emissions (CO2-positive) has a significant positive impact on the agricultural sector, with a 8.3 percent increase in agricultural production for each percentage increase in CO2 emissions. This suggests that, in the long term, increased CO2 emissions significantly benefit the agricultural sector, leading to an 8.3 percent increase in agricultural production for each percentage increase in CO2 emissions. However, this benefit could be temporary, as long-term negative effects such as climate change might offset these gains. Reductions in CO2 emissions do not have a significant impact on agricultural GDP in the long term, suggesting that other factors may compensate for this effect. Similarly, variations in inflation, whether increasing or decreasing, are not significant in explaining agricultural production.

**Table 6: Long-Term Results of CO2 Emissions on Agricultural GDP**

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| CO2_POS | 8.302126 | 1.582927 | 5.244794 | 0.0000 |
| CO2_NEG | 18.26418 | 11.81605 | 1.545709 | 0.1364 |
| INFL_POS | -7.974302 | 118.3847 | -0.067359 | 0.9469 |
| INFL_NEG | 87.43660 | 101.3586 | 0.862646 | 0.3976 |

Source: Author

## 2.2.8 Conclusion and Recommendations

Integrating climate risks into macroeconomic analysis has become an increasing priority for central banks due to the significant impacts of climate change on economic and financial stability. This study used both descriptive and quantitative approaches to assess the macroeconomic impact of climate change and the role of the Central Bank of Congo.

The descriptive analysis shows that DRC is highly vulnerable to climate change and its effects but is poorly prepared to cope with them, and that it was ranked 185th out of 192 countries according to the ND-Gain Index Report of 2021. Moreover, the analysis showed that the DRC would incur up to 13 percent in GDP losses by 2050 in the absence of mitigation and adaptation measures. The analysis further showed that extreme climatic events have a significant negative impact on key indicators in the banking sector, with implications for financial stability. In this case, the study reveals that extreme climatic events reduce agricultural and mining revenues, which deteriorate asset quality and bank capital, leading to an increase in non-performing loans.

The econometric results show a positive relationship between CO2 and agricultural production both in the short run and in the long run, implying that elevated CO2 levels enhance agricultural production, especially in C3 plants such as wheat, rice, and potatoes. In addition, given the level of economic development of DRC, emissions may contribute to increased economic expansion through increased energy use in agricultural production and other sectors such as transport that are linked to agricultural production. The study provides three recommendations. First, the DRC authorities should integrate climate stress tests, adjust macroprudential measures, and regularly update their models to enhance the financial sector's resilience to climate risks. This entails financial regulators imposing requirements on financial institutions to adjust their capital reserves based on their exposure to vulnerable sectors such as agriculture and mining. Secondly, increased regulation of climate risk disclosures is necessary. In line with the recommendations of the Task Force on Climate-related Financial Disclosures, regulators should mandate financial institutions to publish reports detailing their exposure to climate risks. This would ensure better transparency and proactive risk management within the financial system. Thirdly, the study recommends that the Central Bank of Congo consider integrating climate risks into the formulation of its monetary, exchange rate, and financial stability policies. It is crucial to strengthen the monitoring and analysis of climate-related risks, as well as to coordinate efforts with the authorities responsible for environmental and development policies.

“ This study used both descriptive and quantitative approaches to assess the macroeconomic impact of climate change and the role of the Central Bank of Congo

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# Annexes

### Annex 1: Unit Root Test Results

| Variables | ADF at Level | P-value | ADF at First Difference | P-value | Order of Integration |
|---|---|---|---|---|---|
| Log(PIBMIN) | 0.97330 | 0.9120 | -2.2273 | 0.0025 | I(1) |
| Log(CO2) | 0.40525 | 0.9031 | -9.19800 | 0.0000 | I(1) |
| Log(CH4) | 1.41078 | 0.9601 | -2.31647 | 0.0204 | I(1) |
| Log(NPL) | 0.41786 | 0.7996 | -8.45302 | 0.0000 | I(1) |
| Log(M2) | -2.168091 | 0.0304 | - | - | I(0) |
| Infl | 1.880043 | 0.0579 | - | - | I(0) |
| Log(PIBAGRIC) | 2.653673 | 0.9975 | -2.22970 | 0.0264 | I(1) |

Source: Author's calculations.

### Annex 2: Correlation Matrix of Economic and Environmental Variables

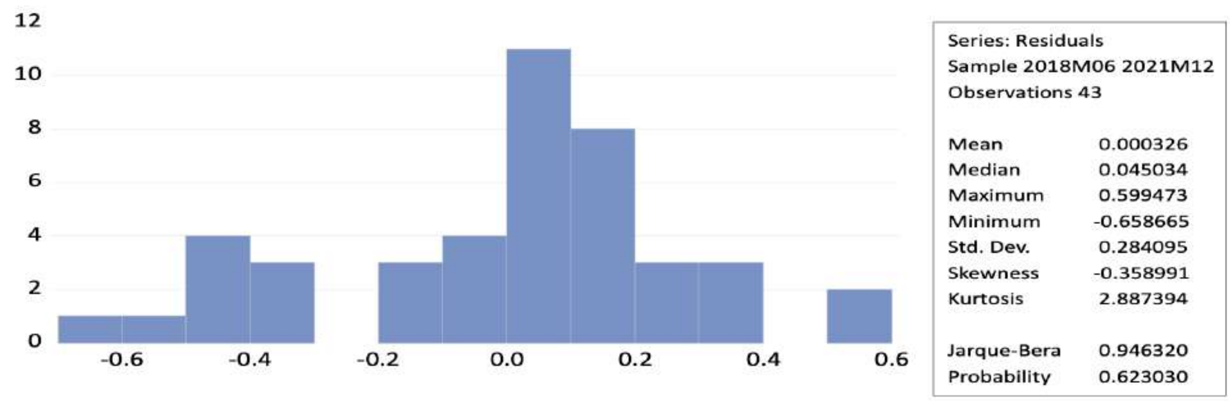
| Probability | LPIBNIM | LNPL | LM2 | LCH4 | INFL | LCO2 |
|---|---|---|---|---|---|---|
| **LPIBNIM** | 1.000000<br>----- | | | | | |
| **LNPL** | -0.075418<br>0.6104 | 1.000000<br>----- | | | | |
| **LM2** | **0.973412**<br>**0.0000** | -0.136544<br>0.3547 | 1.000000<br>----- | | | |
| **LCH4** | -0.059115<br>0.6898 | -0.118018<br>0.4243 | 0.023365<br>0.8747 | 1.000000<br>----- | | |
| **INFL** | 0.015034<br>0.9192 | **0.270586**<br>**0.0629** | 0.028284<br>0.8487 | -0.225328<br>0.1236 | 1.000000<br>----- | |
| **LCO2** | **0.436213**<br>**0.0019** | **-0.640820**<br>**0.0000** | **0.585805**<br>**0.0000** | **0.456962**<br>**0.0011** | -0.121089<br>0.4123 | 1.000000<br>----- |

### Annex 3: Autocorrelation Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

| | | | |
|---|---|---|---|
| F-statistic | 1.212973 | Prob. F(21,21) | 0.3311 |
| Obs*R-squared | 23.56912 | Prob. Chi-Square(21) | 0.3144 |
| Scaled explained SS | 5.817015 | Prob. Chi-Square(21) | 0.9996 |

**Annex 4: Residual Normality Test**




**Annex 5: Autocorrelation Test**

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

| | | | |
|---|---|---|---|
| F-statistic | 0.811727 | Prob. F(2,20) | 0.4582 |
| Obs*R-squared | 3.228369 | Prob. Chi-Square(2) | 0.1991 |

**Annex 6: Heteroscedasticity Test**

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

| | | | |
|---|---|---|---|
| F-statistic | 0.370495 | Prob. F(2,116) | 0.6912 |
| Obs*R-squared | 0.825149 | Prob. Chi-Square(2) | 0.6619 |

## 2.3 Impact of Climate Shocks on Inflation and GDP: Evidence from Uganda

*Jimmy Apaa and Deo Sande*

### 2.3.1 Introduction

The primary mandate of the Bank of Uganda (BoU) is to maintain price stability. Achieving this objective requires continuous assessment of the risks that may hinder the attainment of low and stable inflation. This necessitates careful identification and evaluation of nature and magnitude of the shocks that affect macroeconomic dynamics. In recent years, climate change has emerged as a critical source of such shocks, raising concerns about its implications for macroeconomic management and the formulation of monetary policy.

The increasing frequency and intensity of climate-related events such as droughts, floods, and erratic rainfall patterns have had significant repercussions on economic growth and price stability, particularly in low-income countries. These developments have sparked an important debate in the literature regarding the role of monetary policy in managing climate-induced risks (Barret, 2022). Given the potential for climate shocks to generate both inflationary and deflationary pressures, central banks face a complex policy dilemma, underscoring the importance of integrating climate risk assessments into monetary policy frameworks to ensure effective climate change responses.

Extreme weather events can directly impair agricultural production by reducing yields and disrupting supply chains, thereby exerting an upward pressure on food prices. In Uganda, such shocks often force farmers to adopt costly mitigation measures, including irrigation, fertilizers, and pest control, to preserve productivity. These additional input costs further increase in production expenses, reduce supply, and contribute to inflationary pressures (Abidi et al., 2024).

However, the relationship between climate shocks and inflation is not linear. In certain instances, extreme weather events may depress economic activity and reduce firm profitability. Moreover, post-disaster increases in loan defaults can cause banks to tighten credit conditions, resulting in a contraction in investment and consumption, which may introduce deflationary tendencies into the broader economy (Abbas et al., 2021). At the household level, the destruction of property and livelihoods due to climate events can lead to diminished consumption and aggregate demand, exacerbating downturns and reinforcing price declines.

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The primary mandate of the Bank of Uganda (BoU) is to maintain price stability.

In Uganda, the unique nature of climate shocks, particularly their supply side origins and direct impacts on food production, requires a more tailored approach. The effectiveness of monetary policy in this context requires a deep understanding of both the transmission channels of climate shocks and institutional and economic realities that shape policy responses. This study empirically investigates the effects of climate shocks on inflation and economic growth in Uganda, focusing on their implications for monetary policy design and implementation. This study seeks to understand how climate shocks influence the inflationary environment and whether the central bank's response is consistent with its inflation-targeting mandate.

Preliminary evidence suggests that the Bank of Uganda has greater flexibility in managing inflation during positive climate shocks, whereas negative climate shocks are associated with disinflationary pressures. Understanding the dynamics of this relationship is critical for informing policy adjustments in the face of increasing climate risk.

The remainder of this paper is organized as follows. Section 2 provides stylized facts on climate indicators while section 3 reviews the relevant literature on climate change, inflation dynamics, and monetary policy's role. Section 4 discusses the data sources of the key variables used in the analysis and outlines the methodological framework. Section 5 presents and discusses the main findings while section 6 provides the conclusion and policy implications as well as suggestions for future research.

## 2.3.2 Stylized Facts on Climatic Indicators in Uganda

The climate of Uganda is predominantly shaped by its equatorial location, varied topography, and the presence of significant water bodies, including Lake Victoria, Albert, and Kyoga. Most of the country experiences a bimodal rainfall pattern, with two distinct rainy seasons that occur from March to May and September to December. However, the northern Uganda region, which lies outside the central equatorial belt, is characterized by a unimodal rainfall regime with a single rainy season extending from March to October.

Despite its location within a relatively humid equatorial climate zone, substantial spatial variations in rainfall patterns have been observed throughout Uganda. These differences are driven by factors, such as altitude, prevailing wind systems, and proximity to lakes and rivers in the region. The Indian Monsoon system significantly influences seasonal rainfall in Uganda, particularly during the long rainy season. Furthermore, the air mass of Congo, the Inter-Tropical Convergence Zone (ITCZ), and fluctuations in the Indian Ocean Dipole (IOD) significantly affect the distribution and intensity of rainfall and temperature patterns across the country.

Over the past several decades, Uganda has experienced notable climatic changes, with a bias towards decreases in annual and seasonal rainfall. The most pronounced reduction occurred during the first rainy season (March–May), when an average decrease of approximately 6.0 mm per month per decade was observed. This trend has been particularly severe in the northern districts, which are already more vulnerable owing to their dependence on a single rainy season. Consequently, the frequency and intensity of drought episodes have increased, and several parts of the country have experienced prolonged dry spells over the past 60 years.

Simultaneously, rising temperatures have become a consistent feature of Uganda's climate. Since the 1960s, the country has recorded an average temperature increase of 1.3°C, with minimum temperatures rising by 0.5°C to 1.2°C and maximum temperatures increasing by 0.6°C to 0.9°C over the same period. The rate of warming has been estimated to be approximately 0.28°C per decade, affecting both diurnal and nocturnal temperature ranges. Over the past three decades, the country has witnessed a marked increase in the frequency of extreme weather events, including floods, droughts, and landslides. In particular, flooding has become more frequent mainly because of the intensification of rainfall, a trend that is consistent with larger global patterns of climate change.

These climatic developments have significant implications for Uganda's agricultural productivity, water resource management, and macroeconomic stability and thus warrant integration into national development and macroeconomic policy frameworks, including monetary policies (Table 7).

**Table 7: Frequency of Natural Disasters in Uganda (1900-2020).**

| Natural Hazard 1900–2020 | Subtype | Events Count | Total Deaths | Total Affected | Total Damage ('000 USD) |
|---|---|---|---|---|---|
| **Drought** | Drought | 9 | 194 | 4,975,000 | 1,800 |
| **Earthquake** | Ground Movement | 5 | 115 | 58,100 | 71,500 |
| **Epidemic** | Bacterial Disease | 28 | 3,204 | 237,665 | 0 |
| | Viral Disease | 10 | 466 | 108,036 | 0 |
| **Flood** | Flash Flood | 4 | 76 | 8,614 | 0 |
| | Riverine Flood | 15 | 267 | 1,051,945 | 6,871 |
| **Storm** | Convective Storm | 1 | 23 | 47 | 0 |
| **Landslide** | Landslide | 8 | 540 | 151,546 | 0 |
| | Mudslide | 1 | 51 | 0 | 0 |

Source: World Bank

Climate change projections for Uganda indicate a continued rise in average temperatures, along with increased variability and intensity of precipitation patterns. These changes are expected to have profound implications for water access and distribution in all regions of the country. Flooding is projected to intensify in the central and southern regions, primarily because of the increasing frequency of high-intensity rainfall events. In contrast, other regions, particularly the north, northeast, west, and southwest, are expected to experience prolonged dry spells, reduced water availability, and frequent future drought episodes.

Climate change poses significant risks to climate-sensitive sectors, including agriculture, water resources, public health, wetlands, and forestry. The agricultural sector, which remains a critical source of income and employment in Uganda, is particularly vulnerable to excessive rainfall and drought-induced crop failure. Similarly, water scarcity and flooding threaten the sustainability of natural ecosystems and availability of clean water for domestic and industrial use in the region. In the health sector, climate-induced disruptions are expected to exacerbate the burden of diseases, particularly vector- and waterborne diseases.

Generally, the projected impacts of climate change underscore the urgent need for adaptive policy responses, particularly to enhance sectoral resilience and to integrate climate considerations into national planning and macroeconomic management.

### 2.3.3 Literature Review

The literature on the role of monetary policy in mitigating climate-related risks can be broadly categorized into two themes. The first strand views monetary policy as a complementary tool to climate policy, particularly for addressing climate-induced financial and macroeconomic risk. Scholars in this line of thought argue that climate strategies should not be implemented in isolation, but should be integrated within broader macroeconomic frameworks. Earlier studies, such as Kahn et al. (2021), assessed the long-term macroeconomic impacts of climate change using cross-country panel regressions. Although valuable for capturing broad trends, these studies of-ten fail to explicitly account for business cycle dynamics, thereby overlooking the short-to medium-term transmissions of climate shocks.

Ciccarelli & Marotta (2024) attempted to fill this gap by employing a structural vector autoregression (SVAR) model covering 24 OECD countries between 1990 and 2019. Their empirical framework disentangled the macroeconomic effects of physical risks (e.g., climate-driven disasters) and transition risks (e.g. policy responses and technological changes). The findings of this author showed that climate shocks behave like negative demand shocks, depressing economic activity, whereas green innovation and well-calibrated environmental policies can mitigate these adverse effects. Importantly, they argued for balanced policy mixes that combine demand support with technology-driven supply improvements tailored to country-specific conditions.

Cevik & Jalles (2024) investigated the macroeconomic effects of climate-induced natural disasters on inflation and output growth using a panel of countries from 1970 to 2020. Applying the local projection method, they estimated the dynamic responses of inflation and GDP growth to distinct disaster categories, accounting for both demand and supply side transmission channels. The analysis revealed significant but heterogeneous effects across disaster types and regions. Advanced economies experience more contained and short-lived impacts, reflecting stronger fiscal capacities and institutional frameworks, whereas developing economies face more severe and persistent disruptions. These results underscore the critical role of economic structure and fiscal health in shaping resilience to climate shocks and highlight the persistent cross-country asymmetries in macroeconomic vulnerability.

Within the same strand, Benmir & Roman (2020) developed a macro-financial environmental Dynamic Stochastic General Equilibrium (E-DSGE) model to investigate how different policy instruments, fiscal, monetary, macroprudential, and carbon taxation, interact to shape the transition process toward clean technology. By embedding environmental considerations into monetary frameworks, they highlight how central banks can enhance macroeconomic stability while supporting their transition to a low-carbon economy. Chan (2020) extended the analysis by applying an E-DSGE model to assess the comparative effectiveness of monetary and fiscal instruments in addressing air pollution. Their simulations revealed that monetary policy can reduce pollution-related economic costs by lowering the general price level, although they underscored the superior effectiveness of carbon taxation when combined with monetary tools. Similarly, Campiglio (2016) employed a theoretical financial market framework to examine the limitations of carbon pricing. He highlighted how structural market failures and underinvestment in low-carbon technologies undermine purely price-based approaches to climate policy. To address this, the author advocated for combining monetary policy with macro-prudential regulation through instruments, such as targeted credit allocation, green refinancing facilities, and differentiated capital requirements. Such measures are particularly relevant in emerging and developing economies, where central banks retain greater discretion in credit allocation.

The second strand of literature emphasizes the direct role of monetary policy in advancing climate objectives, particularly through innovative central banking. Notably, Böser & Senni (2020) developed a calibrated dynamic general equilibrium model to evaluate the effectiveness of a novel emission-based monetary policy interest rate, in which the cost of central bank liquidity provision to banks increases with the carbon intensity of their portfolios. Calibrated from Euro Area data, their simulations show that such climate-adjusted monetary policy mechanisms can enhance financing conditions for low-carbon sectors, incentivize cleaner technologies, and reduce long-term climate damage by reshaping credit allocation. Similarly, Boneva et al. (2022) adopted a policy-orientated institutional analysis to assess how central banks can foster green financial markets. They emphasized regulatory support for green bonds and liquidity facilities for green assets as mechanisms through which monetary policy can expand the availability of climate-aligned instruments to achieve net zero emissions.

McConnell et al. (2022) combined green policy instrument with a stylized general equilibrium model that includes a banking sector. They simulated the impact of "brown collateral haircuts", which apply steeper valuation discounts to carbon-intensive assets pledged as collateral to central banks. Their findings indicate that such measures redirect investments toward low-carbon sectors, reduce financing for high-carbon activities, and promote emission reductions, thus demonstrating a pragmatic and implementable green monetary policy instrument for the central bank. Taken together, these contributions highlight the growing recognition that monetary policy, through both conventional instruments (e.g. interest rate policy and open market operations) and unconventional tools (e.g. collateral frameworks and targeted refinancing), can significantly influence climate outcomes.

Beyond methodological innovations, the literature reflects a broader debate on the role of central banks. One school of thought emphasizes the maintenance of traditional mandates of price stability, growth, and financial stability while playing a supportive role in climate transition. Another, more interventionist perspective calls for embedding climate risks directly into monetary policy frameworks, recognising that climate shocks, particularly in developing countries, often manifest as severe supply-side disruptions with far-reaching macroeconomic consequences. This study is based on the latter perspective. In climate-vulnerable economies, such as Uganda, where extreme weather events and agricultural disruptions drive inflation volatility, demand management frameworks are inadequate. Addressing these challenges requires recalibrating monetary policy, rethinking inflation-targeting regimes, and adapting tools such as interest rate policy, liquidity provision, and open market operations to account for climate-related supply shocks. Thus, a climate-sensitive monetary policy is essential to maintain macroeconomic stability and support sustainable development amid intensifying climate risks.

Image: unsplash.com

### 2.3.4 Data and Methodology

Monthly precipitation data for Uganda was obtained from the Climate Research Unit (CRU) of the University of East Anglia. The rainfall measurements, recorded in millimetres, were aggregated quarterly by computing the arithmetic mean of the monthly observations within each quarter. To account for recurring intra-annual fluctuations, the data was seasonally adjusted using standard seasonal decomposition techniques. Finally, a natural logarithmic transformation was applied to the seasonally adjusted series to approximate the normality and enhance the interpretability of the results. To empirically assess the effect of climate variability, specifically, precipitation shocks on inflation, and monetary policy, rainfall was used as a proxy for climate shocks. In the analysis, we used the 91-day treasury bill rate as a proxy for monetary policy. This choice accommodates the monetary and inflation targeting frameworks employed by the Bank of Uganda (BoU) between 2000 and 2022. The inflation-targeting framework became operational in July 2011, marking a shift in monetary policy implementation. The 91-day Treasury bill rate was used as the key monetary policy instrument in this study for several reasons. First, it provides consistency across different monetary policy regimes, covering both the monetary and inflation-targeting periods in Uganda. This continuity enables a coherent long-term analysis of monetary policy dynamics, as shown in Annex 1.

Second, the 91-day Treasury bill rate serves as a forward-looking indicator, capturing market expectations of future interest rates and inflation more effectively than other proxies such as the interbank rate. This forward-looking property is particularly relevant in an inflation-targeting regime in which expectations play a critical role in the transmission of monetary policy.

Third, while money aggregates have traditionally functioned as intermediate targets of monetary policy, their effectiveness as proxies for monetary policy is limited, particularly in forward-looking frameworks. Unlike money aggregates, the 91-day Treasury bill rate directly reflects market perceptions of the central bank's policy intentions, making it a more reliable indicator of the BoU's monetary policy stance. Collectively, the use of the 91-day Treasury bill rate enabled a comprehensive assessment of the impact of monetary policy over time, capturing both historical and contemporary policy practices.

Inflation data were sourced from the Uganda Bureau of Statistics (UBoS) and included indices for headline (overall price level), core, and food crop inflation. The decomposition of headline inflation follows the Classification of Individual Consumption According to Purpose (COICOP) framework, which reveals the contributions of various expenditure categories to overall inflation.

Based on the two most recent rebasing exercises[6], the composition of the consumption basket is as follows: Food and non-alcoholic beverages: 27.1% (28.5%), housing, water, electricity, gas, and other fuels: 10.42% (11.9%), transport: 10.45% (13.8%), restaurants and accommodation services: 8.7% (5.7%). These components exert a substantial influence on the overall inflation rate, with food and nonalcoholic beverages being the largest contributors (Annex 3).

Figures in parentheses correspond to the 2009/10 rebased consumption basket, with weights derived from the Uganda National Household Survey

In particular, food crop inflation significantly shapes headline inflation trends in Uganda. Periods marked by elevated food crop inflation frequently coincide with increases in the overall inflation, as shown in Annex 2. This strong relationship underscores the importance of closely monitoring and managing food crop prices to achieve price stability and to effectively control inflation. For the empirical analysis, inflation indices were seasonally adjusted and transformed using natural logarithms to ensure stationarity and facilitate interpretation.

Exchange rate data was sourced from the Bank of Uganda. The data were prepared for analysis as follows: Monthly exchange rates were averaged to obtain quarterly averages. This ensured that the data aligned with the frequencies of the other economic variables considered. Quarterly exchange rates were logarithmically transformed. This step is essential for stabilizing the variance of the data and ensuring that the relationship between the variables is linear, which is a common assumption in many econometric models. GDP data was sourced from the UBoS.

This study used quarterly data covering the period from 2000Q1 to 2022Q4. This sample period was determined by the availability of quarterly GDP data, which is essential for capturing the real economic impact of climate shocks.

This study investigated the impact of climate shocks on inflation and monetary policy in Uganda using a Vector Autoregression (VAR) framework. The VAR approach, is particularly suited for analyzing the dynamic interrelationships among macroeconomic time series. In this framework, each variable in the system is expressed as a linear function of its past values (lags) and the lagged values of all other variables in the model.

The baseline VAR model is specified as follows:

$$Y_t = \alpha + \sum_{j=1}^{p} \beta_j Y_{t-j} + \epsilon_t, \qquad (1)$$

Where:

- $Y_t$ is a vector of endogenous variables at time t,
- a is a vector of constants,
- $\beta_j$ are coefficient matrices associated with j lags,
- $\epsilon_t$ is a vector of reduced-form error terms that are assumed to be white noise.

The set of endogenous variables included in the model is as follows.

- the first difference of the logarithm of real GDP,
- the first difference of the logarithm of headline inflation,
- the 91-day Treasury bill rate (serving as the monetary policy rate), and
- the logarithm of the rainfall.

To identify the structural shocks underlying reduced-form residuals, the study specifically used Structural VAR (SVAR). SVAR extends the above specified VAR model by imposing economically motivated restrictions to disentangle contemporaneous relationships among variables and recover orthogonal structural innovations. Unlike reduced-form VAR, which lacks a theoretical structure and assumes the independence of shocks, SVAR allows for contemporaneous and dynamic interactions by imposing economically motivated restrictions. It is therefore most appropriate, considering that climate change operates largely as a supply side disturbance. This ensures that the identified shocks are both empirically tractable and economically interpretable, making the framework well suited for analyzing the macroeconomic effects of climate shocks.

The SVAR model can be represented as follows:

$$A_0 Y_t = \sum_{j=1}^{p} A_j \, Y_{t-j} + \mu_t, \tag{2}$$

Where:

- $A_0$ is a matrix of contemporaneous coefficients,
- $A_j$ are matrices of lagged coefficients,
- $\mu_t$ is a vector of structural shocks assumed to be serially uncorrelated and economically interpretable.

The corresponding reduced-form VAR is

$$Y_t = \sum_{j=1}^{p} A_0^{-1} \, A_j Y_{t-j} + A_0^{-1} \mu_t, \tag{3}$$

Thus, the reduced-form residuals $\epsilon_t$ are linear combinations of structural shocks: $\epsilon t = A_0^{-1} \mu_t$. To recover the structural matrix $A_0$, we impose Blanchard and Quah (1989) type restrictions, which are widely used in macroeconomic applications for identification. These restrictions exploit long-term neutrality assumptions, typically assuming that certain shocks have no long-term effect on specific variables (e.g. monetary shocks do not affect output in the long run). We specify the order of the variables to ensure that climate shocks are identified separately from the other disturbances in the economy. In this framework, climate shock/rainfall, considered the most exogenous factor, is placed first, followed sequentially by CPI (headline inflation), GDP growth, and the policy interest rate (see Annex 2). This ordering reflects a recursive identification strategy guided by monetary theory, particularly the Taylor rule, which posits that central banks adjust their policy rates in response to inflation and output dynamics.

Additionally, two dummy variables were introduced to control for major exogenous shocks during the sample period.

- One capturing the 2008–2009 global financial crisis, and
- Another capturing the 2020–2021 COVID-19 pandemic.

Each dummy variable takes a value of one during the relevant period and zero otherwise.

## 2.3.5 Empirical Results

Table 8 presents the summary statistics for the key variables used in the empirical analysis, providing an overview of their distributional characteristics, including measures of central tendency and dispersion over the study period. The average growth of the real gross domestic product (GDP) was 6.0%, with a median of 5.9%. The highest quarterly gross domestic product (GDP) growth rate was 39. 8%, whereas the lowest was −19.3%, reflecting considerable variation in economic performance over the period. Headline inflation had an average rate of 6.1%, with a median of 5.2%. The maximum headline inflation reached 24.1%, while the minimum was 4.3%, indicating notable volatility in consumer prices. Food inflation exhibited even greater variability, averaging 7.9% with a median of 6.3%. The highest rate of food inflation was 37.7 In response to inflation dynamics, the policy rate—proxied by the 91-day Treasury bill rate—averaged 10.3%, with a median of 9.4%. The highest recorded rate was 22.1%, while the lowest was 3.8%, indicating the wide range of monetary policy stances adopted over the sample period. These summary statistics highlight substantial fluctuations in Uganda's macroeconomic conditions and underscore the importance of investigating the interaction between climate shocks, inflation, and monetary policy responses.

**Table 8: Summary Statistics of Key Macroeconomic Variables**

| Statistic | Rainfall (mm) | Real GDP Growth (log diff) | Food Inflation (log diff) | Policy Rate (91-day T-bill) | Headline Inflation (log diff) |
|---|---|---|---|---|---|
| Minimum | 43.73 | -0.1931 | -0.2552 | 3.76 | -0.0429 |
| 1st Quartile | 79.14 | 0.0239 | -0.0303 | 7.73 | 0.0266 |
| Median | 109.55 | 0.0586 | 0.0625 | 9.38 | 0.0515 |
| Mean | 105.84 | 0.0601 | 0.0788 | 10.30 | 0.0610 |
| 3rd Quartile | 121.56 | 0.0834 | 0.1824 | 11.16 | 0.0806 |
| Maximum | 202.07 | 0.3982 | 0.3771 | 22.12 | 0.2408 |

Notes: This table presents summary statistics for the main variables used in the empirical analysis, based on quarterly data from 2000Q1 to 2022Q4. Rainfall was measured in mill

Visual inspection of the time-series plots (Annex 5) revealed that several variables used in the analysis exhibited distinct stochastic characteristics. In particular, headline inflation, food inflation, core inflation, exchange rate, and real GDP displayed non-stationary behaviour characterized by trends and persistent shocks. Conversely, rainfall and the 91-day Treasury bill rate exhibited mean-reverting tendencies, suggesting stationarity. We employ the augmented Dickey (ADF) test to formally assess the stationarity properties of these variables. The null hypothesis of the ADF test posits the presence of a unit root, indicating that the series is nonstationary, whereas the alternative hypothesis suggests stationarity. The results for the unit-root tests are presented in Annex 6.

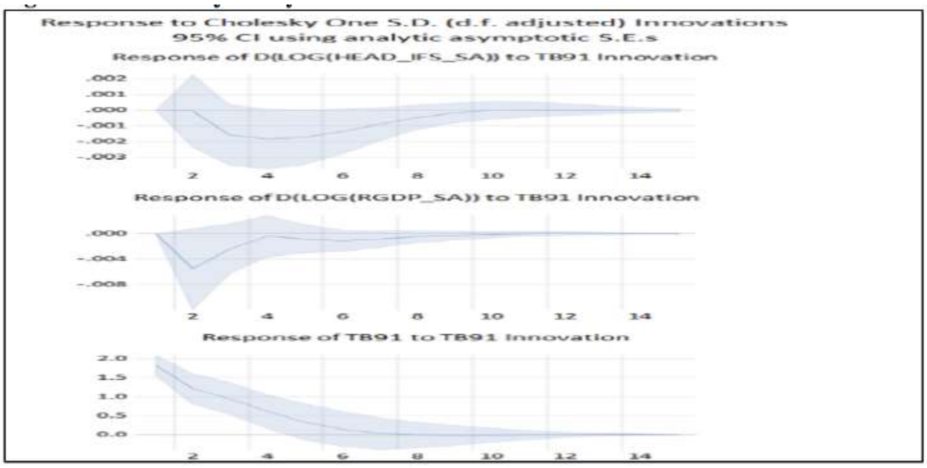
## 2.3.6 Impulse Response Functions

To investigate the dynamic effects of climate shocks on inflation and output, we employ impulse response functions (IRFs) derived from the estimated VAR and SVAR models. These IRFs en-able analysis of how headline inflation and GDP respond to a one-standard-deviation structural innovation in the variables of interest.

### 2.3.6.1 Baseline VAR without Climate Variable

First, we estimate a baseline VAR model that excludes climate variables (rainfall). A one-standard-deviation monetary policy shock to headline inflation produces no immediate response in approximately two quarters. Thereafter, headline inflation declines by approximately 0.18 percentage points by the fourth quarter. This disinflationary effect is temporary; inflation gradually increases thereafter, and the effect of the shock dissipates by the tenth quarter (Figure 15). In response to the same monetary policy shock, GDP contracts by approximately 0.5 percentage points in the second quarter. The contraction is short-lived as the economy recovers to its pre-shock level by the fourth quarter, after which the effect of the shock fades away. This finding is consistent with expectations that tighter monetary conditions dampen economic activity in the short term.

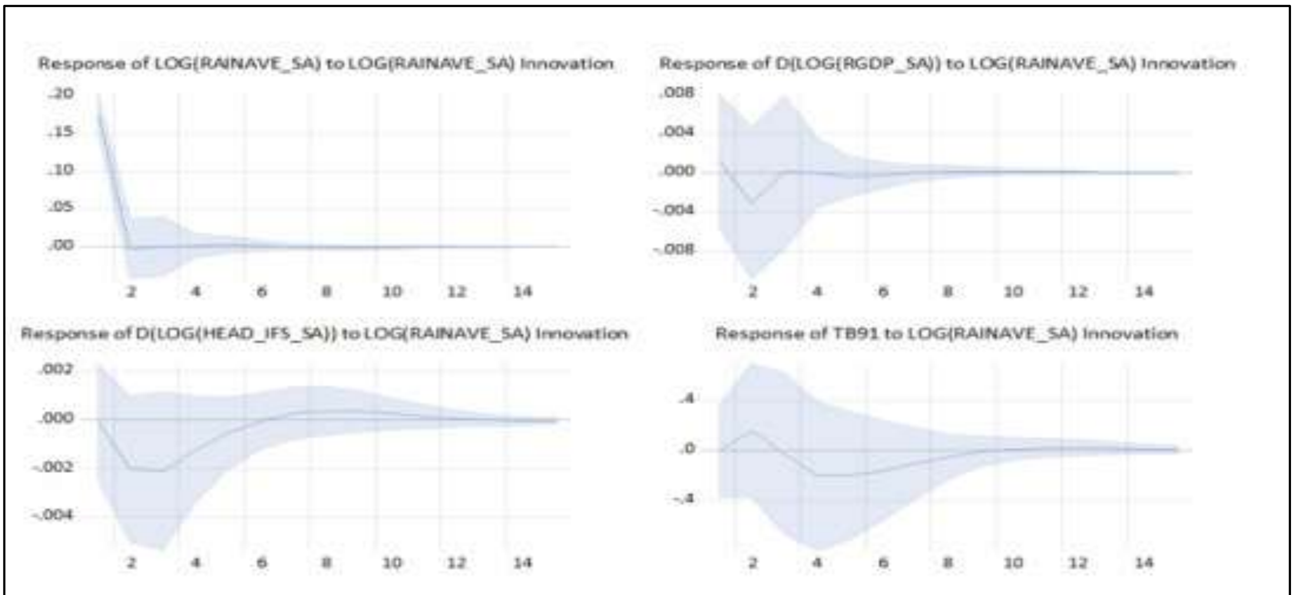
**Figure 15: Monetary Policy Shock on Headline Inflation under the Baseline Scenario**



## 2.3.6.2 VAR with Climate Shocks

In the second phase of the analysis, we re-estimated the VAR model by incorporating rainfall as a proxy for climate shocks. The impulse response of headline inflation to a climate shock indicated an initial decline of approximately 0.2 percentage points by the second quarter. This is fol-lowed by a short plateau, after which inflation increases modestly for two quarters before the shock effect diminishes. The response of the GDP to climate shocks was immediate and pronounced. Real output contracts by approximately 0.3 percentage points by the third quarter, before beginning a gradual recovery, with the shock fading thereafter (see Figure16).

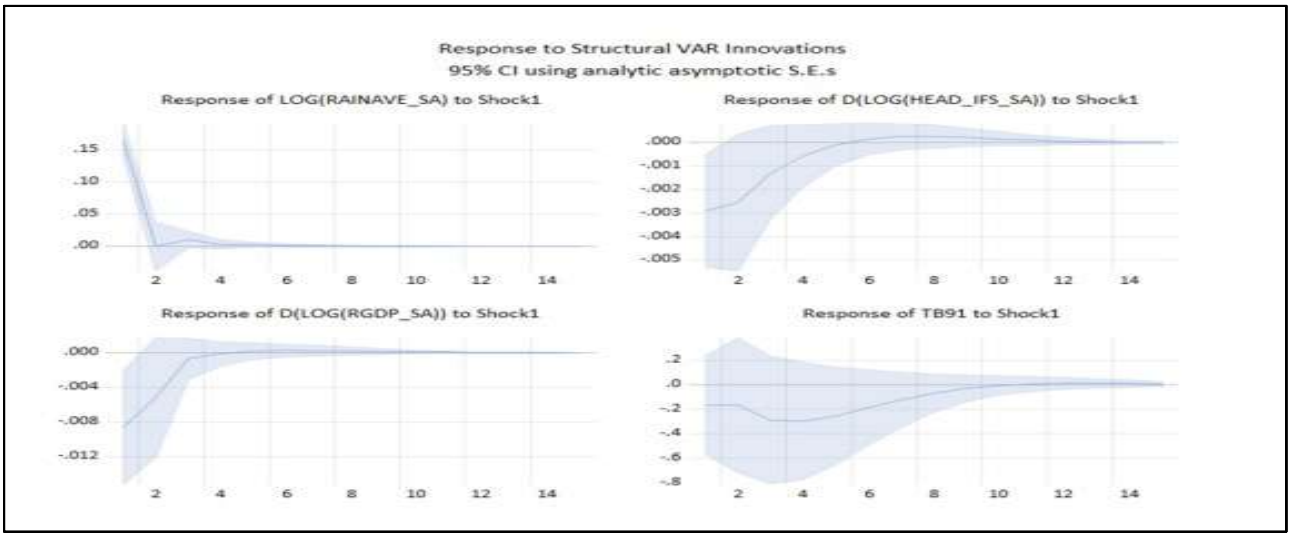
**Figure 16: Responses of Headline Inflation, Policy Rate, and GDP to Various Shocks**




In Figure 17, the results show a SVAR estimation that represents a more rigorous identification of structural shocks involving imposing contemporaneous restrictions. The results indicate that climate shock leads to a decline in headline inflation of approximately 0.3 percentage points. This is followed by a sustained increase in inflation over the six quarters, suggesting that the effect of the shock is persistent and may influence the monetary policy transmission mechanism over an extended horizon.

The SVAR results for GDP reveal a sharper contraction: real output declines by 0.8 percentage points following a climate shock, before beginning to recover over the subsequent four quarters. Although the shock eventually dissipated, its immediate effects were significant. However, it should be noted that the duration and magnitude of the impact of a shock may depend on the type and severity of the climate event. For example, extreme floods are likely to generate more profound and prolonged effects than moderate rainfall anomalies.

**Figure 17: Responses of Headline Inflation, Policy Rate, and GDP to Rainfall Shock**




### 2.3.6.3 Variance Decomposition

To assess the relative contribution of different structural shocks to system variability, we perform a variance decomposition of the endogenous variables. The decomposition results revealed that the variation in rainfall is largely explained by its own shocks (84%).

For headline inflation, own shocks account for approximately 74% of the forecast error variance, followed by a policy rate of 17%, highlighting the importance of monetary policy in price dynamics.

In the case of GDP, 86% of the variance is attributed to own shocks, whereas climate shocks (rainfall) contribute approximately 9%, underscoring the significant role of climate variability in output fluctuations.

Lastly, policy rate dynamics are largely influenced by innovations in headline inflation and GDP, indicating that the central bank responds to both price and output developments when setting monetary policy.

**Table 9: Forecast Error Variance Decomposition**

Variance Decomposition of LOG(RAINAVE_SA):

| Period | S.E. | Shock1 | Shock2 | Shock3 | Shock4 |
|---|---|---|---|---|---|
| 1 | 0.173696 | 90.46692 | 2.980936 | 4.080392 | 2.471748 |
| 2 | 0.179381 | 84.82405 | 2.921265 | 8.164209 | 4.090475 |
| 3 | 0.180043 | 84.52831 | 3.168179 | 8.158528 | 4.144980 |
| 4 | 0.180270 | 84.34001 | 3.351770 | 8.139097 | 4.169121 |
| 5 | 0.180358 | 84.27080 | 3.430469 | 8.132868 | 4.165861 |
| 6 | 0.180384 | 84.24916 | 3.453943 | 8.130673 | 4.166221 |
| 7 | 0.180393 | 84.24100 | 3.457523 | 8.130985 | 4.170489 |
| 8 | 0.180399 | 84.23545 | 3.457318 | 8.132080 | 4.175155 |
| 9 | 0.180404 | 84.23089 | 3.457749 | 8.132969 | 4.178394 |
| 10 | 0.180408 | 84.22764 | 3.458859 | 8.133441 | 4.180060 |

Variance Decomposition of D(LOG(HEAD_IFS_SA)):

| Period | S.E. | Shock1 | Shock2 | Shock3 | Shock4 |
|---|---|---|---|---|---|
| 1 | 0.011755 | 6.086572 | 73.65667 | 2.449434 | 17.80732 |
| 2 | 0.013943 | 7.618075 | 75.97318 | 2.948428 | 13.46032 |
| 3 | 0.014546 | 7.766201 | 77.07533 | 2.711274 | 12.44719 |
| 4 | 0.014730 | 7.727060 | 76.65152 | 2.776112 | 12.84531 |
| 5 | 0.014825 | 7.633837 | 75.75374 | 3.018118 | 13.59430 |
| 6 | 0.014902 | 7.563500 | 75.02193 | 3.248148 | 14.16643 |
| 7 | 0.014962 | 7.528228 | 74.61551 | 3.393627 | 14.46263 |
| 8 | 0.015001 | 7.516288 | 74.45138 | 3.462138 | 14.57019 |
| 9 | 0.015021 | 7.514637 | 74.40867 | 3.485753 | 14.59094 |
| 10 | 0.015030 | 7.515670 | 74.40747 | 3.490534 | 14.58632 |

Variance Decomposition of D(LOG(RGDP_SA)):

| Period | S.E. | Shock1 | Shock2 | Shock3 | Shock4 |
|---|---|---|---|---|---|
| 1 | 0.032388 | 7.052893 | 0.780667 | 88.70259 | 3.463850 |
| 2 | 0.033039 | 9.198846 | 0.799490 | 86.55266 | 3.449000 |
| 3 | 0.033139 | 9.193320 | 0.824615 | 86.43629 | 3.545771 |
| 4 | 0.033181 | 9.172055 | 0.824250 | 86.30384 | 3.699851 |
| 5 | 0.033212 | 9.157555 | 0.851378 | 86.19197 | 3.799093 |
| 6 | 0.033234 | 9.150802 | 0.894681 | 86.10582 | 3.848701 |
| 7 | 0.033246 | 9.148469 | 0.932301 | 86.05236 | 3.866874 |
| 8 | 0.033252 | 9.147937 | 0.955728 | 86.02512 | 3.871218 |
| 9 | 0.033254 | 9.147922 | 0.966922 | 86.01371 | 3.871444 |
| 10 | 0.033255 | 9.147948 | 0.970972 | 86.00981 | 3.871268 |

Variance Decomposition of TB91:

| Period | S.E. | Shock1 | Shock2 | Shock3 | Shock4 |
|---|---|---|---|---|---|
| 1 | 1.957871 | 0.708792 | 18.52449 | 11.08911 | 69.67761 |
| 2 | 2.635469 | 0.769832 | 11.28432 | 15.22034 | 72.72550 |
| 3 | 3.086080 | 1.421271 | 13.91497 | 16.91661 | 67.74715 |
| 4 | 3.353893 | 1.968830 | 17.91103 | 16.95574 | 63.16440 |
| 5 | 3.491848 | 2.335477 | 20.88581 | 16.63535 | 60.14335 |
| 6 | 3.552241 | 2.532584 | 22.58166 | 16.35225 | 58.53351 |
| 7 | 3.574318 | 2.617199 | 23.34240 | 16.19392 | 57.84648 |
| 8 | 3.581095 | 2.643282 | 23.59026 | 16.13286 | 57.63360 |
| 9 | 3.583218 | 2.646817 | 23.62980 | 16.12105 | 57.60233 |
| 10 | 3.584370 | 2.645301 | 23.61765 | 16.12499 | 57.61206 |

### 2.3.7 Conclusion and Policy Implications

This study investigated the macroeconomic effects of climate shocks proxied by precipitation variability on inflation and output in Uganda. The empirical findings reveal that climate shocks have a persistent impact on headline inflation, whereas their effects on real GDP, although negative, tend to be short-lived. Notably, headline inflation is heavily influenced by food prices, which are vulnerable to climate shocks. The results thus imply that incorporating climate indicators into macroeconomic modelling is essential, particularly for economies such as Uganda, where weather-sensitive sectors such as agriculture contribute significantly to both output and price dynamics.

From a policy perspective, the results underscore the importance of enhancing the resilience of the Ugandan economy to climate change. Given the significance of food in the Consumer Price Index (CPI), targeted investments in climate adaptation strategies are critical. These may include expanding irrigation infrastructure, promoting the adoption of drought-resistant seeds, supporting reforestation initiatives, and improving environmental management.

The findings, therefore, emphasize the importance of integrating climate considerations into monetary policy frameworks. In weather-dependent economies, climate variability is a supply-side concern and a potential source of inflationary volatility. Therefore, central banks such as the Bank of Uganda should explore avenues to incorporate climate-related risks into inflation forecasting and macroeconomic policy design.

However, further research is needed to examine the disaggregated effects of climate shocks, specifically on food inflation, which more directly captures agricultural price movements, and agricultural GDP, which may respond differently to aggregate outputs. In addition, future research should distinguish between positive and negative climate shocks. For example, the economic and inflationary consequences of droughts may differ significantly from those of floods given their distinct effects on agricultural production, infrastructure, and supply chains.

“The empirical findings reveal that climate shocks have a persistent impact on headline inflation, whereas their effects on real GDP, although negative, tend to be short-lived. Notably, headline inflation is heavily influenced by food prices, which are vulnerable to climate shocks.

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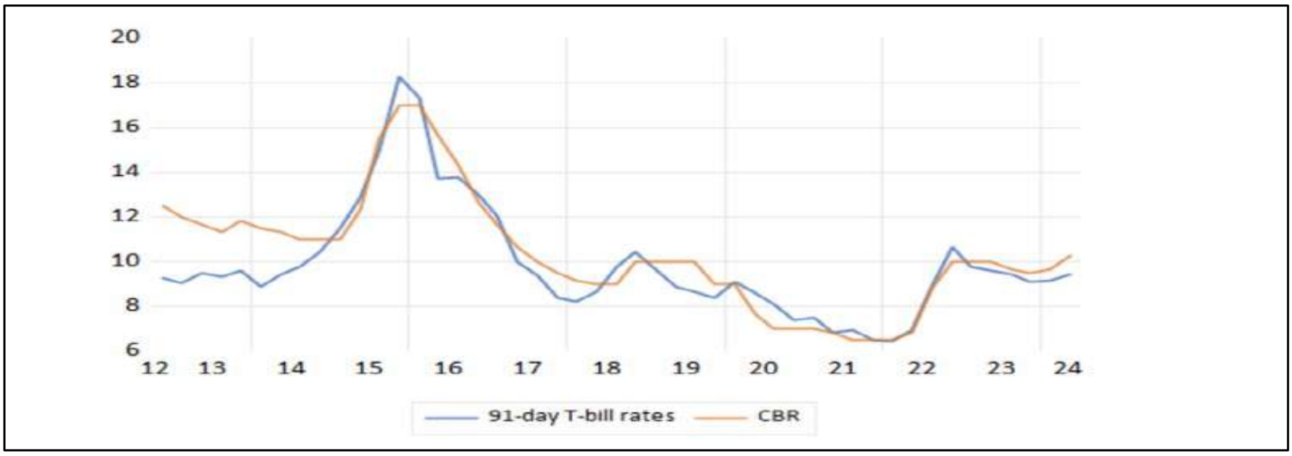
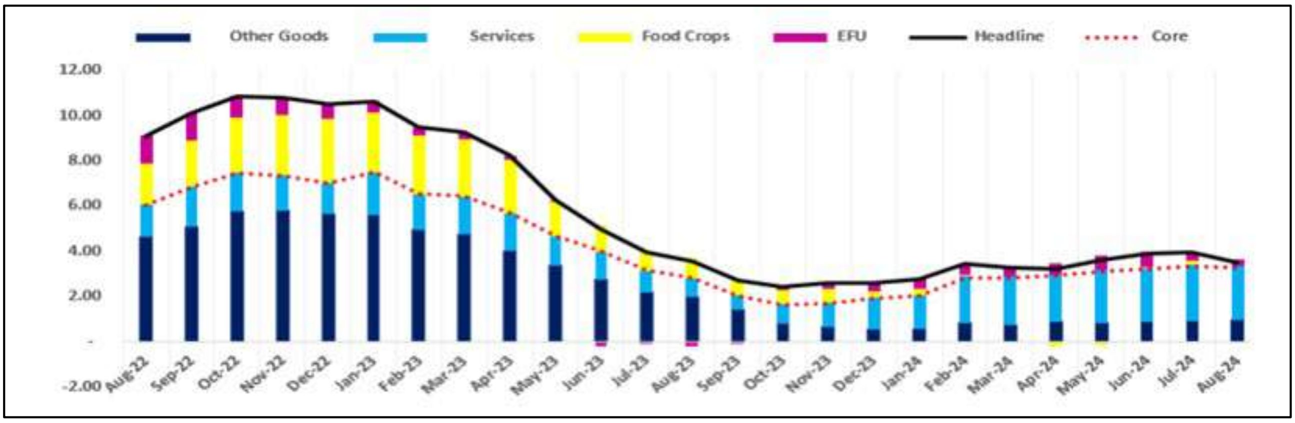
# Annexes

**Annex 1: Evolution of 91-Day Treasury Bill Rate and Central Bank Rate (CBR)**




Note: The x-axis represents quarters, whereas the y-axis represents interest rates in percent.

**Annex 2: Contribution of Inflation Components to Headline Inflation.**



**Annex 3: Components of Headline Inflation in Uganda (CPI Weights)**

| CPI Component | 2016/17 (%) | 2009/10 (%) |
|---|---|---|
| Food and Non-Alcoholic Beverages | 27.1 | 28.5 |
| Alcoholic Beverages, Tobacco and Narcotics | 3.9 | 2.8 |
| Clothing and Footwear | 7.0 | 5.1 |
| Housing, Water, Electricity, Gas and Other Fuels | 10.4 | 11.9 |
| Furnishings, Household Equipment and Routine Household Maintenance | 4.8 | 3.9 |
| Health | 4.7 | 5.8 |
| Transport | 10.5 | 13.8 |
| Information and Communication | 4.4 | 5.2 |
| Recreation, Sport and Culture | 5.0 | 5.5 |
| Education Services | 5.8 | 5.5 |
| Restaurants and Accommodation Services | 8.7 | 5.7 |
| Insurance and Financial Services | 2.3 | 6.4 |
| Personal Care, Social Protection and Miscellaneous Goods | 5.4 | 0.0 |
| **Total** | **100.0** | **100.0** |

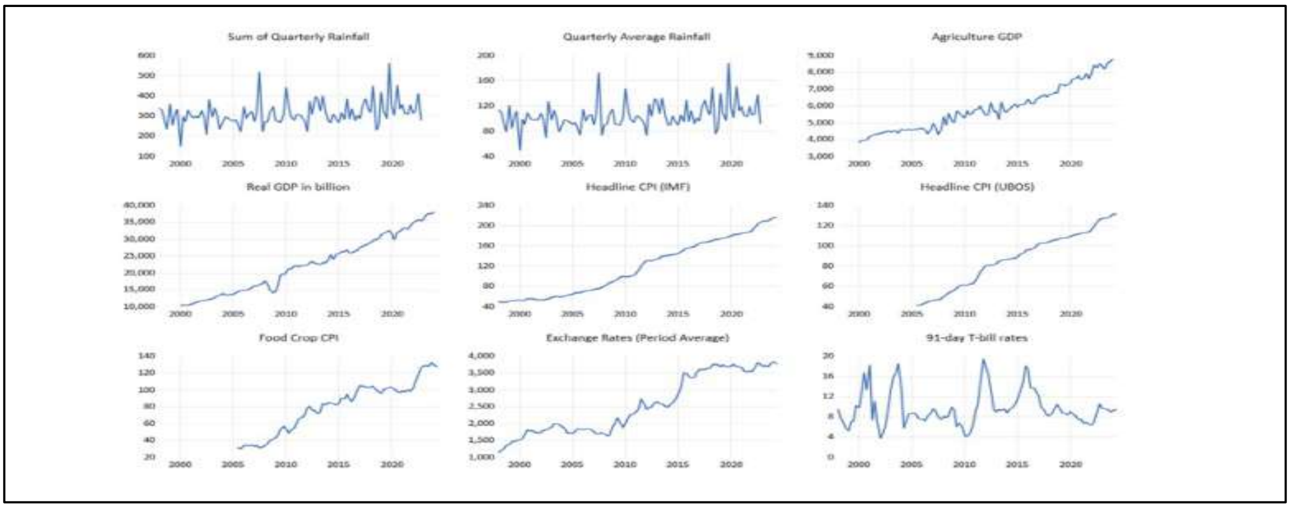
**Annex 4: Lag Selection and Diagnostic Tests**

The optimal lag length is selected based on standard information criteria, including the Schwarz Bayesian Criterion (SBC) and Hannan–Quinn Criterion (HQC). Both criteria suggest inclusion of one lag in the VAR system. After the estimation, the VAR model was subjected to a series of diagnostic tests.

• Stability tests (AR roots) confirmed that all the roots lie within the unit circle, indicating that the system is stable.

• Serial correlation tests indicate that the residuals are not autocorrelated, confirming the adequacy of the model specification.

**Annex 5: Trends of the Variables Used in the Study (2001-2022).**




Note: The figure presents a graph of headline inflation, policy rate (TB-91), oil prices, food inflation, and GDP. The x-axis represents the quarters, while the y-axis depicts fluctuations in inflation and growth rates.

**Annex 6: ADF Unit Root Test Results**

| Variable | Specification (c,t,l) | P-value | Order of Integration |
|---|---|---|---|
| log(Headline Inflation) | (c,t,0) | 0.7192 | I(1) |
| log(Food Inflation) | (c,t,0) | 0.7818 | I(1) |
| log(Core Inflation) | (c,t,0) | 0.7329 | I(1) |
| log(Real GDP Growth) | (c,t,0) | 0.7328 | I(1) |
| log(Exchange Rate) | (c,t,0) | 0.3592 | I(1) |
| log(Rainfall) | (c,0,0) | 0.0000*** | I(0) |
| 91-Day Treasury Bill Rate | (c,0,0) | 0.0056** | I(0) |
| Δlog(Headline Inflation) | (c,t,0) | 0.0083** | I(0) |
| Δlog(Food Inflation) | (c,t,0) | 0.0000*** | I(0) |
| Δlog(Core Inflation) | (c,t,0) | 0.0000*** | I(0) |
| Δlog(Real GDP Growth) | (c,t,0) | 0.0000*** | I(0) |
| Δlog(Exchange Rate) | (c,t,0) | 0.0000*** | I(0) |

Note: This table reports the augmented Dickey (ADF) unit root test results. The variables include the log of real GDP growth, the 91-day Treasury bill rate (policy rate), and the logs of headline, food, core inflation, exchange rate, and rainfall. Where necessary, the first differences were applied to achieve stationarity. Specification columns (c,t,l) indicate the inclusion of a constant, trend, and lag order, respectively. The null hypothesis states that the variable contains a unit root (nonstationary). Asterisks denote the significance levels: *** 1%, ** 5%, and * 10%. I(0) denotes stationarity, and I(1) indicates non-stationarity

## 2.4 The Impact of Climate Change on the Macroeconomic Situation of the MENA Region and its Implications on Monetary and Macroprudential Policies

*Ingy El Tawdy, Anwar Nasr, Mayar Mohamed*

### 2.4.1 Introduction

Climate change has evolved from a potential threat to an immediate and tangible challenge with far-reaching implications for global economies. The literature highlights that climate shocks manifest through multiple channels, including heat waves, sea level rise, droughts, floods, and lower precipitation, with profound effects on agriculture, labor productivity, energy supply, and ultimately on growth and inflation dynamics (Dell et al., 2012). These "physical risks" often translate into financial losses, supply chain disruptions, and population displacement. In parallel, "transition risks" emerge from policy changes, technological innovations, and market adjustments required to reduce carbon emissions, creating additional macroeconomic uncertainties (NGFS, 2019; IMF, 2020).

The Middle East and North Africa (MENA) region has a unique geographical location characterized by a hot and dry climate, where extremely high temperatures of up to 56°C may become the norm in the region, making it highly vulnerable to climate shocks. This is amplified by its economic concentration on sectors that are highly vulnerable to climate-related risks, both physical and transition, including agriculture, oil and gas, and tourism. A prominent example is the impact that climate-related risks have on agriculture and, by proxy, food production, posing a threat to food security in the region and, accordingly, on price levels, resulting in supply-driven inflationary environment.

Climate change risks are posing new threats to price and financial stability, requiring central banks to develop policies to mitigate these risks, including both physical and transition risks, given that these risks can impede the effectiveness of the monetary policy and threaten the stability of the financial system. On the price stability front, climate disruptions generate higher inflation volatility, as extreme weather shocks destabilize agricultural production, supply chains, and energy supply (Batini et al., 2022; Boneva et al., 2021). Transition risks, such as carbon taxes and energy policy reforms, can also raise prices of carbon-intensive goods, complicating monetary policy efforts (Krogstrup & Oman, 2019).

On the other hand, banks financing carbon-intensive sectors with high exposure to transition risks may face declining profitability due to asset price drops and increasing probability of defaults among clients. The overlap between physical and transition risks can create systemic risks in the banking sector and the broader financial system by amplifying the impact of each type of risk and increasing the likelihood of widespread financial instability. Previous work on the Euro Area shows that physical risks result in asset damage, production disruptions, and a rise in non-performing loans (NPLs) in the affected sectors and areas, which results in substantial financial losses for individuals and businesses as well as banks (ECB, 2023).

Although an expanding body of research has examined the macroeconomic and financial implications of climate change globally, few studies have analyzed these dynamics within the MENA region. This paper seeks to fill this gap by assessing the impact of climate-related disasters on inflation and growth in MENA countries, while differentiating outcomes by income levels (low, middle, and high). This study thus provides policymakers with an evidence-based understanding of how climate risks shape macroeconomic variables in the region, thereby supporting the design of effective strategies to mitigate and adapt to such risks.

The rest of the paper is structured as follows: Section II provides a description of the macroeconomic structure as well as a brief description of climate-risk mitigation efforts and regulatory responses in the MENA Region. Section III presents an overview of the relevant literature, while Section IV describes the data and methodology used in the study. Section V discusses the results of the empirical model, while Section VI concludes with some policy recommendations.

## 2.4.2 Overview of the Macroeconomic Structure in the MENA Region

### 2.4.2.1 Economic Structure of the Region

Before delving into the effect of climate change on the Macroeconomics of the MENA region, it is important to have a clear view of the current Macroeconomic situation in the region. The MENA region is characterized by considerable heterogeneity encompassing oil-exporting economies, the Gulf Cooperation Council (GCC countries) on one side, and oil-importing economies (Egypt, Jordan, Morocco, Tunisia) on the other. This heterogeneity implies different macroeconomic structures, where oil exporters benefit from hydrocarbon revenues yielding fiscal and external balances while in contrast, oil importers deal with chronic fiscal and current account deficits, elevated debt burdens, and dependence on external financing.

Despite the heterogeneity, MENA countries have some common economic features such as persistent unemployment, high population growth with low productivity, and vulnerability to external shocks leading to economic performance that is below the potential. The region is one of the most food-import-dependent in the world, making local inflation highly sensitive to global agricultural commodity prices, besides the associated imported inflation due to the exchange rate path, which together make inflation dynamics in the region highly volatile.

Image: unsplash.com

## 2.4.2.2 Monetary Policy Framework in the Region

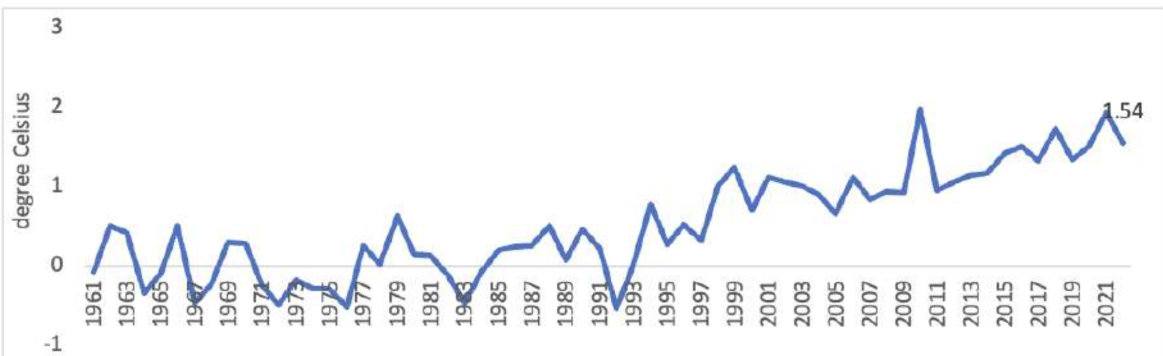
Monetary policy frameworks in the region are also heterogeneous. Some countries in the MENA region, such as the GCC, have pegged exchange rates, which on one hand provide nominal stability but on the other hand limit the scope for independent monetary policy. Interest rates closely follow U.S. Federal Reserve decisions, constraining central banks' ability to respond to domestic shocks. Other non-peg economies have gradually moved toward more flexible exchange rate arrangements with greater reliance on interest rate instruments. However, shallow domestic financial markets, limited monetary policy credibility, and fiscal dominance weaken the transmission mechanism in these economies.

Monetary policy in the MENA region is also highly vulnerable to Global Financial conditions as global risk sentiment affects capital flows, sovereign spreads, and exchange rate stability. Overall, monetary policy in MENA faces a dual challenge: balancing price stability amid repeated supply shocks, while supporting growth in economies constrained by structural rigidities and external vulnerabilities.

## 2.4.2.3 Climate Change as an Additional Challenge for Monetary Policy in the MENA region

Given the aforementioned fragile macroeconomic structure, climate change is considered an additional risk as rising temperatures, declining water availability, and increasing frequency of extreme weather events directly affect agricultural productivity, food prices, and energy demand. The MENA region is considered one of the most climate-vulnerable regions. This is explained by the geographical position characterized by arid and semi-arid climates, leading to more intense heat waves and limited water resources. Over the last fifty years, the average surface air temperature across the countries in the region has increased significantly. The Food and Agriculture Organization of the United Nations (FAO) data, from 1961 to 2022, indicate that the Surface Temperature Change with respect to a baseline climatology has increased from an average of -0.07°C to 1.54°C, as shown in Figure 18.

**Figure 18: MENA Surface Temperature Change**




Source: Climate Change Indicators Dashboard, International Monetary Fund

This has led to severe heat waves posing a significant risk to the region's water availability. According to the World Bank, the region is considered the world's most water-scarce where 60% of people live in high or extremely high water-stressed areas. The situation is further accentuated by the high dependence of the region on the agriculture sector, which is 70% rainfed, hence highly exposed to climate risk. Shorter growing seasons are then expected, which are threatening not only the production and the income of the region but also food security. Furthermore, rapid population growth and urbanization are exacerbating the situation by increasing demand for water and energy.

These climate shocks have implications for both oil importers and exporter countries; for oil importers, climate shocks exacerbate food and energy import bills, worsening current account deficits and inflation volatility. While oil exporter countries are exposed to transition risks caused by the climate policies and global decarbonization trends, which may undermine fiscal sustainability and asset valuations in the long run. These risks have major implications on monetary policy as they complicate inflation management, weaken the credibility of inflation-targeting frameworks and put pressure on the exchange rate.

### 2.4.2.4 Climate-Risk Mitigation Efforts and Regulatory Responses in the MENA Region

Addressing the impacts of climate change requires a holistic approach, one that involves both private and public sector. MENA economies have begun to institutionalize climate-risk mitigation through national strategies, supervisory guidance, and market instruments in order to dampen macroeconomic volatility transmitted via food, energy, and investment channels. As an example for a national strategy employed, the United Arab Emirates launched a Net Zero 2050 initiative and hosted COP28 (2023), where the "UAE Consensus" committed parties to a transition away from fossil fuels and to tripling global renewables and doubling energy efficiency by 2030. Moreover, Morocco submitted long-term strategies toward about 80% renewable electricity by 2050, positioning the power sector to lower cost-push pressures from imported fuels. While on the financial market side, Egypt issued the region's first sovereign green bond worth US$750m in 2020 to finance clean transport, water, pollution control, and renewables, signaling a pipeline for green public spending. The UAE also moved to develop market infrastructure for carbon credits. Abu Dhabi Global Market licensed ACX in 2022 as the world's first regulated carbon exchange and clearing house for environmental instruments, to channel private finance toward mitigation.

In addition, financial authorities are integrating climate risk into supervision to contain credit and liquidity spillovers from climate shocks. In Egypt, the Central Bank of Egypt (CBE) issued the Sustainable Finance Guiding Principles (July 2021) and the Binding Regulations on Sustainable Finance (November 2022) that require banks to integrate sustainability into policies, establish dedicated departments, report periodically, and consult environmental experts.

The Financial Regulatory Authority (FRA) has also demonstrated a proactive approach by requiring listed companies and significant non-banking financial firms to include climate change financial impacts in their ESG disclosure reports, aligning with TCFD guidelines. Collectively, these measures aim to internalize climate risk by shifting climate impacts from being an "external shock" to a measurable, managed, and priced factor inside the economic and financial system. Although the implementation risks remain present, the direction of policy is broadly consistent with lowering medium-term climate-macro vulnerabilities in MENA.

## 2.4.3 Literature Review

### 2.4.3.1 Theoretical Literature Review

The theoretical literature identifies three main channels that relate climate change to monetary policy, namely, the asset prices channel, the natural rate of interest channel, the macroeconomic objectives channel, and the expectations channel. The first channel highlights the transmission of climate change effects to the banking sector. In this case, the effect is expected to occur during the shift toward a low-carbon economy, which may result in significant swings in asset prices and the creation of large volumes of stranded assets. This may cause severe stress on financial institutions' balance sheets, leading to a reduction in the flow of credit to the real economy. Extreme weather events further aggravate this risk by potentially causing direct credit losses. Central banks are not immune to this risk as they are facing potential losses from securities acquired through asset purchase programs and from the collateral provided by counterparties in monetary operations. This vulnerability creates tighter financial conditions in the economy, which impairs the transmission channel of monetary policy to firms and households.

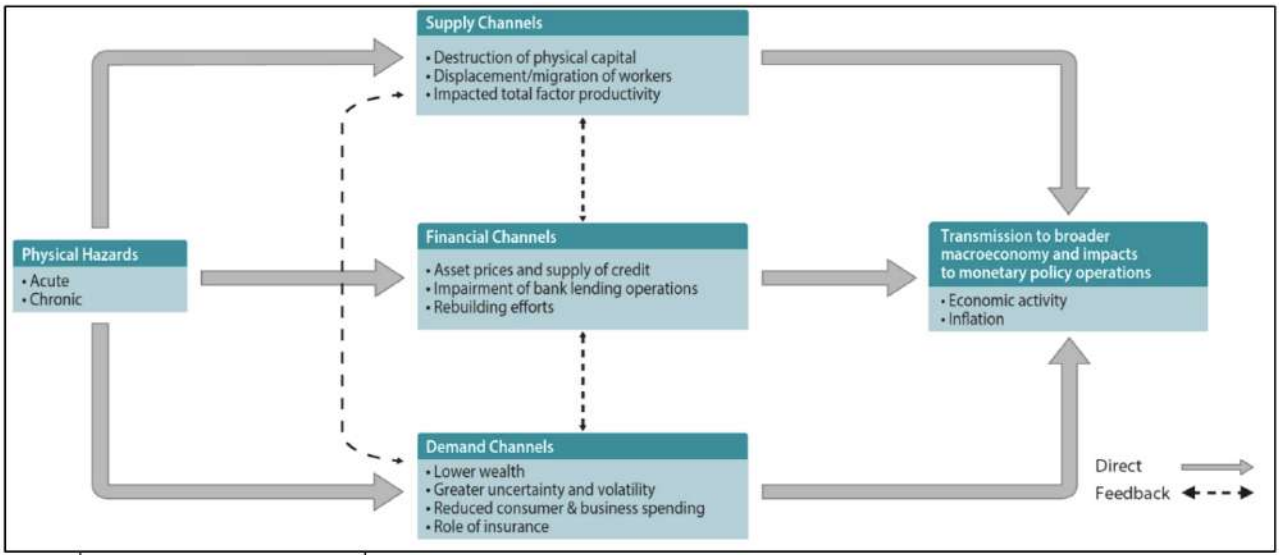
The second channel of transmission of climate risk to monetary policy is by diminishing the space for conventional monetary policy tools. Climate shocks pose downward pressure on the equilibrium real interest rate (r*), which is the rate at which the aggregate economic activity is at its potential level and inflation is at the monetary authority's target level. The downward pressure is because extreme weather events affect productivity, raise risk aversion, increase precautionary savings, and reduce incentives to invest. These factors combined tend to reduce r*, which limits the ability of central banks to employ their conventional monetary policy tools in case of a downturn before hitting the zero lower bound.

A third channel is the macroeconomic objective channel. Extreme weather events can be primarily thought of as supply shocks, which tend to increase prices and lower output. This arises from physical climate risks that cause a shortage of commodities or damage to infrastructure and accordingly lead to price volatility. This has ramifications on trade as higher temperatures lead to reduced productivity and food supply, and consequently, the quantity of goods exported, particularly by poor countries. In addition, there might be disruptive effects on labor supply and productivity by reducing the physical and cognitive performance of human capital, as extreme heat can lead to a rise in the mortality rate in the population.

Supply shocks are difficult to counter from a central bank perspective as policymakers are faced with a dilemma between stabilizing inflation and maintaining economic activity. Climate shocks amplify the frequency and severity of supply shocks making them more persistent, hence there could be risk of de-anchoring of inflation expectations making the task more difficult for central banks to set suitable monetary policy. Extreme climate events such as floods and storm can also cause a demand side shock as these events reduce household wealth and hence private consumption. In addition, uncertainty, financial losses and tighter climate policy which cause dislocation in high carbon sectors, can negatively affect investment.

Another indirect way through which climate change affects monetary policy is the expectations channel. Anticipations of future environmental regulations, carbon pricing, and the green transition significantly influence economic behavior; consumer and investor expectations about future policy impacts may lead to precautionary savings or speculative behavior, intensifying macroeconomic fluctuations. These behaviors influence long-term interest rates and credit conditions. For example, if households expect future carbon taxes to reduce real income, they may cut spending today, potentially lowering aggregate demand and inflation. This also applies to firms as they adjust their own expectations around input costs, wages, and pricing strategies in response to anticipated regulatory changes. These expectation-driven effects further complicate the task for central banks as they could deviate the monetary policy from achieving its desired targets.

**Figure 19: Summary of the Different Channels of Transmission**




Source: NGFS (2024)

## 2.4.3.2 Empirical Literature

The reviewed empirical literature focuses on three key questions: how asset returns are affected by climate change, how asset prices could be affected by climate-related costs, and whether financial markets are efficiently pricing these risks. Campiglio et al. (2022) surveyed academic literature on the influence of climate-related risks on financial assets. The authors found strong evidence that natural disasters like hurricanes and droughts already have a detrimental impact on debt and equity instruments, resulting in increased non-performing loans and lower payoffs. The authors also pointed out that certain financial assets are more impacted by transition costs, which are associated with the move to a low-carbon economy, than others. Their findings show that these risks are monetarily significant in terms of future climate-related costs. Nevertheless, the degree to which investors have factored these risks into asset prices will determine how significant they are.

Levine & Pontines (2024) also examined the effect of climate shocks on the natural interest rate by incorporating an environmental aspect into a Keynesian growth model. They build on the baseline Keynesian growth model of Fornaro & Wolf (2023), which found that temporary supply shocks in the form of an increase in energy prices or the emergence of a pandemic cause a reduction in the natural real interest rate. By extending the model to include an environmental aspect, the simulation results proved that a decline in the natural rate of interest following a supply shock is aggravated when the environmental component is part of the model.

Dell et al. (2012) studied the relationship between changes in a country's temperature, precipitation, and changes in its economic performance using panel data for 125 countries. Their model results prove that higher temperatures result in a significant negative effect on growth in poor countries, as 1◦C rise in temperature reduces economic growth by 1.3%, but this effect is not significant in rich countries. Higher temperature also leads to wide-ranging effects such as reducing agricultural and industrial output in the countries. Changes in precipitation, however, have relatively mild effects on economic growth both in rich and poor countries. Abdelfattah et al. (2021) investigated the effect of temperature and precipitation deviation from the historical average on growth in the MENA countries. The analysis was conducted in 20 countries over the period 1980 to 2017 using a stochastic growth model. The results show that climate change has long-term negative impacts on economic growth.

Byrne and Vitenu-Sackey (2024) studied the impact of climate variability on real GDP growth by differentiating between the impact of global climate risk and country-specific climate risk using a factor model. The study employed a Bayesian Panel VAR in 30 countries over the period 1901 to 2020. The findings showed that global climate risk has a significant negative and relatively more important impact on GDP than country-specific climate shocks. Both advanced and emerging economies are impacted to a greater extent by common, rather than idiosyncratic, climate risk, which emphasizes the global dimension of climate change. In addition, results indicate the presence of spillover effects from one country to another.

Using a stochastic growth model where productivity is affected by deviations in temperature and precipitation from their long-term moving average historical norms, Kahn et al. (2021) assessed the impact of climate change on growth using panel data for 174 countries from 1960 to 2014. A panel ARDL model was estimated, where the results show that per-capita real output growth is negatively affected by persistent changes in the temperature above or below its historical norm, but no statistically significant effects were identified for changes in precipitation. They estimated that a rise (or fall) in temperature above (or below) its historical norm by 0.01 ◦C annually for a long period of time will decrease income growth by 0.0543 % per year. The authors have estimated the differential impact of weather shocks across climates and income groups where they concluded that the marginal effects of weather shocks are larger in low-income countries as they have a lower capacity to deal with the consequences of climate change.

Other studies have also investigated the effect of climate shocks on inflation in addition to the effect on growth where some of them have counterintuitive results. Cevik and Jalles (2024) studied the effect of climate-induced natural disasters on inflation and economic growth in a large panel of 173 countries over the period 1970–2020. Using local projection methodology, the results show that inflation and real GDP growth react significantly but differently in terms of direction and magnitude to different types of climate disasters as extreme temperatures yield lower inflation while storms lead to higher inflation. By splitting the sample into income groups (advanced and developing countries), the study showed that the impact of climate shocks on headline inflation differ in economies with varying levels of economic development showing that developing countries are more vulnerable. While for growth, it was found that the initial effect of climate shock on growth is negative but the magnitude and pattern of response show variation over the long run. A similar study by Mukherjee et al. (2021) used a panel VAR model to estimate the impact of temperature shocks on inflation for a sample of developed and developing countries from 1961 to 2014. Their findings suggest that in fact temperature shocks lead to inflationary pressure in all the countries under study while the effect is persistent and prolonged for developing countries only. These findings support the analysis by Barrios, et al. (2008), which concluded that Africa has been disproportionately affected by climate change and this has been a major contributor to its weaker agricultural performance compared with other developing regions.

Faccia et al. (2021) investigated how extreme temperatures affect various measures of inflation in 48 advanced and emerging economies (EMEs) during the period 1951–1980. The analysis was done on a range of prices such as consumer prices, producer prices and the GDP deflator where they found that higher temperatures increase food price inflation in the near term, especially in EMEs while over the medium term, the impact on the various price indices tends to be either insignificant or negative.

Abidi et al. (2024) empirically investigated the impact of climate shocks on inflation and monetary policy transmission in the Middle East and Central Asia (ME&CA) region. Local projection methodology was used to estimate the impact of climate shocks on headline and food inflation for 18 countries over the period 2013 to 2022. The results proved that changes in water availability, other climate-related disturbances and negative climate shocks can significantly impact food prices and inflation. On the other hand, positive climate shocks such as increase in rainfall have reduced inflation. The findings also showed that ME&CA countries that are more severely impacted by negative climate shocks exhibit diminished sensitivity to monetary policy tools. This study sheds some light on the importance of considering climate-related supply shocks when designing monetary policy, particularly in countries where food makes up a significant part of the CPI-basket.

## 2.4.4 Data & Methodology

This section provides an econometric model representing the effect of climate shocks on the macroeconomic situation of the MENA region. In line with previous studies, the analysis used a panel estimation due to the limited availability of large and consistent dataset for single countries. The utilized a vector autocorrelation (VAR) methodology, as the VAR treats all variables as endogenous and hence facilitates analysis of the dynamics between the different variables over the short run through running impulse response functions and variance decomposition approach.

$$y_{it} = \alpha + \sum_{l=1}^{p} A_l y_{i,t-1} + B c_{it} + \varepsilon_{it}$$

The above equation is estimated where $A_\ell$ are autoregressive coefficient matrices; B captures contemporaneous impacts of climate on macroeconomic variables. This study is based on an-nual data from 1990 to 2022 on MENA countries. Some countries were excluded from the analysis due to data unavailability hence the study considered 15 countries (shown in Annex 1), including Egypt.

The following are the variables used in this study:

**1. Variables of Interest:**

• **Inflation (ϖ):** Annual percentage change in consumer price index (CPI), obtained from the World Economic Outlook, (IMF, 2024).

• **GDP Growth (g):** Annual percentage change in real GDP, sourced from World Development Indicators, (WorldBank, 2024).

• **Climate disaster frequency:** Annual number of climate-related disasters (floods, droughts, storms, extreme temperatures, wildfires) per country, sourced from IMF Climate Change Dashboard (EM-DAT / CRED). A disaster is recorded when at least 10 deaths, 100 affected people, a state of emergency, or an international aid request is reported.

• **Average mean temperature** (used in the robustness check of the model): Sourced from the World Bank Climate Change Knowledge Portal (CCKP) and measures the annual average near-surface air temperature (°C) for each country, based on gridded climate data from the Climatic Research Unit (CRU) and other observational datasets.

**2. Other Variables**

• **Gross capital formation (GCF):** Gross capital formation as a share of GDP (%), measuring investment in productive assets.

• **Broad money growth (ΔM2):** Annual percentage change in broad money (M2), representing monetary liquidity conditions.

• **Lagged variables** are included to capture the dynamic interdependence of a panel VAR framework.

The choice of variables is guided by previous studies, notably Mukherjee & Ouattara (2021), who employed a panel-VAR to demonstrate pronounced inflationary pressures from temperature shocks in a sample of developed and developing countries.

The following is the equation form of the model.

$$\pi_{it} = \beta_0 + \sum_{p=1}^{P} \beta 1 \,\mathrm{Disaster}_{\mathrm{i,t-p}} + \sum_{p=1}^{P} \beta 2 \,\pi_{i,t-p} + \sum_{p=1}^{P} \beta 3 \,\mathrm{g}_{i,t-p} + \sum_{p=1}^{P} \beta 4 \,\mathrm{GCF}_{i,t-p} + \sum_{p=1}^{P} \beta 5 \,\Delta\mathrm{M2}_{i,t-p} + \varepsilon\mathrm{it}$$

$$\mathrm{g}_{it} = \propto_0 + \sum_{p=1}^{P} \propto 1 \,\mathrm{Disaster}_{\mathrm{i,t-p}} + \sum_{p=1}^{P} \propto 2 \,\pi_{i,t-p} + \sum_{p=1}^{P} \propto 3 \,\mathrm{g}_{i,t-p} + \sum_{p=1}^{P} \propto 4 \,\mathrm{GCF}_{i,t-p} + \sum_{p=1}^{P} \propto 5 \,\Delta\mathrm{M2}_{i,t-p} + \varepsilon\mathrm{it}$$

## 2.4.5 Expected Signs (Guided by Theory and Regional Context):

**Climate disasters coefficient** ($\beta1>0$) is expected to be positively correlated with inflation. In the MENA region, climate shocks affect agricultural output and food supply which increase food prices and import dependence. This results in cost-push inflation.

**The climate disasters coefficient** ($\alpha1<0$) is expected to be negatively correlated with GDP growth. Disasters damage infrastructure, reduce labor productivity due to heat stress, and disrupt production, leading to lower output growth.

**Money supply growth** ($\beta5>0$ and $\alpha5>0$) is expected to be positively correlated with both inflation and growth. Monetary expansion increases liquidity and demand, potentially fueling financially shallow economies. A similar relationship is expected on GDP growth as expansion in M2 can stimulate economic activity by lowering borrowing costs, increasing liquidity, and supporting credit to the private sector.

**Gross capital formation** ($\beta4>0$ and $\alpha4>0$) is expected to be positively correlated with both inflation and growth. Higher investment boosts productive capacity, enhances infrastructure, and stimulates economic activity.
The study tests the null hypothesis, which postulates that 'climate shocks do not affect either inflation or growth', versus the alternative hypotheses below:

**H1** ***(Climate–Inflation link):*** Climate shocks have a positive effect on inflation through supply-side disruptions, especially food and energy prices.

**H2** ***(Climate–Growth link)*****:** Climate shocks harm GDP growth, reflecting lower productivity, damage to capital, and disruptions to economic activity.

As a preliminary analysis of the data, Table 10 presents a summary statistic of the main variables of interest. In addition, a correlation matrix between climate disasters, growth, and inflation is presented in Annex 2. Annex 2 shows that inflation is positively correlated to the frequency of climate disasters, while growth shows a small negative correlation.

**Table 10: Descriptive Statistics**

| | Average Mean air temperature (°C) | Number of Climate disasters | GDP growth | Inflation YoY |
|---|---|---|---|---|
| Mean | 23.04 | 0.71 | 0.04 | 0.08 |
| Median | 23.17 | 0.00 | 0.04 | 0.04 |
| Maximum | 29.42 | 7.00 | 0.86 | 1.71 |
| Minimum | 13.48 | 0.00 | -0.50 | -0.1 |
| Std. Dev. | 4.11 | 1.16 | 0.08 | 0.15 |
| Observations | 495 | 495 | 495 | 495 |

## 2.4.6 Empirical Findings

### 2.4.6.1 Unit Root and Lag Structure results

In order to conduct a Vector Autoregressive analysis, the first step is to test for the stationarity of the data, many of the widely adopted panel unit root tests were used such as Levin et al. (2002) test (LLC), Im et al. (2003) (IPS) and the Fisher-type test (ADF-Fisher) proposed by Maddala and Wu (1999). The different models showed almost same conclusions, as shown in Annex 3, suggesting that the null hypothesis of the presence of a unit root is rejected for all variables, except for broad money, implying that all the variables are stationary in level. For the broad money, the results indicate that the variable is integrated of order (1), hence the variable will be differentiated to be used in the model. The second step is the choice of the lag structure of the VAR. Using the lag length criteria, it appears that the different criteria show different optimal lags lengths, so we decided to stick to the Akaike information criteria (AIC). The AIC suggests using 3 lags as shown in Annex 4.

## 2.4.7 VAR Results

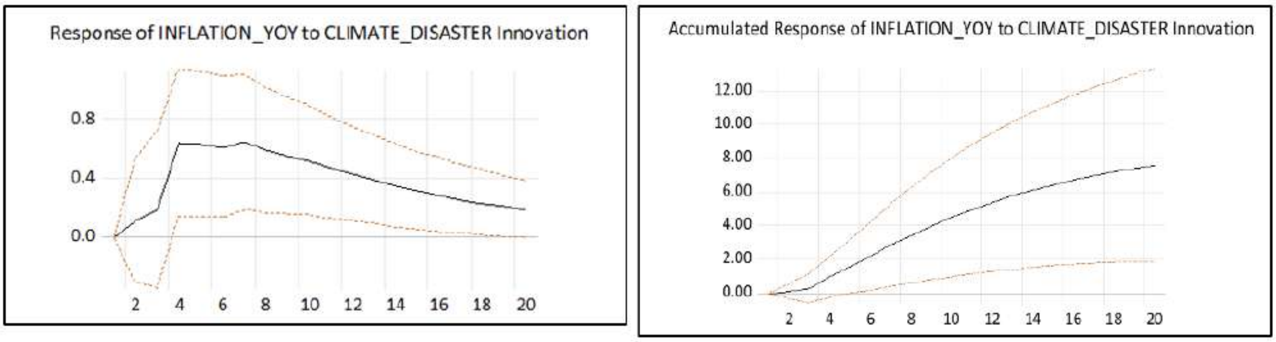
### 2.4.7.1 Results of the Estimation on the Full Sample of Countries

The VAR model was then estimated using a Cholesky ordering of the variables, such that the climate disaster variable is set first, as it is not contemporaneously affected by all the other variables but could respond to the shock in the other variables with a lagged effect.

To analyze the results of the VAR model, the Impulse Response Function (IRF) is utilized to observe how shocks or changes in one variable affect the others over time. Given that the research question of the paper focuses on growth and inflation, the impulse response graphs will present the effect of a climate disaster shock on inflation and growth over time. Shocks are defined as one standard deviation innovations.

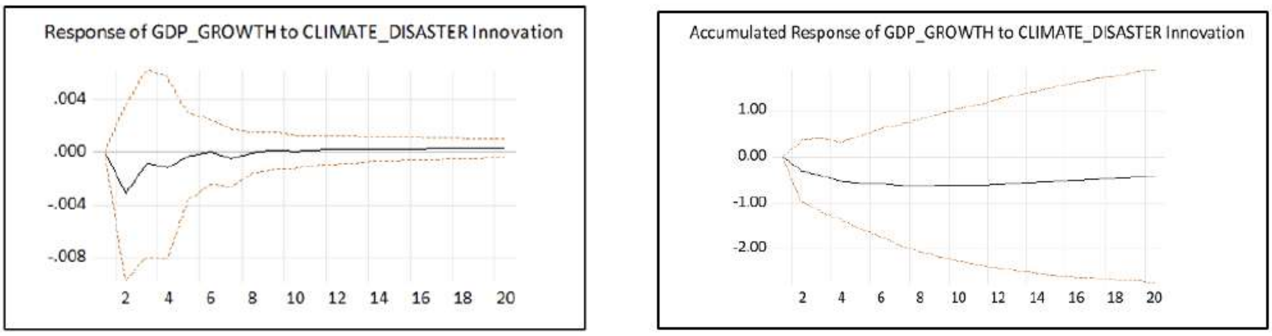
As shown in Figure 20, a climate disaster shock has an effect on inflation in the MENA region, but the effect starts to be significant (where the two confidence bands lie in the same positive territory) after 3 years of the shock. Inflation reaches its peak in year 4 of the shock, recording a change of 0.6% before the effect starts to decrease over time. The accumulated response figure indicates that after 20 years, inflation could increase by 6% on the back of a climate disaster shock.

**Figure 20: IRF of Inflation to Climate Disaster**




Unlike the significant effect of climate disaster shock on inflation, the impulse response function indicates that a one standard deviation climate shock yields a negative effect on growth; however, this effect is insignificant and fades completely over time, as shown in Figure 21. This is confirmed by the accumulated response, which shows that after 20 years, the effect of the shock on growth is very close to zero.

**Figure 21: IRF of Growth to Climate Disaster**




The study used the variance decomposition analysis to quantify the degree to which the volatility of one variable can be explained by a shock in another variable. This analysis is used to assess the relative importance of different variables in explaining the variability of the system. In this study, the variance decomposition helps in gaining insights into the relative contribution of the climate shock in explaining volatilities in inflation and growth. The results shown in Annex 5 indicate that inflation volatility is mainly driven by its own shocks. However, climate shocks appear to be the second contributor to inflation volatility, and their effect becomes more explicit in a longer horizon, contributing by 6% to inflation volatility after 20 years. Despite the modest contribution of climate shock, these results confirm that over the long run, climate disasters will have a clear impact on inflation. In line with the results of the impulse response function, the variance decomposition of growth shows that climate shocks have almost no effect on the GDP growth volatility.

As a robustness check, the same model exercise was estimated using another climate variable, which is the average mean air temperature instead of the climate disaster variable (Annex 6). The findings in Annex 6 indicate the same trend as in Figure 20, but of a different magnitude. It appears that a shock in the average mean air temperature has a smaller effect on inflation compared to a climate disaster shock. It can thus be concluded that changing the definition of climate conditions does not change the results, confirming the robustness of the model.

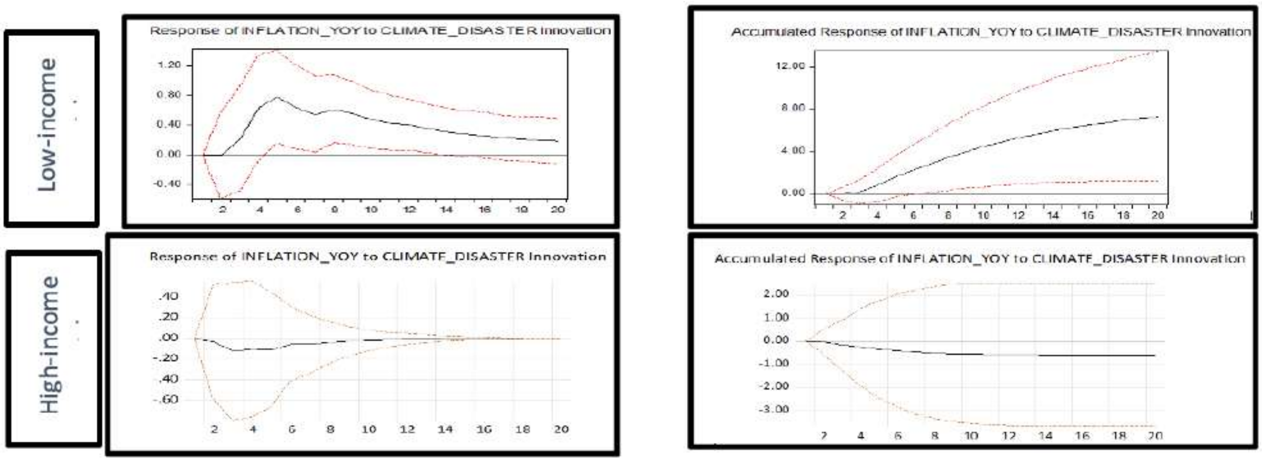
## 2.4.7.2 Results of the Estimation with a Split Sample (Low Vs High Income Countries)

Despite their geographical proximity, MENA countries are heterogeneous in terms of economic development and income level. To gauge the impact of climate shock on inflation and growth, considering this heterogeneity, this study focused on a more granular level by splitting the sample into 2 groups according to their income level as per the World Bank classification. The two groups are high-income groups encompassing high and higher middle-income countries and low-income groups, including low and lower middle-income countries.

The same analysis was conducted on both groups, where the results show a contrast in the impact of climate shock on inflation. Low-income countries are more vulnerable to climate disaster shocks. The effect becomes significant at year 4 and until year 14, and the accumulated response indicates that inflation increases by 7% in year 20, as shown in Figure 22. This is higher than the accumulated response estimated on the whole sample analysis. This could be explained by the high reliance of these economies on climate-sensitive sectors such as agriculture and tourism, and the high share of food in household consumption baskets. Consequently, extreme weather events disrupt agricultural production and supply chains which translates directly into a sharp rise in food prices and higher inflation in those economies.

This is amplified by the limited fiscal space, which hinders the capacity of governments to stabilize prices through subsidies or buffer stocks. Moreover, exchange rate pressures and import dependence exacerbate the pass-through effects of climate shocks into domestic prices. In contrast, results for high-income countries show that climate disaster has an insignificant effect, as shown in Figure 22. However, splitting the sample didn't change the results as they remain insignificant for both income groups with regard to the effect of the climate change shock on growth (Annex 7).

**Figure 22: IRF of Inflation to Climate Disaster Segregated by Income Level**




The heterogeneity in the effect of climate shock on inflation is consistent with many previous studies, such as Mukherjee et.al (2021) and Cevik & Jalles (2024), where the results show a striking contrast in the impact of climate shocks on inflation according to income level, state of the economy, and fiscal space. They also indicated that shocks in developing countries have a more prolonged effect on inflation. This conclusion reflects the high vulnerability of low-income countries in terms of the structure of the economy, fiscal and institutional capacity that limit the ability to adapt and mitigate the consequences of climate shocks compared to high-income countries.

## 2.4.8 Conclusion and Policy Recommendations

Climate change risk is global in its nature, but the effects may be heterogeneous on different countries according to their geographical location, income, development level, and capacity to adopt mitigation and adaptation policies.

This study assessed the impact of climate change using different climate indicators on the main macroeconomic variables of the MENA countries. The study estimated the effect of climate disasters on growth and inflation over the period 1990 to 2022. Using a VAR model, the findings show that a climate disaster has a significant and prolonged effect on inflation in the MENA region countries, while the effect on growth is insignificant. The findings also show that low-income countries are more vulnerable to inflationary pressure caused by climate risk than high-income countries.

The significant and prolonged effect of climate change on inflation is a signal for Central banks to be vigilant and to consider this effect when setting their monetary policy. This is even more critical for central banks with an inflation targeting regime, as climate shocks could delay the progress to accomplish this mandate, requiring an increase in interest rates to manage inflation.

The problem is further amplified by the fact that climate shocks are classified as supply shocks, presenting a dilemma for central banks between stimulating economic output and controlling inflation. Central banks are thus forced to increase interest rates to curb inflation while impeding economic growth.

Accordingly, central banks must prioritize proactive measures to address climate change risks by integrating climate shocks into their monetary policy frameworks to ensure more accurate inflation and output forecasting. This requires the development of new analytical tools and models to assess climate impacts and project their long-run effects on the economy. In addition, central banks should implement green policies such as promoting green lending and greening their own portfolios, while actively communicating with the public and financial community about climate risks through disclosure of their own carbon footprint, speeches, research, and conferences that raise awareness.

Policy-specific instruments also provide an effective way to address climate challenges. On the monetary policy side, this could include adopting dual interest rate systems that offer lower borrowing costs for environmentally friendly projects, adjusting reserve requirements in favor of green portfolios, incorporating climate risks into collateral frameworks, and pursuing green quantitative easing through the purchase of sustainable assets. Macroprudential tools can further strengthen resilience by embedding climate stress tests into supervisory frameworks, adjusting capital requirements in line with climate exposures, monitoring sectoral leverage ratios and imposing large exposure restrictions in sectors highly vulnerable to climate risks. At the micro-prudential level, regulators should require banks to incorporate climate risks into their risk management systems, disclose their exposures to climate-related risks, and maintain a minimum share of green assets in their portfolios. Beyond their direct role, central banks can also act as advocates for broader government policies that incentivize sustainable investment and carbon reduction. Taking together, these measures are crucial to preserving economic and financial stability in the face of climate change and to mitigating the threat of climate-related disasters.


Image: unsplash.com

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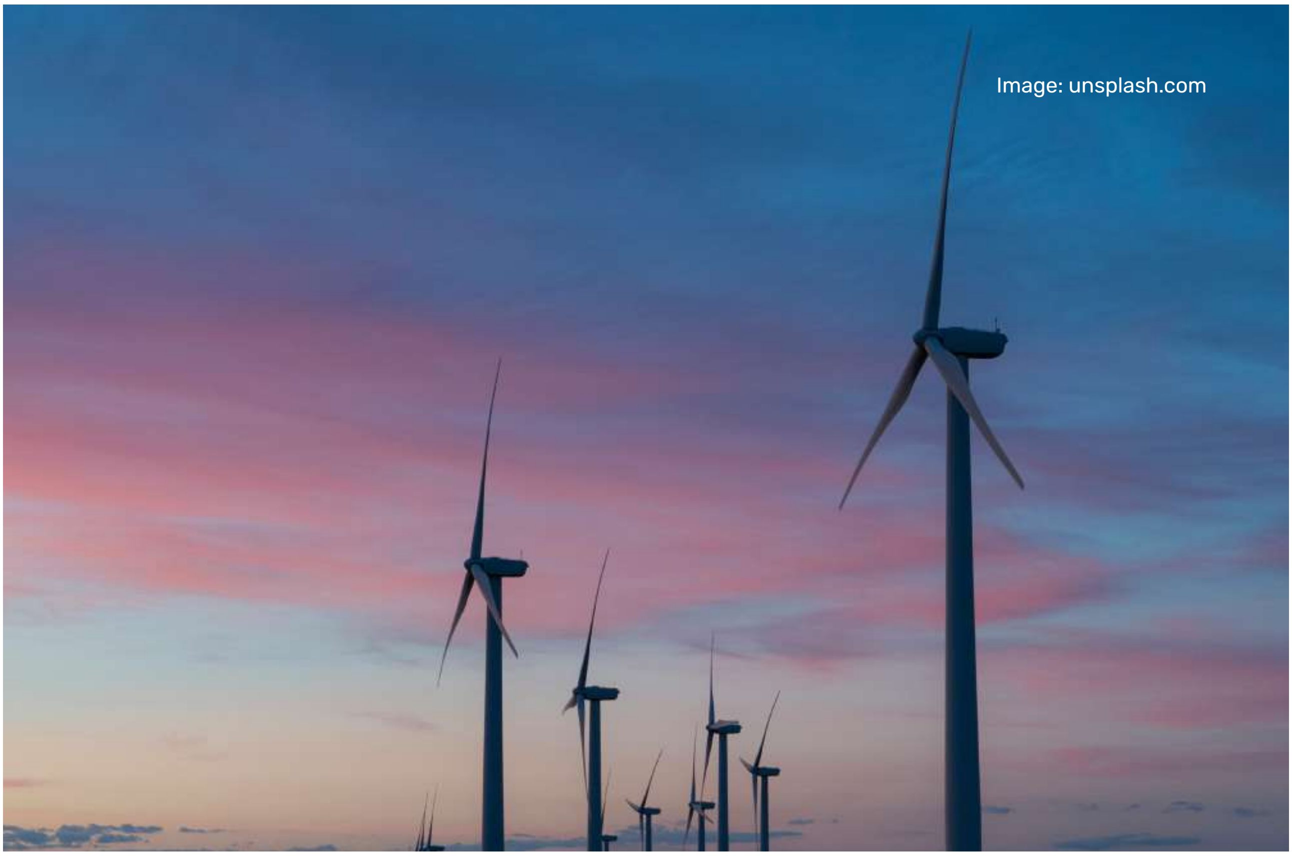


Image: unsplash.com

# Annexes

### Annex 1: List of countries included in the Sample Classified According to their Income Level as per the World Bank Classification.

**• Low and Lower Middle-Income Countries**

| | |
|---|---|
| Algeria | Lower middle income |
| Egypt | Lower middle income |
| Djibouti | Lower middle income |
| Iran | Lower middle income |
| Jordan | Lower middle income |
| Lebanon | Lower middle income |
| Morocco | Lower middle income |
| Yemen | Low income |
| Tunisia | Lower middle income |

**• High and Upper Middle -Income Countries**

| | |
|---|---|
| Israel | High income |
| Libya | upper middle income |
| Oman | High income |
| Qatar | High income |
| Saudi Arabia | High income |
| United Arab Emirates | High income |

### Annex 2: Correlation Matrix

| Correlation matrix | Climate disaster | GDP growth | Inflation YoY |
|---|---|---|---|
| Climate disaster | 1 | -0.07 | 0.14 |
| GDP growth | -0.07 | 1 | -0.02 |
| Inflation YoY | 0.14 | -0.02 | 1 |

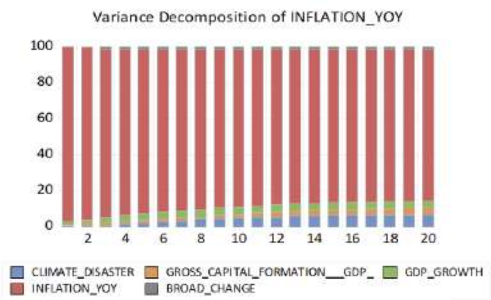
### Annex 3: Panel Unit Root Test Results

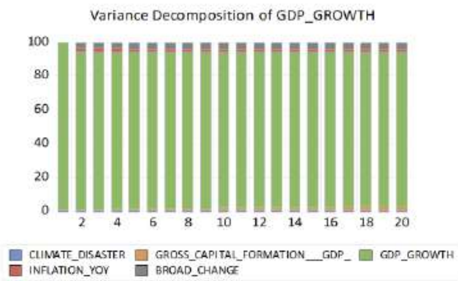
| **Panel Unit Root Tests** | **LLC** | **ADF- Fisher Chi-square** | **IPS** |
|---|---|---|---|
| **Average Mean air temperature change** | 0.000*** | 0.0313** | 0.0039*** |
| **Broad Money (%GDP)** | 0.6774 | 0.9311 | 0.9622 |
| **Climate disaster** | 0.000*** | 0.000*** | 0.000*** |
| **GDP Growth** | 0.000*** | 0.000*** | 0.000*** |
| **Gross capital formation (%GDP)** | 0.3399 | 0.0443** | 0.0665* |
| **Inflation YoY** | 0.0001*** | 0.000*** | 0.000*** |
| **Note: *, ** and *** denote 10%, 5% and 1% significant level respectively.** | | | |

## Annex 4: Lag Length Criteria

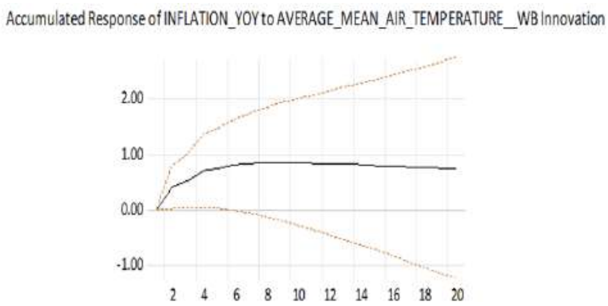
| Lag | AIC | SC |
|---|---|---|
| 0 | -5.424575 | -5.367013 |
| 1 | -7.644851 | -7.299479* |
| 2 | -7.738133 | -7.104951 |
| 3 | **-7.841790*** | -6.920798 |
| 4 | -7.826957 | -6.618155 |
| 5 | -7.829996 | -6.333383 |
| 6 | -7.784543 | -6.000121 |
| 7 | -7.767741 | -5.695509 |
| 8 | -7.817824 | -5.457781 |

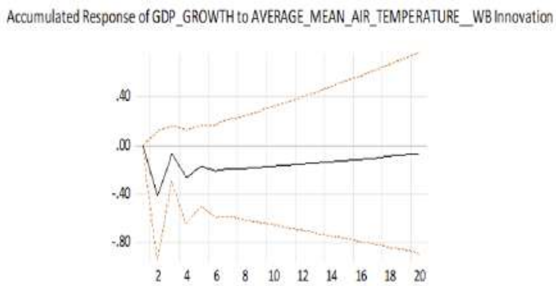
## Annex 5: Variance Decomposition Analysis of Climate Disaster Shock on Inflation and Growth on the Whole Sample of Countries.



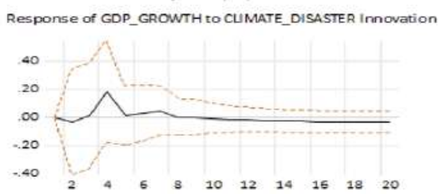




## Annex 6: Impulse Response Function Results of Average Mean Air Temperature Shock on Inflation and Growth Over the Full Sample of Countries

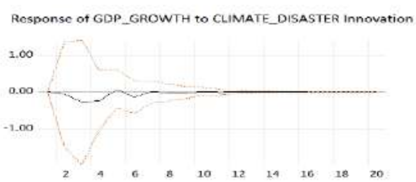



## Annex 7: Impulse Response Function Results of the Climate Disaster Shock on Growth with a Split Sample into Low and High-Income Countries.




IRF for high income



# 2.5 Macroeconomic Impact of Climate Change and the Role of Central Bank in Mauritius

*Mahima Bhurtha and Urvashi Bolaky*

## 2.5.1 Introduction

Climate change has turned out to be a dominant concern worldwide, representing the greatest global challenge due to its manifold, long-lasting and profound impact. As climate change gathers momentum, the occurrence and severity of climate-related hazards are anticipated to intensify. The projected rise in global temperatures and associated changes in climate, notably variations in rainfall or storm characteristics, as well as the transition to a low-carbon economy implied by the Paris Agreement have far-reaching consequences for the macroeconomy and, subsequently, on monetary policy.[7] Assessing the macroeconomic impact of climate change on the economy is thus considered as one of the most pressing issues, (NGFS, 2020). As such, central banks across the world have been increasingly incorporating climate change considerations into their policies as these can be major hurdles in achieving their price stability and economic development mandates.

Climate-related calamities and their erratic patterns have taken a toll on many economies including Mauritius. Indeed, as a small island developing state (SIDS) and tropical island, Mauritius is highly vulnerable to the vagaries of nature, particularly, cyclones and heavy rains in spite of contributing less than 0.01 percent of global greenhouse gas (GHG) emissions.[8]

While Mauritius is vulnerable to climate change, the extent to which weather-related shocks influence macroeconomic outcomes, particularly inflation and output, is not clear. Inflation and economic growth are key policy variables directly linked to the mandate of the Bank of Mauritius, which is to maintain price stability and promote orderly and balanced economic development. Although inflation has generally remained moderate over time, bouts of unexpected price volatility could have implications for the cost of living and overall welfare of the population, posing challenges for monetary authorities. Similarly, output, particularly in the agricultural sector, is highly sensitive to climate change. Having a clear understanding of the role of climate-related shocks in shaping these macroeconomic outcomes is therefore crucial for designing effective fiscal and monetary policies.

This study does not assume that climate-related shocks directly drive macroeconomic outcomes but tests the hypothesis that these shocks, proxied by rainfall and temperature variations may influence inflation and growth dynamics in Mauritius.

7 In December 2015, 196 Parties adopted the Paris Agreement to set a goal of limiting global warming to well below 2°C compared to pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.
8 As per the Update of the Nationally Determined Contributions of the Republic of Mauritius, October 2021.

Thus, the contribution of this study is two-fold. Firstly, SIDS are highly exposed and susceptible to the hazardous consequences of climate change on the macroeconomy but there is a paucity of research relating climate change to key economic variables in SIDS as most studies are overwhelmingly geared towards developed economies as opposed to their developing and SIDS counterparts. This study, therefore, attempts to fill the research gap by providing empirical evidence on Mauritius. In the same vein, while there is substantial empirical evidence on the consequences of extreme climate-related events such as floods and drought, research is relatively lacking in terms of less acute climatic shocks, for instance, evolving rainfall pattern and rise in temperature, which equally have detrimental effects on the economy.

Despite numerous global studies on the impact of climate change on macroeconomic outcomes, there is essentially no prior empirical research for Mauritius which examines the interaction between these two indicators. Existing studies focus on developed economies or extreme climate events, leaving a gap in gauging the role of climatic shocks on inflation, growth and monetary policy in a small island context. The current study addresses this gap by analyzing the impact of climate shocks, specifically, rainfall and temperature variations on output, inflation, exchange rate, and interest rate in Mauritius using a Structural Vector Autoregression framework, with quarterly data spanning from 2005Q1 to 2022Q4.

The remainder of the paper is organized as follows. The next section focuses on climate indicators for Mauritius and measures taken by the authorities to address climate change. Section three provides a review of the empirical literature on the link between climate change and economic growth, inflation and monetary policy. Section four describes the data and econometric methodology used and discusses the empirical results while the last section provide conclusions of the study policy recommendations.

## 2.5.2 Stylized Facts

### 2.5.2.1 Climate Change and the Mauritian Economy

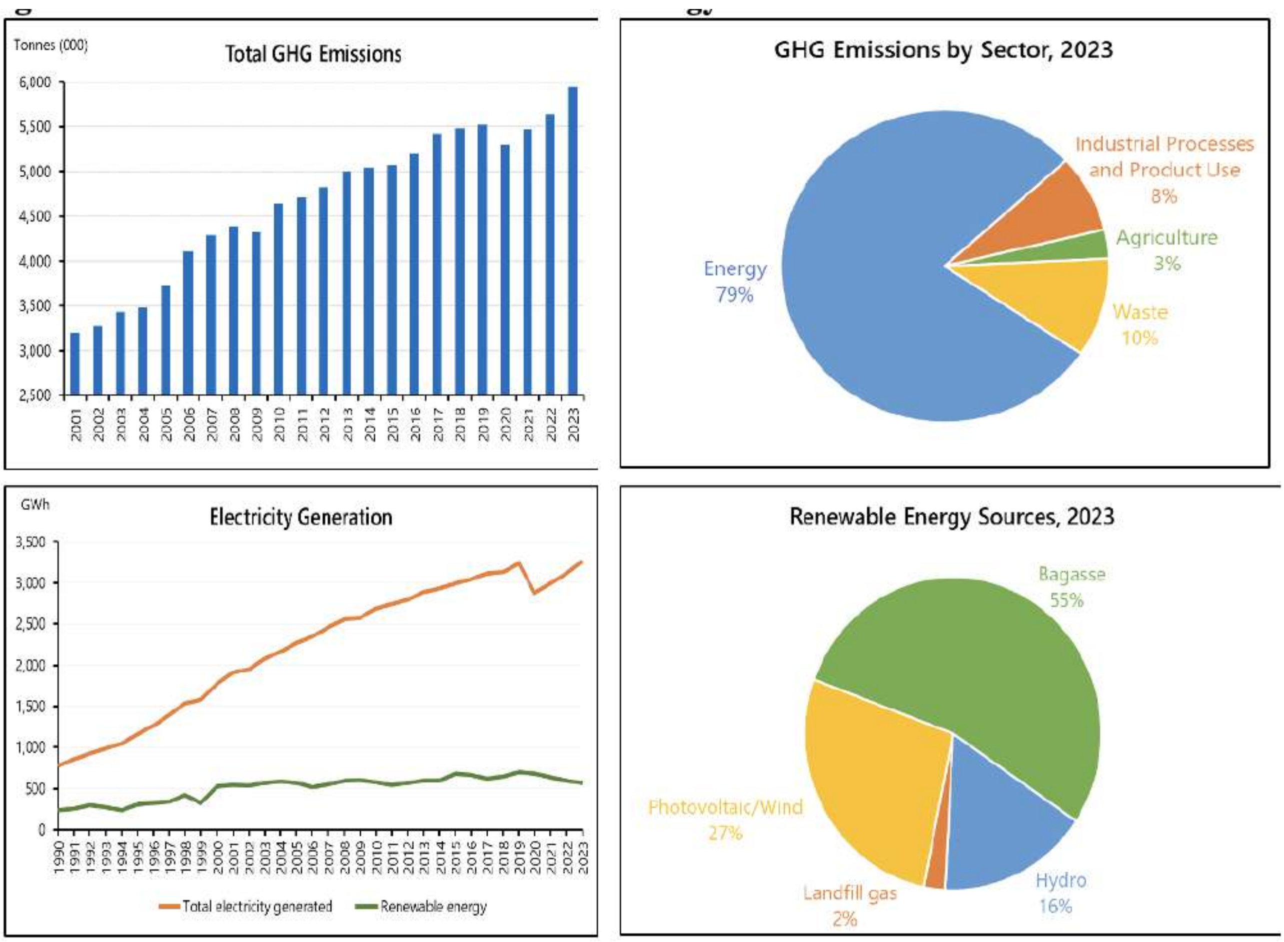
As a tropical island, Mauritius is highly exposed to the harmful consequences of climate change and resulting extreme weather events. Torrential rains, floods and the frequency and intensity of tropical cyclones have increased markedly over the past three decades. According to the UN Report, (2020), describes Mauritius as being exceptionally vulnerable to rising temperatures/sea levels/ beach erosion and loss of biodiversity.[9] Annual temperature is projected to rise by as much as 3.8°C by 2100, based on temperature trends. The country's disaster risk profile indicates that flooding is the second-largest risk after cyclones. Indeed, Mauritius is experiencing a rise in the frequency of occurrence of high intensity rainfall events, resulting in flash floods on several occasions.

9 In December 2015, 196 Parties adopted the Paris Agreement to set a goal of limiting global warming to well below 2°C compared to pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.
As per the Update of the Nationally Determined Contributions of the Republic of Mauritius, October 2021.

## 2.5.2.2 Evolution of Climate Change Indicators and Inflation and Output

Greenhouse gas emissions (GHG) induced by human activities are considered as the main driver intensifying the greenhouse effect and contributing to climate change. Data for Mauritius point to an increase in total GHG emissions over time, with the energy sector remaining the largest contributor (79 percent), followed by waste (10 percent) and industrial processes and product use (8 percent) as depicted in Figure 23. It can further be observed from Figure 1 that in Mauritius, 17.6 percent of electricity generated was from renewable sources in 2023, indicating that the energy mix is still dominated by diesel, fuel oil and coal. Bagasse is currently the leading source of renewable energy (55 percent), followed by photovoltaic/wind (27 percent), hydro (16 percent) and landfill gas (2 percent).

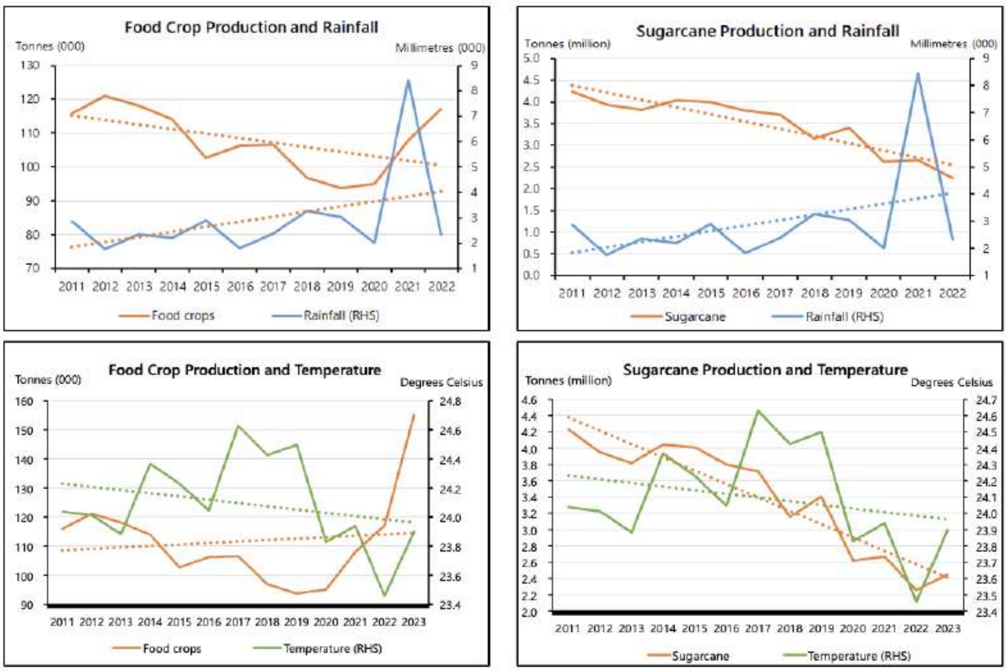
**Figure 23: GHG Emissions and Renewable Energy Sources**



Mauritius, as a small island economy, is highly dependent on agriculture and therefore vulnerable to fluctuations in weather conditions. Data from the Ministry of Environment's database on risk drivers of climate change indicate that the frequency and intensity of extreme weather events, such as heavy rains, storms of tropical cyclone strength, and periods of dry spells, have increased significantly over the past two decades. This trend heightens the exposure of the agricultural sector to climate-related risks and amplifies the risks of inflationary shocks. While the immediate impact of weather-related disturbances on inflation may not always be apparent, the long-term effects of climate change are expected to forge a more persistent link between environmental variability and price stability in Mauritius. Erratic weather patterns, including an increase in the frequency of rainfall as well as rising temperatures, strain agricultural production and reduce the quality of farm outputs. Such shocks can diminish crop yields, interrupt supply chains, and raise production costs. These higher costs are often passed on to consumers, directly contributing to inflation. Furthermore, according to the Ministry of Environment, Solid Waste Management and Climate Change, Mauritius may become a water-scarce region by 2030. Limited water availability can curtail agricultural production and increase reliance on imported food. These constraints can raise production costs and reduce supply, pushing prices up and contributing to overall inflation. As climate change exacerbates both rainfall variability and water scarcity, the economy may experience more frequent inflationary pressures.

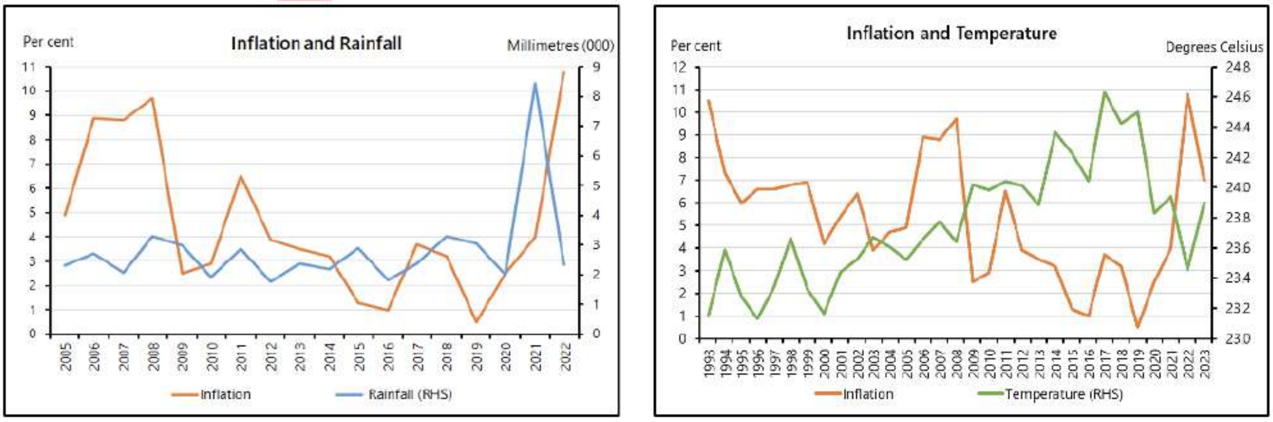
A visual inspection of rainfall patterns alongside the production of food crops and sugarcane suggests co-movements between rainfall and output (Figure 24). Additionally, temperature declines seem to benefit food crop production. In contrast, sugarcane yields seem to decrease when temperatures fall, indicating that higher temperatures may be favourable for sugarcane cultivation.

**Figure 24: Production of Food Crops/Sugarcane and Rainfall /Temperature**



Decline in agricultural production stemming from weather-related events tends to exert upward pressure on prices, ultimately leading to a rise in inflation. This is reflected in Figure 25, which shows a positive relationship between rainfall and inflation. However, the relationship between temperature and inflation seems to be counterintuitive. Over the period 1993 to 2023, a temperature rise is associated with receding inflation, suggesting that inflation is dominantly influenced by factors other than temperature.

**Figure 25: Inflation and Rainfall, and Temperature**




In Mauritius, food is a key driver of inflation as it accounts for about 25 percent of the consumer basket. Climate-related events can raise food inflation by damaging agricultural output. Food inflation seems to move closely with rainfall patterns, but its link with temperature is less clear (Figure 26). Severe tropical cyclones also disrupt activity at the port, as shown by temporary drops in container movement, although these effects generally do not last long (Figure 27).

**Figure 26: Food Inflation and Rainfall and Temperature**

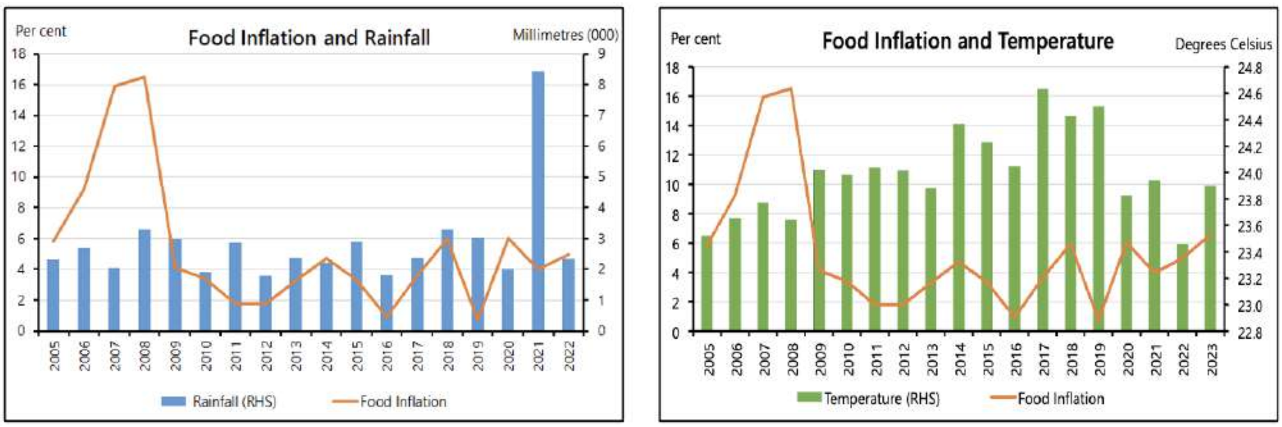
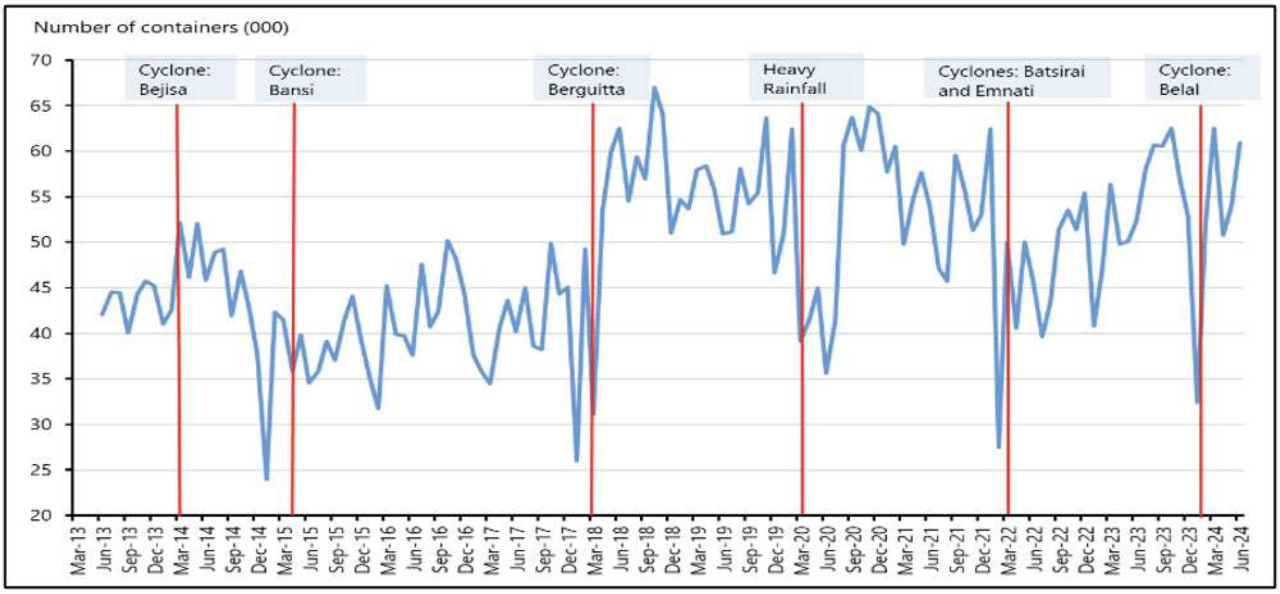


**Figure 27: Port Activity**




Note: Vertical lines pertain to severe cyclones and heavy rainfall.

## 2.5.2.3 Climate Change Response Measures by the Government of Mauritius

Mitigation and adaptation strategies are instrumental to achieving the goals set under the Paris Agreement. Mauritius has committed to combating climate change through the implementation of comprehensive strategies and policies on climate change mitigation and adaptation. The Climate Change Act 2020, in force as from April 2021, provides a legal framework towards making Mauritius a climate-resilient and low-emission country by defining the tasks and functions of institutions regarding climate change governance. Furthermore, in its Nationally Determined Contributions (NDCs), the Government of Mauritius has set ambitious objectives, notably the reduction of its GHG emissions by 40 percent by 2030. The total financial requirements to meet such obligations are estimated at USD 6.5 billion, of which USD 2 billion is earmarked for mitigation actions and USD 4.5 billion for adaptation strategies. The multi-fold strategy on climate change mitigation and adaptation aimed at achieving the goals set in the NDCs is summarized in Figure 27a.

**Figure 27a: Summary of NDCs Goals**

| Mitigation | Mitigation |
|---|---|
| • **Energy sector**<br>• 60% of green energy in energy mix by 2030<br>• Phasing out of coal in electricity generation by 2030<br>• Biomass framework<br>• Energy efficiency labelling of appliances<br>• **Transport sector**<br>• Improve fuel economy of vehicles<br>• Reduce peak time congestion to improve traffic fluidity<br>• Increase adoption of lower-carbon emissions vehicles and promote electric vehicles<br>• **Waste sector**<br>• Promote a circular economy by diverting 70% of wastes from landfill by 2030<br>• **Agricultural sector**<br>• Promote smart agriculture and undertake island-wide tree-planting programmes | • **Infrastructure, water management and disaster risk reduction**<br>• Enhance disaster preparedness and response mechanism<br>• Vulnerability assessment for the port<br>• Land Drainage Master Plan<br>• Improved forecasting management and protection of water resources, including rainwater harvesting systems/desalination<br>• **Agriculture and biodiversity**<br>• Promote climate smart agriculture practices<br>• Improve management of terrestrial biodiversity<br>• **Tourism, fisheries and coastal zone management**<br>• Sustainable fishing management and marine biodiversity<br>• Coastal protection and breach rehabilitation works<br>• **Health**<br>• Improved surveillance of diseasess associated with climate change |

Source: Ministry of Environment, Solid Waste Management and Climate Change.

## 2.5.2.4 Climate Change Response Measures by Bank of Mauritius

The Bank of Mauritius has also taken several initiatives on the climate front. In June 2020, it engaged with financial institutions to raise awareness on climate-related risks and the opportunities associated with the transition to net-zero emissions. In July 2020, the Bank further strengthened its commitment by joining the NGFS, enabling closer collaboration with central banks on sustainability-related research and technical resources.

The sustainable bond market has witnessed rapid growth in recent years, and Mauritius is likewise promoting investment in green technologies and renewable energy, recognizing of their critical role in the transition towards a greener and more sustainable economy. In June 2021, the Bank published its Guide for the Issue of Sustainable Bonds in Mauritius, which the framework for issuing Green, Blue, Social, Climate and Sustainability Bonds in the country. The Guide sets out the requirements that issuers must meet, including pre-issuance arrangements, use of proceeds and reporting obligations. It also seeks to safeguard the integrity of the sustainable finance ecosystem in Mauritius and prevent greenwashing. To enhance Mauritius' appeal to foreign sustainable finance investors, the Guide recommends aligning bond issuances with global benchmarks and standards.[10]

10 Green Bond Principles of the International Capital Market Association and the International Climate Bonds Standards of the Climate Bonds Initiative.

In October 2021, the Bank established the Climate Change Centre with the objective of integrating climate-related and environmental financial risks into its regulatory, supervisory and monetary policy frameworks. The Climate Change Centre also supports the development of sustainable finance and reviews the Bank's internal operations with a view to reducing its carbon footprint. The Bank has also embedded sustainability considerations into its internal investment strategy in the area of reserves management. In April 2022, the Bank issued the Guideline on Climate-related and Environmental Financial Risk Management, which calls for financial institutions to integrate climate risks into every stage of their decision-making processes and operations. The Guideline also introduces disclosure requirements aimed at enhancing market transparency and supporting businesses and investors in evaluating and pricing risks associated with green projects. Its key components include governance, strategy, risk management, data, measurement and disclosure. By providing this framework, the Guideline enables financial institutions to better assess and manage climate-related risks in their lending and investment activities, thereby reducing the potential for losses resulting from adverse impacts of climate change.

Further, the Climate Change Centre is currently collaborating with international institutions to develop a high-integrity carbon trading framework covering both blue and green credits. The Bank is also advancing its climate agenda through multiple stakeholders' partnerships. For example, it is working with various government agencies to develop a National Green Taxonomy, considered essential for strengthening investor confidence, stimulating climate-related investments in Mauritius, and addressing concerns around greenwashing. In addition, the Bank collaborates with the Financial Services Commission, the regulator for the non-bank financial services sector and global business, through a coordination committee that examines, among other matters, the implications of climate change on the Mauritian financial system. Collectively, these initiatives aim to foster a robust and trustworthy sustainable finance ecosystem in Mauritius and, through the Mauritius International Financial Centre across the region. The measures introduced by the Bank have begun to yield results, as reflected in the growing momentum of sustainable finance within the banking sector. According to a survey conducted by the Bank in August 2023, bank exposures to sustainable projects increased by 64 percent between June 2022 and June 2023, while loan applications for sustainable project financing rose by more than 50 percent over the same period. The survey further shows that, of the 19 banks operating in Mauritius, 11 offer sustainable financial products. In addition, several banks are financing mitigation projects, even though these projects often present less attractive risk–reward profiles. Many banks have also established strategies and action plans aimed at supporting sustainable growth.

The Bank, in collaboration with the Ministry of Finance, Economic Planning and Development, devised the Sustainable Finance Framework for Mauritius and established the regulatory framework for the issue of sustainable bonds by Government. The framework, published in August 2023, outlined, among other things, the specific types of sustainable debt instruments Government can issue in order to reinforce the country's sustainability strategy. The proceeds from these instruments will be directed towards ESG-related projects, including renewable energy and improved access to essential services such as education, healthcare and social housing.

## 2.5.3 Literature Review

The study provides both theoretical and empirical literature highlighting the linkages between climate-related events, policies, and shifts in environmental conditions and the evolution of key macroeconomic variables such as output, inflation, interest rates and exchange rates, amongst others and associated effects on the broader economy.

### 2.5.3.1 Theoretical Review

Generally, climate change affects both inflation and economic growth through complex demand- and supply-side channels. Extreme weather and rising temperatures increase the frequency of shocks, complicating monetary policy. On the demand side, reduced investment, lower household wealth, and disrupted trade can weaken economic activity. On the supply side, climate shocks raise production costs and create upward pressure on prices, challenging central banks' price stability mandates. Moreover, climate change may limit central banks' policy space and increase trade-offs between stabilizing inflation and output. While demand shocks typically affect growth and inflation in the same direction, supply shocks push growth down and prices up. Frequent and uncertain climate-related supply shocks make it harder to distinguish temporary from permanent effects, complicating monetary policy, forecasting, and communication (NGFS, 2020).

Climate shocks can spread through the broader economy via linkages with the real, external, and monetary sectors. On the supply side, extreme weather events directly reduce agricultural and industrial output, as declining crop yields and disrupted production depress overall output (Parker, 2018). These shocks also cause substantial infrastructural damage, weakening productive capital accumulation and constraining a country's long-term growth prospects. This occurs through several channels, including reduced labour supply due to higher mortality and migration, lower labour productivity, and the diversion of investment towards climate-resilient infrastructure and technologies and away from potentially more productive, innovation-enhancing activities (Fankhauser and Tol, 2005; Dell et al., 2014; Hallegatte et al., 2017).

In parallel, the demand side of the economy is affected through weaker domestic demand resulting from lower employment and income. On the external front, climate shocks influence both exports and imports. Reduced domestic output can constrain exports of both goods and services, in particular, tourism activities, thereby weakening foreign exchange earnings (Dell et al., 2014). At the same time, reconstruction and adaptation efforts require substantial investment, much of which imported materials and machinery. This increases imports and worsens the trade balance, and exerts downward pressure on the domestic currency (Parker, 2018). Currency depreciation, in turn, raises the cost of imported goods, including essential production inputs, which feeds into domestic inflation (Mukherjee and Ouattara, 2021).

Climate-related events are increasing in relevance for central banks' price stability mandates (Parker, 2018; Faccia et al., 2021; Mukherjee and Ouattara, 2021; Natoli, 2022; Kotz et al., 2023). Rising food and energy prices, exchange rate pass-through and supply chain disruptions arising from climate-related disturbances, create inflationary pressures that may prompt tighten monetary policy. The agriculture sector is particularly vulnerable as climatic shocks reduce crop yields and raise food prices. In developing economies, where food has a large share in the consumption basket, these shocks lead to higher and more volatile inflation.

The transition to net zero may lead to sharp increases in carbon prices, which can raise electricity, gas and petrol costs and increase production expenses, thereby fueling inflation. However, Andersson et al. (2020) argue that ongoing innovation in renewable energy and improvements in energy efficiency would lower renewable energy costs, reducing the share of energy in the consumption basket. If inflation rises above the target, central banks may respond by raising interest rates.

### 2.5.3.2 Empirical Review

Climate change is a negative externality that threatens economic output. Temperature fluctuations and extreme weather generally reduce growth both in developed and developing countries, with the strongest effects in low-income economies (Dell et al., 2012; 2014; Burke et al., 2015; Hsiang, 2013; Tol, 2022). Dell et al. (2009) finds that higher temperatures significantly lower growth in poor countries, while rich countries are less affected. However, Colacito et al. (2019) find a contrasting result - higher temperatures are a drag on growth in the US. Dell et al (2012) estimate that climate change could reduce growth in poor by 0.6-2.9 percentage points.

The literature on climate change and inflation is limited (Heinen et al., 2016; Parker, 2018). Heinen et al. (2016) report a strong inflationary effect of extreme weather in developing countries, later confirmed by Parker (2018). Faccia et al. (2021) show that extreme summer temperatures can have lasting effects on inflation. Kabundi et al. (2022) find that the impact of climate shocks on consumer prices depends on the shock type and intensity, country income, and monetary policy. Ciccarelli et al. (2023) temperature shocks on prices that rising average temperature and summer temperature variability, increase inflation in the four largest Euro area economies, especially in warmer countries.

## 2.5.4 Empirical Methodology

### 2.5.4.1 Data Sources and Description

The study used quarterly data from 2005Q1 to 2022Q4 on GDP, alternative CPI measures (headline, core and food), climate indicators (rainfall and temperature), nominal short-term interest rate (interbank rate and 91-Day Bills yield) and exchange rate indicators (MUR/USD and nominal effective exchange rate, NEER). A detailed description of the data and their sources is provided in Table 11, while Annex 2 presents the trends over the sample period. Descriptive statistics are included in Annex 3. The selection of variables is guided by the standard macroeconomic transmission mechanism and by their established linkages between climatic conditions and economic activity. Rainfall and temperature serve as key indicators of climate shocks, as they directly influence agricultural output, food supply and consequently domestic price pressures. Inflation reflects overall price level response, while the output gap is a proxy for economic growth. The interest rate represents the monetary policy response, which in turn influences the exchange rate. Together, these variables provide a coherent framework for analyzing how climate shocks propagate through the economy and how policy responds to such disturbances.

**Table 11: Data Description**

| Variable | Transformation | Denomination |
|---|---|---|
| GDP | Output gap (Current GDP-Potential GDP) | *OUTPUT_GAP* |
| Headline CPI | Log of Seasonally adjusted (SA) CPI | *LCPI* |
| Core CPI | Log of SA Core | *LCORE* |
| Food CPI | Log of SA CPI Food | *LFOODCPI* |
| Exchange rate | Current log of nominal effective exchange rate (NEER) - trend NEER | *NEER_GAP* |
| Interest rate | Current 91-Day Bills yield - trend 91-Day Bills yield | *YIELD_GAP* |
| Rainfall | Log of SA rainfall | *LRAINFALL* |
| Temperature | Log of SA temperature | *LTEMP* |

### 2.5.4.2 Estimation Approach

This study employs a Structural Vector Autoregressive (SVAR) framework to investigate the effects of climate shocks, measured through variations in rainfall and temperature, on growth and inflation and their broader macroeconomic linkages. The SVAR approach is particularly appropriate for this analysis because it enables the structural identification of exogenous shocks and allows tracing of their dynamic impacts on interconnected macroeconomic variables. Unlike reduced-form VAR models, SVARs incorporate economically meaningful restrictions, making it possible to disentangle supply, demand, and climate-related disturbances in a theoretically consistent manner (Sims, 1980).

As described in Bwire (2019), the SVAR model is specified as follows:

$$AY_t = C(L)Y_{t-1} + Bu_t\,; \qquad \mu_t \sim N(0, I) \tag{1}$$

where Yt represents a n×1 vector of endogenous variables. The structural shocks vector, $u_t$, is assumed to be normally distributed, i.e., $u_t$~N(0, Σ), where Σ is specified as a diagonal matrix and is usually normalized such that E($u_t u'_t$) = Σ = $In$ and $ut$~N(0, $I$). A and B refer to n×n parameter matrices while C is the matrix of lagged coefficients of interactions in Yt. The reduced-form structural model is given as:

$$Y_t = A^{-1}C(L)Y_{t-1} + A^{-1}Bu_t\,; \quad u_t \sim IID\,(0, I) \tag{2}$$

The structural model in equation (2) cannot be estimated directly due to identification issues (Enders, 2015), and must be recovered from the unrestricted VAR counterpart in equation (3).

$$Y_t = F_1Y_{t-1} + F_2Y_{t-2} + \cdots F_pY_{t-p} + \varepsilon_t \tag{3}$$

with $Y_t$ being a nxn vector of endogenous variables, $\varepsilon_t$ is a nxn vector of normally and independently distributed disturbance terms, with zero mean and non-diagonal covariance matrix, Σ. Parameter restrictions using Cholesky decomposition are introduced on A and B (Sims, 1980) as follows:

$$A = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{12} & 1 & 0 & 0 & 0 \\ a_{13} & a_{23} & 1 & 0 & 0 \\ a_{14} & a_{24} & a_{34} & 1 & 0 \\ a_{15} & a_{25} & a_{35} & a_{45} & 1 \end{pmatrix} \quad B = \begin{pmatrix} b_{11} & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 \\ 0 & 0 & 0 & 0 & b_{55} \end{pmatrix} \varepsilon_t =$$

$$\begin{pmatrix} \varepsilon_{1t}^{clim} \\ \varepsilon_{2t}^{gdp} \\ \varepsilon_{3t}^{cpi} \\ \varepsilon_{4t}^{int} \\ \varepsilon_{5t}^{exch} \end{pmatrix} u_t \begin{pmatrix} u_{1t}^{clim} \\ u_{2t}^{gdp} \\ u_{3t}^{cpi} \\ u_{4t}^{int} \\ u_{5t}^{exch} \end{pmatrix}$$

The SVAR strategy is implemented in three phases: (1) specify and estimate the reduced-form VAR, (2) identify the structural shocks; and (3) generate impulse response functions (IRFs). In the first phase, an important decision concerns the number of variables to include in the model.[11] This study adopts a 5-variable model, consisting of GDP (gdpt), CPI (cpit), nominal short-term interest rate (intt), exchange rate (excht) and the climate indicator (climt). The vector Yt is thus given as follows:

$$Y_t = [gdp_t, cpi_t, int_t, exch_t\ clim_t] \tag{5}$$

The variables evolve over time with a trend-like behavior, except for the output gap, suggesting that they may be non-stationary in levels (Annex 2). The study conducted tests for stationarity using the Augmented Dickey Fuller (ADF) unit root test (Dickey and Fuller, 1979). The variables were transformed into either gaps or logs to make them stationary, and the results of the stationarity tests are provided in Annex 4. The study used the Schwarz (SC) and Hannan–Quinn (HQ) criteria to determine the appropriate lag length and conducted additional robustness checks to validate the specification. The model passed all standard diagnostic tests, indicating that the residuals show no signs of serial correlation, heteroskedasticity, or instability over the sample period. The second phase of the SVAR strategy involves imposing restrictions on contemporaneous relationships among the variables. Since ordering of variables is crucial in a SVAR framework, we arrange them in such a way that isolates the climate shock from other disturbances affecting the economy. Accordingly, Thus, the climate indicator, considered the most exogenous variable, is placed first, followed by the output gap, inflation, interest rate and exchange rate. This ordering implies that the climate shock, viewed as a supply-side disturbance, can affect all other variables contemporaneously, while it is itself not influenced by movements in the other macroeconomic variables.

Based on the above ordering, Equation (4), which can be re-written as $\varepsilon_t = A^{-1}Bu_t$, is represented in matrix form as follows:

$$\begin{pmatrix} \varepsilon_t^{clim} \\ \varepsilon_t^{gdp} \\ \varepsilon_t^{inf} \\ \varepsilon_t^{int} \\ \varepsilon_t^{exch} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{12} & 1 & 0 & 0 & 0 \\ a_{13} & a_{23} & 1 & 0 & 0 \\ a_{14} & a_{24} & a_{34} & 1 & 0 \\ a_{15} & a_{25} & a_{35} & a_{45} & 1 \end{pmatrix}' \begin{pmatrix} b_{11} & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 \\ 0 & 0 & 0 & 0 & b_{55} \end{pmatrix} \begin{pmatrix} u_t^{clim} \\ u_t^{gdp} \\ u_t^{inf} \\ u_t^{int} \\ u_t^{exch} \end{pmatrix}$$

where $u_t^{clim}$ denotes climate (supply) shock, $u_t^{gdp}$ is output gap (demand) shock; $u_t^{inf}$ is inflation shock; $u_t^{int}$ is interest rate (monetary policy) shock; and $u_t^{exch}$ is exchange rate (external) shock.

11 While a VAR with a large number of variables would enable ample interactions, a relatively more parsimonious model with higher degrees of freedom is likely to be simpler to estimate and more stable.

Identification requires that (3k2 – k)/2 restrictions in matrices A and B be imposed, where k is the number of variables. For recursive identification, restrictions are imposed on the A matrix for it to become lower triangular, and for the structural shocks to be uncorrelated. Thus, with five variables, a total of 35 restrictions need to be imposed, comprising 10 zero restrictions in matrix A, 20 zero restrictions in matrix B and 5 normalisation restrictions from the diagonal of matrix A.

## 2.5.5 Discussion of Findings

In this section, we report findings of impulse response functions using rainfall and temperature as proxies for climate indicators and three measures of inflation to capture prices (Headline inflation, core inflation and food inflation). Figure 28 illustrates the impulse response functions from the SVAR model in which rainfall serves as the climate indicator and headline inflation as the indicator of prices. The figure evaluates how rainfall shocks affect the output gap, CPI inflation, the yield gap, and the NEER gap.

The first graph shows how a rainfall shock affects rainfall itself. The shock has an initial magnitude of roughly 50mm, but its effect gradually dissipates after four quarters. Although the rainfall shock exerts a slightly positive influence on the output gap in the first period, it has a negative lasting effect up to the sixth quarter, after which the output gap returns to broadly neutral levels. Conversely, the effect on inflation is positive on impact but steadily declines in the following quarter and converges to the actual inflation rate thereafter. The relatively volatile responses of interest rate and exchange rate suggest that these variables may be more sensitive to factors other than the climate shock. Figures 29 and 30 illustrate the IRFs from the same model specification using core and food inflation, respectively, and their patterns are broadly similar to those in Figure 28. Although the impulse response functions appear statistically insignificant, as noted by Kim et al. (2024), economic intuition and theoretical coherence can still offer meaningful interpretation, even when statistical insignificance is limited.

**Figure 28: Impulse Response Functions of Shock to Rainfall (Headline inflation)**

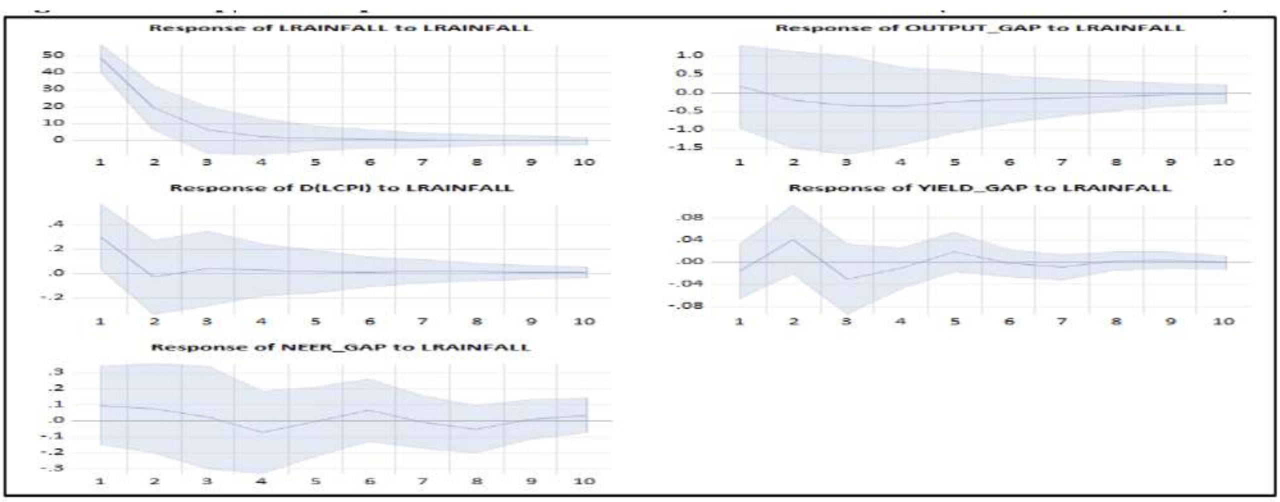


**Figure 29: Impulse Response Functions of Shock to Rainfall (Core inflation)**

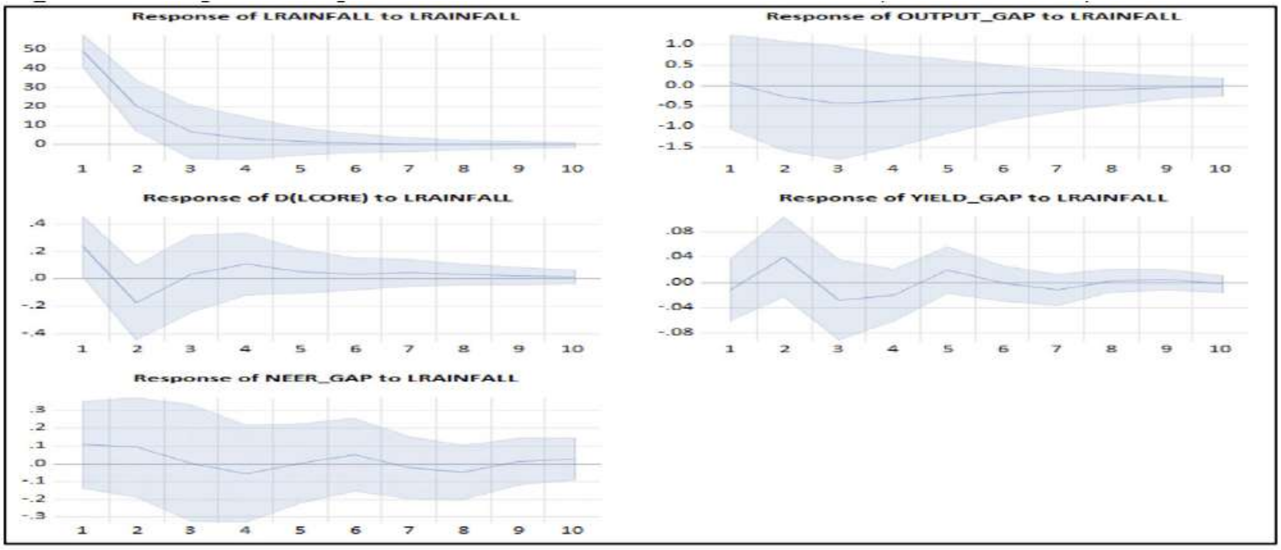
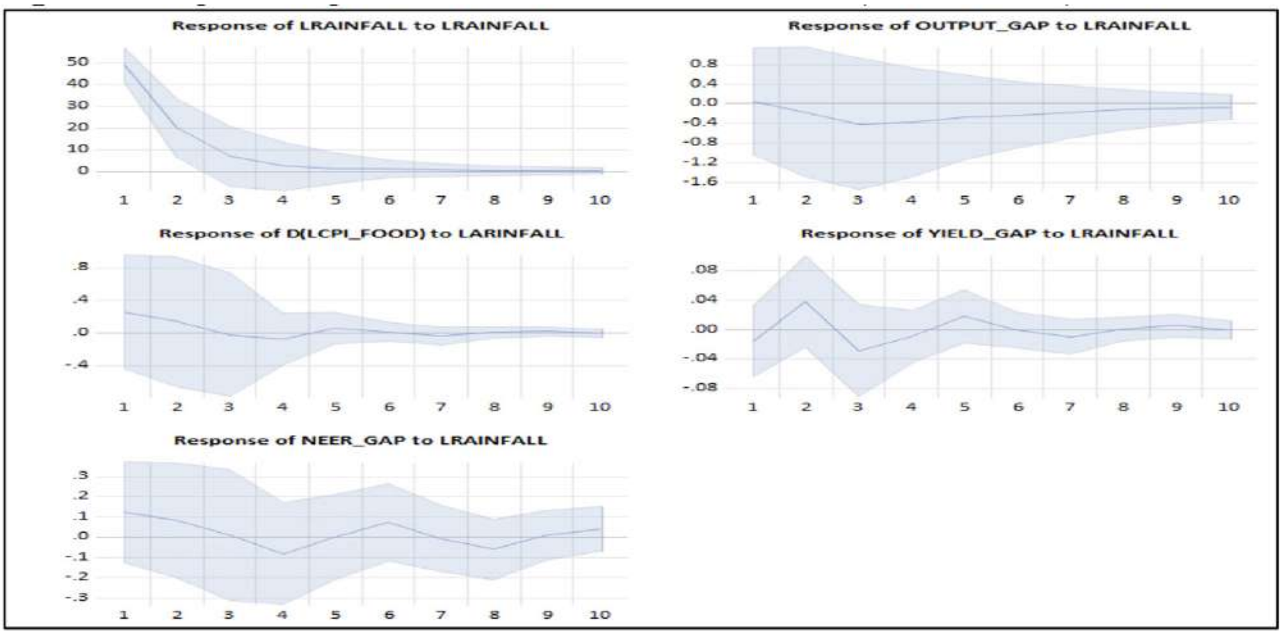



**Figure 30: Impulse Response Functions of Shock to Rainfall (Food inflation)**




In Figures 31-33, temperature shock was used as a proxy for climate change. The temperature shock has an initial magnitude of around 1.3 degrees Celsius but on impact gradually dissipates over the forecast period. The IRFs for model specifications using CPI inflation, core inflation and food inflation, shown in Figures 31 to 33, indicate that the output gap rises in the initial periods before eventually declining, while inflation responds negatively to the temperature shock. These results are broadly consistent with the findings of Eltayb et al. (2024). As in the previous set of IRFs, the interest rate and exchange rate exhibit comparatively volatile trajectories.

**Figure 31: Impulse Response Functions of Shock to Temperature (Headline inflation)**

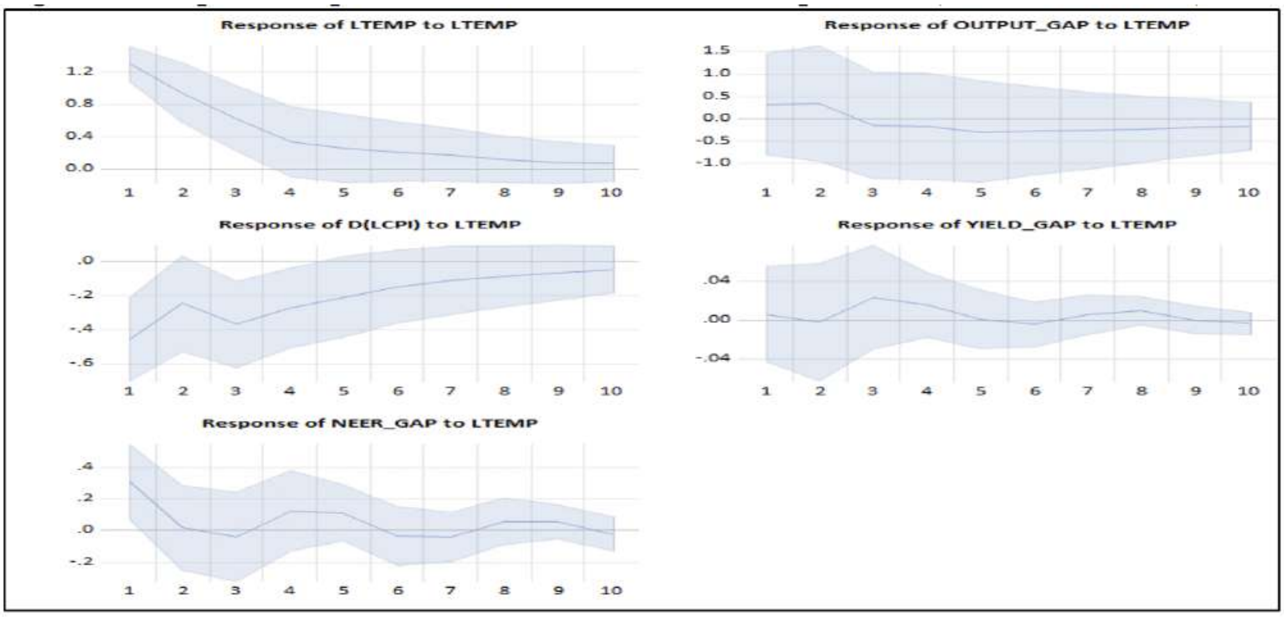



**Figure 32: Impulse Response Functions of Shock to Temperature (Core inflation)**

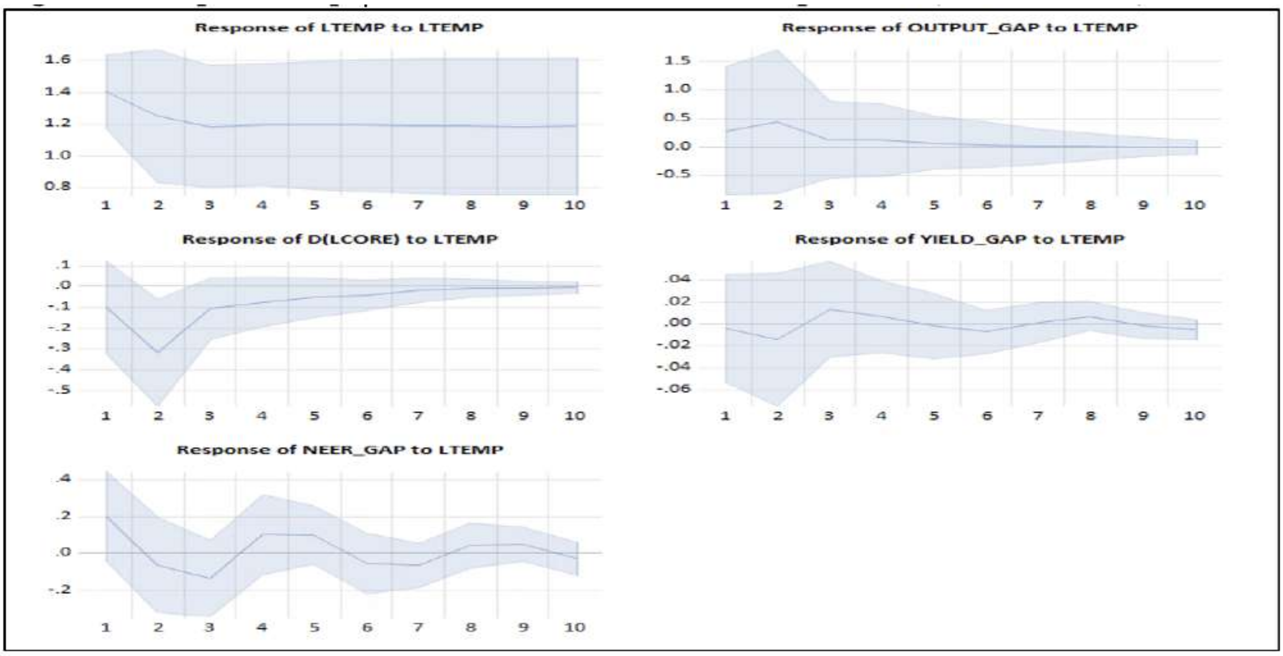
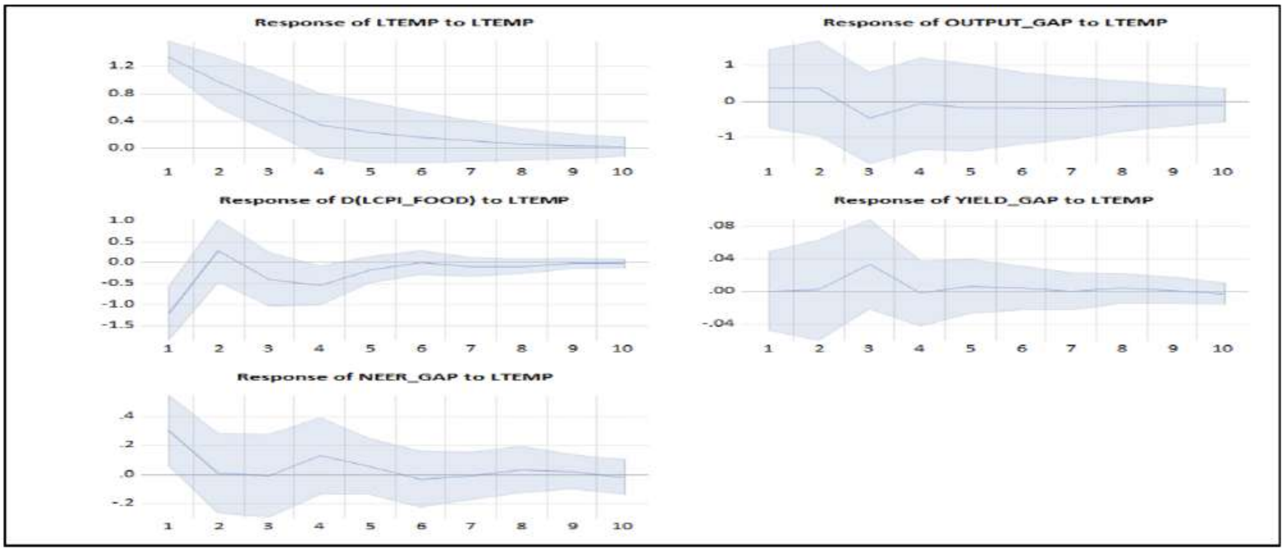


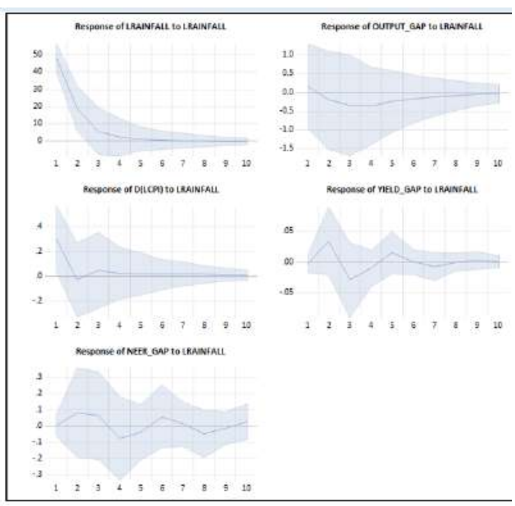
**Figure 33: Impulse Response Functions of Shock to Temperature (Food inflation)**



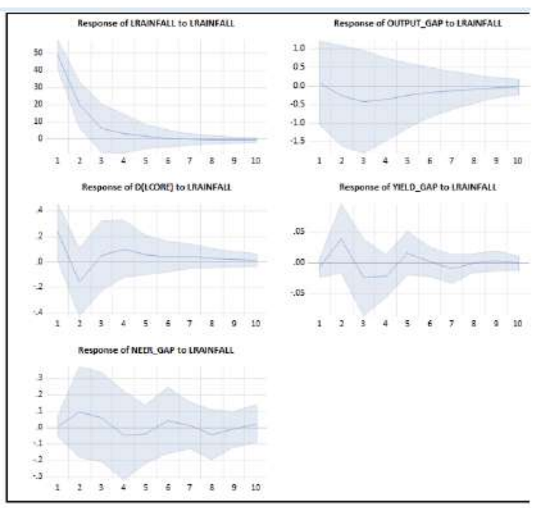

As a robustness check, alternative identifications were estimated by varying the contemporaneous restrictions in the A matrix. The baseline specification relied on a Cholesky decomposition, which provides a convenient just-identified structure but is often criticized for its limited theoretical underpinning and sensitivity to variable ordering. To address this concern, the model was re-estimated using alternative variable orderings to assess the stability of the results. The re-estimated A matrix is presented in Annex 5. Across these specifications, the impulse response functions remained broadly unchanged (Figure 34), both in sign and magnitude. This consistency suggests that the main conclusions are not dependent on the specific recursive structure imposed but instead reflect robust underlying relationships among the variables in the system.

**Figure 34: Impulse Response Functions (Over-identified Model)**

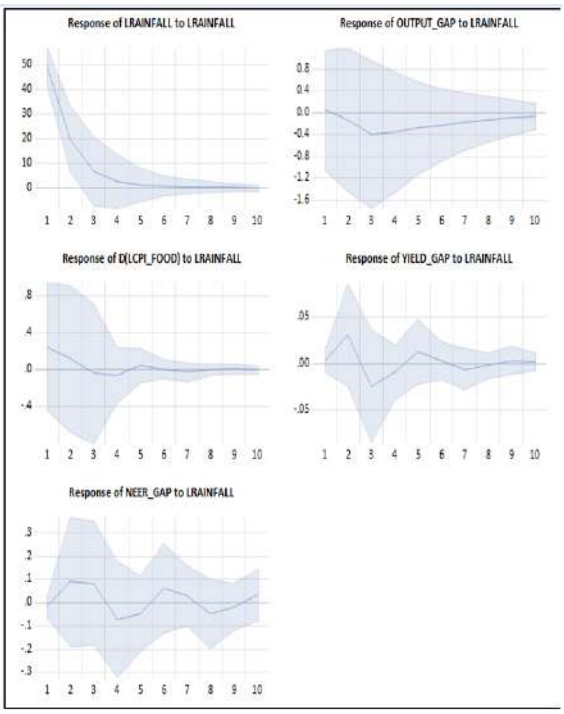
Impulse Response Functions of Shock to Rainfall (Headline inflation)



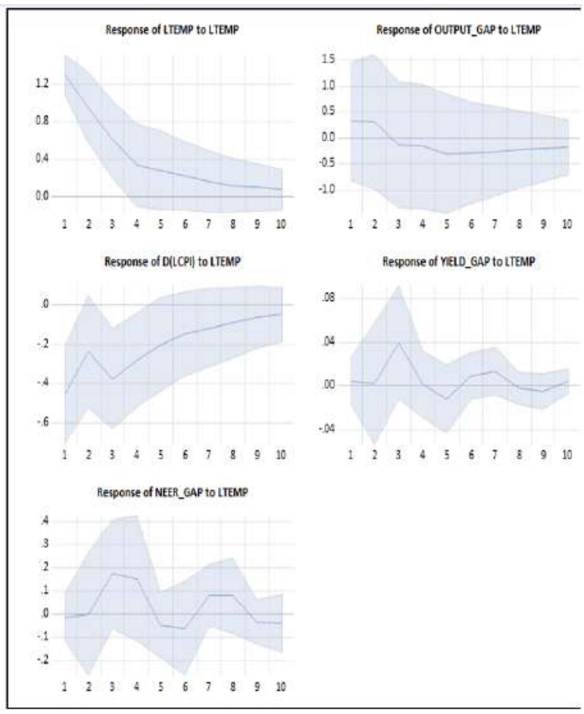

Impulse Response Functions of Shock to Rainfall (Core inflation)



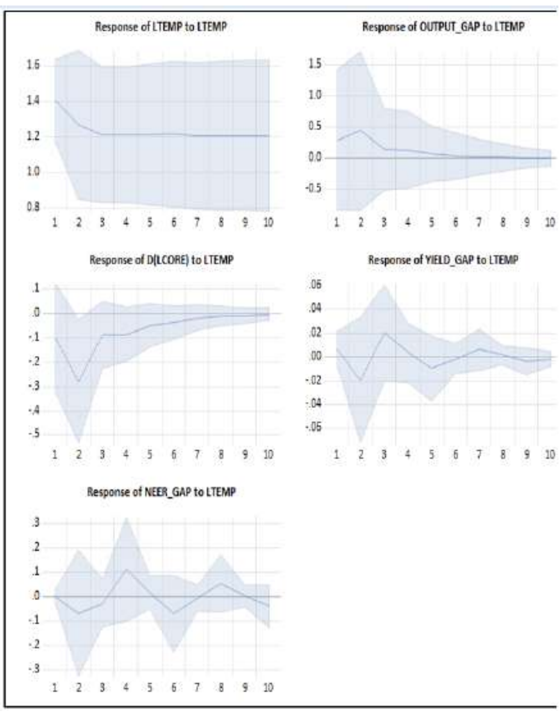
Impulse Response Functions of Shock to Rainfall (Food inflation)



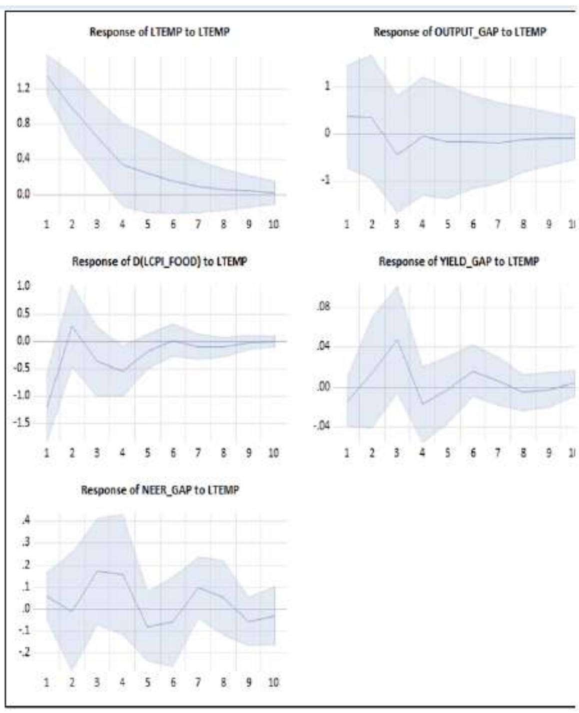

Impulse Response Functions of Shock to Temperature (Headline inflation)




Impulse Response Functions of Shock to Temperature (Core inflation)




Impulse Response Functions of Shock to Temperature (Food inflation)



## 2.5.6 Concluding Remarks and Policy Recommendations

The study examined how weather-related shocks, specifically, rainfall and temperature, affect key macroeconomic variables, in particular, growth and inflation. The analysis used the SVAR methodology based on quarterly data from 2005Q1 to 2022Q4. The results suggest that rainfall shocks have negative effects on economic activity, and the shocks are inflationary. However, the shocks have statistically insignificant effects on the Mauritian economy. The effects of temperature shocks differ slightly but still align with broader empirical evidence. Output initially increases but then declines and remains persistently negative, while inflation tends to fall.

Given Mauritius' geographic exposure to tropical cyclones, heavy rainfall, and coastal flooding, the government needs to take proactive steps to strengthen climate adaptation and mitigation. Priorities include investing in resilient coastal protection, restoring and conserving coral reefs and mangroves, improving water management, diversifying agricultural production, and upgrading infrastructure to withstand extreme weather events. Accelerating the transition to clean energy is also critical. In addition, strong institutional coordination, climate-informed planning, and expanded access to climate finance will be essential to safeguard long-term economic stability and support sustainable development.

Additionally, given the potential implications of climate change on inflation, it may be important for the central bank to integrate climate-related shocks into the monetary policy framework to better assess their impact on the broader economy. This would include promoting green financial instruments, such as green bonds, to help finance sustainable projects and support the transition to a low-carbon economy. Moreover, greening monetary policy operations would involve directing asset purchases and collateral towards low-carbon assets, thereby lowering the cost of capital for environmentally friendly sectors relative to high-carbon ones. Implementation of all the suggested recommendations requires a concerted effort of both fiscal and monetary interventions. The results are also robust to alternative model specifications. Future research could explore the use of sign restrictions and more advanced modelling approaches, such as Dynamic Stochastic General Equilibrium (DSGE) models, to further assess the influence of climate change on the macroeconomy.

> “The effects of temperature shocks differ slightly but still align with broader empirical evidence. Output initially increases but then declines and remains persistently negative, while inflation tends to fall.

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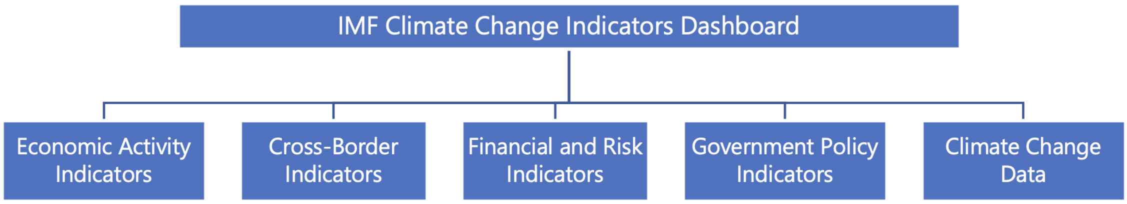
# Annexes

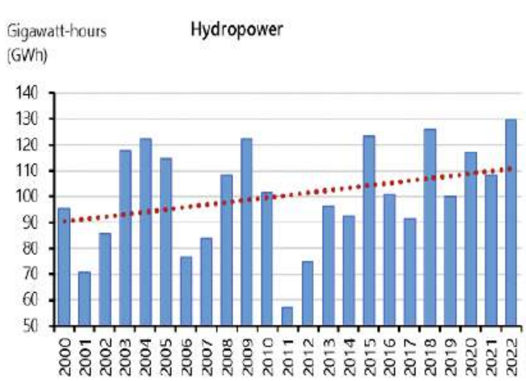
**Annex 1: IMF Climate Change Indicators Dashboard – Data for Mauritius**

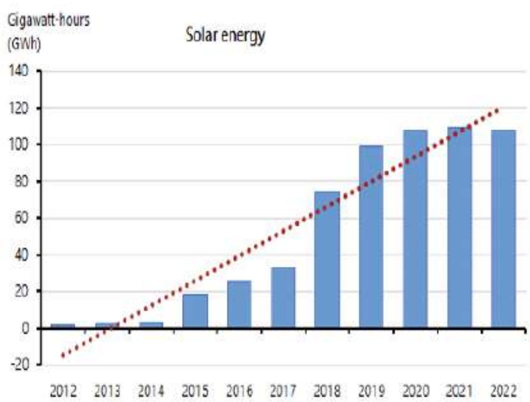
The IMF has launched a climate change indicators dashboard to address the growing need for climate-related data used in macroeconomic and financial policy analysis. The data, developed in collaboration with other international organizations, are classified into five categories, and further into indicator groups and a number of indicators within the group. The broad categories are illustrated as follows.



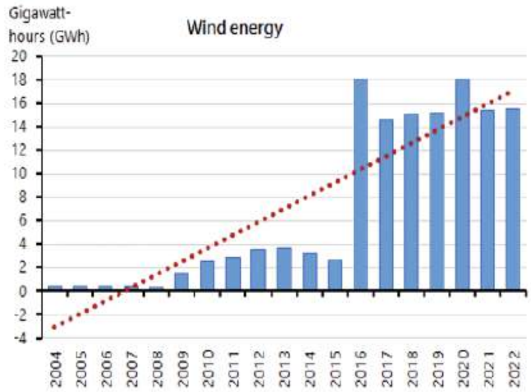

Mauritius is gradually transitioning its energy sector, with the share of total renewable energy increasing over time. Nevertheless, the economy remains heavily dependent on imported energy sources. According to the IMF dashboard, the Climate-driven INFORM Risk index, which measures exposure to natural disasters, has remained broadly stable at around 2.5 in recent years.[12] Government policy indicators show progress: both environmental taxes and public spending on environmental protection have risen over time. Climate data also point to a long-term warming trend, with annual surface temperatures generally increasing since 1961. Between 1982 and 2022, Mauritius experienced 14 recorded disasters, including 12 storms, one drought, and one flood.

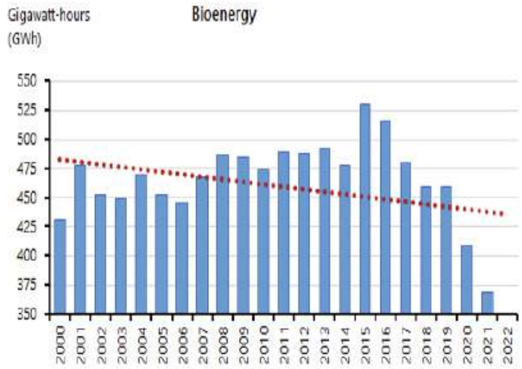
**Annex 1a: Energy Transition**

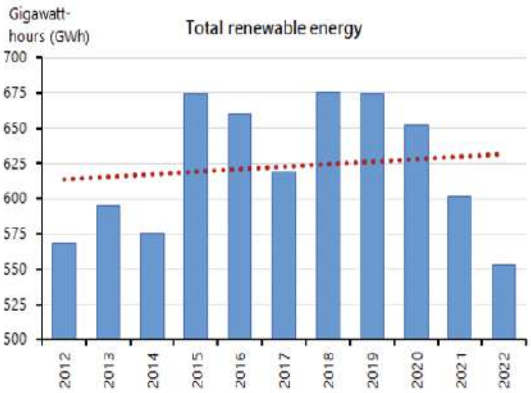


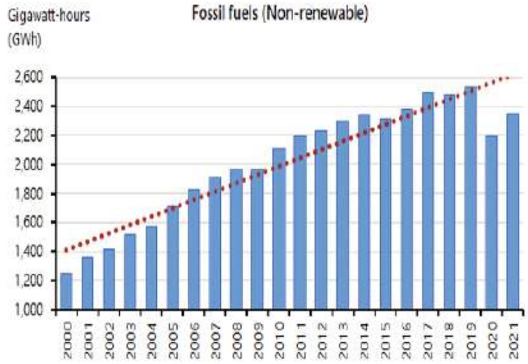




12 The indicator has three dimensions - climate-driven hazard and exposure, vulnerability, and lack of coping capacity.

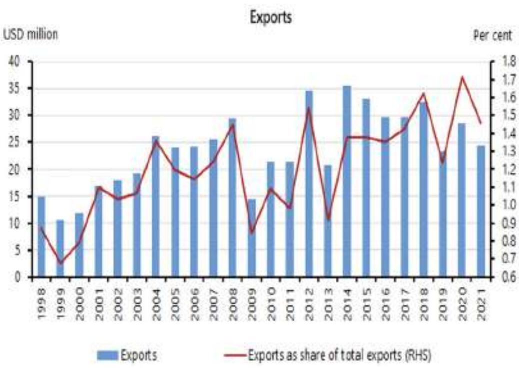


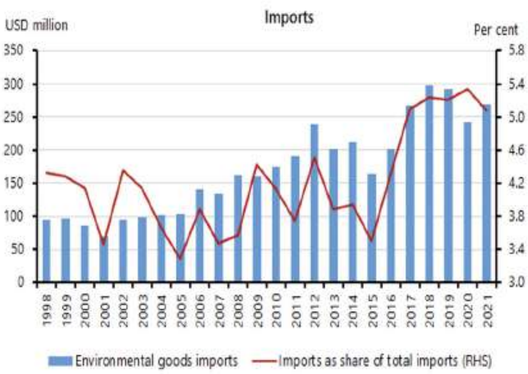



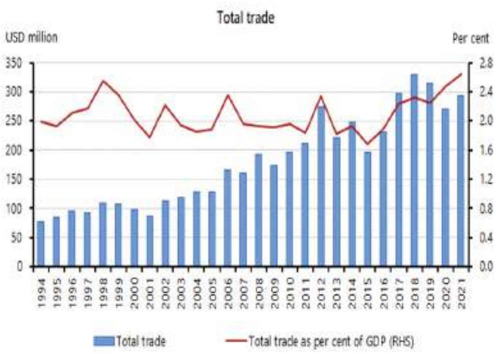



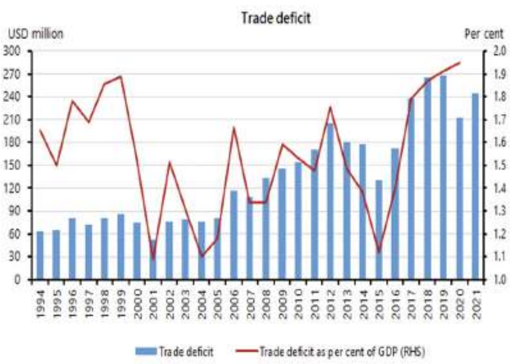




## Annex 1b: Trade in Environmental Goods

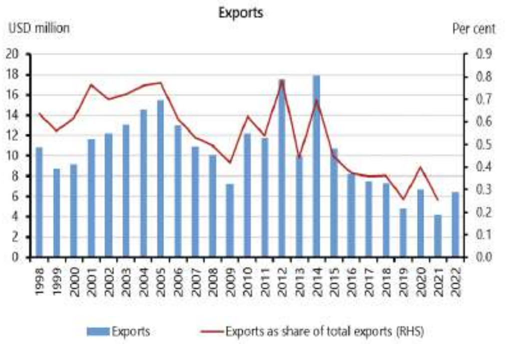


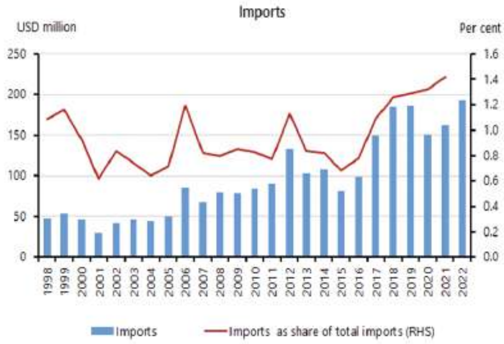



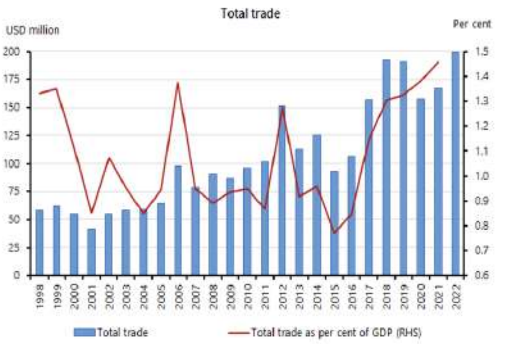



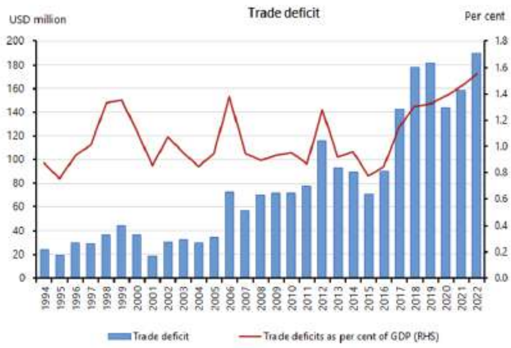



## Annex 1c: Trade in Low Carbon Technology Products

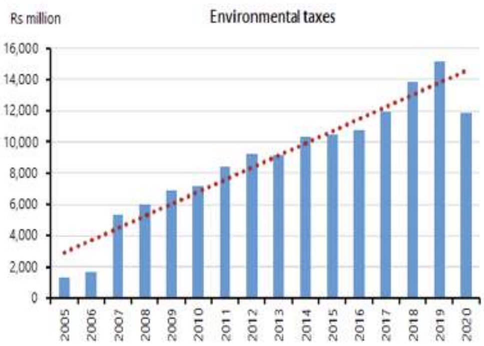


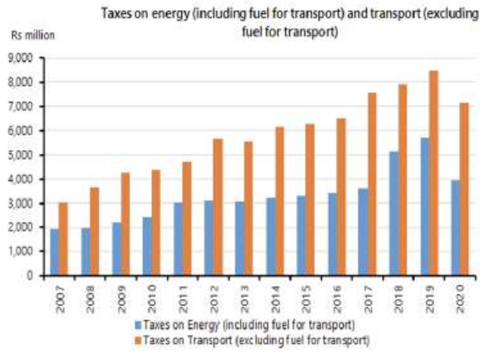



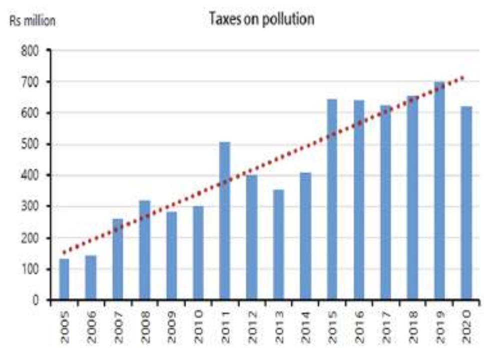



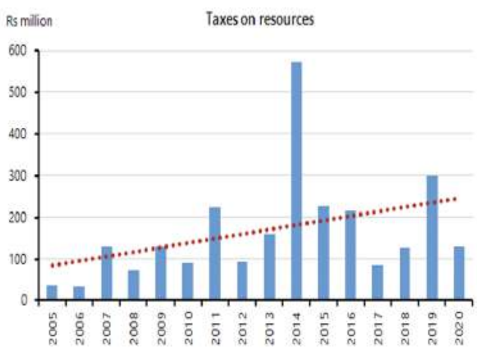




## Annex 1d: Environmental Taxes

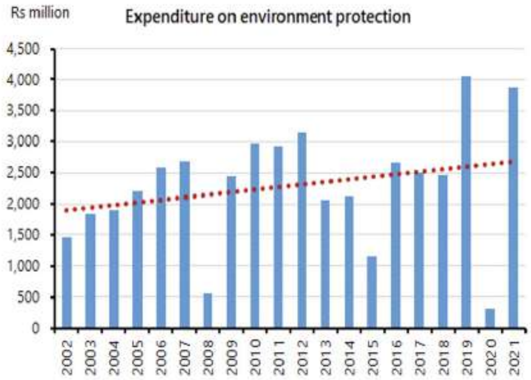


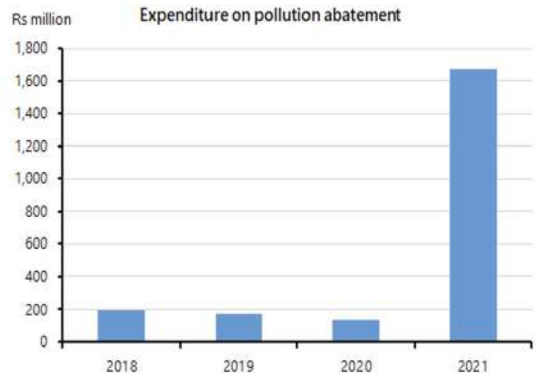



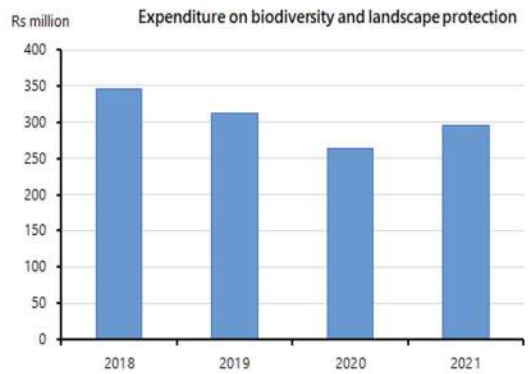



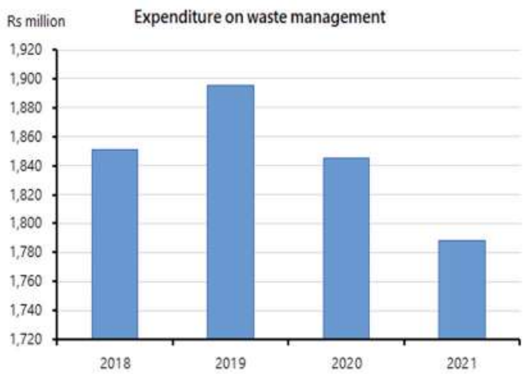



## Annex 1e: Environmental Protection

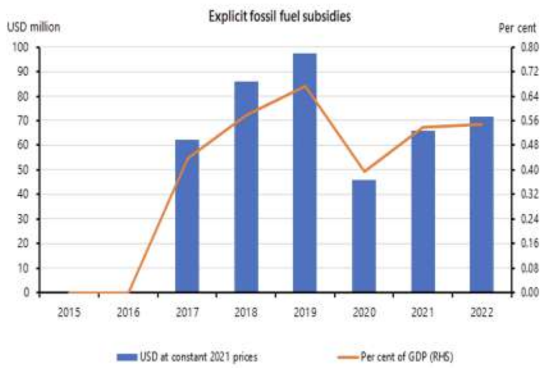


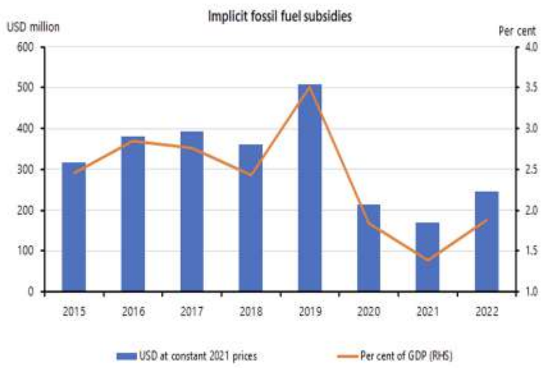



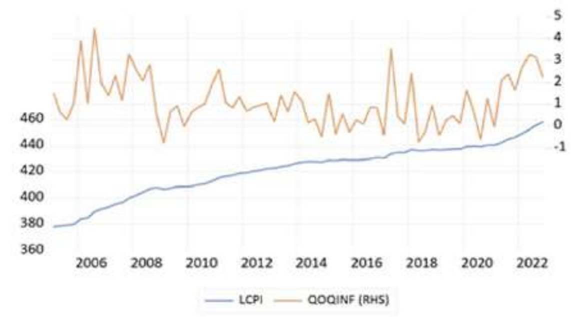

## Annex 1f: Fossil Fuel Subsidies



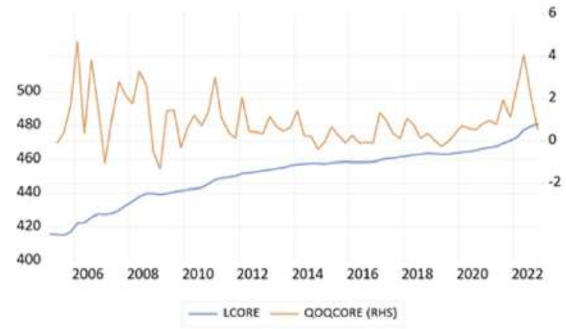



**Annex 2: Data Trends**

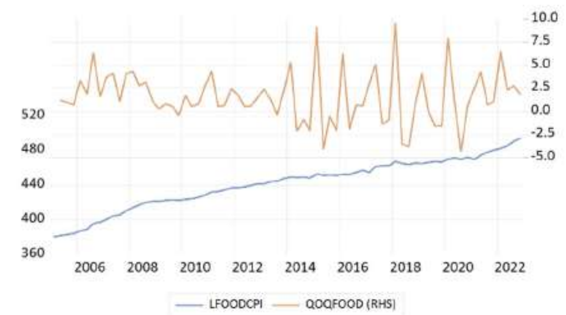
## Headline CPI



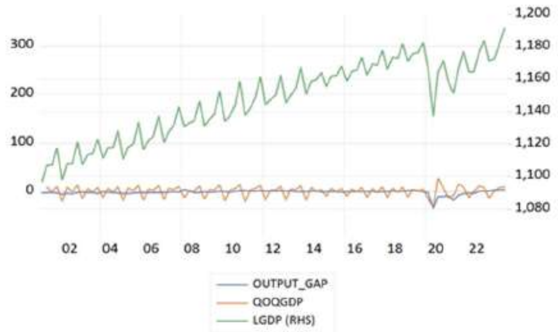

## CORE CPI



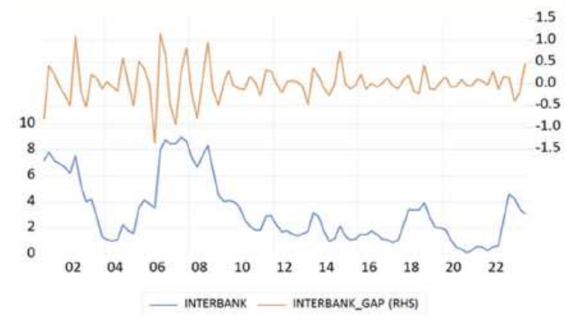

## FOOD CPI



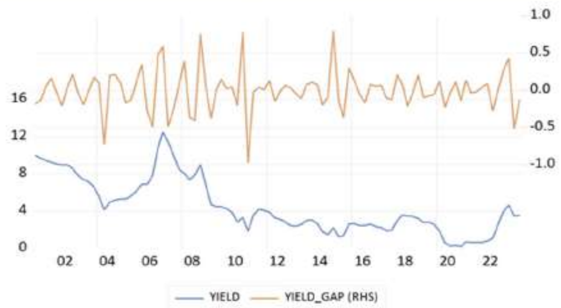

## GDP



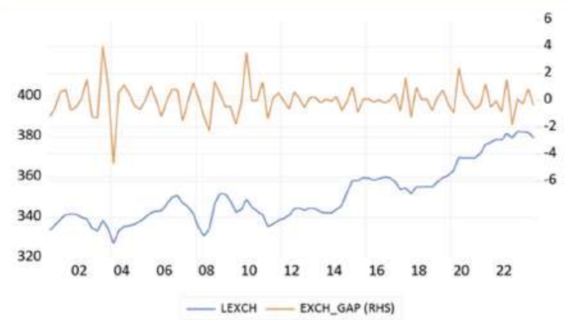

## Interbank Rate



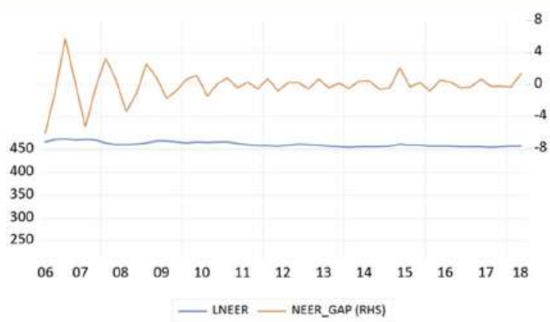

## 91-Day Bills Yield

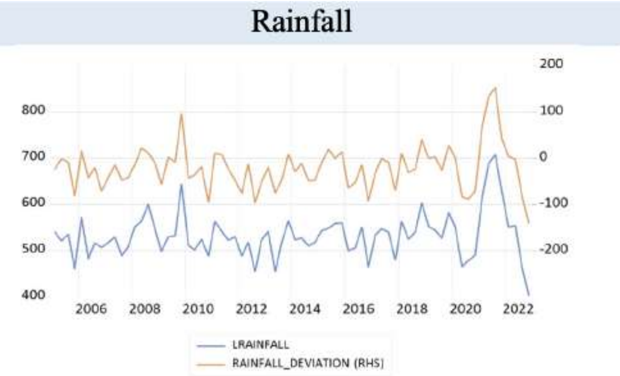


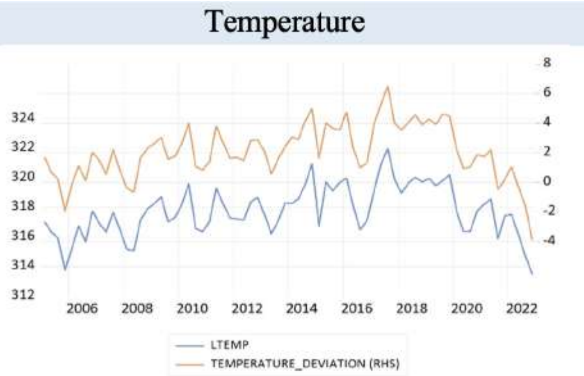

## MUR/USD Exchange Rate




## Nominal Effective Exchange Rate






## Annex 3: Descriptive Statistics

| | Output gap | Headline inflation | Core inflation | Food inflation | Yield gap | NEER gap | Rainfall deviation | Temperature deviation |
|---|---|---|---|---|---|---|---|---|
| Mean | -1.14 | 421.07 | 441.55 | 451.13 | 0.00 | 0.12 | -20.38 | 2.08 |
| Median | 0.16 | 426.84 | 447.97 | 456.69 | 0.00 | -0.11 | -18.40 | 1.94 |
| Maximum | 3.92 | 457.78 | 494.28 | 480.65 | 0.80 | 20.24 | 151.85 | 6.50 |
| Minimum | -33.99 | 378.22 | 380.73 | 415.26 | -0.98 | -6.09 | -140.32 | -3.88 |
| Std. Dev. | 5.14 | 19.61 | 28.76 | 16.00 | 0.28 | 3.06 | 49.21 | 1.84 |
| Skewness | -4.27 | -0.53 | -0.45 | -0.62 | 0.27 | 3.82 | 0.83 | -0.35 |
| Kurtosis | 25.60 | 2.58 | 2.42 | 2.69 | 5.57 | 27.62 | 5.22 | 3.57 |
| Jarque-Bera | 1750.65 | 3.96 | 3.44 | 4.88 | 20.73 | 1993.76 | 23.16 | 2.41 |
| Probability | 0.00 | 0.14 | 0.18 | 0.09 | 0.00 | 0.00 | 0.00 | 0.30 |
| Sum | -82.30 | 30316.84 | 31791.67 | 32481.43 | -0.27 | 8.95 | -1467.43 | 149.69 |
| Sum Sq. Dev. | 1875.64 | 27307.95 | 58729.49 | 18168.16 | 5.65 | 666.67 | 171930.62 | 239.93 |
| Observations | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |

## Annex 4: Unit Root Test Results

| Variables | Levels | | First Difference | | Order of Integration |
|---|---|---|---|---|---|
| | T-statistics | Probability | T-statistics | Probability | |
| **LRAINFALL** | -5.0024 | 0.0006 | | | I(0) |
| **LTEMP** | -3.1733 | 0.0982 | | | I(0) |
| **OUTPUT_GAP** | -5.1657 | 0.0003 | | | I(0) |
| **LCPI** | -3.7381 | 0.0263 | | | I(0) |
| **LCORE** | -2.7470 | 0.2218 | -5.5591 | 0.0001 | I(0) |
| **LFOODCPI** | -2.2410 | 0.4599 | -8.9559 | 0.0000 | I(0) |
| **NEER_GAP** | -22.8864 | 0.0001 | | | I(0) |
| **YIELD_GAP** | -10.4312 | 0.0000 | | | I(0) |

**Annex 5: Alternative Model**

$$\begin{pmatrix} \varepsilon_t^{clim} \\ \varepsilon_t^{gdp} \\ \varepsilon_t^{inf} \\ \varepsilon_t^{int} \\ \varepsilon_t^{exch} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{12} & 1 & 0 & 0 & 0 \\ a_{13} & a_{23} & 1 & 0 & 0 \\ 0 & a_{24} & a_{34} & 1 & 0 \\ 0 & 0 & a_{35} & a_{45} & 1 \end{pmatrix}' \begin{pmatrix} b_{11} & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 \\ 0 & 0 & 0 & 0 & b_{55} \end{pmatrix} \begin{pmatrix} \mathrm{u}_t^{clim} \\ \mathrm{u}_t^{gdp} \\ \mathrm{u}_t^{inf} \\ \mathrm{u}_t^{int} \\ \mathrm{u}_t^{exch} \end{pmatrix}$$

Image: unsplash.com

# Part 2

## Sovereign-Bank Nexus in COMESA Countries

# 3.1 Assessing the Sovereign-Bank Nexus: The Case of Eswatini

*Busika Themba and Shongwe Kwanele*

## 3.1.1 Introduction

The IMF (2022) report defines the sovereign-bank nexus as the strong ties between banks and governments, mainly through banks' large holdings of government debt. This connection can create negative feedback loops, where shocks in one sector amplify risks in the other, worsening financial instability—as demonstrated during the Eurozone debt crisis. Banks are central to the financial system, primarily tasked with mobilizing savings and providing liquidity not only to individual borrowers but also to various institutions, including governments. However, fiscal crises often prompt governments to implement austerity measures, such as significant cuts in public spending and an increase in taxes. While these actions might improve fiscal stability in the long term, they tend to depress economic activity in the short term by reducing aggregate demand, and this has a direct effect on financial stability (Borio et al., 2023).

The immediate impact of these measures includes higher default rates among borrowers and decreased demand for credit. Increased default rates and weakened economic activity can strain banks' balance sheets, as they face higher loan losses and lower profitability. Moreover, when governments themselves face fiscal stress (increasing sovereign risk), it can lead to increased borrowing costs for banks and a more cautious approach to lending, thereby constraining the availability of credit for the non-financial corporate sector (Borio & Restoy, 2020). This reduction in credit can lead to lower capital expenditure by firms, which can dampen economic growth and recovery prospects.

The sovereign-bank link is a known source of systemic risk, but the research on its impact on financial stability remains limited and largely inconclusive (Foglia et al., 2023; Bolton and Jeanne, 2011). Foglia & Angelini (2020) suggest that bank risk leads to sovereign risk via bailouts, while Langedijk & Fontana (2019) and Alter & Schüler (2021) find the direction shifts—from banks to sovereigns before bailouts, and vice versa thereafter. Fratzscher & Rieth (2023) also noted a stronger Sovereign-bank nexus but without clear causality, during the debt crisis. Additionally, in the literature, the linkages between sovereign and banking sector risk have been well explored for advanced economies but there is a dearth of knowledge on developing economies, which tend to have different structural characteristics—such as a lower level of financial sector development, a larger share of foreign-currency denominated public debt and higher refinancing risks (Acharya et al. 2022; Foglia and Angelini, 2020; International Monetary Fund, 2022). These factors could render them more sensitive to external shocks and strengthen the interconnectedness between the sovereign and banking sectors.

Moreover, while the potential risks and challenges associated with the sovereign-bank nexus relationship have been recognized, there is a lack of empirical evidence that provides a comprehensive understanding of the specific channels through which the nexus particularly affects financial stability, especially in developing countries. Though the theoretical channels have been somewhat explored, the linkages between sovereign-bank risk and financial stability are not clear in Eswatini. It is therefore important to comprehensively analyses and understand the effects of the sovereign-bank nexus on financial stability as well as to determine which of the identified theoretical channels are most effective in Eswatini. Understanding this nexus is vital for policymakers and financial actors. The primary objective of this study therefore is to investigate how the interdependencies between sovereign debt and the banking sector influence systemic risk and potential contagion effects in the case of Eswatini. Specifically, this study aims to achieve the following objectives:

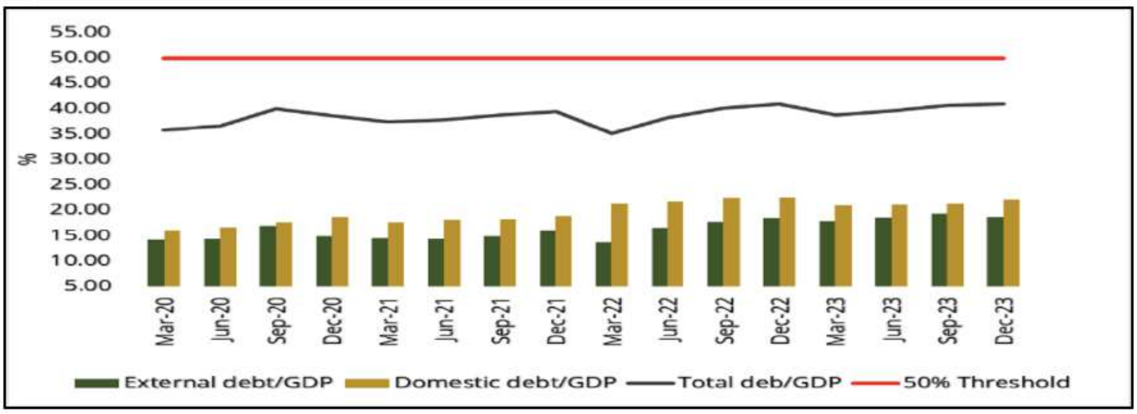
- To analyse the transmission mechanisms and contagion effects between the sovereign and banks during periods of stress and crisis.
- To assess the impact of the sovereign-bank nexus on the stability of the financial system.

This study contributes to the existing literature by providing valuable insights for policymakers and regulators, and offer a comprehensive understanding of the effects of the sovereign-bank nexus on financial stability based on data from Eswatini

## 3.1.2 Stylized Facts of the Sovereign-Bank Nexus in Eswatini

The public debt indicators in Eswatini depict an increasingly constrained fiscal sector as public debt ratios remain elevated (Figure 35). The total public debt-to-GDP ratio has remained above 40 percent since 2022 and above 30 percent over the last 13 years, with domestic debt rising in recent years, leading to elevated risks of sovereign-bank exposure. Despite the total debt-to-GDP ratio remaining below the observed critical ratio of 50 percent, government debt persists on a gradual upward trajectory, approaching the observed critical ratio.

**Figure 35: Public Debt-to-GDP Ratio**




Source: Central Bank of Eswatini

Domestic debt, as a proportion of total debt, exceeds external debt. In 2023Q4, external public debt as a percentage of total debt stood at 46 percent from 45 percent recorded in Q4-2022. Domestic debt to total debt stood at 54 percent in Q4-2023 from 55 percent in Q4-2022. Figure 36 depicts public debt as a percentage of total banking sector assets, which has been on an upward trend, from about 28 percent in March 2018 to about 54 percent in December 2023. This shows that the risks to the sovereign-bank nexus have almost doubled in a space of five years, with the highest risks being recorded in 2020 due to the COVID-19 pandemic and 2022/2023 in line with geopolitical tensions and resultant supply constraints. The increasing dependence of the sovereign sector on domestic banks for financing needs, with a higher exposure to government debt, increases the probability of transmission of shocks within the sectors.

**Figure 36: Public Debt as a Percentage of Banking Sector Assets**


Source: Central Bank of Eswatini

### 3.1.3 Literature Review

This literature review explores the mechanisms, empirical evidence, post-crisis developments, emerging market perspectives, and policy implications related to the sovereign-bank nexus.

Data from most emerging and developing economies over the last decade suggest that this nexus is rising. The growth of the nexus is observed from several perspectives. First, banks have increased their exposure to their sovereigns. Second, government debt has grown while fiscal positions have deteriorated. Third, banking sector assets and bank credit to the private sector are growing, making it harder for sovereigns to contain a banking crisis. Fourth, there is growing evidence of the existing nexus, which suggests that it has increased in the last decade. (Feyen and Zuccardi, 2019).

Banks typically hold large quantities of sovereign debt due to regulatory frameworks that often treat such debt as low risk. However, during periods of fiscal stress, the value of these assets can decline, directly impacting bank balance sheets and solvency. Acharya et al. (2022) highlight how deteriorations in sovereign creditworthiness led to significant losses for banks with large holdings of government bonds, demonstrating the direct link between sovereign risk and banking stability.

The Eurozone crisis provides a compelling case study of the sovereign-bank nexus. Banks in countries like Greece, Italy, and Spain held substantial amounts of their own governments' debt. When these governments faced fiscal difficulties, the banks' solvency was directly impacted. Altavilla et al. (2017) showed that increases in sovereign spreads led to higher funding costs for banks, reducing their lending capacity and further deepening the economic downturn.

Concerns over the sustainability of public finance caused negative feedback loops between vulnerable banks, indebted sovereigns, and weak economies. This led to a sequence of downgrading of sovereign ratings and most marketable securities issued by banks in the stressed countries. These reductions in banks and sovereign prices of securities weakened their balance sheets and increased the cost of recapitalization through the issuance of new equity. (Hobelsberger et al., 2023).

Langedijk & Fontana (2019) examined the Bank-Sovereign Loop and Financial Stability in the Euro Area, focusing on the link between bank and sovereign credit risk. The study developed a framework based on detailed actual bank balance sheets and tested the model on 35 large EU banking groups across 7 European countries. The effects of the feedback loops, in most cases, more than double the effect of the initial shock on bank losses and the sovereign risk premium. The study further documented that a single EU bank resolution mechanism, the European Stability Mechanism (ESM), direct bank recapitalizations, and bondholder "bail-in" can be effective to dampen the bank-sovereign loop. Addressing the home bias in banks' sovereign bond holdings by reducing excessive exposure to domestic sovereigns has only a limited benefit in terms of lower crisis doom loop effects, as contagion effects increase.

Studies using African data and scanty and they mainly focused relationship between macroeconomic variables and bank stability without highlighting the impact of sovereign debt on bank performance. Notably, Kwofie (2022) examined the relationship between macroeconomic variables and banking sector stability in Ghana using the ARDL approach.

This study analysed the short and long-run dynamics between macroeconomic variables and bank stability measured by the capital adequacy ratio. The bounds test results showed a long-run relationship between the variables of the study. From the ARDL error correction model, the exchange rate and return on assets have a positive long-term impact on bank stability.

On the other hand, the Ghanaian bank's stability was negatively impacted in the short term by the exchange rate. The study shows that the variables return to equilibrium at a rate of 28.9 percent. The study recommended that banks should establish internal policies that ensure adequate liquidity levels, strengthen the institutional environment in the country, ensure strict compliance with laws and regulations, and implement currency hedging.

In a similar study, Atiti et al., (2022) used the ARDL model in examining the linkages between macroeconomic shocks and credit risk in the Kenyan banking sector. The study established the existence of short-run and long-run relationships. The study also found that there is a negative relationship between credit risk and GDP growth, although not significant. The relationship between bank profitability and asset quality was found to be negative in the short run but positive in the long run. The paper also documented a positive short-run relation between asset quality and private sector credit growth, which turns negative in the long run. Furthermore, the bank asset quality-capital nexus was positive in the short run but turned negative in the long run. The concave relationship suggested that NPLs will rise with increases in capital to a certain threshold (moral hazard effect), after which more capital build-ups decrease NPLs (disciplinary or regulatory effect).

## 3.1.4 Methodology

### 3.1.4.1 The Model

To capture both the short- and long-run dynamics between sovereign debt exposure and banking sector performance, this study employs the Autoregressive Distributed Lag (ARDL) framework, consistent with prior empirical work (Atiti et al., 2022; Kwofie, 2022). The ARDL model is well-suited for small samples and for variables integrated of different orders, I(0) and I(1).

The general ARDL representation is given by:

$$\begin{aligned}\Delta Y_t = {} & \beta_0 + \beta_1 Y_{t-1} + \beta_2 INT_{t-1} + \beta_3 INF_{t-1} + \beta_4 VIX_{t-1} + \beta_5 Dom\_debt\_GDP_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} \\ & + \sum_{i=1}^{q} \alpha_i \Delta INT_{t-i} + \sum_{i=1}^{q} \alpha_i \Delta INF_{t-i} + \sum_{i=1}^{q} \alpha_i \, \Delta VIX_{t-i} \\ & + \sum_{i=1}^{q} \alpha_i \, \Delta DOM\_DEBT\_GDP_{t-\mathrm{i}} + \varepsilon_t\end{aligned}$$

where t denotes time, $\beta_0$ is the intercept, $\beta_i$ are the long-run coefficients, and $\alpha_i$ represent the short-run coefficients. $Y_t$ represents banking sector variables, including capital adequacy (CAR), liquidity ratio (LIQR), and profitability (ROA). INF denotes inflation, INT represents the discount rate, DOMDEBTGDPis the domestic debt-to-GDP ratio, VIX measures market volatility, and $\varepsilon_t$ is the error term.

The ARDL framework allows for both long-run equilibrium relationships and short-run dynamic adjustments. Accordingly, three separate models are estimated for capital adequacy, liquidity, and profitability to assess how banks' exposure to government securities influences each of these stability indicators, while controlling relevant macroeconomic factors.

## 3.1.4.2 Description of Variables and Unit Root Tests

Three categories of variables were selected: Commercial Banks' share of government securities as an indicator of sovereign debt variables, Banking Sector (capital adequacy, liquidity ratio and return on assets-ROA) and Macroeconomic variables (Inflation rate, discount rate and market volatility).

The study used quarterly data from 2014 to 2023, equivalent to 40 observations. The specific variables used in the study are mostly ratios and they are as follows: Commercial banks' share of government securities, capital adequacy ratio, domestic debt to GDP, liquidity ratio, return on equity, return on assets, inflation rate, discount rate, and exchange rate volatility (VIX). The data was sourced from the Central Bank of Eswatini, the South African Reserve Bank, and the Ministry of Finance, Eswatini.

The discount and inflation rates were relatively high from 2014 to 2019. However, in 2020, the discount rate dropped drastically as monetary authorities cut interest rates in response to the COVID-19 pandemic. Inflation, on the other hand, increased in 2020 due to decreased production and increased demand. The inflation rate remains elevated, hovering around 4 percent in 2021 and increasing further in 2022 due to the Russia-Ukraine conflict and resultant supply chain disruptions. In a bid to control the rising inflation, the Central Bank of Eswatini increased the discount rate, which grew steadily from 2021 through to 2023 (Annex 1).

The liquidity ratio was on a steady upward trend from 2014 to 2019, recording its maximum of 42.8 percent in 2019. Notably, the bank's liquidity fell in 2020 due to the COVID-19 pandemic and remained on a downward trend through 2021 to 2023. The banks' profitability measures, ROE and ROA, were tracking each other throughout the sample period, on a downward trend from 2014 to 2020. The profitability measures dipped in 2020 before growing steadily through to 2023.

The study employed the Augmented Dicky Fuller (ADF) test to determine whether the variables are stationary and the Akaike Information Criterion (AIC) test for optimum lag length selection. The unit root results are reported in Annex 2. The results indicate that the domestic debt to GDP ratio, capital adequacy ratio, liquidity ratio, return on assets, inflation, and interest rates have a unit root, indicating that they are non-stationary, and they are integrated of order one, i.e., I(1). On the other hand, Market volatility (VIX) is stationary, hence the ARDL model can be used since the variables are I(0) and I(1).

The study further used the Bounds test for cointegration to establish the existence of a long-run relationship between the variables (Nkoro and Uko, 2016; Narayan, 2005). The null hypothesis of no cointegration was tested, and it was rejected if the F-statistic was higher than the upper bound critical values or if the p-value was less than the significance level. Pesaran et.al (2001) posits that the test is inconclusive if the F-statistic lies between the upper and lower bound values. All relevant diagnostic tests were also conducted to validate the appropriateness of the selected model (Annex 3).

## 3.1.5 Empirical Results

The study estimated three different models using the risk on liquidity, capital adequacy and profitability of the banks as dependent variables.

### 3.1.5.1 Bounds Test for Cointegration

The bounds test results for cointegration are presented in Tables 12, 13 and 14. The results of the tests indicate that the variables in the liquidity and profitability models are cointegrated since the F-statistic is higher than the critical upper bound at the 5 percent level. The test for the capital adequacy model points to the existence of a long-run relationship but at the 10 percent significance level.

### 3.1.5.2 Capital Adequacy Ratio Model

**Table 12: Cointegration Tests Results for the Capital Adequacy Model**

| Test Statistic | Value | Significance | I(0) | I(1) |
|---|---|---|---|---|
| F-statistic | 4.83167 | 10percent | 2.46 | 3.46 |
| K | 4 | 5percent | 2.94 | 4.08 |
| | | 1percent | 4.09 | 5.53 |

### 3.1.5.3 Liquidity Model

**Table 13: Cointegration Tests Results for the Liquidity Model**

| Test Statistic | Value | Significance | I(0) | I(1) |
|---|---|---|---|---|
| F-statistic | 7.884108 | 10percent | 2.46 | 3.46 |
| K | 4 | 5percent | 2.94 | 4.08 |
| | | 1percent | 4.09 | 5.53 |

### 3.1.5.4 Profitability Model

**Table 14: Cointegration Tests Results for Profitability Model**

| Test Statistic | Value | Signif. | I(0) | I(1) |
|---|---|---|---|---|
| F-statistic | 5.736155 | 10percent | 2.46 | 3.46 |
| K | 4 | 5percent | 2.94 | 4.08 |
| | | 1percent | 4.09 | 5.53 |

### 3.1.5.5 Long-run ARDL Model Results

The results in Table 15 indicate that interest rates and the banks' share of government securities have a positive effect on the capital adequacy ratio in the long run. A 1 percent increase in the bank's share of government securities increases the capital adequacy ratio by between 0.06 to 0.07 percent, indicative of a positive relationship between the capital adequacy ratio and the bank's holding of government securities.

### 3.1.5.6 Capital Adequacy Ratio Model

**Table 15: ARDL Long-run Estimates-Capital Adequacy Ratio Model**

| Variable | Coefficient | Std. Error | t-Statistic | Prob.* |
|---|---|---|---|---|
| CAR(-1) | 0.242518 | 0.143905 | 1.685268 | 0.1020 |
| GOVSEC | 0.070076 | 0.031730 | 2.208539 | 0.0347 |
| GOVSEC(-1) | 0.059526 | 0.034468 | 1.726996 | 0.0941 |
| INF | -0.107539 | 0.179164 | -0.600227 | 0.5527 |
| INT | 0.277608 | 0.208135 | 1.333790 | 0.1920 |
| VIX | -0.005880 | 0.037973 | -0.154860 | 0.8779 |
| VIX(-1) | -0.048957 | 0.040700 | -1.202883 | 0.2381 |
| C | 10.49390 | 2.739397 | 3.830733 | 0.0006 |
| R-squared | 0.855095 | Mean dependent var | | 19.87197 |
| Adjusted R-squared | 0.822375 | S.D. dependent var | | 2.570907 |
| S.E. of regression | 1.083524 | Akaike info criterion | | 3.178997 |
| Sum squared resid | 36.39477 | Schwarz criterion | | 3.520240 |
| Log likelihood | -53.99044 | Hannan-Quinn criter. | | 3.301432 |
| F-statistic | 26.13338 | Durbin-Watson stat | | 1.995367 |
| Prob(F-statistic) | 0.000000 | | | |

*Note: p-values and any subsequent test results do not account for model Selection

The results further show that an increase in interest rates has a positive effect on the capital adequacy ratio in the long run. This result can be explained by the fact that higher interest rates lead to higher earnings for banks from lending activities and investment portfolios, which boost their overall capital base, thus improving the CAR. Additionally, as interest rates rise, banks reprice their assets, such as loans and securities, at higher rates, leading to an increase in the value of the banks' assets, which positively affects the capital base. However, the relationship between interest rate and capital adequacy is not statistically significant.

The positive long-run relationship between banks' holdings of government securities and capital adequacy suggests that sovereign exposure strengthens rather than weakens banks' solvency in Eswatini. This outcome aligns with the sovereign–bank nexus literature (Atiti et al., 2022; Kwofie, 2022), which posits that government securities, classified as low-risk assets under Basel II/III capital regulations, enhance banks' capital buffers by reducing risk-weighted assets. These instruments provide stable income streams and serve as reliable collateral, particularly in small, bank-dominated financial systems with limited investment alternatives. Thus, banks' exposure to sovereign debt can improve their capital adequacy through both risk mitigation. However, the relationship may reverse in cases of fiscal distress or debt concentration, underscoring the importance of prudent portfolio diversification and sovereign risk monitoring.

### 3.1.5.7 Liquidity Ratio Model

Table 16 shows that there is a negative relationship between the bank's liquidity ratio and all the regressors; however, the results are not significant in the long run for exchange rate volatility, interest rates, and the inflation rate. The result show that a 1 percent increase in the bank's share of government securities decreases the bank's liquidity by 0.12 percent in the long run.

**Table 16: ARDL Long-run Estimates – Liquidity Ratio Model**

| Variable | Coefficient | Std. Error | t-Statistic | Prob.* |
|---|---|---|---|---|
| LIQR(-1) | 0.526297 | 0.154090 | 3.415524 | 0.0017 |
| VIX | -0.060364 | 0.104220 | -0.579199 | 0.5664 |
| INT | -0.383047 | 0.507930 | -0.754132 | 0.4561 |
| INF | -0.004235 | 0.458722 | -0.009232 | 0.9927 |
| GOVSEC | -0.127871 | 0.067945 | -1.881986 | 0.0687 |
| C | 23.83167 | 8.245067 | 2.890416 | 0.0068 |
| R-squared | 0.644463 | Mean dependent var | | 33.82426 |
| Adjusted R-squared | 0.590593 | S.D. dependent var | | 4.897969 |
| S.E. of regression | 3.133959 | Akaike info criterion | | 5.263110 |
| Sum squared resid | 324.1162 | Schwarz criterion | | 5.519042 |
| Log likelihood | -96.63064 | Hannan-Quinn criter. | | 5.354936 |
| F-statistic | 11.96346 | Durbin-Watson stat | | 2.240303 |
| Prob(F-statistic) | 0.000001 | | | |

*Note: p-values and any subsequent test results do not account for the model Selection

### 3.1.5.8 Profitability Model

Results for the profitability model in Table 17 indicate that the interest rates and inflation have a negative and significant impact on return on assets (profitability indicator) while the banks' share of government securities have a positive effect on the banks' return on assets in the long run.

**Table 17: ARDL Long-run Estimates-Profitability Model**

| Variable | Coefficient | Std. Error | t-Statistic | Prob.* |
|---|---|---|---|---|
| ROA(-1) | 0.686713 | 0.116533 | 5.892852 | 0.0000 |
| VIX | -0.012143 | 0.007798 | -1.557159 | 0.1299 |
| INT | 0.165446 | 0.106384 | 1.555177 | 0.1304 |
| INT(-1) | 0.001809 | 0.157623 | 0.011479 | 0.9909 |
| INT(-2) | -0.171447 | 0.095043 | -1.803893 | 0.0813 |
| INF | -0.077992 | 0.038445 | -2.028681 | 0.0514 |
| GOVSEC | 0.011088 | 0.005933 | 1.868785 | 0.0714 |
| C | 0.966756 | 0.355383 | 2.720322 | 0.0107 |

| | | | |
|---|---|---|---|
| R-squared | 0.848696 | Mean dependent var | 2.312160 |
| Adjusted R-squared | 0.813392 | S.D. dependent var | 0.527938 |
| S.E. of regression | 0.228059 | Akaike info criterion | 0.066241 |
| Sum squared resid | 1.560330 | Schwarz criterion | 0.410996 |
| Log likelihood | 6.741429 | Hannan-Quinn criter. | 0.188902 |
| F-statistic | 24.03957 | Durbin-Watson stat | 2.284156 |
| Prob(F-statistic) | 0.000000 | | |

*Note: p-values and any subsequent test results do not account for the model selection.

## 3.1.6 Short Run ARDL Estimates

### 3.1.6.1 Profitability Model

The results of the short-run model are presented in Table 18. The results show that the exchange rate volatility has a negative impact on the return on assets, which is the measure of profitability used in the study. A 1 percent increase in the exchange rate volatility decreases profitability by 0.01 percent. The lagged twice exchange rate volatility also has a negative impact on the bank's profitability; a 1 percent increase in the exchange rate volatility lagged twice results in a 0.03 percent decrease in the bank's profitability. The results also indicate that interest rates have a positive impact on the bank's profitability. A 1 percent increase in the interest rate and the one-lag interest rate results in a 0.39 and a 0.17 percent increase in the bank's return on assets.

This result would imply that higher interest rates lead to an improved net interest margin NIM, which is the difference between the interest income generated by banks and the amount of interest paid out to their lenders. A better NIM contributes to higher profitability.

The inflation rate has a negative effect on bank profitability, whilst the lagged inflation rate has a positive effect on bank profitability. A 1 percent increase in the inflation rate results in a 0.14 percent decline in the return on assets in the short run. A 1 percent increase in the inflation rate lagged once and twice resulted in a 0.30 and 0.29 percent increase in the return on assets, respectively. The banks' share of government securities has a negative effect on the banks' profitability. A 1 percent increase in the first lag of the bank's share of government securities will result in a 0.03 percent decline in the return on assets. Similarly, a 1 percent increase in the bank's share of government securities lagged twice will result in a 0.02 percent decrease in the return on assets. The results also indicate that about 86 percent of the deviation from the long-run path is corrected in each quarter.

**Table 18: Short Run ARDL Estimates- Profitability Model**

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| COINTEQ* | -0.856378 | 0.128319 | -6.673796 | 0.0000 |
| D(VIX) | -0.013814 | 0.006221 | -2.220532 | 0.0370 |
| D(VIX(-1)) | -0.005198 | 0.006739 | -0.771333 | 0.4487 |
| D(VIX(-2)) | -0.029074 | 0.007102 | -4.093967 | 0.0005 |
| D(VIX(-3)) | -0.020872 | 0.007212 | -2.894121 | 0.0084 |
| D(INT) | 0.385790 | 0.085265 | 4.524617 | 0.0002 |
| D(INT(-1)) | 0.176404 | 0.081264 | 2.170754 | 0.0410 |
| D(INF) | -0.148698 | 0.037687 | -3.945643 | 0.0007 |
| D(INF(-1)) | 0.306099 | 0.059608 | 5.135155 | 0.0000 |
| D(INF(-2)) | 0.289522 | 0.061395 | 4.715743 | 0.0001 |
| D(INF(-3)) | 0.205108 | 0.047835 | 4.287845 | 0.0003 |
| D(GOVSEC) | 0.012284 | 0.005997 | 2.048515 | 0.0526 |
| D(GOVSEC(-1)) | -0.034201 | 0.010776 | -3.173881 | 0.0044 |
| D(GOVSEC(-2)) | -0.020746 | 0.007104 | -2.920124 | 0.0079 |

| | | | |
|---|---|---|---|
| R-squared | 0.789217 | Mean dependent var | -0.011768 |
| Adjusted R-squared | 0.664663 | S.D. dependent var | 0.276561 |
| S.E. of regression | 0.160152 | Akaike info criterion | -0.540087 |
| Sum squared resid | 0.564270 | Schwarz criterion | 0.075726 |
| Log likelihood | 23.72157 | Hannan-Quinn criter. | -0.325152 |
| F-statistic | 6.336348 | Durbin-Watson stat | 2.251434 |
| Prob(F-statistic) | 0.000084 | | |

* p-values are incompatible with t-Bounds distribution.

### 3.1.6.2 Liquidity Model

The results presented in Table 19 indicate that the lagged liquidity ratio has a significant negative effect on the bank's liquidity ratio. A 1 percent increase in the liquidity ratio lagged once, twice and three times will result in a 0.70, 0.34 and 0.29 percent decline in the liquidity ratio, respectively. An increase in the interest rate has a significant negative impact on the liquidity ratio. A 1 percent increase in the interest rates decreases banks' liquidity by 2.93 percent in the short run, the interest rate lagged three times results in a decline of 2.50 percent in the bank's liquidity ratio in the short run. The inflation rate, on the other hand, has a positive effect on liquidity, with a 1 percent increase in its first lag increasing banks' liquidity by 2.27 percent in the short run.

The results also indicate that there is no statistically significant relationship between the bank's share of government securities and the liquidity ratio in the short run. Approximately 11 percent of the deviation from the long-run path is corrected every quarter, reflecting slower adjustment dynamics relative to capital adequacy.

**Table 19: Short Run ARDL Estimates-Liquidity Ratio Model**

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| COINTEQ* | -0.108787 | 0.013993 | -7.774627 | 0.0000 |
| D(LIQR(-1)) | -0.702490 | 0.103580 | -6.782136 | 0.0000 |
| D(LIQR(-2)) | -0.347546 | 0.114830 | -3.026623 | 0.0060 |
| D(LIQR(-3)) | -0.285080 | 0.091343 | -3.120971 | 0.0048 |
| D(VIX) | -0.280420 | 0.053017 | -5.289217 | 0.0000 |
| D(VIX(-1)) | -0.091333 | 0.052861 | -1.727794 | 0.0974 |
| D(VIX(-2)) | -0.174522 | 0.047354 | -3.685507 | 0.0012 |
| D(INT) | -2.934373 | 0.639539 | -4.588264 | 0.0001 |
| D(INT(-1)) | -0.705027 | 0.801471 | -0.879666 | 0.3881 |
| D(INT(-2)) | 0.983959 | 0.795267 | 1.237270 | 0.2285 |
| D(INT(-3)) | -2.492925 | 0.756926 | -3.293486 | 0.0032 |
| D(INF) | 0.223803 | 0.278149 | 0.804615 | 0.4293 |
| D(INF(-1)) | 2.267410 | 0.333441 | 6.800042 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.887755 | Mean dependent var | 0.054188 |
| Adjusted R-squared | 0.829192 | S.D. dependent var | 3.326595 |
| S.E. of regression | 1.374846 | Akaike info criterion | 3.748758 |
| Sum squared resid | 43.47465 | Schwarz criterion | 4.320585 |
| Log likelihood | -54.47765 | Hannan-Quinn criter. | 3.948341 |
| F-statistic | 15.15903 | Durbin-Watson stat | 2.343843 |
| Prob(F-statistic) | 0.000000 | | |

* p-values are incompatible with t-Bounds distribution.

** The variable representing banks' holdings of government securities (DOMDEBTGDP) was included in the initial short-run ARDL specification but excluded due to statistical insignificance

### 3.1.6.3 Capital Adequacy Model

Table 20 indicates that the banks' share of government securities has a positive relationship with the banks' capital adequacy. A 1 percent increase in the domestic debt and the banks' share of government securities increases the capital adequacy ratio by 0.08 percent, in the short run. However, the capital adequacy ratio does not have a significant relationship with interest rates, inflation rate and the exchange rate volatility in the short run. The results also indicate that about 72.6 percent of the deviation from the long run is corrected every quarter.

**Table 20: Short Run ARDL Estimates -Capital Adequacy Ratio Model**

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| COINTEQ* | -0.726460 | 0.205420 | -3.536460 | 0.0014 |
| D(CAR(-1)) | -0.012707 | 0.152001 | -0.083599 | 0.9340 |
| D(VIX) | -0.006201 | 0.034640 | -0.179015 | 0.8592 |
| D(VIX(-1)) | -0.017155 | 0.036143 | -0.474626 | 0.6387 |
| D(INT) | -0.155313 | 0.478031 | -0.324902 | 0.7477 |
| D(INT(-1)) | 0.110433 | 0.455232 | 0.242587 | 0.8101 |
| D(INF) | -0.280107 | 0.215351 | -1.300704 | 0.2040 |
| D(INF(-1)) | 0.101941 | 0.191967 | 0.531032 | 0.5996 |
| D(GOVSEC) | 0.085279 | 0.035646 | 2.392395 | 0.0237 |
| D(GOVSEC(-1)) | 0.022622 | 0.042024 | 0.538311 | 0.5946 |
| R-squared | 0.556287 | Mean dependent var | | -0.085001 |
| Adjusted R-squared | 0.413666 | S.D. dependent var | | 1.392033 |
| S.E. of regression | 1.065914 | Akaike info criterion | | 3.186477 |
| Sum squared resid | 31.81284 | Schwarz criterion | | 3.617421 |
| Log likelihood | -50.54306 | Hannan-Quinn criter. | | 3.339803 |
| F-statistic | 3.900436 | Durbin-Watson stat | | 1.932285 |
| Prob(F-statistic) | 0.002635 | | | |

* p-values are incompatible with t-Bounds distribution.

### 3.1.7 Conclusion and Recommendations

The primary objective of this study was to examine the impact of the sovereign bank nexus on financial stability using the ARDL model. Specifically, the study sought to investigate how the interdependencies between sovereign debt and the banking sector influence systemic risk and potential contagion effects in the case of Eswatini. The study focused on three models with dependent variables as follows: Capital adequacy, liquidity, and profitability.

The results show that an increase in bank holdings of government securities has a positive effect on the capital adequacy ratio and profitability, but a negative effect on liquidity in the long run. In the short run, the results also show a positive relationship between bank holdings of government securities and capital adequacy, but no relationship between the holdings of government securities and liquidity. The relationship between holdings of government securities by banks is both positive and negative on profitability, depending on the number of lags on the coefficient of bank holdings of government securities.

The negative impact of holdings of government securities by banks on liquidity would imply decreased lending to the private sector with potential negative implications on monetary policy transmission. Additionally, the more banks hold sovereign debt, the more exposed their balance sheet is to the sovereign's debt levels and fiscal fragility with negative implications on businesses and investment and possible increase in non-performing loans and negative effects on bank liquidity.

The results further show that the exchange rate volatility, interest rate and inflation have a negative impact on profitability while an increase in interest rates has a positive effect on the capital adequacy ratio in the long run. In the short run, the results indicate that the inflation rate has a positive effect on the bank's liquidity but a negative effect on bank profitability. However, the capital adequacy ratio does not have a significant relationship with interest rates, inflation rate and the exchange rate volatility in the short run.

Based on these results therefore, the study recommends imposition of limits on the proportion of a bank's portfolio that can be invested in sovereign debt, higher capital requirements for sovereign debt holdings to make it less attractive for banks to hold large amounts of government securities, strengthening of credit infrastructure to enhance the attractiveness of lending to the private sector and fiscal discipline

"In the short run, the results indicate that the inflation rate has a positive effect on the bank's liquidity but a negative effect on bank profitability.

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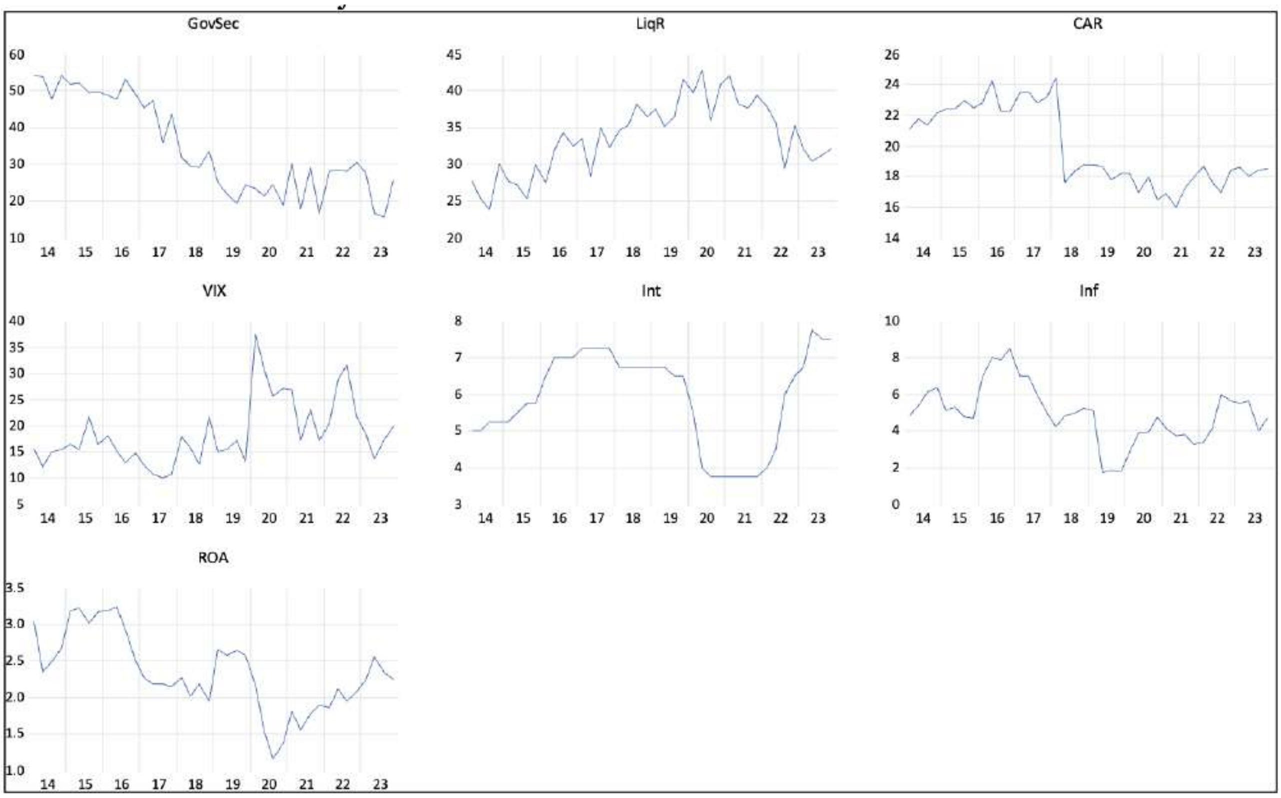
Image: unsplash.com

# Annexes

**Annex 1: Evolution of Key Variables**




**Annex 2: Unit Root Test Results**

| Variable | Levels | 1st Difference | Decision |
|---|---|---|---|
| GovSec | -1.254633 | -11.84709 | I(1) |
| CAR | -1.677590 | -8.154760 | I(1) |
| LIQR | 0.213929 | -10.39326 | I(1) |
| ROA | -0.855808 | -6.035983 | I(1) |
| INF | -0.608990 | -5.669074 | I(1) |
| INT | -1.794540 | -3.645599 | I(1) |
| VIX | -3.326806 | | I(0) |

### Annex 3: Model Diagnostics

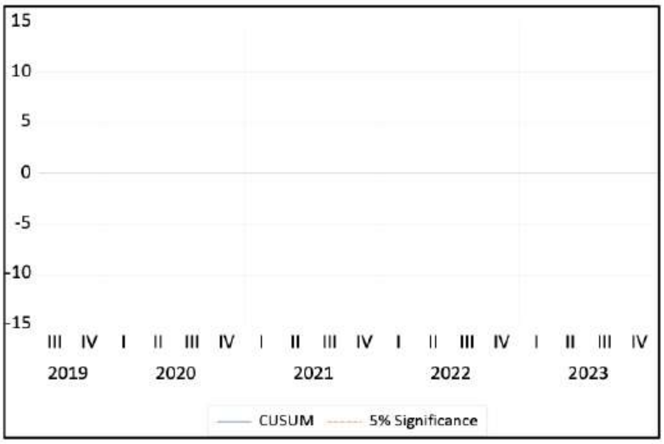
| Model | Capital Adequacy | | Liquidity | | Profitability | |
|---|---|---|---|---|---|---|
| **Test** | **F-statistic** | **Prob.** | **F-statistic** | **Prob.** | **F-statistic** | **Prob.** |
| LM Test | 0.057972 | 0.9438 | 2.131782 | 0.1746 | 3.163472 | 0.0696 |
| Breuch-Pegan-Godfrey | 0.528558 | 0.9095 | 0.860835 | 0.6381 | 0.762754 | 0.7095 |
| Jarque Bera | 2.069 | 0.3552 | 0.7592 | 0.6841 | 1.1223 | 0.5704 |

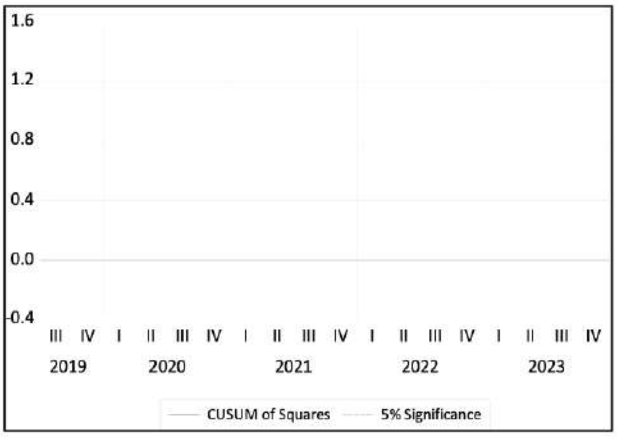
The results in Annex 3 show that the serial correlation LM test for all the models was insignificant, indicating that there is no serial correlation; hence, we fail to reject the null hypothesis of no serial autocorrelation. The Breusch-Pagan-Godfrey test for heteroskedasticity was not significant, hence the null hypothesis of homoskedasticity cannot be rejected. Lastly, the residuals were found to be normally distributed as the Jarque-Bera test for normality was found to be statistically insignificant.

### Annex 4: CUSUM and CUSUM of Squares

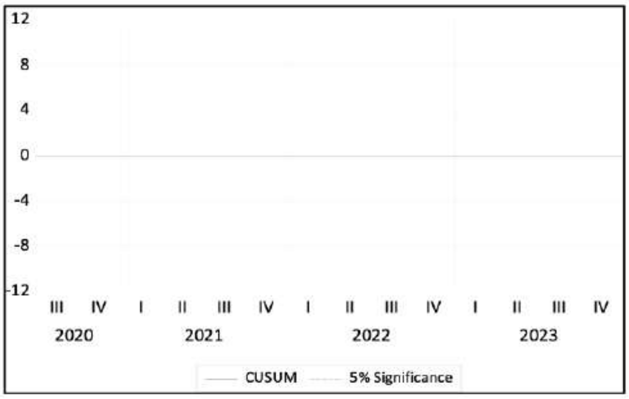
The CUSUM and CUSUM of Squares graphs lie within the 5 percent confidence bounds, implying that the models are stable.

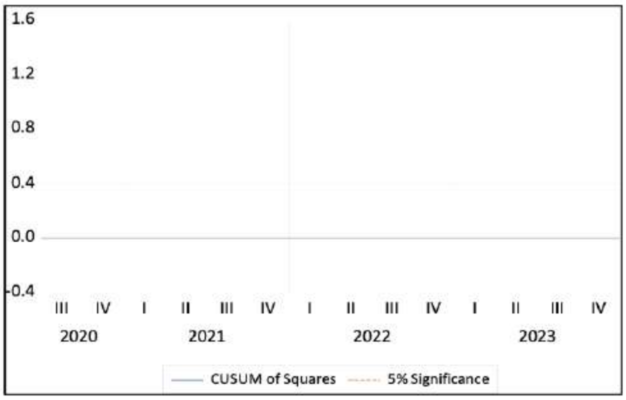
### Profitability Model



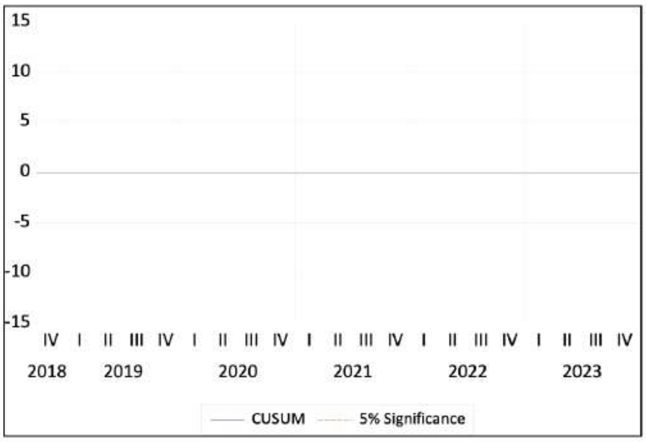



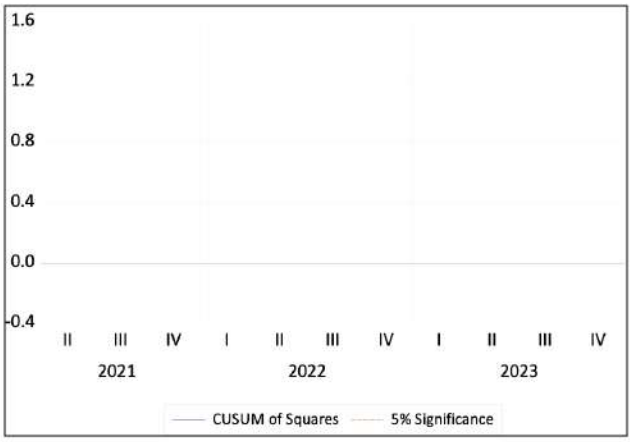
**CAR Model**




**Liquidity Model**




# 3.2 Sovereign Exposure Risk and Macroprudential Policy in Uganda

*Brian Musumba and Samuel Namwanja Musoke*

## 3.2.1 Introduction

The holding of sovereign debt exposes the financial sector to credit, interest rate, market, and refinancing risks as well as losses due to unexpected increases in inflation and fluctuations in the value of sovereign exposures. However, the financial sector has always perceived sovereign debt as risk-free due to the ability of the government to refinance its debt by issuing new debt and levy taxes to meet its budget deficits. It is against this background that this study seeks to examine the sovereign risk arising from banks' holdings of government securities and to assess its implications for financial stability in Uganda. Specifically, the study has three objectives. The first objective is to quantify the determinants of banks' sovereign exposure by maturity structure. Using an administrative dataset of monthly bank balance sheets, we distinguish between short-term (less than one year) and long-term (one year or more) holdings. This analysis estimates the effects of securities pricing (yield curve shifts), prudential requirements (capital and liquidity ratios), and macroeconomic conditions (inflation and GDP) over the period between 2011 and 2024. The second objective is to explore market heterogeneity by comparing primary dealers and non-primary dealers, and to identify how dealership status influences both the level and elasticity of sovereign exposure in response to movements in short- and long-term yields. Finally, the third objective is to assess the potential crowding-out effect of sovereign holdings on private-sector credit and to propose macroprudential policy interventions, which would be leveraged to mitigate related financial stability risks.

Our results show that banks' investment decisions are strongly influenced by movements along the yield curve, liquidity requirements, and macroeconomic performance. Short-term sovereign exposure is highly sensitive to short-term yield fluctuations, while long-term holdings are shaped by both capital adequacy conditions and broader economic trends such as inflation and GDP growth. We show that an increase in short-term yields in the previous quarter induces banks to increase short-term exposure to government securities, while an increase in long-term yields in the previous quarter induces banks to reduce their exposure to short-term securities. The results further indicate that exposure is partly explained by heterogeneity across the banks. Primary dealers that enjoy privileged access to auctions exhibit greater responsiveness to yield dynamics, indicating their pivotal role in intermediating liquidity and risk across the market. The findings also reveal evidence of a crowding-out. Increases in sovereign holdings are associated with a measurable decline in private credit growth, suggesting that fiscal expansions financed through the domestic banking system can constrain credit intermediation to the real economy.

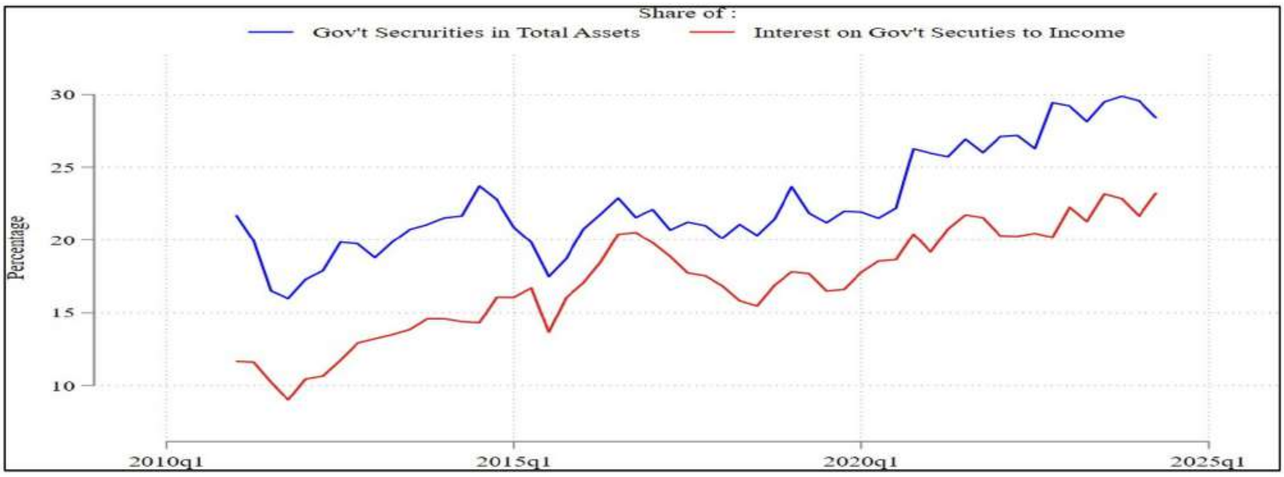
These results show the need for reinforcing sovereign-risk management within Uganda's macroprudential framework, including the introduction of exposure limits with surcharges, routine sovereign-risk stress testing, and dynamic sovereign risk-weighting practices that better reflect underlying vulnerabilities. The rest of the paper is as follows. Section 2 provides details about the balance sheet exposure of commercial banks to sovereign holdings, as well as the evolution and maturity structure of sovereign exposure. Section 3 provides a review of the literature, while Section 4 describes the data and methodology used in this study. Section 5 provides evidence on determinants of sovereign exposure and the role of market heterogeneity, whereas Section 6 concludes.

## 3.2.2 Stylized Facts: Sovereign-Bank Nexus in Uganda

### 3.2.2.1 Evolution of Sovereign Exposure in Uganda

The share of government securities in total assets increased from about 16% to 30% while the share of interest on government securities in total income increased from about 10% to 20%, between 2011 to 2022. This increase reflects the reliance of the government on the domestic bond market to finance fiscal deficits and the attractiveness of the government securities to banks. Government securities are safer, and liquid compared to loans, placements, and fixed assets.

**Figure 37: Exposure of Commercial Banks to Sovereign Risk**




Note: The figure represents the contribution of treasury holdings to the asset side of the commercial bank balance sheet and the income statement. Treasury holdings are reported at fair value for securities held to maturity and reported at market value for securities held for trade. The marketable securities are valued as of the end quarter.

### 3.2.2.2 Capital Requirements and Liquidity Regulations

The literature partly attributes the increasing holdings of sovereign debt by banks to the liquidity and capital regulations (Baule et al., 2021; Kirschenmann et al., 2017). These regulations, designed to ensure financial stability, have reinforced the concentration of bank balance sheets with sovereign debt. Previously, according to section 4(2)(d) of the Financial Institutions (Liquidity) regulations of 2005, liquid assets included not only cash and balances held at the Central Bank but also Uganda treasury bills and marketable government bonds. These regulations of 2005 were revoked and replaced by the financial institutions (Liquidity) regulations, 2023. The new regulations further provided for the inclusion of (i) funds held under a special deposit facility and the standing deposit facility at the Central Bank; (ii) Bank of Uganda Bills; (iii) inclusion of government securities held in available for sale portfolios or held in accordance with "hold to collect and sale" business models subject to a haircut. These regulations incentivize banks to hold significant amounts of sovereign debt to meet liquidity requirements as required under section 4(3) of the 2023 regulations which require a financial institution to maintain a sufficient stock of high-quality liquid assets for purposes of complying with the liquidity coverage ratio (Financial institution in Uganda must maintain the 100 percent liquidity coverage ratio for all currencies in which they hold 10 percent or more of their liabilities).

The Capital Requirement Regulations of 2005, 2010, and 2022 provide a basis for holding government securities. The regulations require financial institutions to hold and maintain adequate capital to protect depositors and creditors against the risk of loss that may arise from their business activities. The Financial Institutions (Revision of Minimum Capital Requirements) instrument of 2022 raised the minimum paid-up capital and required that the capital be invested in liquid assets in Uganda as prescribed by the Bank of Uganda. The Bank of Uganda specifies that core capital should be invested in government securities, which have a risk weight of 0%; additionally, the financial institution shall at all times maintain a core capital of not less than 8% and a total capital of not less than 12% of the total risk-adjusted assets plus risk-adjusted off-balance sheet items. Non-compliance with these ratios may attract penalties equivalent to a thousandth of the amount of the deficiency for every day on which the deficiency occurs, coupled with the submission of corrective plans provided to the Central bank. These regulations have penalties and benefits which encourage compliance, and which provide incentives for holding government securities.

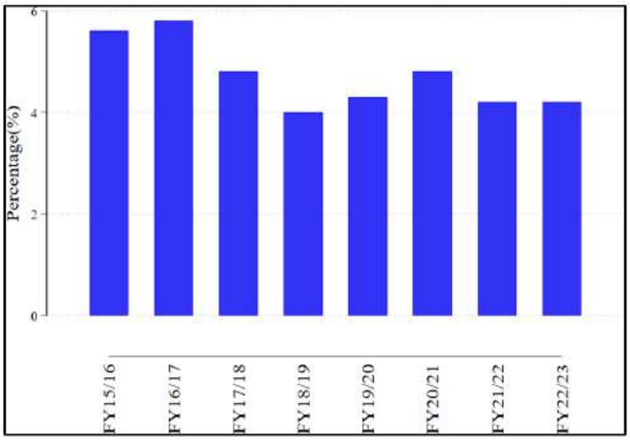
"The Capital Requirement Regulations of 2005, 2010, and 2022 provide a basis for holding government securities.

### 3.2.2.3 Domestic Debt Dynamics

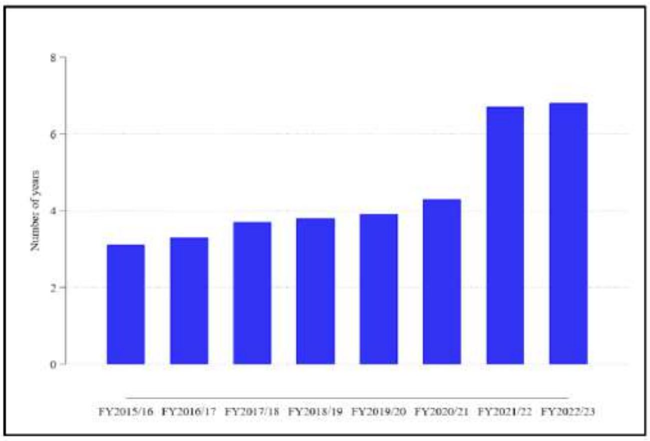
Despite the fact that Uganda benefited from debt relief initiatives in 1998 and the 2000s under the Highly Indebted Poor Countries (HIPC) framework, an increase in government consumption, a decline in the growth rate of tax revenue, and difficulties in obtaining concessional loans have public debt levels. The ratio of public debt to GDP increased from about 31 percent in 2015 to 52 percent in 2024. Even though the Uganda Revenue Authority has enhanced tax revenue administration, the fiscal deficit, financed through the issue of government securities and loans, has increased. Over the years, Uganda has taken measures to ensure the sustainability of the domestic debt. Domestic debt maturing in one year as a percentage of total debt declined to 23.20% at the end of FY 2022/23 from 45.1% in FY 2015/16. This shows that Uganda has progressively tilted towards longer-dated securities, although this may have significant implications for the cost of debt. Furthermore, the average time to maturity has increased to 6.8 years from 3.10 over the same period (See Figure 38). These steps have ensured an improvement in refinancing and rollover risks.

**Figure 38: Evolution of Domestic Debt in Uganda**

(a) Debt maturing in 1 year (% of GDP)




(b) Average time to maturity (Years)

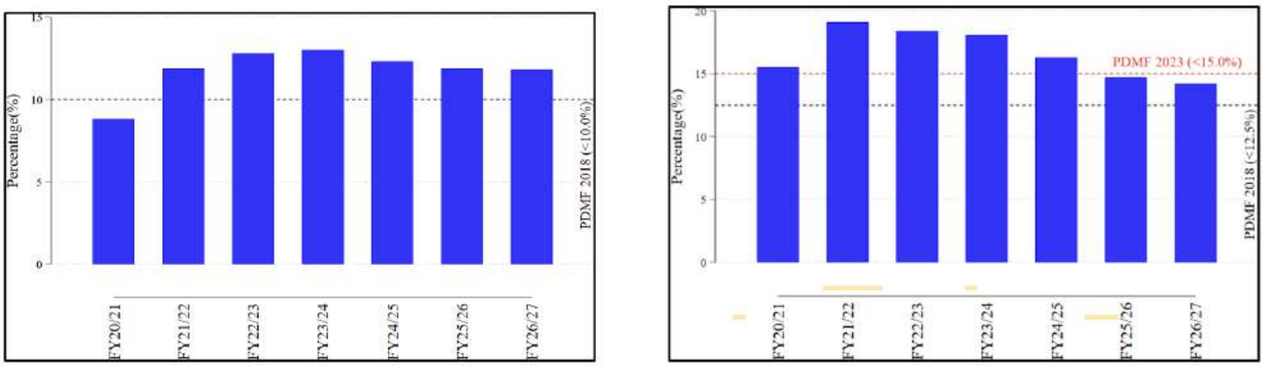



Note: The figure shows the evolution of key debt indicators in Uganda. Reported debt includes both domestic and External debt maturing in 1 year. The data is based on publicly available Debt Sustainability Reports from FY2015/16 to FY2022/24 conducted by Ministry of Finance, Planning and Economic Development.

**Figure 39: Performance Against PDMF 2018 Benchmarks**

(a) Domestic Interest to Total Government Expenditure

(b) Domestic Interest to Domestic Revenue




Note: PDMF stands for the Public Debt Management Framework. The PDMF of 2018 was amended in 2023, leading to adjustments in key benchmarks. The reported debt in the figure is only domestic. The data is based on publicly available Debt Sustainability (DSA) Reports from FY2015/16 to FY2022/23 conducted by the Ministry of Finance, Planning, and Economic Development. The DSA of FY2022/23 provides an outlook for the indicators up to FY2026/27.

## 3.2.3 Literature Review

Numerous studies have analyzed the sovereign-bank nexus, often yielding different conclusions. Studies have shown that banks' holdings of sovereign debt are influenced by a variety of factors, including prudential regulation, fluctuations in yield curves, macroeconomic conditions, and the heterogeneity of the securities market. Boz et al. (2014), Altavilla et al. (2017), and Baule et al. (2021) have examined the relationship between macro prudential regulation and the sovereign-bank nexus. They show that the privileged treatment of government securities in assessing risk and liquidity requirements tends to influence banks toward greater sovereign exposure. However, Lamas and Mencía (2018) contest this by showing that government securities are less risky relative to other assets, and the value of government securities is less likely to change on maturity. As a result, holding government securities has a higher chance of preserving the value of the assets as well as bearing higher returns. Under the standardized approach of assigning risk weights to government exposure, the Basel II Framework provides a range of weights (0% to 150%) where a credit rating is available from a ratings agency. For example, Banks exposed to sovereigns with a rating of BB+ to B are expected to assign 100% risk weight. Hence, it becomes imperative to consider the divergence between national regulations governing risk weights and global standards. And yet any attempt to apply Basel II risk weights to Uganda may significantly increase risk-weighted assets and capital provisions to absorb potential losses. Stringent prudential requirements, such as tighter risk-weighted capital requirements, not only accentuate bank fragility due to the fact that endogenous equity holdings adjust at a slower pace relative to capital requirements, but also reduce private sector credit (Mankart et al., 2018).

Other studies focus on the role of market heterogeneity and bank-specific characteristics (Affinito et. al., 2022; Egesa et al., 2015). They contend that bank-specific characteristics such as bank balance sheet size, primary dealership and residence of the parent company (i.e. whether foreign or domestic) influence sovereign exposure. The findings suggest that primary dealer banks and foreign-owned banks tend to hold government securities for shorter durations, reflecting their liquidity hedging strategies. However, we argue that the approach to estimating models with the residence of a bank may make empirical inference difficult in the case of Uganda. This study notes that most of the commercial banks in Uganda are owned by foreign holding companies. This would create systematic sample bias. Moreover, incorporating bank size in the same model as the primary dealership would lead to multicollinearity, given that large banks are normally the privileged traders in primary markets.

In certain circumstances, sovereign exposure has been viewed as a direct result of the profit-maximizing motive of banks. For example, banks may increase the uptake of low-priced debt of stressed sovereigns in anticipation that these countries will stabilize in the medium term.

A common phenomenon identified in the literature is the carry trade strategy, in which banks observe price differentials between stressed and stable sovereigns. Several studies have found evidence of a robust response of domestic exposures to fluctuations in yields. Testing the carry trade hypothesis is more complex in our study in part because the data only observes banks licensed in a single country (Acharya and Steffen, 2015; Breckenfelder and Schwaab, 2018). However, our data is granular enough to observe bank-specific responses to changes in treasury pricing. Moreover, the shallowness of secondary markets in Uganda's neighboring countries, or countries that would receive portfolio flows, should Uganda be adversely stressed, may make the carry trade hypothesis much weaker. Moreover, models using country-to-country analysis have greatly diverged from this view (ESRB, 2015). Additionally, macroeconomic conditions have also been identified as key drivers of sovereign exposure. However, several studies diverge from this perspective in terms of direction. For example, Funyina (2023) argues that weak economic activity amplifies exposure of banks to government securities, and this would be in line with the carry trade hypothesis.


Image: unsplash.com

## 3.2.4 Data and Methodology

This section provides the empirical model and the key variables used in analyzing the sovereign bank nexus in Uganda. The detailed description of these key datasets, including the computation of sovereign exposure in the financial system, and the decomposition of securities holdings along the maturity profile of holdings, is provided in Annex 1. The main source of the administrative datasets is the Bank of Uganda, while the source of public data on macroeconomic variables is the Uganda Bureau of Statistics.

## 3.2.5 Empirical Model

### 3.2.5.1 Identification of Sovereign Exposure

When considering the sovereign exposure of a bank, it is important to take into account how the portfolio decomposition of securities would be affected by market risks. A bank with short-term securities may be more exposed to interest risk rather than duration risk, which is higher when banks have long-term securities held to maturity. To control this, we construct variables that measure exposure at different maturities. First, the study defines short-term exposure as the aggregate treasury securities held for trading to maturity that are less than one year. This is denoted by short_expit, which is the outstanding stock of short-term securities for each bank (i) quarter (t). Secondly, we define long-term exposure as the aggregate treasury securities that are over one year, whether for trading or held to maturity. This is denoted as long_expit. This approach has the advantage of identifying the exposure on securities classified as bonds, but the days to maturity have fallen to below one year.

The above variables are key in explaining why banks hold treasury securities. However, this does not explain why a bank would rebalance its portfolio of treasury securities in relation to other assets. To address this issue, we extend the analysis to measure the share of short_expit and long_expit in the total net assets of bank i during quarter, t. The baseline specification is provided below:

$$\text{Exposure}_{it} = \beta 1 + \beta 2\text{Pricing}_{it} + \beta 3\text{Prudential}_{it} + \beta 4\text{Macro\_Controls}_{t} + \gamma_i + \epsilon_{it} \qquad (1)$$

In this specification, $\text{Exposure}_{it}$ denotes the measure of short-term or long-term securities holdings for bank i at time t; $\text{Pricing}_{it}$ captures the short-term and long-term yields; $\text{Prudential}_{it}$ reflects compliance with prudential regulation; $\text{Macro\_Controls}_{t}$ includes macroeconomic control variables such as inflation and GDP; $\gamma i$ accounts for bank-specific fixed effects; and $\epsilon it$ is the error term clustered at the bank level.

The description of variables incorporated in the specification is provided in Table 1. We present the results from the baseline specification in Table 21. We iteratively extend the baseline by interacting key variables with market structure indicators (e.g., primary dealer status) and by changing the dependent variable to capture both the level and proportional exposure to government securities. Each column in the results tables represents an adjusted version of the baseline that accounts for different outcome variables. In each iteration, the core set of covariates (pricing, prudential, and macro controls) is preserved, but the interpretation evolves to suit the context of the outcome variable

**Table 21: Variable Descriptions**

| Variable | Description |
|---|---|
| short_exp_bn (maturity less than 1 year). | Average bank-level holdings of short-term sovereign securities |
| long_exp_bn (maturity of 1 year or more). | Average bank-level holdings of long-term sovereign securities |
| shr_short_exp | Share of short-term sovereign securities in total net assets. |
| shr_long_exp | Share of long-term sovereign securities in total net assets. |
| gvt_share | Overall share of government securities in total bank assets- |
| d_Yield_364Day term rate). | Quarterly change in the 364-day Treasury Bill yield (short- |
| d_Yield_10yr (long-term rate). | Quarterly change in the 10-year Treasury Bond yield |
| reg_t1_capital_to_rwa | Tier 1 capital as a percentage of risk-weighted assets. |
| short_term_gap (liquidity gap). | Difference between short-term liabilities and liquid assets |
| gdpg | Quarterly GDP growth rate. |
| inflh | Quarterly inflation rate. |
| PDSi | Dummy variable equal to 1 if the bank is a primary dealer, 0 otherwise |
| PSC | Share of private sector credit in total assets of bank *i* at time *t*. |
| Securities | Share of government securities in total assets of bank *i*. |

## 3.2.6 Empirical Results

### 3.2.6.1 Determinants of sovereign exposure

We first assess whether securities pricing, prudential regulation, and macroeconomic variables influence a commercial bank's decision to hold short-term government securities by using the fixed effects regression model outlined above. The results are presented in column one of Table 22. The results show that an increase in short-term yields in the previous quarter induces banks to increase short-term exposure to government securities by about 6.8% in the current quarter, and it is statistically significant. However, an increase in long-term yields in the previous quarter induced banks to reduce their exposure to short-term securities by 15%. This is consistent with the theory that an increase in long-term rates ideally triggers a sale of assets as banks are likely to incur unrealized losses. Note that an increase in rates is inversely related to the price, as we showed in equation 3 in Annex 1. We also note that prudential regulation has a limited explanation for why banks may be exposed to securities in the short term. The interpretation would be that assessment of interest rate risk plus macroeconomic fundamentals play a greater role than prudential requirements. Indeed, we observe that on the macro side, inflation plays a significant role in the short term. Banks reduce their short-term exposure by about 6.1% when inflation rises by 1%. This is consistent with the fact that, as real short-term yields decline, banks tend to hedge against duration risk by deleveraging from non-inflation-indexed securities.

In column 2, we provide an assessment of what drives long-term exposure. In contrast to column 1, we note that the magnitude of the effect of short-term rates is even higher, increasing to 7.1%, although this is unexpected. One explanation could be that banks, in an environment of rising short-term rates, might shift their portfolios towards longer-term securities to lock in higher yields for an extended period, particularly if they anticipate that short-term rates might peak soon. This strategy could help stabilize income over a longer horizon, even though it may expose banks to greater interest rate risk if long-term rates increase in the future.

Moreover, prudential regulations appear to play a more significant role in determining long-term exposure compared to short-term exposure. The need to meet regulatory requirements in the short term for liquidity may incentivize banks to hold a larger proportion of long-term government securities, which are often considered high-quality liquid assets (HQLA) under regulatory frameworks. Additionally, the influence of macroeconomic variables such as GDP growth and inflation rates becomes more pronounced in the long-term model. For example, higher growth in GDP is associated with a 2.6% increase in long-term exposure, while an increase in inflation reduces holdings of long-term bonds. This suggests that banks are more willing to hold longer-term securities when growth is robust and inflation is stable, because sustained growth increases profitability as a result of increased incomes and the ability to meet debt obligations. Indeed, an increase in inflation rates is associated with a reduction in long-term exposure by 4.5%, reflecting concerns about future economic downturns and the associated risks of holding long-duration assets in a weakening economy.

We complement the above analysis by extending the results presented in columns 1 and 2 of Table 22 to incorporate proportionality of banks' exposure to short and long-term government securities relative to their total net assets. The results in columns 3 and 4 suggest that, in comparison to other assets (on the bank balance sheet), an increase in short-term yields does not necessarily trigger a substantial reallocation towards short-term securities. Instead, banks appear to re-balance their portfolios by increasing their holdings of long-term securities as a proportion of their total assets. As earlier shown, this behavior is likely driven by the anticipation that short-term rates, largely triggered by policy rate hikes, particularly in the context of Uganda, are typically short-lived and reflective of temporary monetary policy actions. The results also suggest that the short-term funding gap plays a key role for banks holding securities in relation to other assets. However, we must apply several robust checks to reaffirm these results and determine whether they can be explained by market heterogeneity.

**Table 22: Determinants of Sovereign Exposure**

| | (1)<br>ln_short_exp | (2)<br>ln_long_exp | (3)<br>shr_short_exp | (4)<br>shr_long_exp |
|---|---|---|---|---|
| ***Yield Curve*** | | | | |
| d_Yield_364Day | 0.068** | 0.071* | 0.14 | 0.22* |
| | (0.020) | (0.026) | (0.157) | (0.102) |
| d_Yield_10yr | -0.15*** | -0.10 | -0.89* | -0.15 |
| | (0.035) | (0.058) | (0.386) | (0.229) |
| ***Prudential Regulation*** | | | | |
| reg_t1_capital_to_rwa iv | 0.00043 | 0.0011 | 0.16** | 0.093 |
| | (0.005) | (0.008) | (0.052) | (0.047) |
| short_term_gap iv | 0.0047 | 0.030*** | -0.033 | 0.17*** |
| | (0.005) | (0.008) | (0.051) | (0.045) |
| ***Macro Variables*** | | | | |
| gdpg | -0.0041 | 0.026* | -0.032 | 0.18*** |
| | (0.005) | (0.010) | (0.057) | (0.038) |
| inflh | -0.061*** | -0.045** | -0.35** | -0.051 |
| | (0.012) | (0.015) | (0.114) | (0.079) |
| Constant | 18.3*** | 17.1*** | 13.1*** | 3.18 |
| | (0.163) | (0.248) | (1.575) | (1.571) |
| R-Squared | 0.79 | 0.69 | 0.58 | 0.39 |
| Observations | 1129 | 892 | 1129 | 892 |
| Bank FE | Yes | Yes | Yes | Yes |
| Auction Group | All | All | All | All |

Standard errors in parentheses
$* p < 0.05$, $** p < 0.01$, $*** p < 0.001$

### 3.2.6.2 The Role of Securities Market Heterogeneity

In this section we analyze how market heterogeneity influences sovereign debt exposure. The market for government securities consists of primary dealers and non-primary dealer banks. The results presented in Table 3 indicate that the yield curve plays a crucial role in explaining why primary dealers adjust their short-term exposure. Specifically, an increase in long-term yields, with the 10-year yield serving as the benchmark, triggers primary dealers to offload their short-term securities. However, other interest rates do not significantly impact long-term exposure or the proportion of these securities in total assets. Furthermore, primary dealers appear to be more sensitive to changes in inflation, which drives them to reduce their short-term exposure by approximately 49%. In contrast, there is no significant change in short-term exposure among non-primary dealers in response to inflation. For non-primary dealers, the results in columns 2 and 4 suggest that prudential regulation and the macroeconomic environment are the main factors influencing their sovereign exposure. The need to meet regulatory Tier 1 capital requirements motivates non-primary dealers to increase their long-term securities exposure by 15%. When considering the size of the balance sheet, these regulations also trigger non-primary dealers to boost their short-term holdings by 16%, driven by the need to address the short-term funding gap. The improvement in GDP would trigger a 17% increase in long term exposure for the non-primary dealers but 20% for the primary dealers.

### 3.2.6.3 Sovereign Bank Nexus and Private Sector Credit Outcomes

What is imperative to note is the asymmetric pass-through of sovereign risk to other economic activities. There is evidence that high sovereign exposure crowds out private sector lending (Önder et al., 2024; Bocola, 2016). This evidence implies that the banking sector substitutes private sector credit with public debt, hence reducing the intermediation role of banks in the economy. The banking sector prefers government securities due to lower risks. However, they have lower returns compared to loans and advances. Hence, banks that maximize return would extend more loans and advances relative to government securities. However, the decision to preserve capital and a conservative approach to risk taking led to an increase in sovereign exposure, which led to a decline in intermediation of funds between deposits and borrowers in the private sector. This undermines the realization of social economic transformation in which the private sector plays an active role. To answer the question of how banks' holding of sovereign debt affects private sector credit, we provide a simple linear estimation in equation 2 of the trade-offs and plot the conditional estimates as shown in Annex 5.

$$Psc_{it} = \theta + \gamma Securities_{it} * \mathbf{I}[Auction\ Status]_i + \epsilon_{it} \quad (2)$$

where Pscit refers to the share of outstanding private sector credit in total assets of bank i. Securities imply the share of outstanding stock of treasuries in total assets for a given bank i. Auction status refers to whether a bank has privilege status to trade as a primary dealer or a non-primary dealer in the auction system. The term $\alpha$ indicates the constant loan advances, while $\theta$ denotes the coefficient on securities.

**Table 23: Determinants of Sovereign Exposure: Primary Dealership Privilege**

| | (1) ln_short_exp | (2) ln_long_exp | (3) shr_short_exp | (4) shr_long_exp |
|---|---|---|---|---|
| ***Yield Curve*** | | | | |
| d_Yield_364Day | 0.43 | -0.095 | 0.016 | 0.27 |
| | (0.217) | (0.151) | (0.160) | (0.141) |
| d_Yield_10yr | -1.95* | -0.14 | 0.16 | -0.15 |
| | (0.807) | (0.293) | (0.307) | (0.272) |
| ***Prudential Regulation*** | | | | |
| reg_t1_capital_to_rwa iv | 0.41 | 0.15** | 0.51*** | 0.060 |
| | (0.296) | (0.050) | (0.102) | (0.037) |
| short_term_gap iv | 0.055 | -0.076 | 0.19* | 0.16* |
| | (0.053) | (0.069) | (0.065) | (0.058) |
| ***Macro Variables*** | | | | |
| Gdpg | -0.083 | 0.011 | 0.20* | 0.17*** |
| | (0.096) | (0.072) | (0.087) | (0.032) |
| Inflh | -0.49* | -0.23 | -0.095 | 0.067 |
| | (0.188) | (0.117) | (0.090) | (0.129) |
| Constant | 10.6 | 11.0*** | -4.62 | 2.66 |
| | (6.368) | (1.723) | (2.736) | (1.560) |
| R-Squared | 0.45 | 0.62 | 0.42 | 0.40 |
| Observations | 440 | 689 | 356 | 536 |
| Bank FE | Yes | Yes | Yes | Yes |
| Auction Group | PDs | Non-PDs | PDs | Non-PDs |

Standard errors in parentheses

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

The results further confirm that increased sovereign debt reduces lending to the private sector. The fact that banks prefer government securities to lending to the private sector raises financial stability concerns related to the high exposure of financial institutions to sovereign holdings. Should a systemic event occur that induces funding constraints for banks, the balance sheet net worth of banks with significant exposure to securities may be affected (Morelli et al., 2022), which would further discourage private sector lending. Shocks to the financial system can emanate from domestic and global economies. For example, the COVID-19 Pandemic, the 2022 synchronized global monetary policy tightening, among others. These shocks affected the value of the bonds and, hence, the balance sheet of banks. Moreover, market heterogeneity plays a critical role in determining the elasticity of substitution between government securities and loans. Primary dealers are more exposed to sovereign holdings than non-primary dealers and tend to allocate less credit to the private sector than to the securities.

### 3.2.7 Conclusions

This study analyzed the link between government securities and financial stability. The study estimated an econometric model using monthly data from 2011 to 2024 and examined the role of securities pricing and macro prudential regulatory requirements, such as capital adequacy and liquidity regulations, in driving banks' holdings of government securities. The results showed that first, regulatory requirements on building high-quality liquid stocks and the lower risk ratings for securities, as compared to loans, encourage banks to substitute loans for more exposure to the sovereign. Second, primary dealers are more sensitive to interest rate changes and as such, would be significantly affected in the case of failure by the sovereign to honor its obligations or when changes in interest rates occur. Third, profit maximization drives banks to invest in government securities due to their lower risk. The study therefore suggests three recommendations. First, regulators consider setting limits beyond which surcharges are applied to encourage diversification of bank balance sheets and hence minimize sovereign exposure risk. Second, the study proposes an assessment of the resilience of banks to plausible scenarios of sovereign exposure through regular stress testing. Finally, the introduction of dynamic risk rating of securities as opposed to classifying sovereigns as risk-free can enable regulators to control the direction of sovereign exposure for attainment of sound and resilient financial systems.

> “The results showed that first, regulatory requirements on building high-quality liquid stocks and the lower risk ratings for securities, as compared to loans, encourage banks to substitute loans for more exposure to the sovereign.

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# Annexes

**Annex 1: Details of Data Description**

**Annex 1a: Monthly Balance Sheet Data**

We begin our analysis by leveraging a novel data set derived from the monthly financial returns submitted to the Bank of Uganda, which has variables relevant to the assessment of sovereign exposure within the banking sector. These returns have bank-level holdings of central government securities from 2011 to 2024, specifically treasury bills and treasury bonds, across various categories. The variables of interest include the fair value of these securities, further categorized by their intended purpose (trading or investment) and their holding period (greater than or less than one year).

The distinction between securities held for trading versus those held for investment purposes provides a unique dataset that enables the disentanglement of short-term and long-term exposure to sovereign risk. Securities for trading are more susceptible to price volatility and interest rate fluctuations, which can result in immediate gains or losses. In contrast, investment securities, particularly those held to maturity, represent a more stable and long-term exposure to sovereign debt. Additionally, disaggregating treasury bonds based on their holding period enables the analysis of duration risk based on realized and unrealized losses.

The implications for financial stability are significant. The shift towards short-term exposure may increase the susceptibility of banks to volatility in prices in the secondary market and interest rate changes in the primary market, which can lead to immediate gains or losses. For instance, synchronized global monetary policy tightening in 2022 to 2023 reduced the market value of longer-term securities substantially, leading to realized and unrealized losses for securities held for sale and held to maturity (Choi et al., 2023). The losses accentuated bank runs and the failure of Silicon Valley Bank in the United States, which provided an impetus for analyzing duration risk emanating from sovereign exposure.

For example, the figure in Annex 1c shows that there is increasing reliance on short-term securities in the Ugandan financial sector, which could similarly heighten the risk of contagion, especially if a sudden market correction or rate hike were to occur. The existence of liquidity constraints in Uganda's secondary markets may reduce trading in securities held for trading to enable banks to improve liquidity or hold optimum liquidity levels. Therefore, we define short-term exposure to be all securities with a maturity of less than one year, while securities above one year constitute long-term exposure. Hence, the interaction between sovereign exposure and liquidity risk, particularly in a volatile macroeconomic environment, remains a critical area of concern for regulators and policymakers.

**Annex 1b: Secondary Market Quote System**

The second dataset utilized in this study is the secondary market auction quoting system. This is a daily dataset that captures secondary market trading activities from 2012 to 2024. The key variables included are short-term and long-term yields to maturity (YTM) and price quotes on treasury securities. The data is provided at the level of a primary dealer, who is responsible for reselling securities in the secondary market. Yields are computed with a focus on controlling for the average days to maturity of any quoted security, ensuring consistent analysis and comparison across securities, given that the face value may diverge from the intrinsic value. Note that the YTM calculations for Treasury Bills is provided as:

$$YTM = \frac{100-P}{P} \times \frac{365}{Days\ to\ Maturity} \tag{1}$$

where P is the primary market price quoted by the bidder, and the 'days to maturity' represent the time remaining until the security matures.  For treasury bonds, the relationship between bond price and YTM is established using the following formula:

$$P = \sum_{t=1}^{n} \frac{C}{\left(1+\frac{YTM}{2}\right)^{t}} + \frac{M}{\left(1+\frac{YTM}{2}\right)^{n}} \tag{2}$$

where P is the price of the bond, C is the semi-annual coupon payment, M is the maturity value, YTM is the yield to maturity, and n represents the total number of coupon payments over the bond's life. From the above equation, we can derive the quoted yield to maturity as shown in equation 3:

$$YTM = 2 \times \left[\left(\frac{C}{P-\frac{M}{\left(1+\frac{YTM}{2}\right)^{n}}}\right)^{\frac{1}{t}} - 1\right] \tag{3}$$

This approach ensures a robust analysis of the secondary market trading activities, providing insights into the pricing and yield behaviors of treasury securities over time. Using these prices and YTM quotes provides an opportunity to disentangle the role of primary dealers and non-primary dealers in the auction system.

**Annex 1c: Sovereign Exposure by Maturity Profile**


Note: Short exposure is the average holdings per bank of central government securities with a maturity of less than one year. Long exposure is the average holdings per bank of central government securities with a maturity of more than one year. The figure shows a notable increase in short-term exposure relative to long-term exposure, particularly post-2021. This shift reflects a strategic preference among banks to manage liquidity and mitigate duration risk amid an uncertain economic environment.

**Annex 1d: Primary Dealership System**

The main objective of reforms in the Uganda's financial market is to improve transparency, liquidity, and domestic participation in the government securities market. Central to these reforms is the establishment of a Primary Dealer (PD) system, which grants exclusive bidding rights for government securities to a select group of banks in an auction. These banks, typically large market leaders, are expected to enhance market depth by actively engaging in the secondary market.

The system is also designed to streamline the auction process, to enhance liquidity and ensure efficient price discovery in the primary market. The selected Primary Dealers are required to meet specific criteria, including financial soundness, operational capacity, and a demonstrated ability to participate actively in both primary and secondary markets. These requirements are consistent with international best practices, such as those highlighted by Arnone and Iden (2003) and central banks. In 2020, competitive bidding was restricted to the gazette primary dealers.

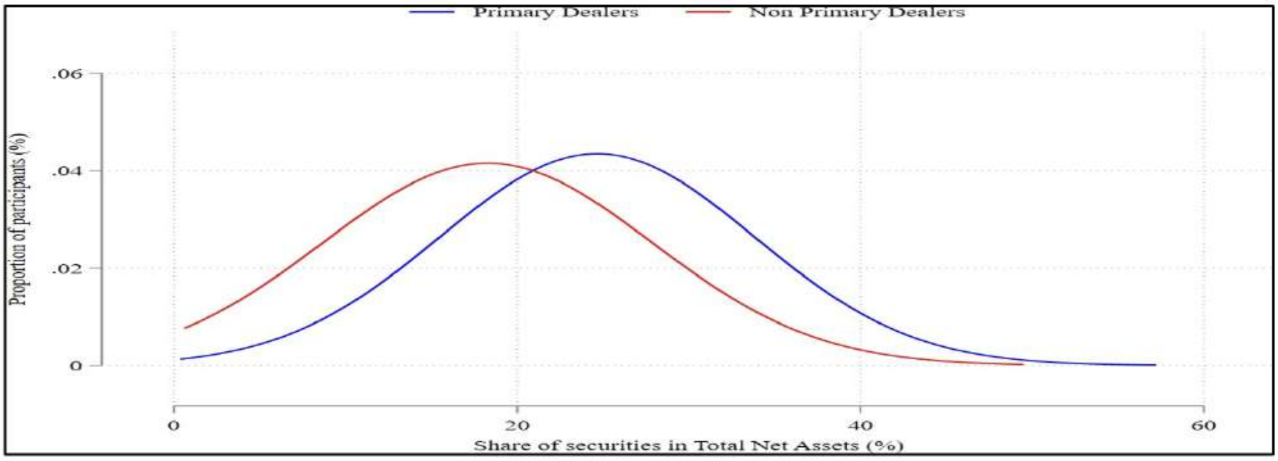
The PD system by mandating banks holding and trading significant stock of government debt, increases exposure of banks to sovereign risk distress. The sovereign risk distress is amplified during fiscal distress, especially with the concentration of bank assets in government securities. Primary dealers also have a market-clearing role, and in some circumstances (e.g, where a subscription auction may be low or in the event of private placements and tap sales) may hold the government securities on-book until they find an interested buyer from the secondary market.

While this is essential in achieving a steady flow of liquidity for the government, a dealer may lock in critical resources towards securities held for trading purposes, which reduces its high-quality liquid asset required to meet customer withdrawal needs as well as other liquidity requirements. In addition, holding government securities reduces resources available for lending to firms and households, which is the main objective of financial intermediation. Therefore, reforms in the government securities market, despite supporting liquidity, depth and participation of domestic investors, increase sovereign risk exposure

We capture the reforms in the government securities market using a dummy variable based on the status of being granted a privilege in the trading system of securities in the primary and secondary market. Let $PDS_i$ be a dummy variable that represents whether bank i has attained Primary Dealership status (PD):

$$PDS_i = \begin{cases} 1 & if\ bank\ i\ is\ a\ Primary\ Dealer\ (PD) \\ 0 & if\ bank\ i\ is\ not\ a\ Primary\ Dealer\ (Non-PD) \end{cases}$$

**Annex 1e: Distribution of Sovereign Holdings: Primary Verses Non-Primary Dealers**




Note: Normal distribution plot of sovereign exposure by market participants, categorized into Primary Dealers (PDs) and Non-Primary Dealers (non-PDs). Primary Dealers exhibit a higher concentration of sovereign exposure, with a peak at a higher percentage compared to Non-Primary Dealers. This suggests that Primary Dealers, who are more involved in government securities markets, bear a greater proportion of sovereign risk on their balance sheets.

**Annex 1f: Quarterly Financial Soundness Indicators Data.**

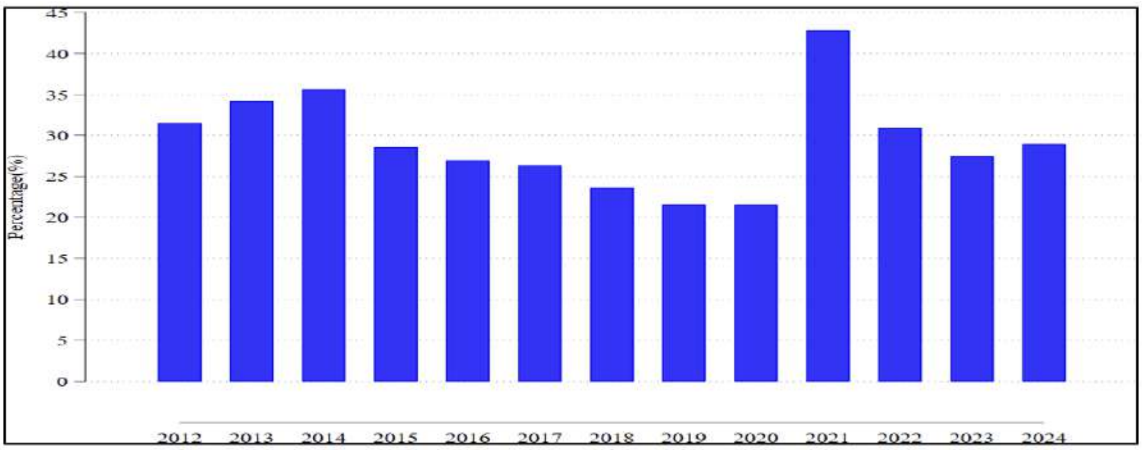
The study combines government securities data with quarterly financial Soundness indicators data, compiled according to the IMF's Financial Soundness Indicators (FSI) Compilation Guide. The main variables of interest as identified in the literature relate to a bank's capacity to absorb losses from sovereign bond holdings and the associated liquidity risk, (Altavilla et al., 2017). The proximate variables are therefore regulatory tier 1 capital to risk-weighted assets and short-term funding gap.

Regulatory Tier 1 Capital to Risk-Weighted Assets is measured as the ratio of a bank's core equity capital to its risk-weighted assets, providing a measure of the bank's financial strength and it determines a bank's buffer against potential losses from sovereign bonds, particularly in periods of sovereign stress. Altavilla et al., (2017) shows that banks with lower regulatory capital ratios tend to increase their holdings of distressed sovereign debt as part of a "carry trade" strategy, thereby exposing themselves to greater risk. A lower Tier 1 capital ratio suggests that a bank might be more vulnerable to sovereign debt repricing, which can lead to significant capital losses and force banks to deleverage, thereby amplifying the transmission of sovereign stress to the broader financial system.

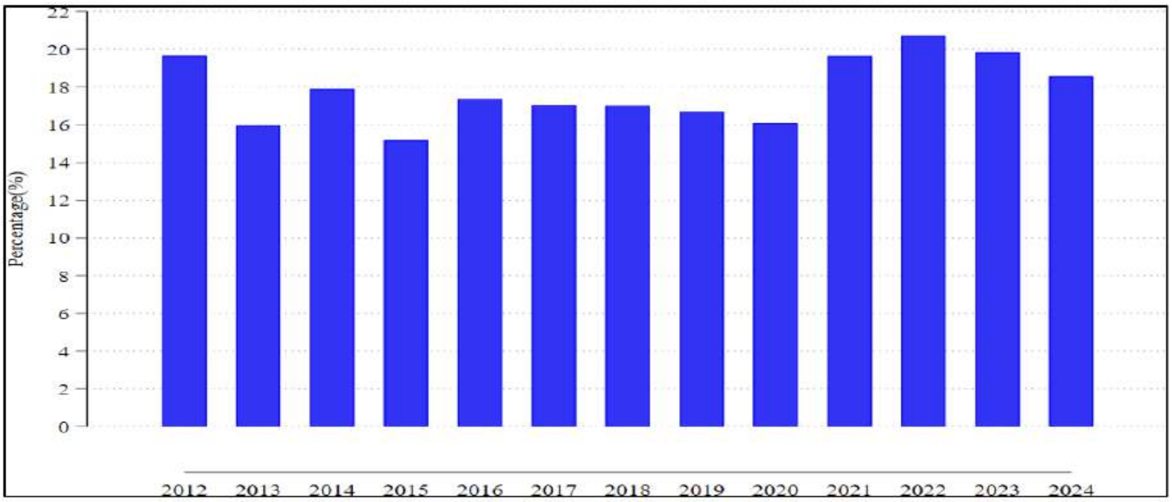
The 'short-term funding gap' is used to measure the difference between a bank's liquid assets and short-term liabilities. A negative short-term funding gap indicates that a bank does not have adequate liquid assets to meet its short-term obligations, even with government securities in its asset portfolio. In periods of sovereign distress, banks with large sovereign exposures may face a sudden increase in funding costs or a liquidity shortage, especially if the value of their sovereign holdings declines. The short-term funding gap can thus serve as a key indicator of a bank's liquidity risk and its ability to withstand sovereign-induced market disruptions.

**Annex 2: Prudential Regulation**

**Annex 2a: Regulatory Tier 1 Capital to Total Risk Weighted Assets**



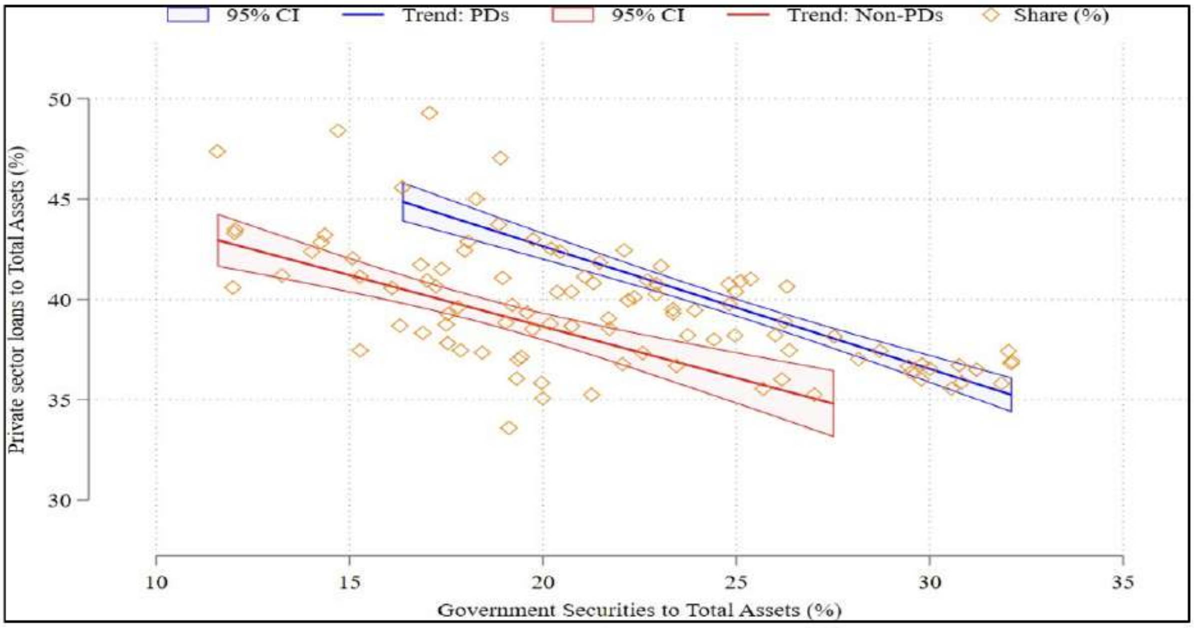
## Annex 3: Short-Term Funding Gap




## Annex 4: Descriptive Statistics

| | Mean | Standard Deviation | 10th percentile | Median |
|---|---|---|---|---|
| ***Sovereign Exposure*** | | | | |
| (mean) short_exp_bn | 204.60 | 93.18 | 94.55 | 199.72 |
| (mean) long_exp_bn | 108.23 | 74.68 | 40.06 | 84.98 |
| (mean) shr_short_exp | 15.39 | 2.01 | 13.08 | 15.28 |
| (mean) shr_long_exp | 9.08 | 3.56 | 5.44 | 7.87 |
| (mean) gvt_share | 20.93 | 3.77 | 17.11 | 19.68 |
| ***Yield Curve*** | | | | |
| (mean) d_Yield_364Day | -0.10 | 1.73 | -1.92 | -0.15 |
| (mean) d_Yield_10yr | -0.03 | 0.94 | -1.27 | -0.00 |
| ***Prudential Regulation*** | | | | |
| (mean) reg_t1_capital_to_rwa | 29.24 | 7.35 | 21.83 | 26.84 |
| (mean) short_term_gap | 17.79 | 2.02 | 15.37 | 17.68 |
| ***Macro Variables*** | | | | |
| (mean) gdpg | 4.65 | 3.40 | 0.14 | 5.25 |
| (mean) inflh | 5.05 | 4.18 | 2.05 | 3.56 |

**Annex 5: Crowd Out Effects: Portfolio Switching Behaviour of Commercial Banks**




Note: Scatter plot of unweighted relations between private sector credit and government securities, both scaled by total net assets of financial institutions. Each plotted symbol corresponds to the share of each asset in percentage terms, held in a given quarter. Private sector loans refer to outstanding stock of credit issued by all financial institutions and their share in total assets is on the y-axis. The government securities compound both securities held for trading purposes and those held to maturity. The x-axis displays the stock of end quarter balances of government securities divided by the total net assets held by all financial institutions. The plot illustrates the portfolio switching behavior between treasury holdings and loans, with an inverse relationship accounting for both PDs (primary dealers) and Non-PDs (non primary dealers).

## 3.3 The Impact of the Sovereign-Bank Nexus on Financial System Stability in Rwanda

*Placide Aime Kwizera and Ferdinand Murezi*

### 3.3.1 Introduction

Financial connections between banks and the public sector can pose risks to financial stability. These connections primarily arise because banks typically hold significant amounts of government debt securities. Moreover, fiscal intervention is seen as a final resort if the banking sector faces solvency issues. Potential problems within either the banking system or sovereign debt could lead to what's known as a "doom loop". This loop, linking the banking system and the sovereign, became evident immediately after the global financial crisis and during the subsequent sovereign debt crisis of 2012, impacting various European countries. During banking crises, economic activity declines, as does the government's fiscal position. Subsequently, during fiscal crises, governments implement austerity measures that, at least temporarily, dampen economic activity. This, in turn, impacts the banking system by increasing default rates and reducing demand for credit. The prevailing discussion in the ancient and current stock of knowledge often characterizes this connection as mutually beneficial yet occasionally harmful, particularly concerning the dimension of home bias i.e., preferences for domestic sovereign holdings (Díaz-Alejandro, 1984; Kaminsky & Reinhart, 1999; Reinhart & Rogoff, 2015; Acharya et al., 2014; Valencia & Laeven, 2008; Laeven & Valencia, 2012; Laeven & Valencia, 2018; Honohan, 2010; Farhi & Tirole, 2017; Dell'Ariccia et al., 2018). On a positive note, this connection has significantly contributed to bolstering bank liquidity, enabling fiscal support and enhancing capital markets, and facilitating policy transmission. Although these benefits exist, financial market imperfections have fostered binding constraints, which culminate in systemic distress in most cases, for example, the great depression (1930s), the global financial crisis (GFC) in 2008, and the European debt crisis in late 2009 and 2010. As a result, credit, liquidity, solvency, and reputational risks are also inherent in this relationship. In prosperous periods, the benefits of the relationship generally outweigh its drawbacks.

However, recent crises such as COVID-19 have necessitated government intervention, revealing the potential vulnerabilities associated with these connections and emphasizing the importance of understanding these dynamics. Various tools have been developed to address sovereign-bank linkages. Risk-based supervision has emerged as the primary tool for regulators to achieve financial stability goals.

Understanding financial relationships and the extent of interconnections within different parts of the macro-financial system is essential for effectively managing the financial system. The allocation of financial resources in a small, open economy like Rwanda, is greatly shaped by the government, which acts as the economy's manager, and banks serve as crucial intermediaries. Consequently, these economic entities are the primary providers of funding for each other, as well as for corporations and consumers. Therefore, evaluating the sovereign-bank relationship is of systemic significance.

Most prior research has focused on the drivers behind the increase in banks' holdings of sovereign debt securities from either a balance sheet (bank-specific), macroeconomic, or a combination of both perspectives. A number of these studies concentrated on advanced economies, particularly those affected by the sovereign debt crisis in Europe and Asia, (Rodrigues, 1993; Egesa, et al, 2015; Affinito, & Santioni, 2022; Chronopoulos, & Milonas, 2019; Dang & Huynh, 2020; Affinito et al., 2022; Chronopoulos et al., 2019; Ongena et al., 2019; Singh et al., 2022). In sub-Saharan Africa, research on the determinants of banks' holdings of sovereign debt securities is limited, with one of the few studies focusing on balance sheet conditions only in the Ugandan banking sector, (Egesa et al., 2015). Previous work focused on Rwanda is also scanty with limited evidence and quantification of sovereign exposure in banking sector, partly because no significant sovereign-bank stress episodes have historically been observed in the country. Nevertheless, with the ongoing development of the financial sector and lessons from best practices else-where, there is a growing need to analyze the current level of sovereign exposure and assess potential vulnerabilities, not only in Rwanda but also across the broader region and other developing economies.

From an empirical perspective, there is a broad understanding globally of the factors influencing banks' holdings of government securities and their implications for financial stability. Yet, in the case of Rwanda, empirical evidence remains scarce. To the best of our knowledge, no empirical studies have specifically addressed the impact of the sovereign-bank nexus on financial stability in Rwanda. Understanding the sovereign-bank nexus on financial system stability in Rwanda can not only support current and future prudential policy actions but also contribute to the literature and debate that is still open, since the sovereign-bank nexus remains insufficiently explored and requires more attention, particularly in developing economies like Rwanda, where the financial system is typically dominated by banks. This study employs the Bias-Corrected Fixed Effects (BC-FE) estimator to capture the dynamic structure, following Kiviet (1995) and Bruno (2005). Robustness of the results was assessed using pooled OLS and standard fixed effects (FE) models, allowing comparison of coefficient magnitudes, signs, and significance across specifications. The findings of this study can provide crucial insights for policymakers aiming to enhance financial stability through informed prudential policies tailored to the country's specific economic context. Moreover, empirical findings from Rwanda could contribute valuable perspectives to the global discourse on managing sovereign risk and enhancing financial stability in developing economies. The paper is structured as follows. The next section provides stylized facts while section 3 and 4 discuss the empirical studies and the methodology, respectively. The findings are presented in section 5 and section 6 provides conclusions of the study.

"From an empirical perspective, there is a broad understanding globally of the factors influencing banks' holdings of government securities and their implications for financial stability.

## 3.3.2 Stylized Facts: Banking Sector Stability in Rwanda

### 3.3.3.1 Soundness of the Banking Sector

Table 24 shows that Rwanda's banking sector achieved significant strengthening across all key financial soundness indicators from 2018-2024, with capital adequacy ratios consistently exceeding international standards at 21.5-25.5%, exceptionally strong liquidity positions (Liquidity coverage ratios-LCR ranging 192-637%, net stable funding ratios-NSFR above 136%), and notably improved asset quality as NPL ratios declined from 5.0% to 3.1% while provisioning coverage increased significantly from 68.2% to 102.6% reflecting forward-looking risk assessments, especially in uncertain economic periods (e.g., COVID-19 ). The sector demonstrated enhanced profitability with return on assets rising from 1.9% to 4.9% and return on equity increasing from 11.2% to 20.8%, alongside healthy credit growth averaging 16.8% and controlling foreign exchange exposure at moderate levels (8.3-11.4%).

**Table 24: Key Financial Soundness Indicators for Banks (Percent)**

| | Dec-18 | Dec-19 | Dec-20 | Dec-21 | Dec-22 | Dec-23 | Dec-24 |
|---|---|---|---|---|---|---|---|
| Capital Adequacy Ratio (min 15% benchmark) | 25.5 | 24.1 | 21.5 | 21.6 | 21.7 | 21.5 | 20.5 |
| LCR (min 100% benchmark) | 637.0 | 191.8 | 254.7 | 268.9 | 215.9 | 229.8 | 340.0 |
| NSFR (min 100% benchmark) | 222.0 | 129.3 | 161.4 | 147.1 | 136.8 | 137.4 | 148.4 |
| FX loans/Gross loans | 10.7 | 11.4 | 9.7 | 8.3 | 9.0 | 10.4 | 11.3 |
| NPLs/Gross loans | 5.0 | 4.5 | 4.5 | 4.6 | 3.1 | 4.1 | 3.1 |
| Provisions / NPLs | 68.2 | 83.6 | 106.3 | 119.8 | 141.9 | 99.1 | 102.6 |
| Return on Assets (RoA) | 1.9 | 2.2 | 2.0 | 2.5 | 3.0 | 4.8 | 4.9 |
| Return on Equity (RoE) | 11.2 | 12.5 | 11.8 | 15.0 | 17.8 | 20.7 | 20.8 |
| Growth of loans | 12.4 | 5.4 | 33.9 | 15.6 | 21.0 | 19.2 | 10.5 |

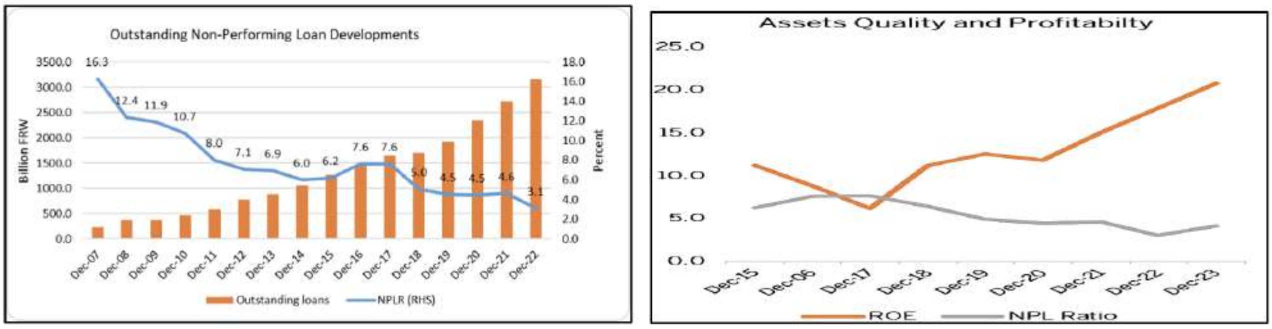
Source: The National Bank of Rwanda (2025)

Overall, these indicators collectively demonstrate Rwanda's banking sector evolution toward enhanced financial stability relative to the benchmarks in parentheses (Table 1), improved risk management capabilities, and strengthened resilience while maintaining adequate credit intermediation to support economic development objectives.

### 3.3.3.2 Dynamics of NPLs in the Rwandan Banking Sector

Figure 40 indicates that Rwanda's banking sector has seen steady improvement in the quality of its loan portfolio, with non-performing loans (NPLs) gradually declining to meet the 5% bench-mark by 2018. From the end of 2018 to 2022, outstanding NPLs decreased slightly by an aver-age of 0.5% and the NPL ratio stood at 4.3%. This marked a notable improvement, in view of the fact that before 2011, NPLs had averaged double-digit levels, around 12.8% between 2007 and 2010. The turnaround on NPLs reflects the combined impact of several initiatives introduced by the National Bank of Rwanda (NBR) to strengthen the prudential and regulatory framework. These measures included enhancing supervisory oversight, encouraging banks to clean up long-overdue loans, and establishing a credit reference bureau in 2010 to help address information gaps between lenders and borrowers. Additionally, the 2011 regulation on credit classification and provisioning played an important role in facilitating banks to proactively identify and address problem loans.

**Figure 40: Development in Non-Performing Loans and Asset Quality**




Source: The National Bank of Rwanda (2025)

The profitability of banks, measured by the Return on Equity (ROE) is negatively correlated with non-performing loans. The higher the NPL ratio, the lower the ROE and vice versa. This inverse relationship between expanding credit volumes and declining NPL ratios on Figure 40 on left-hand side demonstrates the success of Rwanda's banking sector reforms, including the NBR's enhanced regulatory framework, improved supervision, and the 2011 credit classification regulations, ultimately transforming the sector from a high-risk environment into a stable, growing financial system that supports economic development while maintaining asset quality standards. On the right-hand side, Figure 40 shows that the NPLs consistently declined while ROE substantially increased during the review period, reflecting the successful implementation of banking sector reforms and improved risk management that not only reduced problem loans but also enabled banks to achieve significantly higher returns, demonstrating the dual benefits of sound banking practices for both financial stability and sector profitability.

The bond market continued to grow as presented in Figure 41, reflecting a rising preference for long-term government securities, likely driven by stable yields, lower credit risk, and confidence in fiscal management, in addition to increased attention to short-term liquidity management in response to evolving market conditions.

These trends in Table 24, Figure 40, and Figure 41 highlight the simultaneous development of Rwanda's domestic bond market and the strength of the financial sector manifested in the continued growth in credit to the private sector and stable financial soundness indicators. These developments show that in Rwanda, there is no 'doom loop' in the sovereign-bank nexus, as banks' exposure to government debt remains at sustainable levels and the government's fiscal management is prudent. This balanced relationship helps maintain financial stability and prevents the emergence of any self-reinforcing negative cycles between the government and the banking sec-tor.

**Figure 41: Evolution of Investments of Banks in Government Securities**


Source: The National Bank of Rwanda (2025)

## 3.3.3 Literature Review

Since the early 1990s, ensuring financial stability has emerged as the primary goal of economic policies, leading numerous central banks and international financial institutions to release routine financial stability reports.

The 2008 financial crisis highlighted the critical connection between sovereign risk and financial system stability, prompting extensive academic investigation into the causal relationship between sovereign risk and financial stability.

From a theoretical perspective, banks' holdings of government securities are driven by portfolio rebalancing and financial repression. The portfolio rebalancing hypothesis suggests that during periods of economic stress, such as weak growth, high levels of NPLs, and undercapitalization, banks prefer safer and more liquid assets like government securities to meet capital and liquidity requirements. For example, Bonner (2016) indicates that regulatory incentives for financial stability make sovereign paper attractive for banks. Dell'Ariccia et al., (2018) argue that banks keep sovereign securities as the safest and most liquid assets, essential for meeting liquidity requirements, particularly in countries with underdeveloped capital markets. Sovereign bonds are crucial in the payment system, commonly used as collateral to secure credit, support hedging activities, and facilitate broader financial market operations due to their low volatility and relative safety. Gennaioli, et al., (2018) suggest that banks maintain an optimal share of sovereign securities to ensure liquidity for future investments, a strategy confirmed by Affinito et al., (2022) in the Italian banking sector.

Additionally, compliance with capital adequacy requirements motivates banks to hold sovereign papers. The Basel Accord mandates that banks hold capital proportional to their perceived credit risks, with sovereign debt securities assigned a risk weight of zero. This incentivizes banks, particularly undercapitalized ones, to purchase sovereign debt securities to meet prudential regulations, encouraging the substitution of low-risk assets for higher-risk loans. Studies by Bonner (2016) and Buch, et al., (2016) found that undercapitalized banks invest more in government securities compared to well-capitalized counterparts, while Rodrigues and Keeton (1993) identified risk-based capital standards as a long-term factor in increasing banks' sovereign debt holdings. Furthermore, portfolio rebalancing is significant during weak loan demand and increased non-performing loans in recessionary periods. Keeton (1994) and Rodrigues (1993) observed that banks' investments in securities tend to rise relative to loans during such times due to reduced business activity, lower private sector loan demand, and declining interest rates. The rise in non-performing loans during recessions also discourages banks from extending more loans, even without interest rate changes.

> “
>
> Sovereign bonds are crucial in the payment system, commonly used as collateral to secure credit, support hedging activities, and facilitate broader financial market operations due to their low volatility and relative safety.

The financial repression hypothesis posits that sovereigns may use moral suasion to pressure banks into purchasing new government securities, particularly when the risk and yield on these issuances rise (Dell'Ariccia et al., 2018; Becker & Ivashina, 2018). Rooted in the work of Shaw, (1973 and McKinnon, (1973), financial repression can crowd out private-sector financing by diverting funds away from loans. Evidence of this practice was observed in European countries during the sovereign debt crisis, impacting corporate lending (Becker and Ivashina, 2018). Despite the challenges of explicit financial repression in modern free markets, implicit financial repression through moral suasion can still occur (Ongena et al., 2019).

From an empirical perspective, the recent studies underscore the intensifying significance of the sovereign–bank nexus in emerging and developing economies. The IMF's Global Financial Stability Report (2022) highlights how the COVID-19 pandemic led to a surge in bank holdings of domestic sovereign bonds, sometimes exceeding 20 percent of bank assets, raising the risk of a destabilizing feedback loop between sovereign distress and banking sector fragility, particularly in economies with weak fiscal buffers and undercapitalized banks. Complementing this, Deghi et al., (2022) delved deeper into the mechanisms of this nexus, namely the exposure, safety net, and macroeconomic channels and found that higher sovereign debt exposure significantly increases banks' probability of default, especially in less capitalized institutions, while sovereign distress curtails lending and hurts corporate investment. Similarly, the Dunz et al., (2024) documents a sharp rise in EMDEs with a 35 percent increase between 2012 and 2023-in banks' exposure to government debt, now averaging 16 percent of bank assets; it warns that even a modest 5 percent drop in the value of those holdings could render a substantial share of banks undercapitalized, heightening the risk of joint sovereign bank crises with severe GDP losses.

Rodrigues (1993) highlighted the role of economic cycles and interest rates in influencing banks' securities holdings. The study's analysis indicated that higher GDP growth and a wider loan-treasury spread decreases banks' holdings of government securities. This suggests that during periods of economic expansion and favorable loan conditions, banks are more inclined to shift their portfolios away from low-yield government securities towards more profitable lending opportunities. Both Rodrigues (1993) and Egesa et al. (2015) emphasized the importance of bank size and capitalization. Larger and well-capitalized banks tend to hold fewer government securities. This could be attributed to their ability to manage risk more effectively and their access to a broader range of investment opportunities. Conversely, undercapitalized banks or those with deteriorating loan quality increase their holdings of government securities as a safer, more liquid asset to mitigate risk and maintain stability.

Affinito et al. (2022) and (Bouis, 2019) focused on the impact of bank-specific balance sheet conditions. Affinito et al. (2022) found that liquidity needs, capital charge convenience, and high yields make government securities particularly attractive during periods of liquidity demand and declining loan quality. Bouis's findings corroborate this, showing that economic downturns and rising non-performing loans lead banks to increase their holdings of government debt, aligning with the financial repression hypothesis.

These insights underscore the strategic use of government securities to bolster liquidity and manage financial stress. Chronopoulos et al. (2019) introduced the dimension of bank ownership and governance quality. Their study showed a strong home bias in domestic sovereign debt holdings, particularly for domestic and government-controlled banks. This home bias is more pronounced in countries with high debt levels and weaker governance structures. This finding suggests that ownership and governance frameworks significantly influence banks' investment strategies, potentially driven by regulatory expectations or implicit guarantees from the government.

Lamas & Mencia (2018) and Dang and Huynh (2020) examined the influence of macroeconomic conditions. Lamas and Mencia found that Spanish banks increase their holdings of domestic sovereign debt during economic downturns and reduce them during upturns. Dang and Huynh's study on Vietnamese banks identified liquidity reserves and profitability needs as key drivers, with no evidence supporting the use of government bonds to improve capital positions. These findings highlight the responsiveness of banks to macroeconomic fluctuations and their strategic use of government securities to navigate economic cycles. Singh, et al., (2022) explored the portfolio rebalancing behavior of Indian banks. They found that weak economic activity and stressed asset quality encourages banks to increase their investment in government securities. While this strategy can improve profitability, it also leads to a crowding-out effect on private-sector credit, especially during periods of high government borrowing. This suggests a trade-off between financial stability and credit availability to the private sector, emphasizing the need for balanced regulatory policies.

Literature collectively underscores the multifaceted determinants of banks' holdings of government securities, shaped by a combination of economic cycles, bank-specific factors, ownership structures, and macroeconomic conditions. One notable gap in the literature pertains to the empirical exploration of the impact of banks' holdings of sovereign debt securities on financial stability in African countries, despite potential exposure given their heavily bank-dominated financial systems and the significant interactions between banks and the government.

## 3.3.4 The Model, Estimation Approach and Data

This section presents the theoretical model, which introduces two key economic agents, the bank and the government, to clarify their respective roles and interactions, thereby guiding the derivation of the empirical specification. The section also outlines the estimation techniques used to achieve the research objectives, followed by a detailed description of the data sources and variables employed in the analysis.

### 3.3.4.1 Theoretical Model

Let's consider a simple two-agent model consisting of a bank and a government. In this setup, the government accrues sovereign securities from the bank, which operates within a context of monopolistic competition. The bank provides a loan *L* to the government, which subsequently repays (1+*r*)*αL*, where *r* denotes the bank's interest rate. *α* ϵ[0,1] captures the level of bank preference for government securities with $\alpha = 0$ representing the bank is not willing to hold more securities due to their lower return, while at higher values $\alpha = 1$ indicate progressively high levels of bank preference. Let *C(L)* denote the costs of the bank, which are assumed to be convex. Therefore, the bank's profit function can be written as follows:

$$\Pr ofit = (1+r)\alpha L - C(L) \qquad (1)$$

Where, *L≥0* and *C(L)≥0*. Furthermore, let $\psi$ be a random variable that captures any random shock that can negatively affect the bank due to sudden government shocks, and it becomes unable to meet its payment obligations to the banks. These shocks could include crises (such as pandemics like COVID-19, natural disasters, wars, etc.). This type of shock does not have a direct impact on the government's debt securities amount *L*. Therefore, we proceed with the assumption that variable $\psi$ is independent of and we also assume that $\psi$ *N*(0,1). From the equation (1), the bank's profit becomes:

$$\Pr ofit = (1+r)\alpha L - C(L) + \psi \qquad (2)$$

Where $\psi \in \Re$, the bank aims to maximize its expected profit. Let $E(\Pr ofit)$ profit, modifying equation (2) leads to

$$E(\Pr ofit) = \int_{t=1}^{T} [(1+r)\alpha L - C(L) + \psi] d\psi \qquad (3)$$

At the optimum, we have $\partial E(\Pr ofit)/\partial L = 0 \rightarrow L^* = L'[(1+r)\alpha]$, $L^*$ is the loan amount the bank must grant to the government if it wants to maximize its profit; this is the government's debt securities. By replacing $L^*$, we obtain the expression of the optimal expected profit of the bank, while d is an infinitesimally small change in the $\psi$.

$$E(\Pr ofit) = \int_{t=1}^{T} [(1+r)\alpha L^* - C(L^*) + \psi] d\psi \qquad (4)$$

Literature indicates that the probability of default (*PD*) of a bank is the likelihood that losses exceed equity Tarazi (1992), In other words:

$$PD = \Pr ob(\mathrm{E}(\Pr ofit^*) \prec -Cap \qquad (5)$$

Where $\mathrm{E}(\Pr ofit^*) \prec -Cap \rightarrow \psi \prec -Cap - [(1+r)\alpha L^* + C(L^*)$

Therefore Eq. (5) leads to

$$PD = f_{\psi}[-Cap - [(1+r)\alpha L^* + C(L^*)] \qquad (6)$$

Furthermore, from Eq. (6), we note that: $\partial PD / Cap \prec 0$ This implies that the higher the bank's capital, the lower its risk of default and the more stable it is. From the above theoretical derivation, two lemmas arise.

-Lemma (1): The risk of bank default can be written as a function of public debt securities (*L**), bank' preference of debt securities (*α*), and bank capital $(Cap)$: $PD = f(L, \alpha, Cap)$ However, given the current levels of bond holdings observed in the Rwandan banking sector, the likelihood of default remains minimal.

-Lemma (2): Bank default risk is a decreasing function of bank capital, meaning that higher capital levels reduce the likelihood of default. Given the capital adequacy ratios observed in the Rwandan banking system, the probability of default is muted, reflecting the overall financial strength and resilience of banks in Rwanda.

## 3.3.4.2 Empirical Model

Using these propositions, we can deduce our empirical model. Indeed, the theoretical modelling shows that we can express the bank default risk (*PD*) as a function of public debts securities (BHGS), bank preference of securities (*BYD*), and bank capital (*Cap*). We augment the model with a vector of variables related to both the bank's characteristics (*W*) and its macroeconomic environment, which are known to influence its stability according to the literature.

$$PD = f(L, \alpha, Cap, W) \tag{7}$$

Taking an approach concerning asset returns, we substitute the probability of default (*PD*) with the default risk indicator (Loan Loss Provision-LLP) considered as a rough proxy for probability of default following the common practice in the literature (Beck et al., 2013; Bilgin et al., 2021; Bourkhis and Nabi, 2013). Therefore, eq (7) becomes:

$$LLP = f(L, \alpha, Cap, W) \tag{8}$$

Starting from Equation (9), the following specification enables the measurement of how the public debt securities and government distress affects-banking stability nexus:

$$LLP_{it} = \beta_0 + B_1 BHGS_{it} + \beta_2 BYD_{it} + \beta_4 BC_{it} + \beta_5 W_{it} + \eta_i + \varepsilon_{it} \tag{9}$$

Where: *LLP* is a measure of financial stability as the dependent variable, while bank holdings of government securities (*BHGS*) is a measure of bank exposure to government securities and bank preferences to invest in securities (*BYD*), bank capital(*BC*), vector of other variables (*W*) affecting bank stability, such as macroeconomic variables and bank characteristics. $\eta_i$ and $\varepsilon_{it}$ represent bank-specific characteristics and error terms, respectively. We extend equation (9) to capture the persistence of loan loss provisions to allow the dynamic set-up nature in the following equation:

$$LLP_{it} = \beta_0 + B_1 BHGS_{it} + \beta_2 BYD_{it} + \beta_4 BC_{it} + \beta_5 W_{it} + \beta_6 LLP_{it-1} + \eta_i + \varepsilon_{it} \tag{10}$$

LLP is computed as the ratio of bank loan loss provisions to bank loans and measures bank loan performance (bank loan quality), a proxy of financial stability. BHGS is a bank holding domestic government securities (treasury bills and bonds) as a share of the bank's total assets, measuring banks' exposure to government securities, i.e., a higher share reflects a stronger sovereign-bank nexus. The BYD captures the advantage of investing in government securities, where an increase denotes improvement in bond yields; banks are more likely to increase their investments in government securities when loan performance deteriorates, as suggested by the portfolio rebalancing hypothesis (Rodrigues,1993; Dang and Huynh, 2020).

Other variables included in the model are as follows: LR is the lending rate that measures the cost of borrowing money, which is a critical component of financial systems and has significant implications for both borrowers and lenders i.e the higher the lending rate, the higher the loan pro-visioning due to increased risk of borrower default. Loans share to total assets (LSTA) is an important financial metric used by financial institutions to assess their asset composition and risk exposure, i.e banks have a larger portion of their assets tied up in loans, which are subject to credit risk. Return on assets (ROA) is a proxy measure for the overall profitability of banking activity. It captures the profit a bank can generate from giving total assets. A higher ROA indicates better profit prospects for growth and resilience to shocks. The literature argues that the least profitable banks have a greater incentive to increase earnings by purchasing high-yielding government securities (Buch et al., 2016; Affinito et al., 2022). Return on equity (ROE) is a financial performance metric that measures the profitability of a financial institution relative to its shareholders' equity. Thus, the expected signs on both ROA and ROE are negative. GDP is the real gross domestic product growth rate (a proxy for economic activity), allowing for the business cycle of the economy, and its expected sign is negative due to economic boom reducing credit defaults. Inflation (INFL) is a measure that can be either positive or negative. Higher inflation is associated with higher nominal asset values in banks, and borrowers' nominal repayment capacity may improve, potentially reducing the need for loan loss provisions. In contrast, higher inflation can pose a financial stability risk.

## 3.3.5 Estimation Method and Data

This study employs the Bias-Corrected Fixed Effects (BC-FE) estimator to capture the dynamic structure of Equation (10), following Kiviet (1995) and Bruno (2005), which mitigates small-sample bias in panels with short time dimensions. Robustness is assessed using pooled OLS and standard fixed effects (FE) models.[13] The analysis uses balance sheet data from nine commercial banks and macroeconomic indicators for 2014Q3-2024Q1. The variables of interest are Loan Loss Provisions (LLP), measured as the ratio of provisions to total loans, serve as a proxy for financial stability. Bank Holdings of Government Securities (BHGS) capture exposure to government debt, while Bond Yields measure (BYD), reflects the incentive to invest in government securities when loan performance deteriorates, consistent with the portfolio rebalancing hypothesis (Rodrigues, 1993; Dang and Huynh, 2020).

13 FE is preferred over other static models because bank-specific unobserved characteristics are likely correlated with explanatory variables, violating RE's orthogonality assumption, and our focus on within-bank variation over time aligns with FE methodology (Wooldridge, 2010; Cameron & Trivedi, 2005; Louzis et al., 2012). However, the FE can-not handle dynamic models, hence the usage of bias-corrected FE.

### 3.3.6 Discussion of the Empirical Results

Before running the regressions, the descriptive statistics in Table 25 show that LLP has a high skewness and kurtosis, indicating a distribution with extreme values. LBHGS is more evenly distributed but slightly negatively skewed. Bond yields measure (BYD) is nearly normally distributed with minor asymmetry. LR has a high mean, significant left skew, and heavy tails. LSTA is symmetrical and peaked. ROA is highly skewed with extremely low values, while ROE has a distribution with some extreme values and a long-left tail. GDP shows a left-skewed distribution with some extreme negative values, and INFL has a right-skewed distribution with a long tail of higher values. Given the data's significant variability, transforming variables and employing techniques specific to panel data, such as fixed effects, which account for within-entity correlations, ensures reliable regression results, which is paramount.

**Table 25: Descriptive Statistics**

| Variables | N | mean | sd | min | max | skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| LLP | 311 | 0.0233 | 0.0337 | 0 | 0.310 | 5.209 | 39.89 |
| LBHGS | 263 | 16.64 | 1.307 | 12.31 | 19.16 | -0.389 | 2.958 |
| BYD | 350 | -0 | 0.0522 | -0.0934 | 0.0706 | -0.758 | 1.754 |
| LR | 350 | 14.87 | 5.295 | 0 | 22.01 | -2.240 | 6.713 |
| LSTA | 311 | 0.454 | 0.158 | 0.0255 | 0.858 | -0.0991 | 2.563 |
| ROA | 311 | 0.0133 | 0.0436 | -0.460 | 0.209 | -4.385 | 50.54 |
| CAR | 311 | 0.321 | 0.453 | 0.0457 | 4.609 | 6.971 | 55.22 |
| GDP | 350 | 0.0692 | 0.0439 | -0.125 | 0.206 | -1.339 | 9.310 |
| INFL | 350 | 5.240 | 4.620 | -0.633 | 21.13 | 1.617 | 5.747 |

Source: Authors' own computation

Furthermore, the results of correlation analysis presented in Annex 1 show key relationships among bank performance metrics and macroeconomic indicators. Loan loss provisions (LLP), which measure loan performance, are negatively correlated with return on assets (ROA), suggesting that banks with deteriorating loan quality tend to have lower profitability. Conversely, higher LLP is associated with a higher loan share to total assets (LSTA), indicating banks with more loans relative to their assets face greater loan losses. Banks' holdings of government securities (LBHGS) are positively correlated with bond yield measures (BYD), aligning with the portfolio rebalancing hypothesis. LBHGS is also positively related to ROA, suggesting that more profitable banks hold more government securities. Inflation is positively correlated with LBHGS, indicating banks may increase their holdings in response to rising inflation.

For the main empirical analysis, the study utilized bias-corrected fixed effects (BC-FE) models, which mitigate potential small-sample bias and capture the dynamic nature of banks' provisioning behavior. The results of the BC-FE estimations are reported in Table 26.[14] The consistently negative coefficients of L.LLP across all BC-FE models (-0.082 to -0.116) indicate that banks exhibit a persistent approach to provisioning overtime. Higher past levels of loan loss provisions (L.LLP) correspond to lower current provisions, highlighting banks' reliance on historical data to manage credit risks effectively. In contrast, banks' holdings of government securities (LBHGS) show negligible coefficients (-0.001 to -0.002) across models. The results have the expected negative sign, but they are not statistically significant.

The results show a negative relationship between bond yields measure and LLP (-0.109 to -0.136), and the results are statistically significant, indicating perceived safety in government securities as banks perceive these securities as safer assets, potentially lowering their anticipated loan losses.

The financial performance metrics such as return on assets (ROA), and capital adequacy ratio (CAR) consistently exhibit negative coefficients (-0.037 to -0.154 for ROA, and -0.017 to -0.081 for CAR). The results would imply that more profitable banks (ROA), and banks with stronger capital positions (CAR) allocate fewer resources to provisions, reflecting their ability to manage risks and absorb potential losses effectively.

Image: unsplash.com

14 BC-Fixed Effects provides more consistent estimates in panel macro analysis by correcting for the Nickell (1981) bias in dynamic panels, delivering superior consistency compared to standard fixed effects and GMM estimators, particularly with small samples and short time dimensions (Kiviet, 1995; Bruno, 2005; Bun & Kiviet, 2003).

**Table 26: Main Estimates- Bias-Corrected Fixed Effects Results**

| | BC-FE1 | BC-FE2 | BC-FE3 | BC-FE4 | BC-FE5 | BC-FE6 | BC-FE7 |
|---|---|---|---|---|---|---|---|
| L.LLP | -0.116*** | -0.118*** | -0.115*** | -0.105*** | -0.090*** | -0.088*** | -0.082*** |
| | (0.044) | (0.045) | (0.013) | (0.021) | (0.027) | (0.022) | (0.016) |
| LBHGS | -0.002 | -0.002 | -0.002 | -0.001 | -0.001 | -0.000 | -0.001 |
| | (0.003) | (0.003) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| BYD | -0.118*** | -0.115*** | -0.109 | -0.122 | -0.130* | -0.138* | -0.136 |
| | (0.011) | (0.011) | (0.081) | (0.079) | (0.076) | (0.083) | (0.083) |
| LR | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| LSTA | | | -0.006 | -0.004 | -0.009 | -0.023 | -0.022 |
| | | | (0.073) | (0.073) | (0.069) | (0.068) | (0.067) |
| ROA | | | | -0.134** | -0.092*** | -0.036*** | -0.037*** |
| | | | | (0.061) | (0.028) | (0.010) | (0.008) |
| CAR | | | | | | -0.084*** | -0.081*** |
| | | | | | | (0.015) | (0.014) |
| GDP | | | | | | | 0.025 |
| | | | | | | | (0.019) |
| INFL | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 | -0.001** | -0.001** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| N | 168 | 168 | 168 | 168 | 168 | 168 | 168 |

Standard errors in parentheses
$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

Source: Authors' own computation

We conducted several robustness checks to validate the main findings of bias-corrected fixed effects (BC-FE) estimates, using additional estimation techniques such as pooled OLS and fixed effects (FE) models. While there are variations in the magnitude and statistical significance of some coefficients across these alternative models, the overall direction of the relationships between the identified variables and loan loss provisions (LLP) remains broadly consistent. Nonetheless, a few variables displayed unexpected patterns, such as the positive relationship between bank holdings of government securities and loan loss provisions.

Regarding estimates from the pooled Ordinary Least Squares (OLS) models to explore the factors influencing banks' provisions for loan losses.[15] The estimated results in annex 2, show that banks' holdings of government securities (LBHGS) suggest a mixed relationship with loan loss provisions (LLP). While some models show a positive association between LBHGS and LLP, the OLS estimates overstate the effect of LBHGS on LLP, as other models show negative and insignificant coefficients, and the main results indicate a muted, non-significant negative effect. Other models demonstrate a negative impact. The negative relationship implies that less loan loss provisions are required with investment in safe assets and a possibility of limited exposure to risk loans.

Bond yields measure (BYD) indicates a negative and statistically significant coefficient across all models, suggesting that when government bond yields rise above their long-term trend, banks tend to reduce their loan loss provisions. This behavior may reflect a portfolio reallocation toward government securities, which are perceived as safer and default-risk-free assets. The Lending Rate (LR) consistently shows a positive coefficient in all models, indicating that higher lending rates are associated with increased provisions for loan losses. This relationship suggests that banks anticipate higher default risks when lending rates are elevated, leading to higher provisions to cover potential losses.

Return on assets (ROA) consistently displays a negative coefficient, indicating that more profitable banks allocate fewer resources to loan loss provisions, possibly due to their stronger financial position and ability to absorb losses. Loan size to total assets (LSTA), capital adequacy ratio (CAR) and gross domestic product (GDP) do not show statistically significant coefficients across any of the models, suggesting that these variables do not significantly impact banks' provisions for loan losses. The negative inflation (INFL) coefficient indicates that inflation rates are associated with slightly lower loan loss provisions (LLP) by banks, i.e. during periods of modest inflation, banks may adjust their provisioning practices, potentially reflecting expectations of increased revenues or asset values that could mitigate loan defaults.

15 In our analysis, we employed the stepwise inclusion of variables in our panel data models to provide a structured framework for assessing the impact of each variable, ensuring a comprehensive understanding of the relationships within the data. Following the literature survey, we consider model 7 to be the most robust and correctly specified model.

The results for the robust checks conducted based on the fixed effects (FE) approach are presented in Annex 3. This method addresses the limitations of OLS by incorporating bank-specific effects, which provide more robust estimates and deeper insights into the dynamics influencing banks' provisions for loan losses. After accounting for heterogeneity between banks, the Pooled OLS, the bank's holdings of government securities (LBHGS) consistently show negative coefficients ranging from -0.001 to -0.004 across all models, i.e. the holding of government securities by banks is associated with reduced provisions for loan losses, indicating no exposure of banks to government securities. Bond yields measure and exhibit negative coefficients (-0.037 to -0.089), indicating perceived safety in government securities as banks perceive these securities as safer assets, potentially lowering their anticipated loan losses. Conversely, the lending rate (LR) shows positive coefficients (0.003 to 0.004) across all models, suggesting that higher borrowing costs increase provisions, reflecting higher default risks. Loan Size to Total Assets (LSTA) demonstrates negative coefficients (ranging from -0.023 to -0.044), suggesting that banks with larger loans relative to their assets provision less for loan losses, suggesting that banks with a larger lending portfolio may rely on effective risk management and diversified, high-quality loans, allowing for a more moderate approach to provisioning. Other variables like return on assets (ROA), capital adequacy ratio (CAR), gross domestic product (GDP), and inflation (INFL) show mixed or insignificant coefficients, indicating varying impacts or no significant influence on LLP in this analysis. Overall, while the general direction of relationships between identified variables and loan loss provisions remains consistent across FE and pooled OLS models, the FE models provide more robust estimates by controlling for time-invariant bank-specific effects, thus offering deeper insights into the dynamics of provisioning decisions within banks over time.


Image: unsplash.com

## 3.3.7 Conclusion

This study examined the sovereign-bank nexus on financial system stability in Rwanda, analyzing data from nine commercial banks over the period from 2014Q3 to 2024Q1. The findings highlight several key determinants influencing banks' allocation for loan losses provision, a crucial indicator of financial instability. Across various models, including pooled OLS, fixed effects, and bias-corrected fixed effects, relatively consistent patterns emerged regarding the factors affecting loan loss provisions. Bank holdings of government securities showed mixed effects on loan loss provisions in pooled OLS models but consistently indicated a negative impact in FE and BC-FE models. Based on the BC-FE models, which constitute the main findings of the study, the holding of government securities by banks does not have a statistically significant im-pact on loan loss provisions, suggesting that the government securities held by banks are still minimal to influence provisions for potential loan losses. The results of bond yields consistently exhibited a negative coefficient across all models, indicating banks tend to reduce provisions for loan losses, potentially due to perceived safety and return in government securities.

On the other hand, lending rate consistently showed a positive coefficient across all models, implying that higher borrowing costs are associated with increased provisions for loan losses. This relationship underscores banks' anticipation of higher default risks during periods of elevated lending rates. Coefficients of return on assets, return on equity, and capital adequacy ratio consistently displayed negative coefficients in FE and BC-FE models, indicating that more profitable and better-capitalized banks allocate fewer resources to loan loss provisions, reflecting their stronger ability to manage risks.

Thus, even in the absence of both sovereign–bank exposure and crowding out of private sector credit in Rwanda, these findings have important policy implications for financial stability and contribute to the debate on the treatment of sovereign exposure in banking regulation and stability. Nevertheless, to forestall the occurrence of such exposures in future, the study recommends that the National Bank of Rwanda to continue implementing prudential policies that focus on optimizing the level of sovereign securities held by banks and establishing exposure limits to pre-vent excessive concentrations on their balance sheets to continue strengthening banking sector stability and enhancing market efficiency.

> "The findings highlight several key determinants influencing banks' allocation for loan losses provision, a crucial indicator of financial instability.

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# Annexes

### Annex 1: Correlation Matrix

| | LLP | LBHGS | SD | LR | LSTA | ROA | CAR | GDP | INFL |
|---|---|---|---|---|---|---|---|---|---|
| LLP | 1.00 | | | | | | | | |
| LBHGS | -0.19** | 1.00 | | | | | | | |
| | (0.00) | | | | | | | | |
| BYD | -0.04 | 0.40*** | 1.00 | | | | | | |
| | (0.44) | (0.00) | | | | | | | |
| LR | 0.08 | -0.08 | 0.30*** | 1.00 | | | | | |
| | (0.18) | (0.19) | (0.00) | | | | | | |
| LSTA | -0.22*** | 0.15* | -0.14* | 0.04 | 1.00 | | | | |
| | (0.00) | (0.01) | (0.01) | (0.47) | | | | | |
| ROA | -0.19*** | 0.38*** | -0.14* | -0.19*** | 0.21*** | 1.00 | | | |
| | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) | | | | |
| CAR | 0.47*** | -0.18** | 0.12* | -0.10 | -0.37*** | -0.24*** | 1.00 | | |
| | (0.00) | (0.00) | (0.04) | (0.07) | (0.00) | (0.00) | | | |
| GDP | -0.04 | 0.01 | -0.02 | -0.05 | -0.02 | 0.07 | -0.03 | 1.00 | |
| | (0.52) | (0.90) | (0.73) | (0.40) | (0.77) | (0.24) | (0.66) | | |
| INFL | -0.14* | 0.25*** | 0.11* | 0.05 | -0.05 | 0.10 | -0.07 | -0.19*** | 1.00 |
| | (0.01) | (0.00) | (0.04) | (0.32) | (0.39) | (0.09) | (0.23) | (0.00) | |

*p*-values in parentheses*: $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Annex 2: Regressions result from Pooled OLS**

| | P-OLS1 | P-OLS2 | P-OLS3 | P-OLS4 | P-OLS5 | P-OLS6 | P-OLS7 |
|---|---|---|---|---|---|---|---|
| LBHGS | -0.001 | -0.001 | -0.001 | 0.001 | 0.002 | $0.002^{*}$ | $0.002^{*}$ |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| BYD | $-0.089^{***}$ | $-0.081^{***}$ | $-0.080^{***}$ | $-0.127^{***}$ | $-0.138^{***}$ | $-0.143^{***}$ | $-0.142^{***}$ |
| | (0.029) | (0.029) | (0.029) | (0.030) | (0.031) | (0.031) | (0.031) |
| LR | | $0.003^{**}$ | $0.003^{**}$ | $0.003^{**}$ | $0.002^{*}$ | $0.003^{**}$ | $0.003^{*}$ |
| | | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| LSTA | | | -0.012 | -0.001 | -0.001 | -0.007 | -0.008 |
| | | | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| ROA | | | | $-0.161^{***}$ | $-0.102^{*}$ | $-0.148^{**}$ | $-0.154^{**}$ |
| | | | | (0.035) | (0.054) | (0.062) | (0.062) |
| CAR | | | | | | -0.023 | -0.024 |
| | | | | | | (0.015) | (0.015) |
| GDP | | | | | | | -0.042 |
| | | | | | | | (0.028) |
| INFL | $-0.001^{**}$ | $-0.000^{*}$ | $-0.001^{*}$ | $-0.001^{*}$ | $-0.000^{*}$ | $-0.001^{**}$ | $-0.001^{**}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *N* | 263 | 263 | 263 | 263 | 263 | 263 | 263 |

Standard errors in parentheses: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

**Source**: Authors' own computation

**Annex 3: Fixed Effects Models Regression Results**

| | FE1 | FE2 | FE3 | FE4 | FE5 | FE6 | FE7 |
|---|---|---|---|---|---|---|---|
| LBHGS | -0.003** | -0.002 | -0.004*** | -0.002 | -0.001 | -0.001 | -0.001 |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| BYD | -0.073** | -0.071** | -0.037 | -0.078** | -0.087** | -0.087** | -0.089** |
| | (0.033) | (0.032) | (0.034) | (0.034) | (0.035) | (0.035) | (0.035) |
| LR | | 0.003* | 0.004*** | 0.003** | 0.003** | 0.003** | 0.003** |
| | | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| LSTA | | | -0.044*** | -0.023 | -0.025* | -0.030* | -0.031* |
| | | | (0.014) | (0.015) | (0.015) | (0.016) | (0.016) |
| ROA | | | | -0.154*** | -0.101* | -0.135** | -0.140** |
| | | | | (0.037) | (0.056) | (0.064) | (0.065) |
| CAR | | | | | | -0.017 | -0.018 |
| | | | | | | (0.016) | (0.016) |
| GDP | | | | | | | -0.033 |
| | | | | | | | (0.028) |
| INFL[16] | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *N* | 263 | 263 | 263 | 263 | 263 | 263 | 263 |

Standard errors in parentheses: $^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

**Source**: Authors' own computation

## 3.4 Can the Sovereign-Bank Nexus Cause Financial System Distress? Evidence from Zambia

*Nason Kapako and Lackson Zulu*

### 3.4.1 Introduction

Zambia's public debt has surged in recent years amidst high inflation, low growth, low international reserves, and tight liquidity conditions. This was arguably caused by an ambitious public infrastructure investment drive post 2011. The attainment of the middle-income status in 2011 meant that Zambia no longer could access concessionary loans from multilateral lenders and fulfill its infrastructure drive. Hence, the country resorted to commercial loans accessed from external markets as well as bilateral lenders, mainly China. This resulted in the buildup of debt, which was further exacerbated by the 2019 drought and the COVID-19 pandemic in 2020, as the government expanded fiscal support to non-financial corporates and households to cushion the impact of these crises. The drought experienced in the 2023/24 farming season further worsened the situation, as the government had to increase spending on food and electricity imports. With debt sustainability deteriorating and credit ratings weakening, the government has relied increasingly on domestic financing to meet its additional funding needs, with banks as the primary source. Consequently, banks' exposure to the government has grown, reinforcing the two-way interdependence between the sovereign and the banking sector.

The interconnectedness between the government and banks, in terms of the latter's exposure to the former (loans and securities) and the government's deposits in banks, is often referred to as the sovereign-bank nexus. Shocks originating in either sector can trigger a negative "feedback loop" amplifying the impact on the other. According to existing literature, this loop, in which banks and the sovereign mutually weaken each other, can occur through three main channels: The exposure channel arises due to the exposure of banks to sovereign debt through their government debt holdings. The safety net channel, on the other hand, arises due to the implicit and explicit guarantees of the sovereign to banks, while the macroeconomic channel arises on the backdrop of the indirect connection between the two sectors. In the face of shocks, these channels tend to reinforce each other, generating an adverse feedback loop (Farhi & Tirole, 2018).

Interest in the sovereign-bank nexus has grown among researchers and policymakers. While many studies exist, most of them are focused on developed economies, and those covering emerging and developing economies often use broad country groups. Their findings are therefore not easily applicable to Zambia, which is characterized by different structural characteristics, including a less developed financial sector, a high share of foreign-currency public debt and greater refinancing risks.

Given this county-specific factors, Zambia requires deeper, country-level analysis. Such work must consider the structure of its sovereign debt, the composition of the investor base and existing data gaps. In addition, recent shocks-COVID-19 and climate-related events (droughts), may have strengthened the sovereign-bank nexus, given the policy responses by the government and the central bank.

Few studies in Zambia have examined the two-way relationship between the sovereign and the banks or assessed their financial stability risks. Most of them have focused on the linkage between fiscal risk and a few selected financial stability and macroeconomic variables.

For example, Funyina, 2024) analyzed how sovereign risk affects banks, but not how the banking sector stress might feed back to the sovereign. This paper, therefore, examines the causality between the sovereign and banking sector stress and the spillover effects, as well as the transmission of risk between the two sectors.

The remainder of the paper is organized as follows. The next section reports on the developments in the sovereign-bank nexus in Zambia. Section three provides the literature review, while section four presents the empirical approach and describes the data used in the analysis. Section five discussed the empirical results, while the last section concludes.

## 3.4.2 Developments in the Sovereign Bank Nexus in Zambia

This section sets out some stylized facts about the evolution of Zambian banks' exposure to the Zambian government and developments in some key bank variables, including capital and assets. These not only help to gauge the correlations in the data at an aggregate level but also point to the additional insights that can be gleaned from bank-level data.

Zambia's public debt-to-GDP ratio increased sharply to 106 percent as of June 2024 from 17.8 percent as of December 2010. Over the same period, domestic public debt rose from 10 percent to 35 percent of GDP, while external debt increased from 7 percent to 70 percent of GDP. The rapid accumulation of public debt can be traced to 2012, when the government adopted an expansionary fiscal policy focused mainly on financing large-scale infrastructure projects and an expanding civil service (Mwamba et al., 2024).

Before 2012, Zambia's economic fundamentals were relatively strong, which enabled the government to issue its first Eurobond. However, macroeconomic conditions began to deteriorate around 2013. GDP growth declined to 4.7 percent from a peak of 7.6 percent, and the fiscal balance steadily worsened. The fiscal deficit, which stood at 3.3 percent of GDP in 2010, widened significantly and reached 14.5 percent in 2020 during the COVID-19 pandemic.

Although the deficit has since narrowed, it remained elevated at 5.7 percent in 2023. These trends indicate that the Zambian economy was already under pressure before the COVID-19 pandemic, which further intensified existing weaknesses. In 2020, the economy contracted by 2.8 percent as a result of the Pandemic (Mwamba et al., 2024).

On 13th November 2020, Zambia became the first African country in the COVID-19 era to default on its Eurobond debt, after the Government missed a coupon payment of US$42.5 million on its 2024 Eurobond. By 2018, the public debt-to-GDP ratio surpassed the IMF-prescribed threshold of 55 percent. Rising debt servicing costs, together with the accumulation of arrears to official bilateral and commercial external creditors following the 2020 default, have left Zambia without access to international capital markets (International Monetary Fund, 2024). Similar to many emerging economies where public debt increased sharply after Covid-19, and additional financing needs were largely met by domestic banks amid declining foreign participation in local-currency bond markets, Zambia has followed the same trajectory (Deghi, et al., 2022).

Consequently, banks' exposure to domestic sovereign debt, including Treasury bills, bonds, loans, and advances, has increased significantly over time, particularly after 2013, and intensified further in the post-COVID-19 period. Banks' domestic sovereign debt holdings as a share of total banking sector assets peaked at 36 percent in September 2022, compared with an average of 17 percent for emerging market economies. As of June 2024, banks' exposure to the sovereign remained elevated at Zambian Kwacha, 62.12 billion, representing 9.7 percent of GDP and 25 percent of total banking sector assets (Figure 42). The persistently high average holdings of sovereign securities over the past decade may reflect preferential regulatory treatment, including lower risk weights as well as the perception of an implicit government guarantee.

While banking system assets and credit have expanded relative to GDP over the past decade, with total bank assets to GDP rising from 18.7 percent in 2010 to 37.1 percent in 2024, bank credit to the private sector relative to GDP has not followed a comparable trajectory. Private sector credit to GDP stood at 9 percent in 2010 and increased only marginally to 11 percent of GPD by March 2024. Further analysis indicates that private sector credit in Zambia is negatively correlated with banks' domestic sovereign exposures, suggesting a prima facie case of 'crowding out' (Figure 43).

This subdued growth in private sector credit has persisted despite a steady strengthening of bank capital buffers over the past decade. The high level of government debt and banks' elevated exposure to the sovereign suggest that risks associated with the sovereign –bank nexus may have increased even as capital buffers have strengthened over the same period. However, these capital buffers may be less robust than they appear. In particular, a shift in banks portfolio composition away from higher risk weighted private sector exposures towards government securities that attract zero or preferential capital charges can mechanically inflate reported capital adequacy by reducing risk-weighted assets (Feyen & Zuccardi, 2019). In addition, non-performing loans increased during both the financial crisis and the COVID-19 shock in 2020. Nevertheless, improvements were noted in 2021 following relief measures instituted by the central bank with the situation remaining stable since then.

**Figure 42: Banks' Exposure to Government and Total Public Debt**

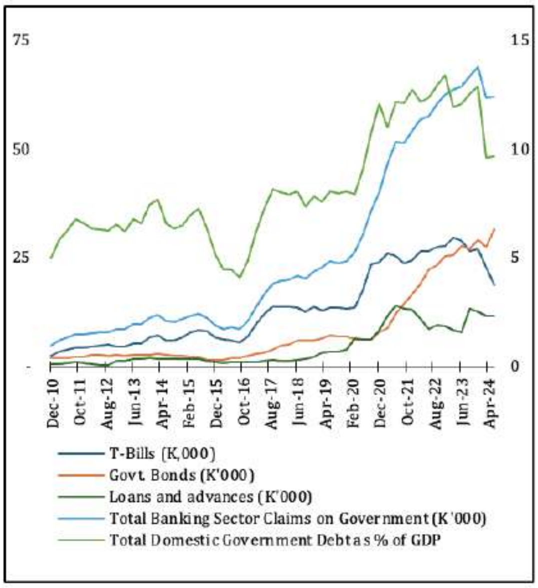
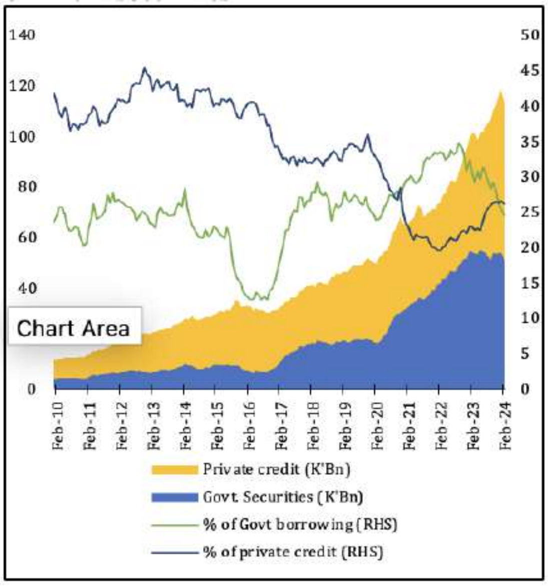



**Figure 43: Correlation between Private Sector Credit and Banks' Holdings of Government Securities**




## 3.4.3 Literature Review

### 3.4.3.1 Theoretical Literature

A review of global literature reveals that numerous studies have investigated why banks purchase public domestic debt, thereby exposing themselves to default risk. These studies also explore whether such exposure to sovereign risk impacts banks' financial stability and, in turn, influences their lending behavior towards the private sector. The literature further highlights the various channels that link the sovereign risk and banking sector exposure.

Banks hold domestic debt in response to regulatory incentives, e.g. preferential treatment of domestic sovereign debt in relation to risk weights, large exposures, market risk, and credit risk mitigation (IMF, 2022). Beyond their preferential capital treatment, government securities are regarded as safe, high-quality liquid assets. Their eligibility for meeting regulatory liquidity requirements and serving as collateral for central bank operations further incentivizes banks to hold them. These incentives are reinforced in times of a crisis, especially when governments and central banks initiate policies, like liquidity injections, to support the economy. Such kind of actions lead banks to increase their holdings of government securities to safeguard their financial health, especially in circumstances where stress induces a decline in private-sector investment opportunities and the quality of other assets is deteriorating (Asonuma et al., 2015).

Dell'Ariccia et al. (2018) provided empirical support for the 'liquidity view' by conducting country-level regressions in which government debt holdings served as the dependent variable. Their analysis incorporated macroeconomic indicators such as the T-bill rate, real GDP growth, and inflation, along with proxies for alternative investment opportunities, including equity market capitalization and the number of listed companies. The results show that banks hold more government debt during periods of high interest rates and in countries with lower private sector credit to GDP ratios. In addition, limited high-quality lending opportunities push banks toward greater investment in government securities.

Furthermore, Dell' Ariccia et al. (2018), show, using a sample of 76 Euro area banks, that domestic banks are significantly more likely than foreign banks to purchase domestic sovereign bonds during periods of elevated government financing needs. On the other hand. Bouis (2019) found that elevated bank holdings of domestic sovereign debt are linked to weaker private-sector credit growth in emerging and developing countries, as banks shift portfolios towards safer and more liquid assets in times of stress.

Altavilla et al. (2017), noted that sovereign stress can influence banks' holdings of government debt and that this exposure can, in turn, be transmitted to the credit markets. Using monthly data for 226 Euro-area banks from 2001 to 2015, the study concluded that bank characteristics affect the strength of this transmission. In particular, publicly owned banks that had recently been bailed out held significantly higher levels of public debt than others, especially during periods of central bank liquidity injections, thereby supporting the moral suasion argument. Furthermore, the authors found that less-capitalized banks not only hold more public debt but also cut lending more sharply during sovereign crises than banks with lower sovereign exposure.

### 3.4.3.1.1 Sovereign-Bank Nexus Transmission Channels

The sovereign and the banking sectors are intertwined through the exposure, safety net, and macroeconomic channels. These channels transmit shocks from one sector to the other and tend to interact with each other and, in turn, amplify the vulnerabilities, resulting in a feedback doom loop (Deghi, et al., 2022).

### 3.4.3.1.2 The Exposure Channel

The exposure channel arises from banks' direct holdings of government debt, which link bank balance sheets to sovereign risk. Sovereign stress reduces the value of government bonds and their liquidity, raising banks' funding costs by weakening collateral values and increasing sovereign yields that serve as a benchmark for pricing private credit. This directly increases borrowing costs for the private sector (Feyen & Zuccardi, 2019).

Lower bond values reduce available collateral in money markets, prompting banks to rebalance portfolios toward sovereign securities and away from private lending, thereby constraining credit supply (Acharya & Steffen, 2015). Sovereign rating downgrades further transmit stress by triggering bank downgrades, increasing funding costs, restricting access to domestic and foreign financing, and threatening bank solvency (Feyen & Zuccardi, 2019). Banks' incentives to hold government securities are reinforced during stress by their relative safety and liquidity, as well as by prudential liquidity regulations such as the LCR and NSFR, particularly in markets with limited supplies of high-quality liquid assets. Government ownership or influence over banks can intensify this nexus, as fiscal pressures may lead authorities to direct affiliated financial institutions to absorb government debt, often at shorter maturities. Losses on sovereign holdings weaken bank capital, while bank distress feeds back to the sovereign through lower dividends, reduced equity values, and potential recapitalization needs. This two-way transmission reinforces the sovereign–bank "doom loop."

### 3.4.3.1.3 The Safety Net Channel

The safety net channel arises from implicit and explicit sovereign guarantees to banks. Implicit guarantees occur because governments cannot credibly commit not to support distressed banks, especially systemically important institutions, or during widespread crises. The expectation of bailouts creates moral hazard, encouraging banks to take greater risks, which increases the likelihood of crises (Deghi, et al., 2022). This reinforces the sovereign-bank 'doom loop'; rising stress increases risk premium and market volatility, limiting banks' capacity to fund the government. When crises materialize, implicit guarantees often become explicit, further straining government fiscal position and increasing borrowing needs. Even with deposit insurance, simultaneous bank failures may require government backstops.

Liquidity assistance from central banks does not eliminate this problem. Central banks require collateral, but distressed banks often lack high-quality assets. During crises, central banks may relax collateral standards and assume some credit risk, seeking indemnity from the government to protect their balance sheets, which exposes the sovereign to potential losses.

### 3.4.3.1.4 Macroeconomic Channel

The macroeconomic channel reflects the indirect feedback between sovereign stress, banking sector distress, and the real economy. Fiscal deterioration and banking stress reduce economic activity, which feeds back into weaker public finances and bank balance sheets through lower incomes, reduced tax revenues, and deteriorating borrower creditworthiness. These effects are often amplified by currency depreciation, higher inflation, and tighter monetary conditions. Governments may respond to fiscal stress through tax increases, spending cuts, or increased debt issuance at higher yields, crowding out private credit and tightening financial conditions (Feyen & Zuccardi, 2019). The resulting economic slowdown leads to an increase in nonperforming loans, erodes bank capital, and weakens the credit supply, further depressing investment and consumption. Banks respond by deleveraging and increasing holdings of liquid sovereign assets.

Additional amplification arises through asset price declines, foreign investor outflows, credit rating downgrades, and shallow domestic financial markets, which increase volatility and impose valuation losses on banks. Government credit guarantees and withdrawals of public-sector deposits during fiscal stress can further strain bank balance sheets, reinforcing the sovereign–bank nexus.[17]

### 3.4.3.2 Empirical Literature

Several studies have examined the sovereign–bank nexus and its channels, particularly in emerging markets. Feyen and Zuccardi (2019) developed a “Strength of Nexus” indicator, capturing the association between financial sector stress (measured by median bank Probability of Default) and sovereign stress (measured by EMBI spreads) in 52 EMDEs. Their results show a strong association: a 1percent increase in public exposure raises the probability of default by 0.16 percent, even after controlling global financial stress via the VIX. However, the measure only captures correlation, not causality or specific transmission channels.

Deghi et al. (2022) address causality using a structural vector autoregression (SVAR) model for sovereign, banking, and nonfinancial corporate sectors. They find statistically and economically significant spillovers, with sovereign distress generally having a stronger effect on banks than vice versa. Banks with higher sovereign exposure increase default risk and reduce lending more following sovereign distress, supporting the sovereign exposure channel. The study also finds that government safety nets provide short-term protection during crises, but weakened sovereign credibility diminishes this effect within six months.

Acharya, et al., (2014) examined the two-way feedback between the sovereign and the banking sector, using a broad panel of bank and sovereign credit default swaps (CDS) data. The study found that subsequent changes in the sovereign’s credit risk impact the financial sector’s credit risk through three channels, namely, bailout payments and subsidies, direct holdings of government debt, and the explicit and implicit government guarantees.

17 The Zambian government in February 2004 through the Ministry of Finance directed that government deposits be withdrawn from commercial banks and be deposited with the Bank of Zambia. This measure has not yet been fully implemented as banks made representation to the Ministry in terms of the potential adverse impacts this measure would have on their liquidity.

They found that an increase in sovereign CDS by 10 percent leads to a 2.21 percent increase in bank CDS, while cautioning that macroeconomic factors affecting both bank and sovereign credit risk, may obscure direct causal interpretation.

While no explicit study has examined the sovereign–bank nexus in Zambia, several studies link fiscal risk to banking stability. Chileshe (2015) showed that fiscal shocks affect inflation and economic activity. Funyina (2020) found evidence of a crowding-out effect, where banks' holdings of government securities and government debt accumulation reduce private-sector credit. Funyina and Muhanga (2021) report that fiscal deficits raise banks' NPL ratios, likely via higher borrowing costs for private borrowers. Funyina (2024) further confirms that fiscal shocks, modeled via government expenditure and tax revenue, reduce lending, lower profitability, increase credit risk, and raise bank insolvency risk. These findings in Zambia are consistent with international evidence that sovereign stress can destabilize the banking sector.

## 3.4.4 Empirical Approach and Data

The study empirically examined the causal relationship underlying the sovereign–bank nexus in Zambia, as well as the spillover effects and the transmission of risk between sovereign and banking sector exposures. To examine causality, the study used Granger causality tests between indicators of sovereign stress and banking sector stress. To assess spillovers and the transmission of risks, the study adopted a structural vector autoregressive (SVAR) framework (Sims and Zha, 1995; Roch, 2017; Funyina, 2024; Deghi et al., 2022). The SVAR model is particularly suitable in this context, as it provides a coherent framework for identifying structural shocks and analyzing the dynamic responses of the system through impulse response functions and forecast error variance decompositions (Andonova and Petkovska, 2011).

The use of either recursive VAR or reduced-form VAR models is subject to unrealistic assumptions, particularly the interpretation of shocks, which implicitly assume that all other shocks are held constant. Both recursive VAR and reduced-form VAR frameworks assume that shocks are orthogonal and uncorrelated. However, as implied by the Wold decomposition, shocks may not always be orthogonal due to the contemporaneous correlation among the variables (Bwire, 2019).

The SVAR model is therefore preferred, as it allows for the imposition of theory informed restrictions, thereby yielding impulse response functions clear economic interpretation, based on the structure of the economy. As such, the SVAR facilitates the examination of the theoretical relationships implied by the variables under study.

From the foregoing, the SVAR model is specified as follows:

$$AY_t = C(L)Y_{t-1} + Bu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1),$$

which when re-arranged gives

$$Y_t = A^{-1}C(L)Y_{t-1} + A^{-1}Bu_t, \quad u_t \sim N(0, I) \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where $Y_t$ is n x 1 vector of endogenous variables, A and B are n ×n parameter matrices, C is the coefficient vector of lagged variables $Y_{t-p}$ and $\mu_t$ is the n ×1 vector of structural shocks with

$$E(u_t|Y_t, \ldots, Y_{t-1}) = 0 \; and \; E(u_t u'_t|Y_t, \ldots, Y_{t-1}) = \Sigma = I_n$$

Considering that the structural model in equation 2 cannot be estimated directly due to identification issues (Enders, 2015; Maturu, 2014). We therefore recover it from the unrestricted VAR counterpart in equation 3 by imposing economic theory informed restrictions on the unrestricted VAR to identify the underlying structure embedded in the data.

$$Z_t = \boldsymbol{\Pi}_1 Z_{t-1} + \boldsymbol{\Pi}_2 Z_{t-2} + \ldots \boldsymbol{\Pi}_p Z_{t-p} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

with $Z_t$ being a vector of endogenous variables, and $\varepsilon_t$ is a (n ×1) vector of normally and independently distributed disturbance terms, such that, $\varepsilon_t \sim N(0,\Sigma)$ . In the estimation strategy, short-run restrictions on equation 2 are imposed, in which the random stochastic residual, is estimated from the residuals, $\varepsilon_t$ of the estimated unrestricted VAR. Comparing the residuals from the unrestricted VAR and those in equation (2), leads to equation 4:

$$\varepsilon_t = A^{-1}Bu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

As in Bernanke and Mihov (1998), Blanchard and Perotti (2002), we use a more general way of relating errors and shocks in structural VARs as shown below:

$$A\varepsilon_t = Bu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4*)$$

To obtain the system's responses to shocks, it is necessary to specify the equation given in equation 5

$$\varepsilon_t = A^{-1}Bu_t \text{ or } \varepsilon_t = Fu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5),$$

The estimated A and B is used to compute F in equation 6

$$F = A^{-1}B \ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

The Cholesky identification scheme is used to recover the structural parameters from the reduced form estimates. It assigns correlations between the orthogonal errors to the equations that come earliest in the ordering and involves decomposing the residuals in a triangular fashion (Enders, 2015; Akosah, 2015). The Cholesky scheme assumes that shocks to a particular variable do not contemporaneously affect the variable preceding it in the ordering, but the effect comes with a lag. This ordering implies that fiscal variables do not respond instantly to financial stability variables, but the financial metrics may be affected by contemporaneous changes in fiscal conditions.

In our study, we adopt the approach by (Deghi et al., 2022), in which two-way relationships between the sovereign and banking sectors' default risks are examined by using an SVAR. The model includes endogenous variables capturing sovereign sector stress, banking sector stress, term spread, the financial stress index (FSI), and the US financial conditions index (USFC). The FSI and USFC are included to measure global financial and stability conditions. We measure sovereign stress by using the ratio of government revenue to expenditure (G2RAG). Financial stress in the banking sector is measured by the banking health index (BHI).

## 3.4.5 Variable Description and Data Sources

This study used monthly time series data for the period 2010M01-2024M06. Table 27 below provides the variables used in the analysis, their description, and the sources of the data.

**Table 27: Variable Description and Data Sources**

| Variable symbol | Definition | Source |
|---|---|---|
| Fiscal resilience (G2RAG) | This refers to a fiscal deficit measure computed as a ratio of total government expenditure to total tax revenue | Ministry of Finance |
| Banking health index (BHI) | The BHI is the index currently used to calculate banking sector stress by the Bank of Zambia. | Bank of Zambia |
| Financial stress index (FSI) | The FSI is computed by the Office of Financial Research (OFR). It is a daily market-based snapshot of stress in global financial markets. It is constructed from 33 financial market variables, such as yield spreads, valuation measures, and interest rates. The FSI is positive when stress levels are above average, and negative when stress levels are below average. The FSI incorporates five categories of indicators: credit, equity valuation, funding, safe assets, and volatility. The FSI shows stress contributions by three regions: United States, other advanced economies, and emerging markets (Office for Financial Research, 2024). | Office for Financial Research |
| Term spread (TS) | The term spread is the difference between interest rates on short (3-month T-bills)- and long-dated government securities (10-year government bonds). It is often referred to as a predictor of the business cycle. Inversions of the yield curve—a negative term spread—are considered an early warning sign. It can also be used to predict the onset of financial crisis events (Parker & Schularick, 2021) | Bank of Zambia |
| US Financial Conditions (USFC) | It is an index that is used to gauge broad financial conditions and assess how these conditions are related to future economic growth. aggregates changes in seven financial variables—the federal funds rate, the 10-year Treasury yield, the 30-year fixed mortgage rate, the triple-B corporate bond yield, the Dow Jones total stock market index, the Zillow house price index, and the nominal broad dollar index—using weights implied by the FRB/US model and other models in use at the Federal Reserve Board (Anon., 2024). | Board of Governors of the Federal Reserve System |

### 3.4.6 Empirical Results

The study tested stationarity using the Augmented Dickey Fuller (ADF) test. The results of the tests are reported in Annex 1. All five variables (G2RAG, BHI, FSI, TS, and USFC) are non-stationary in levels but become stationary in first differences. Following from (Sims & Zha, 1999), (Funyina, 2024) and (Chileshe, 2015), the VAR is estimated in levels rather than differences, as estimation in levels accounts for the cointegrating link among the variables. Furthermore, differencing variables when it is not appropriate may introduce estimation bias.

### 3.4.7 Causality and SVAR

This section presents and discusses the results of the Granger Causality Tests performed between sovereign stress and banking sector stress, as well as the SVAR findings. In the case of Granger causality tests, two null hypotheses were tested as follows: (i) sovereign stress does not Granger-cause banking sector stress, and (ii) banking sector stress does not Granger-cause sovereign stress. Based on the results shown in Table 28, both null hypotheses are rejected at the 5 percent level of significance, indicating that sovereign stress could Granger-cause banking sector stress and banking sector stress could Granger-cause sovereign stress.

**Table 28: VAR Granger Causality/Block Exogeneity Wald Tests**

| Null hypothesis | Chi-sq | P-value |
|---|---|---|
| Sovereign stress to Banking stress | 7.678282 | 0.0056 |
| Banking Stress to Sovereign stress | 3.233223 | 0.0722 |

Thus, the results suggest that banking sector stress helps in predicting sovereign stress and vice versa. This result is consistent with other studies on this subject. For example, (Deghi, et al., 2022) found that spillovers from the sovereign to banks and vice versa are both statistically and economically significant, with spillovers from sovereigns to banks being, on average, larger than those in the opposite direction. This study, however, has not quantified the size of the spillovers.

The SVAR results were evaluated using appropriate lag selection criteria, stability tests and diagnostics to ensure model validity. Consequently, G2RAG, BHI, TS, FSI and USFC are included as endogenous variables. To analyze the results, impulse response functions and variance decompositions were used. The effects of the specified shocks are presented in Figure 44 using impulse response functions (IRFs) over a 10-month horizon, illustrating the responses of the selected variables to an identified shock and the subsequent propagation of the shock over time. Figure 44, panel (b), shows that banking sector stress has a measurable effect on sovereign stress, consistent with theoretical expectations. An increase in banking sector stress initially worsens sovereign stress over the first four months, although the effect is statistically significant only in the fourth month and subsequently weakens. This response likely reflects increased government intervention during periods of banking stress, such as bailouts or liquidity support, which strains public finances and raises sovereign debt. In addition, banking sector stress can undermine investor confidence, leading to higher sovereign bond yields and increased borrowing costs.

**Figure 44: Impulse Response Functions**

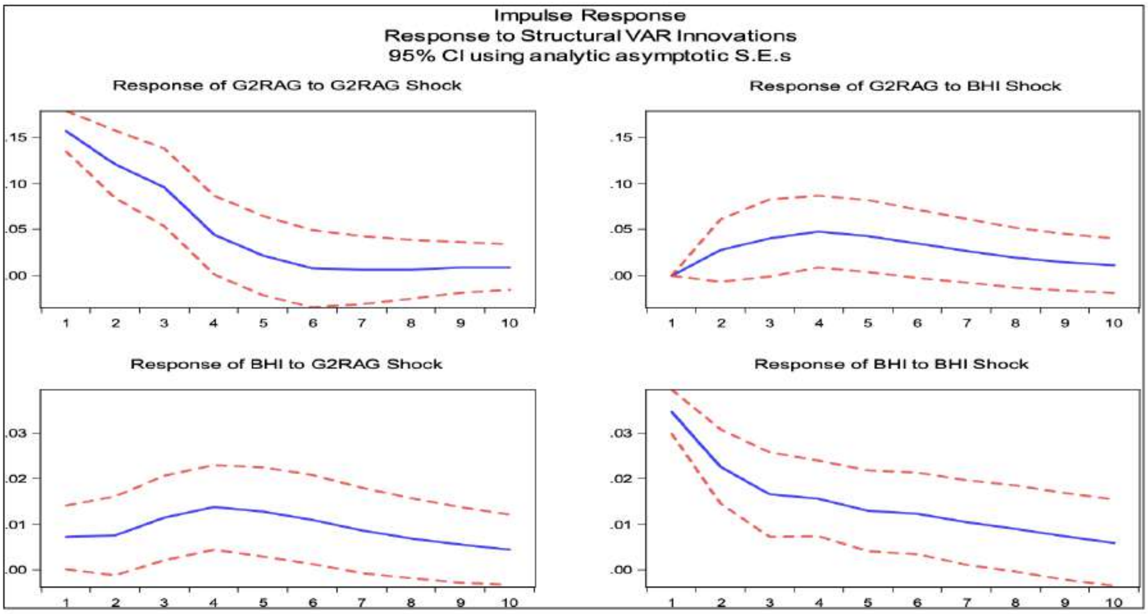



Figure 44, panel (c) shows that banking sector stress responds to a sovereign stress shock with a one-month lag. An increase in sovereign stress leads to higher banking stress from the second to the fifth month, after which the effect subsides. This response is statistically significant from the second to the fifth month and is consistent with prior empirical evidence. One channel through which sovereign stress affects banking sector stress is banks' exposure to government debt. In the case of Zambia, deterioration in sovereign creditworthiness may trigger impairments on government securities under IFRS 9, which was adopted in 2018. Sovereign stress may also prompt banks, particularly subsidiaries of foreign banks, which dominate Zambia's banking sector, to reduce their holdings of domestic government securities and limit future investments, thereby increasing sovereign funding risks.

Sovereign stress can also affect banking sector stress through a crowding-out channel. Limited access to external financing increases the government's reliance on domestic borrowing, particularly from banks, which can crowd out private sector credit. While increased holdings of government securities may temporarily improve banks' liquidity—as reflected in the loan-to-deposit ratio included in the banking health index (BHI), the reduction in private sector lending can weaken asset quality over time.

In addition, sovereign stress may impair bank asset quality through its impact on economic activity. Fiscal adjustment measures, such as tax increases or expenditure cuts, can reduce business revenues and household incomes, while the accumulation of government payment arrears can impair borrowers' ability to service loans. This can lead to higher non-performing loans, prompting banks to tighten credit conditions and reinforcing the sovereign–bank nexus. Similar results are reported by Funyina (2024), who finds that a positive shock to government expenditure is followed by an increase in credit risk.

## 3.4.8 Variance Decomposition

In this section, we assess the relative contributions of the sovereign and banking sector stress variables using the variance decomposition. This is done to ascertain which shocks make the most contribution to sovereign and banking sector stress. The result of this analysis is presented in Table 29. Variance decomposition of sovereign stress (G2RAG) shows that in the initial periods, variations arise largely from G2RAG itself at about 99.1 percent in the first month, but after ten months, banking sector stress contributes about 6.8 percent to variations in G2RAG. The second most important contribution to variations in G2RAG comes from changes in the term spread, which peaks at 3.9 percent in the tenth month. Variance decomposition of banking sector stress (BHI) shows that in the initial periods, variations arise largely from BHI itself, but after four months, G2RAG starts to contribute significantly (7.9 percent) to banking sector stress, peaking at 17.1 percent after 10 months. The second most important contribution to variations in BHI comes from changes in the FSI, which peak at 7.9 percent after ten months.

Given that the analysis shows that sovereign stress (G2RAG) can explain about 17.1 percent of the variability in banking sector stress (BHI) compared to only 6.8 percent of variability in the sovereign explained by banking sector stress, it can be argued that the strength of the nexus seems to be strong from the sovereign to the banking sector than from the banking sector to the sovereign. This is in line with many studies on the subject.

**Table 29: Variance Decomposition for G2RAG and BHI**

Variance Decomposition of G2RAG_SA:

| Period | S.E. | G2RAG_SA | BHI_SA | TS_SA | USFC | FSI |
|---|---|---|---|---|---|---|
| 1 | 0.128295 | 100.0000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| | | (3.4E-16) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| 2 | 0.159550 | 99.10240 | 0.754070 | 0.092094 | 0.003044 | 0.048398 |
| | | (0.09019) | (0.0087) | (0.0016) | (0.0002) | (0.0025) |
| 3 | 0.176072 | 97.61084 | 1.997706 | 0.311424 | 0.008605 | 0.071429 |
| | | (0.20599) | (0.0245) | (0.0055) | (0.0007) | (0.0051) |
| 4 | 0.186467 | 95.95207 | 3.316622 | 0.649029 | 0.015234 | 0.067046 |
| | | (0.34340) | (0.0425) | (0.0113) | (0.0013) | (0.0060) |
| 5 | 0.193679 | 94.35478 | 4.471447 | 1.084315 | 0.021836 | 0.067624 |
| | | (0.50033) | (0.0597) | (0.0187) | (0.0020) | (0.0050) |
| 6 | 0.198983 | 92.91126 | 5.368117 | 1.592711 | 0.027717 | 0.100191 |
| | | (0.67430) | (0.0750) | (0.0273) | (0.0027) | (0.0031) |
| 7 | 0.203026 | 91.64136 | 6.001647 | 2.149886 | 0.032513 | 0.174594 |
| | | (0.86299) | (0.0885) | (0.0366) | (0.0033) | (0.0040) |
| 8 | 0.206176 | 90.53385 | 6.410105 | 2.733766 | 0.036098 | 0.286178 |
| | | (1.06437) | (0.1006) | (0.0465) | (0.0038) | (0.0078) |
| 9 | 0.208666 | 89.56799 | 6.645639 | 3.325389 | 0.038515 | 0.422469 |
| | | (1.27669) | (0.1121) | (0.0567) | (0.0042) | (0.0123) |
| 10 | 0.210655 | 88.72286 | 6.759053 | 3.909155 | 0.039911 | 0.569023 |
| | | (1.49836) | (0.1237) | (0.06732) | (0.00459) | (0.01668) |

Variance Decomposition of BHI_SA:

| S.E. | G2RAG_SA | BHI_SA | TS_SA | USFC | FSI |
|---|---|---|---|---|---|
| 0.029849 | 0.009649 | 99.99035 | 0.000000 | 0.000000 | 0.000000 |
| | (0.00195) | (0.0020) | (0.0000) | (0.0000) | (0.0000) |
| 0.038195 | 1.841163 | 97.38493 | 0.049060 | 0.002237 | 0.722615 |
| | (0.02037) | (0.0853) | (0.0012) | (0.0002) | (0.0094) |
| 0.043257 | 4.827175 | 93.11034 | 0.172748 | 0.007963 | 1.881778 |
| | (0.04921) | (0.1940) | (0.0042) | (0.0007) | (0.0258) |
| 0.046800 | 7.914500 | 88.57450 | 0.370008 | 0.016782 | 3.124207 |
| | (0.07775) | (0.3209) | (0.0087) | (0.0015) | (0.0437) |
| 0.049417 | 10.61488 | 84.44552 | 0.631832 | 0.027699 | 4.280066 |
| | (0.10288) | (0.4644) | (0.0146) | (0.0024) | (0.0603) |
| 0.051387 | 12.78232 | 80.94344 | 0.945945 | 0.039584 | 5.288704 |
| | (0.12459) | (0.6227) | (0.0216) | (0.0033) | (0.0747) |
| 0.052880 | 14.43175 | 78.07709 | 1.299009 | 0.051423 | 6.140726 |
| | (0.14468) | (0.7935) | (0.0293) | (0.0043) | (0.0871) |
| 0.054011 | 15.63822 | 75.77486 | 1.677676 | 0.062422 | 6.846825 |
| | (0.16566) | (0.9746) | (0.0375) | (0.0053) | (0.0983) |
| 0.054867 | 16.48990 | 73.94500 | 2.069268 | 0.072041 | 7.423789 |
| | (0.18985) | (1.1643) | (0.0460) | (0.0062) | (0.1093) |
| 0.055516 | 17.06890 | 72.49981 | 2.462286 | 0.079984 | 7.889023 |
| | (0.21871) | (1.3608) | (0.05487) | (0.00695) | (0.12105) |

### 3.4.9 Conclusion and Policy Recommendations

This study examined the relationship between sovereign and banking sector stress in Zambia, using Granger causality tests and a structural vector autoregression (SVAR) model. The findings show that stress in the banking sector can predict sovereign stress, and vice versa. The SVAR results indicate that banking sector stress initially worsens sovereign stress for the first four months before easing, while sovereign stress increases banking sector stress from the second to fifth month before subsiding. These results align with other studies and highlight the interconnectedness of the two sectors.

Banks are exposed to sovereign stress through direct lending to the government guarantees, and indirect macroeconomic channels such as exchange rate movements and changes in aggregate demand. To reduce these risks, the study recommends coordinated actions by the sovereign, the banking sector, and regulators. The sovereign should build fiscal buffers, strengthen revenue mobilization, and improve public debt and fiscal risk management. The banking sector, supported by regulators, should maintain strong capital and liquidity buffers, adopt Basel II and III standards, strengthen monitoring tools such as stress tests and early warning systems, and improve data quality through better disclosures.

High bank exposure to government debt is a vulnerability that can worsen during sovereign stress. Measures like applying risk weights and exposure limits, diversifying investors, and deepening capital markets can reduce this risk. Government credit guarantee schemes and bailouts should be carefully managed, as they can strain fiscal space and create moral hazard, reinforcing the “doom loop” between sovereign and banking sector stress.

Image: unsplash.com

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# Annexes

| *Annex 1: Unit Root Test Results* | Augmented Dickey-Fuller Test Statistics | | | | |
|---|---|---|---|---|---|
| Variable | Level | p-value | Differences | p-value | Order of Integration |
| Fiscal resilience | -2.3432 | 0.4068 | -11.1338 | 0.0000 | I (1) |
| Bank Health Index | -3.2555 | 0.0798 | -12.0933 | 0.0000 | I (1) |
| Financial Stability Index | -3.9164 | 0.0134 | -13.5415 | 0.0000 | I (1) |
| Term spread | -3.2003 | 0.0878 | -15.9241 | 0.0000 | I (1) |
| US Financial Conditions | -3.6990 | 0.0250 | -9.7573 | 0.0000 | I (1) |
| Total public debt | -0.8981 | 0.9529 | -5.9297 | 0.0000 | I (1) |
| Total bank exposure to sovereign | -1.6734 | 0.7589 | -4.8893 | 0.0005 | I (1) |

Note: The unit root test results for variables in levels were generated under the assumption of trend and intercept.

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| 3 | Impact of Climate Shocks on Inflation and GDP: Evidence from Uganda | Jimmy Apaa and Deo Sande |
| 4 | The Impact of Climate Change on the Macroeconomic Situation of the MENA Region and its Implications on Monetary and Macroprudential Policies | Ingy El Tawdy, Anwar Nasr, and Mayar Mohamed |
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**General Index**

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