UNIVERSITY OF GHANA

# CLIMATE CHANGE AND BANK PERFORMANCE IN AFRICA: THE ROLE OF MONETARY POLICY.

By

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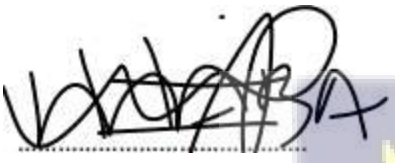
## DECLARATION

This thesis is the outcome of the study that I undertook, and I, Maame Afia Baabo Asante, a Master of Philosophy (Finance) student at the University of Ghana Business School, thus declare that it has not been delivered in whole or in part to any other university or institution. I hereby acknowledge full responsibility for any errors in this study.



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..3rd October, 2023…
Date

## CERTIFICATION

We hereby attest that the supervision of this thesis followed the guidelines established by the University of Ghana.

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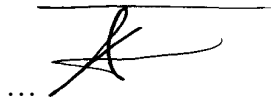
Prof. (Mrs.) Vera Fiador

(Lead Supervisor)

14-11-2023

Date



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Date

**DEDICATION**

This thesis is dedicated to God, my family, and my friends.

## ACKNOWLEDGEMENTS

I want to sincerely thank God for giving me the ability and strength to complete this voyage; without Him, I would not have gotten this far.

My deepest gratitude is also extended to my supervisors, Professors Vera Fiador and Joshua Abor. I appreciate all of your assistance, time, and support and for pushing me to always strive for the best. God bless you much.

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## LIST OF ABBREVIATIONS

IMF - International Monetary Fund, and the Global Economy

ROA - Return on Assets

ROE- Return on Equity

NIM- Net Interest Margin

NPLs -Non-Performing Loans

ASTC - Annual Surface Temperature Change

LNGHG - Log Of Greenhouse Gases

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## ABSTRACT

This study examines the impact of climate change on bank profitability and bank stability in Africa and the moderating role monetary policies play in this relationship. Employing the Panel Corrected Standard Errors (PCSE) to analyze a panel dataset of 40 African countries over eleven (11) years—2008 to 2018—obtained from the World Development Indicators (WDI) and the Climate Change Indicators Dashboard from the International Monetary Fund (IMF), this study finds that annual surface temperature change (ASTC) has an adverse significant effect on bank profitability and stability. Additionally, greenhouse gases also have a substantially negative impact on bank profitability but boost bank stability. However, the study finds that monetary policies can moderate climate change's impact on bank profitability and stability depending on the type of indicator. This study contributes to existing literature by providing insight on the impact climate change can have on the banking industry in Africa, and if central banks using monetary policy tools can curb this impact. In terms of policy recommendation, central banks should mandate banks to carry out climate stress tests and scenario analyses. Additionally, central banks should collaborate with relevant authorities and standard-setting bodies to develop and promote climate-related standards and more relevant monetary policy tools.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background to the Study

The effectiveness of the financial sector, especially the banking industry, is crucial to the growth, development, and stability of every economy. A banking industry that performs poorly does not just destabilize the financial system, but its ripple effects are felt by businesses, governments, and households. A typical example of such impact is the Great Recession of 2008, which resulted from very affordable and relaxed lending rules, causing banks to lose a great number of investments, as well as the ability to lend to each other, credible individuals, and businesses. As a result, the global financial system fell into a state of depression. Unemployment rates increased due to the inaccessibility of funds as businesses cut costs to stay afloat. Economic growth of developing countries saw a decline of 13.8% in 2007 to 6.1% in 2008 and 2.1% in 2009 with some regions experiencing negative growth, and $8 trillion of the world's Gross Domestic Product (GDP) lost within the same period (Massa, 2019).

In general, banks offer entities, countries, and individuals a way to engage in the world's economy and give its clients a stake in a society when they carry out their duties properly. Banks contribute to economic growth by performing the roles of allotting funds, undertaking ex-ante research on new investments, monitoring investments, diversifying portfolios, managing risk, mobilizing and consolidating savings, and facilitating the exchange of goods and services (Levine, 2005). The banking sector makes up 14% of the world's economy (Ross, 2021). On average, financial institutions in Africa provided domestic credit of 25.2% of the GDP to the private sector.

Nonetheless, the significance of the banking sector can only be fully realized when it is stable and profitable. Banks are said to be stable when they are "capable of efficiently allocating resources, assessing and managing financial risks, maintaining employment levels close to the economy's natural rate, and eliminating relative price movements of real or financial assets that will affect monetary stability or employment levels" (World Bank, 2016). Bank profitability is the return a bank can make from its business activities less its expenses, by utilizing its available resources. Profitable, stable, and thriving banking industries foster economic growth while building a reliable financial system.

Profitable and stable banks build enough reserves and build stronger defenses to withstand losses that occur as a result of credit impairment and non-performing loans, and consistently fulfill their obligations within the financial system (De Guindos, 2019; De Nederlandsche Bank, 2022). When banks are stable, they can eliminate financial disparities that may develop because of substantial unfavorable occurrences within an economy. Stable banking systems absorb these shocks through reliable mechanisms which limit the economy's exposure to these shocks (World Bank, 2016). For investors seeking to invest and increase their wealth, the health of the country's financial system is a major concern. Profitable and stable banking businesses serve as indicators of this health. Therefore, profitable, and stable banking industries attract investors and offer them a level of assurance of making a substantial return on investments made in the economy.

The profitability and stability of the banking sector, per Jayakumar et al., (2018) is a significant long-term contributor to economic growth among European countries. Similarly, a study by Jokipii and Monnin (2013) proved that real output growth typically increases after times of stability in the banking industry, while real output growth generally decreases after periods of instability. This demonstrates how a strong banking industry lowers the uncertainty surrounding

real output growth. Furthermore, Hoggarth et al. (2002) admitted that during periods of banking instability, 15-20% of annual GDP is lost on average, and economic losses are significant when combined with a currency crisis. Undoubtedly, the profitability of banks influences economic growth, but according to Klein and Weill (2022), this impact is due to the relationship between the banking sector and a nation's financial stability. Higher levels of profits allow banks to expand their core capital and give them more power to monitor and evaluate the reliability of their borrowers, which lowers the amount of non-performing loans and increases financial stability and economic growth. The banking industry cannot sustain its contribution to society and its incomparable financial intermediation role if found in a state of turmoil and ends up unprofitable. The welfare of the banking industry is of utmost importance in building a resilient and sustainable financial system and economy. A poor-performing banking industry not only has the potential of driving a financial crisis but also can jeopardize an economy's long-term survival. As a result, it is critical to pay more attention to the factors that may impact the stability and profitability of the banking sector.

**1.2 Problem Statement**

Due to the imperativeness of the function that banks play in economies, numerous studies have been conducted to identify the factors that affect or contribute to profitability and stability of banks (Adusei, 2015; Al-Tamimi, 2008; Ali & Puah, 2019; Flamini et al., 2009; Gupta & Mahakud, 2020; Kobeissi & Sun, 2010; Menicucci & Paolucci, 2016; Pham et al., 2021).

In terms of bank profitability, studies by Salike and Ao (2018), Sufian and Habibullah (2009), Trung (2021), and Yakubu and Egopija (2021) reveal that previous bank performance, asset

quality, management, liquidity, ownership, gross domestic product, inflation rate, operational efficiencies, income diversification, number of assets owned by banks , bank size, liquidity, operating costs, network embeddedness, and credit risk are of utmost importance. With regards to stability, Gupta and Mahakud (2020), Ozili (2018) and Trung (2021) found that banking efficacy, capital requirement ratio, foreign bank participation, banking dominance, size of the banking industry, government efficacy, good governance, regulatory quality, investor protection, type and structure of ownership and corruption control are essential drivers of bank stability. Additionally, some researchers believe that other macroeconomic factors, such as the unemployment rate in a nation, can influence the profitability and stability of banks (Aburime, 2011; Batten & Vo, 2019; Contreras et al., 2018; Ozili, 2018; Pham et al., 2021; Sufian & Habibullah, 2009).

However, it has recently been shown that climate change can have an impact on the profitability and stability of banks. First, defaults and the delay of the payments of loans to banks by entities in industries like agriculture, manufacturing, and real estate susceptible to extreme weather conditions resulting from climate change can increase the level of credit risks banks face. Moreover, extreme weather events like floods and storms tend to disrupt the smooth running, operation and the stability of banks and negatively affect their ability to generate steady revenue and thus reduce bank profitability and stability. Secondly, several financial assets may be revalued or stranded because of adjustments in climate laws like carbon taxes, technology, or market opinion, as a country transitions from an intensive carbon economy to a low carbon economy. This might have an impact on the value of carbon-intensive investments and collateral held by banks, which could potentially increase the credit risk that banks and other financial institutions must face. Lastly, banks that own insurance companies or engage in insurance activities may lose huge amounts in insurance claims because of the mass destruction of insured properties. This can derail

the ability of banks to generate revenue from insurance and their stability (Battiston et al., 2021; Bowen & Dietz, 2016; Carney, 2015; Miguel Molico, 2019; Scott et al., 2017; U-din et al., 2021).

Dafermos et al. (2018), Chai (2004), Kamran et al. (2020), Gourdel et al. (2022), and Zhang et al. (2021) indicated that climate change can have an enormous impact on the profitability and stability of banks. On the contrary, a study by U-din et al. (2021) found no significant impact. These studies were carried out in mostly Asian countries and Canada, however no study has been found that looks at how climate change affects the profitability and stability of African banks. While the effects of climate change on bank profitability and stability may be similar across areas, research into the specific vulnerabilities, economic structures, regulatory contexts, and opportunities in Africa is necessary, due to its distinct economic and regulatory systems. Studies that are specifically designed for the African setting provide for a more accurate evaluation of the risks and possibilities encountered by banks in the region and help guide policies and strategies to effectively manage these difficulties.

According to National Oceanic and Atmospheric Administration, Africa is the least contributor to the world's carbon dioxide emissions and records the second lowest temperature anomaly of 1.23 degrees Celsius in 2021, which was also lower than the global average temperature anomaly of 1.39 degrees Celsius (NOAA,2022). However, studies have proven that Africa is most susceptible to the impact of climate change, because of negative direct effects, high agricultural dependence, and limited capacity to adapt (Adzawla et al., 2019; Aluko & Obalade, 2020; Collier et al., 2008; Edmonds et al., 2020. Extreme weather disasters like droughts, floods, and storms pose significant hazards to many African nations, and they can have both direct and indirect effects on the banking industry. Therefore, the question asked in this study is can climate change have dire consequences on the banking industry in Africa like it has on other sectors of their economy? Or does the African

banking industry have resilient infrastructures and systems that can ameliorate the effects of climate change?

The economic shifts brought on by climate change can nevertheless be addressed through monetary policies, which are intended to control economic stability and growth. Diluiso et al. (2021) posited that in mitigating transition risks faced in an economy, a monetary policy focused on inflation can limit the impact of climate change while controlling prices. By affecting the asset quality of banks and the stability of the financial system, climate change can pose hazards to financial stability, when establishing policies on bank capital requirements and liquidity, monetary authorities can take these risks into account, so as to properly assess them and find strategies on how curb them. Kunawotor et al., (2022) suggested that monetary policies by central banks can include short-and-long-run implications of extreme weather events to control the shocks caused. Central banks can influence more investments and initiatives in green and sustainable finance by providing incentives, setting interest rates, or buying green assets as part of their monetary policy operations to reduce the causes and impact of climate change.

Extant literature and reports focused on the effect interactive relationship of monetary policy and climate change on macroeconomic outcomes, the impact of monetary policies on climate change and carbon dioxide emissions, or the direct effect of climate change on the banking sector are available. But none have considered the role monetary policies by central banks can play in minimizing the effect of climate change on the banking industry (Abille & Mpuure, 2020; Chishti et al., 2021; Diluiso et al., 2021; Güney, 2019; Honohan, 2019; McKibbin et al., 2017; McKibbin et al., 2020; Monnin, 2018; Onyeiwu, 2012; Qingquan et al., 2020; Tobin, 1978). This research seeks to further investigate the role monetary policy plays in moderating climate change's impact on banks' performance in Africa.

### 1.3 Research Objectives

The set objectives of this research are :

i. To ascertain the outcome climate change can have on the profitability of banks in Africa.

ii. To evaluate the influence climate change can have on the stability of banks in Africa.

iii. To investigate the role central banks' monetary policies play in moderating the effect of climate change on banks' performance ( profitability and stability).

### 1.4 Research Questions

This study seeks to address the following research questions:

i. What is climate change's impact on bank profitability in Africa?

ii. What is the effect of climate change on bank stability in Africa?

iii. Do central banks' monetary policies play a moderating role in the effect climate change has on bank performance?

### 1.5 Significance of The Study

Evaluating the effect of climate change on the performance of banks gives policymakers, government, the public, academia, and most importantly financial institutions a sense of the extent to which climate change can be disruptive and the channels through which it is disruptive. Firstly, financial regulators and policymakers in Africa, especially, have ignored the influence climate change can have on the financial system, specifically banks. The effects of climate change cause

significant structural changes in the world economy. Such fundamental adjustments certainly affect the operations and balance sheets of banks, presenting both dangers and possibilities.

Therefore, the study seeks to paint a clear picture of the effect of climate change on the banking industry and provides financial regulators with better insight as to the extent to which climate change can affect their performance and how they may take climate issues into account. Additionally, as the effects of climate change become more apparent, financial institutions ought to understand its implications to have a clear performance in place for reducing climate risks and creating portfolios of climate-related businesses as those risks grow.

Secondly, banks can reduce the causes and impact of climate change by boosting green projects through green financing. Knowing the risks climate change poses to their performance tends to encourage them to include policies that will support and boost more green projects. Financial institutions that take the initiative to safeguard their assets, lower their liabilities, and support the low-carbon, resilient transformation process in actual industries may put themselves at the frontline of the green/climate finance revolution. Lastly, the potential effects of climate change on financial stability are the first thing that African central banks must learn to comprehend and assess. Moreover, how their policies and practices affect climate change and, consequently, how well their societies can respond to this problem. Introducing monetary policies gives central banks a better understanding of the role they can play to curb the impact of climate change.

### 1.6 Summary Methodology

To accomplish the study's objectives, the quantitative research method was adopted and carried out on panel data gathered from the Global Financial Development Indicators from the World Bank (GFDI) , Climate Change Dashboard from the International Monetary Fund (IMF), and the Global Economy. Return on assets (ROA), return on equity (ROE), and net interest margin (NIM) were employed as proxies for bank profitability, while non-performing loans were employed as a proxy for bank stability. In addition, monetary policy was measured by real interest rates and broad money . The control variables employed in the study include bank size, bank deposit, non-interest income to total income, liquid assets to total deposits, bank asset concentration, overhead costs, the cost to income, unemployment, inflation, and GDP.

For robustness, the study conducted Pairwise correlation to test for multi-collinearity, the Woolridge test for autocorrelation, the Breusch Pagan Godfrey test for heteroscedasticity, the Hausman specification test to choose the more appropriate model between fixed effects and random effects, and the Cross-sectional Dependence test to check if the dataset was cross-sectionally dependent. Panel Corrected Standard Error is employed as the estimation technique used to analyze the data obtained. This technique was used in the study because it produced efficient and robust estimates by correcting problems of heteroscedasticity, autocorrelation, and cross-sectional dependence present in the panel dataset.

### 1.7 Scope and Limitations of The Research

The data employed for the study was focused on forty (40) African countries for a period of years, from 2008 to 2018. Due to difficulties with the availability in the region understudy, this research

is fundamentally limited in its time frame. A longer period would have given a clearer image of what the study seeks to achieve.

### 1.8 Organization of the Study

There are five chapters in the study. The second chapter is devoted to a survey of previous empirical and theoretical writing on the study's subject. The study's methodology is presented in the third chapter. The outcomes of the data analysis are presented in chapter four. The study's conclusion, which includes a review of the results, suggestions, and areas that require more research, is presented in the fifth chapter.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

The issue of climate change has become one of the most discussed and researched topics in recent times. Its impact is no longer experienced in just certain parts of the world but all around the globe and has become more real. For this reason, countries and organizations are required to put in measures and policies to protect and sustain their society and environment. Therefore, it is of utmost importance to extend the existing literature by assessing how climate change impacts the financial sector, specifically bank performance. This section of the study reviews existing literature on the effects of climate change. The review, however, focuses on empirical and theoretical evidence on the impact of climate change, especially on bank performance.

## 2.2 Concept of Climate Change

Climate change is a global occurrence characterized by unusual changes in the earth's regular weather pattern. The Intergovernmental Panel on Climate Change (IPCC) describes climate change as the "change in climate over time, whether due to natural variability or as a result of human activity." The United Nations Framework Convention on Climate Change (UNFCC) classifies climate change as a "change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable periods". Natural events such as reflectivity, variations in the earth's rotation and solar activity, volcanic eruptions, and naturally occurring

variations in carbon dioxide concentrations account for some of the changes in weather patterns (Rohling, 2019). However, over the years, human actions such as combustion of fossil fuels, the use of old appliances and cars, manufacturing, mining, deforestation, farming, and livestock rearing have been proven to be the largest drivers of climate change. These activities release greenhouse gases (GHG) into the atmosphere contributing to the high concentration of GHG over the years. carbon emissions, which form the largest part of greenhouse gas emissions, increase by 11 billion metric tons each year as a result of human activities (Lindsey & Dahlman, 2022).

These GHG trap energy from the sun and keep it near the earth's surface instead of escaping into space, and this is termed the greenhouse effect (Nunez, 2019). This effect causes the earth's surface temperature to increase leading to global warming. Global warming is explained by the National Aeronautics and Space Administration (NASA) as the "long-term heating of Earth's climate system". One of the effects of 'long-term heating' is climate change (NASA, 2020). Since the 1800s the world has recorded the warmest decade between the years 2011 and 2020, rising by 0.08ºC each decade and resulting in the earth being 1.1ºC warmer than it was during the pre-industrial years (United Nations, 2021). Extreme weather phenomena like prolonged droughts, rising sea levels, flooding, melting polar ice, wildfires, and water scarcity have been brought on by climate change over time.

Globally, extreme weather conditions have become severe, endangering lives and livelihoods. For some regions, the level of droughts caused by global warming has turned farmlands into deserts. In regions like Europe, climate change has led to wildfires seven times more than the average between January and July 2022 (Dixon et al., 2022). In Africa, extremely heavy rainfall has led to unprecedented floods in Nigeria leading to the loss of lives, property, businesses, and means to survive. Africa is bound to face the highest impact of climate change as the region has fewer

resources to adapt to the changing weather conditions although it is the least emitter of greenhouse gases. If greenhouse gas emissions continue at their current pace, the earth's model simulations project that the earth could be 5.4ºC warmer than it is now, leading to far more dire repercussions, especially for the African continent (Dixon et al., 2022).

### 2.3 Theoretical Framework

For some time, the issue of climate change has gained attention as its effects seem to be dire and long-lasting. Additionally, due to the realization of its far-reaching impact, researchers are paying closer attention to its sequel on the performance of the financial sector. According to Battiston et al. (2021), climate change initiates new sources of financial risks, and these risks have features that make it difficult to measure or analyze their impact on banks and the extent of their reach.

Climate change affects the performance of the financial system in three major ways. The first is through physical risks which occur because of extreme weather events such as storms, floods, hurricanes, droughts, and the rise in sea levels. Physical risks lower the value of collateral assets and increase credit as well as market risks and financial liabilities. Additionally, physical risks disrupt the daily operations of firms, their productive capacities, and trade. The second type of risk is transition risks which are associated with the transition of an economy from an intensive-carbon economy to a low-carbon economy, typically conducted in an unorganized manner. Due to the actions taken to lessen the effects of climate change, many different types of assets face the risk of becoming stranded. These criteria typically call for significant adjustments and modifications in the corporate world as well as among households. This is particularly true of industries and assets that are heavily fossil fuel-based, which after a revaluation, might result in higher credit exposure

for banking institutions. The last is the liability risk, which happens as a result of compensation demands made by organizations and persons who have suffered losses related to climate change from those they hold responsible (Battiston et al., 2021; Carney, 2015; Fabris, 2020; Giuzio et al., 2021; Park & Kim, 2020; Roncoroni et al., 2021).

Firms affected by extreme weather events may suffer economic losses due to the destruction of property and inability to continue operations, and as a result, fail to generate enough revenue to pay back the bank's debts. This may lead to an increase in the risk of default loans which could have an impact on the bank's stability (Gourdel et al., 2022; Sutcliffe, 2021). For example, economies that are agriculture-dominated like in Africa may experience a lot of problems when faced with physical risks resulting from floods and droughts. Such events can cause huge losses in agriculture and agriculture-related industries due to the destruction of farmlands, livestock, and agricultural produce. This may elicit a reduction in the income generated in the sector which may affect economic growth. Consequently, jobs are likely to be lost in the process of an economic downturn affecting the capacity of both individuals and businesses to repay their loans leading to an increase in default loan rates and banks' credit risks.

Moreover, in countries where banks are heavily invested in the agricultural industry and other industries like manufacturing and real estate, physical risks can cause these banks to lose lots of money in these investments increasing their liquidity risks. Physical dangers can also have an immediate impact on banks by disrupting their operations, forcing the closure of retail branches, and lowering their income and ultimately, their profits. In examining the impact climate change has on firm performance and financial decisions, Huang et al. (2018) provided evidence of climate risks imposed by extreme-weather events like storms, floods, and heat waves leading to losses in firms through unstable earnings and cash flow. In a similar vein, Sun et al. (2020) reported that

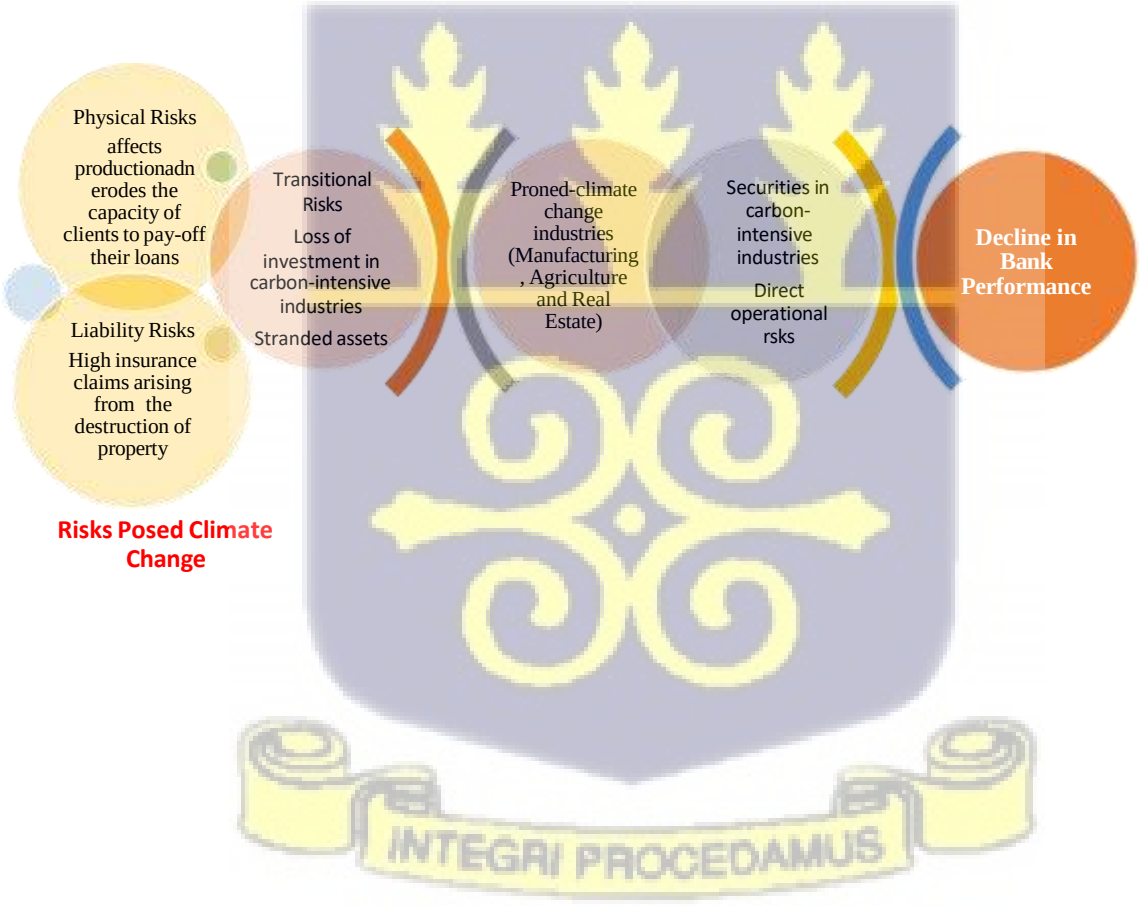
floods have a detrimental impact on the mining industry's operations and subsequently affect their financial performance. Furthermore, Giang et al. (2021) indicated that climate change deteriorates the financial performance of manufacturing firms. Consequently, the creditworthiness of these firms is negatively affected, increasing the risk of non-performing loans, and reducing the income derived by banks from interests. Additionally, an analysis by Moody's Analytics shows that climate change risks increase the expected loss associated with the loan portfolio of banks (Denton & Perrella, 2022).

Transition risks resulting from policies imposed to mitigate the cause and effects of climate change such as the imposition of carbon taxes can pose dire consequences to the banking industry. Numerous banks are heavily involved with carbon-intensive industries whose business plans do not include the possibility of a shift of the economy to a low-carbon economy, leaving them with stranded assets or a decline in the value of their assets. Consequentially, borrowers in carbon-intensive industries face difficulties in repaying their loans because of a decline in their earnings on assets. According to Battiston et al. (2017), in the case of a sudden implementation of carbon-mitigating policies, financial institutions would be unable to completely predict its impact, exposing them directly and indirectly to systematic risks because of the sudden price changes in carbon assets and inability to be compensated for portfolio losses in the non-renewable energy sector.

Furthermore, banks may face heightened market and operational risks because of climate risk. A study by Brei et al. (2019) revealed that after a hurricane, banks encounter deposit withdrawals and an adverse funding shock to which they react by lowering their supply of loans and resorting to liquid assets. Due to the risks of transitioning, considerable volatility in the price of commodities and energy can produce market risks. These risks, accompanied by poor macroeconomic

conditions, may lead to higher transaction costs for banks. The prevalence and intensity of extreme weather conditions, together with climate change, have the propensity to raise operational risks associated with business survival. Bank investments in carbon-intensive assets may also subject them to reputational risks since some may consider such actions as a breach of fiduciary duty because they ignore the factors that create long-term investment value (Batten et al., 2020; Battiston et al., 2021; Fabris, 2020; Giuzio et al., 2021; Monasterolo, 2020; Park & Kim, 2020).

**Figure 2.1: Risks Posed by Climate Change**



## 2.4 Impact of Climate Change

### 2.4.1 Climate Change and Financial Markets

Financial markets play a crucial role in the development of economies. Nevertheless, its effectiveness may be downplayed by the risks posed by climate change. Collender et al. (2021) examined the impact of transition risks which emanate from climate change on sovereign bonds among 23 developed and 16 developing countries between 2000 and 2019. According to the results of the study, developed nations that are unable to manage transition risks may experience increased sovereign borrowing costs, liquidity issues, a decreased ability to manage climate change effectively, as well as a lack of ability to fund economic recovery following major climatic shocks or natural disasters. Additionally, it became clear that helping underdeveloped nations achieve their climate change goals was essential. Similarly, Painter (2020) found that long-term municipal bonds are affected by climate change risks, but that is not the case for short-term municipal bonds. The risk associated with climate change forces impacted countries to pay higher underwriting costs and initial returns when issuing long-term municipal bonds. Additionally, they found that investors are influenced by climate change news in their decision-making.

Pagnottoni et al. (2022) extended the literature by analyzing the effect of natural disasters on international stock markets. Due to the uniqueness of stock markets all over the world, the response of each to climate change risk depends on the type of event or disaster and place. Climatological and biological disasters trigger and elicit the worst reactions in financial markets. They found out that stock indexes more responsive to these climate shocks were financial markets in European countries. Nevertheless, indexes of other financial markets

suffered spillover effects from these shocks. Furthermore, Campiglio et al. (2019), in reviewing empirical evidence on the impact of climate change risks on financial assets, found that extreme weather events caused by climate change like droughts and hurricanes negatively impact equity and debt instruments by reducing their payoffs and increasing non-performing loans. In addition, transition costs that emanate from transitioning from a high-carbon economy to a low-carbon economy harm some financial assets more than others. Finally, most investors are unaware of the future costs that may be incurred as a result of climate change because financial markets fail to price financial assets adequately to include financial risks.

### 2.4.2 Climate Change and Bank Performance

Batten et al. (2017) found that extreme weather events caused by climate change may destabilize the financial and macroeconomic aspects of countries, organizations, and households as a result of the destruction of the balance sheets of corporations. Additionally, an abrupt, unanticipated stiffening of carbon emission restrictions may cause a revaluation of carbon-intensive assets that lead to a bad shock. Brei et al. (2019) also investigated the losses and damages caused to banks on islands in the Eastern Caribbean. Their results provided evidence of an increase in withdrawals and a reduction in loans and drawing of liquid assets to cover for their losses following a hurricane strike. Capasso et al. (2020) explored the nexus between climate change exposure and the credit risks of firms. They found that companies that are carbon intense are more likely to default on loan payments everything being equal. Indicating that climate risks negatively affect loans creditworthiness and bind issued by firms and most especially banks. Nonetheless, can similar results be found in Africa? These studies

do not reveal whether climate change can have an impact on the performance of banks in Africa. Therefore, this study posits to answer this question.

### 2.5 Determinants of Bank Performance

The performance of banks has been attributed to several factors, both internal and external. To begin with, the one-year lag of bank performance, capital requirement ratio, asset quality, management, returns, liquidity, responsiveness, ownership, gross domestic product, and inflation rates were found to be significant drivers of bank performance among Vietnamese commercial banks between the years 2009 and 2020. Asset quality and sensitivity negatively affect bank performance (Trung, 2021). Likewise, Salike & Ao (2018) found that poor asset quality harms banks' profitability, and bank-specific factors like capital adequacy, income diversification, and operating inefficiency are significant determinants of bank performance. Nevertheless, real gross domestic product growth among several macroeconomic factors has the most significant influence on the performance of banks.

Yakubu and Egopija (2021) confirmed that a bank's assets are a factor in determining how well it performs. The study found that a bank's asset quality has the biggest impact on its profitability assets and return on assets (ROA). Furthermore, Gupta & Mahakud (2020) found that privately owned banks performed better in terms of profitability as compared to state-owned banks. In addition, their study showed that bank size harms bank profitability in India. In examining the performance of banks in 11 Asian countries, Saona & Azad (2018) found that ownership structure and capital ratio played a major role in determining the profitability of banks. And a study by Ozili (2018) provided evidence of foreign bank participation, banking

effectiveness, unemployment levels , banking industry size, good governance, political security, quality regulations, safety of investors, regulation of corruption , and bank dominance being key determinants of banking stability in Africa. However, measure used for bank stability and the timeframe adopted determined its depth of significance.

Abaidoo and Agyapong (2022) provided evidence suggesting that increasing government, international, and individual investments generally have a considerable positive influence on stabilizing the banking industry. Moreso, the evidence further suggested that even in times of investment expansion, macroeconomic uncertainties may harm the liquid reserve position of banks. In examining the determinants of bank performance in developing countries, Sufian and Habibullah (2009) found that credit risk, network embeddedness, operating expenses, liquidity, and size have substantial impacts on the profits of Indian financial institutions.

Djalilov and Piesse (2016) extended the literature a step further by examining the determinants of bank performance in transition countries. They discovered that default risk had a favorable effect on early-transition countries and the opposite effect on late-transition countries. Additionally, well-capitalized banks in early-transition countries had much higher profits than banks in late-transition nations. These conclusions were made based on the premise that late-transition countries had poor capitalization and quality of assets. In investigating the drivers of profitability of 534 banks from 19 advancing market economies, Contreras et al. (2018) found that credit expansion was a key determinant as compared to GDP growth of bank profitability whereas greater short-term rates impacted profits by increasing borrowing costs, higher long-term interest rates tended to increase profitability. In addition, they found that risk premium was another significant determinant of bank profitability. An increase in sovereign risk premia hugely reduced the profits of banks.

Osuagwu (2014) investigated the elements that determine of bank profits of selected banks in Nigeria. The study provided evidence of credit risk, market concentration, and exchange rate utilizing return on equity being determinants of bank profitability in Nigeria. Menicucci and Paolucci (2016) concluded that an important factor affecting the profitability of European banks is the size of a bank as measured by total assets. As a result of this, big banks can benefit from economies of scale. Profits in European banks were also influenced by capital strength, which was measured as the percentage of the equity to total assets. Banks with enough capital had lower external borrowing costs, which may translate to increased profitability. Another factor that affects bank earnings is the loan ratio, but a larger percentage of net loans to total assets may not always translate into higher profits. Likewise, Sufian and Habibullah (2009) indicated that the size of banks and all macroeconomic variables except inflation harmed their return on average equity (ROAE) in Bangladesh. Aburime (2011) also analyzed a dataset of 154 banks from 1980 to 2002 to ascertain the macroeconomic determinants of bank profitability in Nigeria. Their findings demonstrated that real interest rates, inflation, monetary policy, and the exchange rate regime are key determinants of bank profitability in Nigeria. In addition, Batten and Vo (2019) revealed that the macroeconomic environment and characteristics of the banking industry influence the profts of banks ; nevertheless, across profitability metrics, there is a variation in the order of causality.

Le and Ngo, (2020) examined factors influencing bank profitability in 23 nations between 2002 and 2016, employing the system generalized method of moments (GMM). Their research revealed that the issuance of cards, the use of ATMs, and point-of-sale (POS) devices all influence bank profitability and enhance it. Furthermore, their study indicated that market dominance undermines bank profits. This means a less concentrated banking system improves

profitability. They also found that the level of capitalization of a bank determines its profitability. Nonetheless, well-capitalized bank systems were found to have lower profitability. Banks with a higher level of capital operate overly cautiously, reducing their ability to invest in potentially profitable opportunities.

According to Petria et al. (2015) some elements, like ROA and ROE, as well as credit and liquidity risk, managerial effectiveness, firm diversity, market concentration/competition, and economic growth, can influence the performance of banks. The EU27's banks' profitability was positively impacted by competition, which was a fascinating and significant finding. Similarly, Andreas, Dietrich, and Wanzenried (2011) used the GMM estimator technique to evaluate the variables influencing the profits of 372 banks in Switzerland between 1999 and 2009. Their study provided evidence of the efficiency of banks, loan volume, ownership, interest income, and funding costs as determinants of the profitability of commercial banks in Switzerland. Per their findings, efficient banks are extra profitable, loan volume of banks above average increased profitability, and an increase in funding costs reduced profitability. Banks that relied solely on interest income earned fewer profits compared to banks that had other sources of income.

A study by Lee and Kim (2013) affirmed the assertion that the ownership type is a determinant of bank profitability. In their study, they found that state-owned banks performed poorly as compared to foreign-owned banks. Athanasoglou et al. (2008) investigated the determinants of Greek banks from 1985 to 2001 using the GMM. Results from the study showed that determinants specific to banks, except for size, significantly affected bank profitability. In exploring the determinants of bank stability of commercial banks in Vietnam adopting GMM, Pham et al. (2021) found that equity-to-asset ratio, bank size, loans-to-assets ratio, revenue

diversification, macroeconomic factors (GDP and inflation), lag of bank stability, and foreign investments had a positive impact on bank stability while the market share from mobilized capital, provision of bad debts and market structure may harm bank stability. On the other hand, Diaconu and Oanea (2014) concluded that the financial stability of banks in Romania was affected by GDP growth and the 3-months inter-bank offering rate.

Nonetheless, the level of significance of each determinant depends on the indicator used and the period of analysis. In a similar vein, research by Peterson (2019) showed that banking stability in Nigeria was significantly influenced by factors such as bank productivity, non-performing loans rate, capital requirement ratios, increased financial depth, and bank dominance. Yensu et al. (2021) also found that bank size, characteristic, gender of CEO, board size, frequency of board meetings, interest cover, inflation, GDP, bank rate, and net profit margin were determinants of bank stability among commercial banks in Ghana. However, bank size, characteristics, gender of CEO, board size, frequency of board meetings, inflation, and growth rate of GDP had positive effects on bank stability, but interest cover and bank rate negatively affected bank stability significantly.

Adopting a panel regression analysis in their study, Ali and Puah (2019) examined internal factors that influenced bank stability and profitability among 24 commercial banks in Pakistan. Their results indicated that size of banks , default risk, risk of financing, liquidity risk, and profitability were key determinants of banks' returns and stability. Finally, Chand et al. ( 2021) explored the causes of the stability of banks in a small economy by focusing on banks on the Island of Fiji. Their results showed that the magnitude of banks, financing risk, and credit risk drove bank stability and positively impacted it. Similarly, inflation and

economic growth determinants of bank stability in Fiji were positively correlated. Liquidity, remittance inflow, and net interest margin, on the other hand, harmed bank stability.

### 2.6 Monetary Policies of the Central Bank

Central banks have a significant role in maintaining financial and economic stability. Central banks use monetary policy to achieve low, stable inflation. Following the global financial crisis, central banks have increased the range of tools at their disposal to counter threats to financial stability and control changing exchange rates. To fulfill their goals, central banks need to establish clear policy frameworks. To execute monetary policy, central banks alter the money supply using open market operations. Central banks influence the amount of money in circulation by buying government debt from commercial banks (quantitative easing) and determining an interest rate (bank rate) at which banks borrow money from them (Bank of England, 2022; International Monetary Fund, 2017). Boneva et al. (2022) describe monetary policies as "decisions, actions, and communications made by central banks to influence the supply of money and availability of credit in the economy, with a view of achieving macroeconomic policy objectives, such as price stability, full employment, and steady economic growth, depending on the mandate." Although central banks contribute to steady economic growth through monetary policies, they do not, on their own, promote economic growth but increase the economy's growth prospects by preserving a climate of stable prices. They have an impact on overall price levels (European Central Bank, 2022).

In reviewing existing literature, Twinoburyo and Odhiambo (2018) found that both long- and short-term economic growth was influenced by central banks' monetary policies. Likewise

using the Ordinary Least Squares Method, Onyeiwu (2012) examined the impact of monetary policy on the Nigerian economy and found that monetary policy measured by money supply has a positive impact on GDP growth and balance of payment. In the same light, Abata et al. (2012) assessed the impact of monetary policies on economic growth and development in Nigeria.

They observed that economic growth and fiscal policy variables in Nigeria had a moderate long-run equilibrium relationship. Abille and Mpuure (2020) examined the role of monetary policy in economic growth in Ghana. Adopting the ARDL bounds test approach, they found that monetary policy had a positive impact on economic growth in Ghana in the long run. Nguyen et al. (2017) explored the influence of monetary policies on profits of commercial banks in Vietnam. They discovered a favorable correlation between bank profits and monetary policy by using panel data regression to examine data from 20 commercial banks. Nikhil and Deene (2021) wanted to determine how monetary policies affected Indian banks' performance. Using the correlation and regression analysis, they found that monetary policy measured by bank rate had a substantial impact on bank performance indicated by deposits, loans, and advances, as well as total asset values. Nguyen et al. (2022) used the two-step system generalized method of moments (S-GMM) estimator in exploring the effect of monetary policy on bank performance in Vietnam. Their study demonstrated that expansionary monetary policies boost bank performance.

### 2.6.1 Monetary Policies and Climate Change

Researchers are of the view that the central bank through monetary policies has the main power to influence not only the economic and bank performance but moderate the effect climate change has on the economy. Supporting this assertion, Alexander Dietrich et al. (2021) were of the view that central banks, through the use of monetary policies, tend to stabilize the economy in times of shifts in business cycles as a result of climate-related disasters. In response to a climate-related disaster, central banks can lower interest rates to encourage borrowing and spending, thereby stimulating economic activity and investment in recovery efforts. Additionally, central banks can provide liquidity to the banking system through open market operations or lending facilities to ensure that banks have access to the funds they need to continue lending to households and businesses. Lastly central banks using monetary policies can stabilize the economy by adjusting their policies to anchor inflation expectations and prevent runaway inflation after climate-related disasters.

Additionally, Monnin (2018) suggested that monetary policies should reflect climate risks by developing suitable environmental risk measures. This initiative will help central banks identify potential vulnerabilities in the banking industry and put in appropriate measures to curb its effects and causes. They must then include such measures in their asset purchasing plans and collateral framework. They would create benefits that are consistent with the decarbonization of the economy and send a clear indication to industry players that climate risks should be considered in their decisions. The impact of climate-related disasters must be evaluated and forecasting models broadened to account for these effects to respond to the

consequences of climate change on the economy rapidly and efficiently (Batten et al., 2020). Kunawotor et al. (2022) also proposed that to develop sound monetary policies, central banks should consider both the long-and short-term impact of supply shocks brought on by catastrophic weather patterns.

Moreover, Qingquan et al. (2020) assessed the consequence of monetary policies on the release $co_2$ in Asian nations. According to them, there exists a substantial long-run association among expansionary monetary policies and $co_2$ emissions, which is a major factor of climate change. In addition, contractionary monetary policies are an effective tool for reducing carbon dioxide emissions. Expansionary monetary policies typically involve lowering interest rates to stimulate economic activity. Lower interest rates reduce the cost of borrowing for businesses and individuals, making it cheaper to finance investments in various sectors, including energy production, transportation, and construction. While this can boost economic growth and job creation, it may also lead to an increase in emissions if it results in more fossil fuel consumption and industrial production. In some cases, an expansionary monetary policy may incentivize investment in carbon-intensive industries like coal, oil, and gas. The increased availability of cheap credit can lead to a higher level of investment in these sectors, potentially increasing emissions. For these reasons, central banks can boost the use of eco-friendly technologies and the use of renewable energy sources by formulating monetary policies that incentivizes its use, reducing the level of GHG emissions and climate change in the long run.

A study that supports the assertion of Qingquan et al. (2020) is a study by Chishti et al. (2021) who developed a new model to examine how monetary policies can influence of on $co_2$ emissions in BRICS economies. The findings showed that expansionary monetary policies reduce environmental quality through the increase of $co_2$ emissions, while contractionary

monetary policies improved environmental quality by doing vice versa. Lower interest rates resulting from expansionary monetary policies can encourage consumer spending on goods and services, including energy-intensive products and transportation. This can potentially lead to higher energy consumption and greenhouse gas emissions, especially if individuals opt for less energy-efficient options.

On the other hand, contractionary monetary policies involve raising interest rates to slow down economic activity and control inflation. Higher interest rates can increase the cost of borrowing for businesses and individuals, which may lead to reduced investment in energy-intensive projects and industries. This can result in lower emissions in sectors that rely heavily on fossil fuels. Contractionary monetary policies can also lead to lower overall economic growth and consumer spending, potentially reducing the demand for energy and emission-intensive goods and services. Despite the number of studies carried out on the impact of monetary policies on the causes and effects of climate change, no study has been found delving into the moderating effect monetary policies can have on the impact of climate change on bank performance. This is an objective the study seeks to achieve.

## 2.7 Chapter Summary

This chapter focused on a theoretical and empirical review of the benefits of environmentally sustainable practices that reduce the risk of climate change on the performance of organizations, climate change, bank performance, and monetary policies of central banks. Extant literature indicated the adverse effect of climate change on agriculture, health, economic growth, poverty, and political stability. Although Africa is the least GHG emitter, it is the most

vulnerable region to the impact of climate change because of its inability to adapt easily and high dependence on agriculture which falls at the mercy of climate change.

Little work has been conducted on the effect of climate change on bank performance worldwide, while none has been done in Africa particularly. The banking industry in Africa is still in its developing stages with several factors affecting the performance of banks, but it is unclear whether climate change may be one of the factors influencing the performance of banks in Africa. Monetary policies however can moderate the influence of climate change on the banks' performance. Nonetheless, for monetary policies to be effective, they should be devoid of any external forces.

# CHAPTER THREE

# METHODOLOGY

## 3.1 Introduction

The methods utilized to accomplish the study's objectives are described in this chapter. It draws attention to the tools and techniques utilized to demonstrate the relationship between bank performance and climate change. This chapter also offers insights into the sources of data, the techniques used for analysis, and the statistical conclusions that were drawn to accomplish the objectives. The section included the research design, data sources, sample size, target and explanatory variables, and the techniques used for analysis.

## 3.2 Research Design

The purpose of the study was to determine how monetary policies were able to moderate the effects of climate change on bank performance in Africa. Therefore, the quantitative research method is the most appropriate approach since the study sought to evaluate numerical data and facts and provide statistical inference. Quantitative methods are based on numerical data and facts generated from statistical techniques, making their outcomes more generalizable. The objective of the quantitative methodology is to obtain precise and dependable observations that enable statistical inference. Data used in this research method are quantifiable and largely considered representative of a population (Queiros et al., 2017). Quantitative research evaluates associations between various variables in research questions by utilizing certain statistical and unbiased techniques (Cresewll & Creswell, 2017; Mehmood et al., 2012). These are the reason the quantitative research method was deemed appropriate for this study.

### 3.3 Data Availability and Sources

Panel data made up of data from countries and across time to capture their time-varying effects were employed in the study depending on their availability. In evaluating the influence of climate change on bank performance and the moderating role of central banks' monetary policies, data from 40 African countries were analyzed. Countries selected for analysis were Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Tanzania, Togo, Tunisia, Uganda, Zambia, and Zimbabwe. Data employed were retrieved from secondary sources (shown in appendix 1) and limited to the period from 2008 to 2018 (11 years) as a result of the availability of data.

### 3.4 Empirical Strategy

#### 3.4.1 Estimation Techniques

Employing panel data to achieve the objectives of the study was well suited as it enabled the integration of data across individual subjects, N, and over a period of time, T. It is a combination of the cross-sectional dataset and the time series dataset, which provides a range of estimating techniques (Asteriou & Hall, 2007). The two-sided dimension of the data increased the depth of the research, the variability, freedom levels and decreased interdependence between variables.

This type of data also allows for heterogeneity by considering the differences among subjects or elements in the dataset. Additionally, because of the repeated cross-sectional observations, panel data was a more appropriate approach to use in examining the extent of variation in the dataset over time and sophisticated models. More precisely, panel data can be utilized to identify and rate outcomes that cannot be seen in cross-sectional data or time series data (Gujarati & Porter, 2009).

However, panel data are usually characterized by issues of heteroscedasticity, serial correlation, and cross-sectional dependence which pose issues for regression analysis. The data used in the study suffered from these problems (as shown in the appendix), hence a more robust model was used in this study. The Panel Corrected Standard Errors (PCSE) was employed as an efficient technique for the estimation of the model for the study. According to Bailey and Katz (2011) and Chen et al. (2010), models employed for the estimation of a panel dataset should be able to take into account the possibility of heteroscedasticity, as well as structural and temporal associated errors. Therefore, using the Ordinary Least Squares (OLS) for panel data may produce biased and inefficient estimates because of its structural and temporal nature ( Beck & Katz, 1995).

The Generalized Least Squares (GLS) model proposed by Parks (1967) to address the shortcomings of the OLS was also problematic as it may have severely understated the coefficients of the variables ( Beck & Katz, 1995). Beck and Katz (1995), therefore, proposed the PSCE as an alternative approach that can be used in the presence of non-spherical errors. The PSCE maintains the OLS estimates but replaces its standard errors with panel-corrected standard errors. It considers the nature of the panel dataset and its complications and corrects the issues of heteroscedasticity, autocorrelation, and cross-sectional dependence by first transforming the data and then applying OLS to the data transformed. The PSCE is an extremely robust approach that derives efficient estimates from the standard errors (Beck & Katz, 1995; Sandow et al., 2021). The PSCE model is

also able to handle the erroneous estimation in panel estimation due to the problem of cross-sectional dependence.

According to Pesaran and Chudik,(2013), panel data approaches tend to exhibit significant problems of cross-sectional dependence in their errors as a result of the presence of prevalent shocks, spatial effects, and unobserved elements that are eventually included in the error term. Cross-sectional dependence is a problem for many panel datasets and often arises when subjects are randomly selected. Disregarding the problem of cross-sectional dependence and integration in African countries, economies and entities may give rise to the cross-sectional dependence problem. Additionally, it might be brought on by regionally prevalent social standards, psychological behavior patterns, and herd behavior that are impossible to quantify. Besides the consistency of heteroscedasticity, the PCSE model is robust to general cross-sectional and temporal dependence.

The general panel econometric model employed is specified as:

$$Y_{i,t} = \alpha_i + \boldsymbol{B}X_{i,t} + \gamma_t + \varepsilon_{i,t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$i = 1, \ldots., N, t = 1, \ldots., T$$

where $\alpha$ represents the constant, $\boldsymbol{\beta}$ represents the coefficients of the explanatory variables, $n_i$ represents unobserved individual heterogeneity or in the case of this study the country-specific effects, $\lambda_t$ represents unobserved time-fixed effects, and $\varepsilon_{it}$ represents unobserved individual country fixed effects, and the idiosyncratic error term.

### 3.4.2 Econometric Model Specification

To achieve the first objective; ascertaining the impact of climate change on profits of banks in Africa, three models were employed consistent with a study by U-din et al. (2021) with changes and additions made to suit the objective and context. The models are estimated as follows:

$$ROA_{it} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1 Astc}_{it} + \boldsymbol{\beta_2} lnghg_{it} + \boldsymbol{\beta_3 nintinc}_{it} + \boldsymbol{\beta_4} n\mathbb{i}m_{it} + \boldsymbol{\beta_5 size}_{it} + \boldsymbol{\beta_6} bd_{it} + \boldsymbol{\beta_7} latd_{it} + \boldsymbol{\beta_8 ba c}_{it} + \boldsymbol{\beta_9} ohc_{it} + \boldsymbol{\beta_{10} inf}_{it} + \boldsymbol{\beta_{11}} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (2)$$

$$ROE_{it} = \lambda_0 + \lambda_1 \boldsymbol{Astc}_{it} + \lambda_2 lnghg_{it} + \lambda_3 \boldsymbol{nintinc}_{it} + \lambda_4 n\mathbb{i}m_{it} + \lambda_5 \boldsymbol{size}_{it} + \lambda_6 bd_{it} + \lambda_7 latd_{it} + \lambda_8 \boldsymbol{ba c}_{it} + \lambda_9 ohc_{it} + \lambda_{10} \boldsymbol{inf}_{it} + \lambda_{11} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (3)$$

$$NIM_{it} = \mu_0 + \mu_1 \boldsymbol{Astc}_{it} + \mu_2 lnghg_{it} + \mu_3 \boldsymbol{nintinc}_{it} + \mu_4 \boldsymbol{size}_{it} + \mu_5 bd_{it} + \mu_6 latd_{it} + \mu_7 \boldsymbol{ba c}_{it} + \mu_8 ohc_{it} + \mu_9 \boldsymbol{inf}_{it} + \mu_{10} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (4)$$

where $\mathbb{i}$ denotes country-specific characteristics, $\boldsymbol{ROA, ROE}$ *and* $\boldsymbol{NIM}$ denote Return on Assets, Return on Equity, and Net Interest Margin, $\boldsymbol{Astc}$ represents annual surface temperature change, $lnghg$ denotes natural log of greenhouse gas emissions, $\boldsymbol{nintinc}$ denotes non-interest income to total income, $\boldsymbol{size}$ denotes bank size, $\boldsymbol{bd}$ denotes bank deposits to Gdp, $\boldsymbol{latd}$ denotes liquid assets to total deposits, $\boldsymbol{ba c}$ denotes bank asset concentration, $\boldsymbol{ohc}$ denotes the bank's overhead costs, $\boldsymbol{inf}$ denotes inflation, $\boldsymbol{unempl}$ denotes unemployment and $\boldsymbol{gdp}$ denotes GDP growth rate.

To achieve the second objective, which was to assess the of climate change on bank stability in Africa, a model was employed similar to the first three models. The model is estimated as follows:

$$NPL_{it} = \phi_0 + \phi_1 \boldsymbol{Astc}_{it} + \phi_2 lnghg_{it} + \phi_3 \boldsymbol{nintinc}_{it} + \phi_4 \boldsymbol{ba c}_{it} + \phi_5 latd_{it} + \phi_6 ct\mathbb{i}_{it} + \phi_7 r\mathbb{i}r_{it} + \phi_8 unempl_{it} + \phi_9 \boldsymbol{inf}_{it} + \phi_{10} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (5)$$

where $NPL$ denotes non-performing loans. All explanations of the other variables hold as in the first three models.

For the third objective, which was to investigate the role monetary policies play in moderating the effect of climate change on the bank performance (profitability and stability), four models were used. The models are estimated as follows:

$$ROA_{it} = \vartheta_0 + \vartheta_1 MP_{it} * \boldsymbol{Astc}_{it} + \vartheta_2 \boldsymbol{nintinc}_{it} + \vartheta_3 nlm_{it} + \vartheta_4 \boldsymbol{size}_{it} + \vartheta_5 bd_{it} + \vartheta_6 latd_{it} + \vartheta_7 \boldsymbol{ba}_{\boldsymbol{c}it} + \vartheta_8 ohc_{it} + \vartheta_9 \boldsymbol{inf}_{it} + \vartheta_{10} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (6)$$

$$ROA_{it} = \delta_0 + \delta_1 MP_{it} * lnghg_{it} + \delta_2 \boldsymbol{nintinc}_{it} + \delta_3 nlm_{it} + \delta_4 \boldsymbol{size}_{it} + \delta_5 bd_{it} + \delta_6 latd_{it} + \delta_7 \boldsymbol{ba}_{\boldsymbol{c}it} + \delta_8 ohc_{it} + \delta_9 \boldsymbol{inf}_{it} + \delta_{10} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (7)$$

$$ROE_{it} = \varphi_0 + \varphi_1 MP_{it} * \boldsymbol{Astc}_{it} + \varphi_2 \boldsymbol{nintinc}_{it} + \varphi_3 nlm_{it} + \varphi_4 \boldsymbol{size}_{it} + \varphi_5 bd_{it} + \varphi_6 latd_{it} + \varphi_7 \boldsymbol{ba}_{\boldsymbol{c}it} + \varphi_8 ohc_{it} + \varphi_9 \boldsymbol{inf}_{it} + \varphi_{10} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (8)$$

$$ROE_{it} = \pi_0 + \pi_1 MP_{it} * lnghg_{it} + \pi_2 \boldsymbol{nintinc}_{it} + \pi_3 nlm_{it} + \pi_4 \boldsymbol{size}_{it} + \pi_5 bd_{it} + \pi_6 latd_{it} + \pi_7 \boldsymbol{ba}_{\boldsymbol{c}it} + \pi_8 ohc_{it} + \pi_9 \boldsymbol{inf}_{it} + \pi_{10} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (9)$$

$$NIM_{it} = \omega_0 + \omega_1 MP_{it} * \boldsymbol{Astc}_{it} + \omega_2 \boldsymbol{nintinc}_{it} + \omega_3 nlm_{it} + \omega_4 \boldsymbol{size}_{it} + \omega_5 bd_{it} + \omega_6 latd_{it} + \omega_7 \boldsymbol{ba}_{\boldsymbol{c}it} + \omega_8 ohc_{it} + \omega_9 \boldsymbol{inf}_{it} + \omega_{10} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (10)$$

$$NIM_{it} = \tilde{\Omega}_0 + \tilde{\Omega}_1 MP_{it} * lnghg_{it} + \tilde{\Omega}_2 \boldsymbol{nintinc}_{it} + \tilde{\Omega}_3 nlm_{it} + \tilde{\Omega}_4 \boldsymbol{size}_{it} + \tilde{\Omega}_5 bd_{it} + \tilde{\Omega}_6 latd_{it} + \tilde{\Omega}_7 \boldsymbol{ba}_{\boldsymbol{c}it} + \tilde{\Omega}_8 ohc_{it} + \tilde{\Omega}_9 \boldsymbol{inf}_{it} + \tilde{\Omega}_{10} gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (11)$$

$$NPL_{it} = \gamma_0 + \gamma_1 MP_{it} * \boldsymbol{Astc}_{it} + \gamma_2 \boldsymbol{nintinc}_{it} + \gamma_3 \boldsymbol{ba}_{\boldsymbol{c}it} + \gamma_4 latd_{it} + \gamma_5 ctl_{it} + \gamma_6 unempl_{it} + \gamma_7 \boldsymbol{inf}_{it} + \gamma_8 gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (12)$$

$$NPL_{it} = \mu_0 + \mu_1 MP_{it} * \boldsymbol{ln}ghg_{it} + \mu_2 \boldsymbol{nintinc}_{it} + \mu_3 \boldsymbol{b_a c}_{it} + \mu_4 latd_{it} + \mu_5 ctl_{it} + \mu_6 unempl_{it} + \mu_7 \boldsymbol{inf}_{it} + \mu_8 gdp_{it} + \boldsymbol{\varepsilon}_{i_t} \quad (13)$$

where $MP_{it} * \boldsymbol{Astc}_{it}$ and $MP_{it} * \boldsymbol{ln}ghg_{it}$ represented the interaction between annual surface temperature change and monetary policy measured by real interest rates and broad money. All explanations are the same as in previous models.

### 3.5 Dependent Variables

#### 3.5.1 Measuring Bank Profitability

ROA, Bank Return on Equity (ROE), and NIM are employed in the study as outcome variables denoting bank profitability consistent with studies by Caby et al. (2022), Lee et al. (2015), Menicucci and Paolucci ( 2016), Osuagwu (2014), Rahman et al. (2015) as well as Saif-Alyousfi and Saha (2021).

ROA is calculated as a proportion of total assets. It highlights how efficiently each unit of assets on average yields profit. It is an indicator that proves how efficiently a bank is run and managed. Using the profit earned from assets invested by the banks and the profits made from those investments, it is used to assess the expertise and operational performance of banks. A higher return on asset ratio indicates how management' efficiency in using the resources available. ROA is calculated by dividing net income by total assets, where net income represents total revenues less total expenses, and total assets denote resources with economic value controlled by a firm and can yield benefits in the future (Caby et al., 2022; Kobeissi & Sun, 2010; Schoeman & Petersen, 2008). ROA is a major indicator of bank profitability.

NIM considers the difference between interest earned and interest paid to customers scaled by the overall earning resources. In other words, it is the proportion of earning assets to the difference between interest revenue and interest expenses, where interest income is interest earned on loans given out to customers, interest expense is interest paid on deposits made may customers and total earning assets are investments that generate money for banks without requiring a lot of work but provide steady income. Net Interest Margin focuses on the profits earned on investment and lending activities. Banks with higher NIM are deemed to be more stable and profitable. It is deemed the best alternative to ROA for measuring banks' or firms' profitability (Lee et al., 2015; Rahman et al., 2015).

ROE measures the ratio of net profits to equity capital which is the return shareholders receive in their equity capital. ROE indicates how well management generates profit from resources invested by shareholders. ROE is derived by dividing net income by total shareholders' equity, where total shareholders' equity denotes shareholders' claim after deducting total liabilities from total assets. A higher ROE indicates an effective use of shareholders' equity (Kobeissi & Sun, 2010).

### 3.5.2 Measuring Bank Stability

Non-performing Loans (NPL) as a percentage of total loans are employed as an outcome variable denoting bank stability like studies by Ali and Puah (2019), Hakimi et al. (2022), Moudud-Ul-Huq (2019), Ozili (2018), Sharma and Anand (2020), U-din et al. (2021) and Zhang et al. (2022).

NPL is an important sign of bank credit risk. It is the ratio of the entire number of non-performing loans held by a bank to the total quantity of loans. The bank's asset quality is shown by the ratio

of NPLs to total loans. Better asset quality is indicated by a low non-performing loan-to-total loan ratio, which enhances financial stability (Ozili, 2018; Zhang et al., 2021). An NPL ratio is used to evaluate the credit risk and loan quality of a bank. A high ratio means the bank stands a substantial risk of losing financially if it is unable to collect the debt, whereas a low ratio means the bank faces less risk from the existing loans.

High non-performing loan levels prevent banks from lending more. Non-performing loans were the only indicator employed for bank stability. This is because several studies conducted on the impact of climate risks highlight this indicator as the main transmitter of risk to the financial sector and stress the key role it plays in the impact climate risks have on the banking industry. In the case of extreme weather events, individuals and industries may lose their property and capacity to generate revenue, affecting their ability to pay back loans taken, eliciting a rise in the risk of default loans the bank faces (Battiston et al., 2021; Brei et al., 2019; Carney, 2015; Chai, 2004; Sutcliffe, 2021; Zhang et al., 2022).

## 3.6 Independent Variables

### 3.6.1 Measuring Climate Change

Greenhouse gas measured in a kiloton and denoted by GHG comprises many gases such as carbon dioxide (which is a major component and emitted through the combustion of fossil fuels and other materials), methane (emitted through the processing of coal, natural gas, and oil and agricultural activities), nitrous oxide (emitted through agricultural and industrial activities) and fluorinated gases made up of nitrogen trifluoride, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. Fluorinated gases are artificial, potent gases emitted through various

domestic, commercial, and industrial operations (EPA, 2022). Greenhouse gases absorb heat emitted from sunlight causing greenhouse effects that lead to global warming and climate change. An increase in industrialization, economic growth, trade openness, population growth, and an increase in the use of non-renewable energy are a few factors cited in the literature that have led to high GHG levels. Some studies have proven that GHG emissions, which lead to climate change, may have lasting effects on various sectors of the economy (Price, 2017; Rezai et al., 2018).

This study also employed the annual surface temperature change measured in degrees Celsius as in the studies by Duan et al. (2022) and Alagidede et al. (2014). This indicator tracks the trends in surface temperatures yearly. Since the preindustrial years, the earth's average temperature has risen by at least 1.1 degrees Celsius because of an increase in GHG emissions from human activities. According to Price (2017), Alagidede et al. (2014), and Zickfeld et al. (2016), abrupt temperature changes lead to an increase in extreme weather events that reduce productivity and output. It was expected that both indicators of climate change have a negative impact on bank performance.

### 3.7 Control Variables

Following the theoretical framework of this study, studies on bank performance by Abaidoo and Agyapong (2022), Fosu (2013), Nyangu et al. (2022), and Yakubu and Bunyaminu (2022) and studies on the impact of climate risks on firm performance by Alvarez (2012), Giang et al. (2021), Laskar et al. (2022), Lee et al. (2015), and Sun et al. (2020), the study controlled for macroeconomic variables and bank-specific variables.

### 3.7.1 Macroeconomic Factors

GDP growth rate is a measurement of a nation's overall economic activity. The profitability and stability of banks are thought to benefit from a good GDP growth rate. According to researchers, loan defaults are typically lower when the economy is growing rapidly, impacting the stability of banks positively. Yakubu and Bunyaminu (2022) and Batten and Vo (2019) found a positive relationship between bank profitability and GDP growth, supporting the argument that a higher GDP growth rate boosts firm performance Chand et al. (2021), Hakimi et al. (2022), Kyei et al. (2022), and Nyangu et al. (2022) furthermore discovered a positive relationship between bank stability and GDP growth rate. In light of this, it was anticipated that GDP growth would have a favorable effect on bank performance.

Inflation accounts for macroeconomic issues affecting bank stability and profitability. In periods where economies face high inflation rates, banks may charge more for the banking services they render to their clients. As a result, most researchers anticipate a positive relationship between bank stability and inflation (Ozili, 2018). On the other hand, Sufian and Habibullah (2009) are of the view that due to the abrupt nature of inflation, the management of banks is unable to adjust and align their rates immediately causing them to earn lesser interest margins. Yakubu and Bunyaminu (2022) and Ozili (2018) found that inflation had a positive impact on bank profitability. On the contrary, in a study by Sufian and Habibullah (2009), inflation was found to harm NIM which was their indicator for profitability. It is expected in this study that inflation may have a positive impact on bank profitability and a negative impact on bank stability.

Unemployment, another macroeconomic factor that influences bank performance, is an essential variable. The assumption is loan defaults are more likely because borrowers are more likely to

request loans when unemployment is high. Due to the difficulty of repaying the principal borrowed and/or any interest that has accrued on the principal due to job loss during periods of high unemployment, the number of defaulted loans is on the rise, which may eventually have an impact on bank stability. On the other hand, Ozili (2018) discovered that non-performing loans and unemployment had a strong inverse relationship. In this study, it is anticipated that unemployment will have a detrimental impact on bank stability.

### 3.7.2 Bank-Specific Factors

Non-interest income to total income denoted by *nintinc* measures efficiency and is the ratio of income earned primarily from fees charged such as account service charges, credit card, and debit card charges, and deposit and transaction fees. Higher bank profits are associated with rises in non-interest revenue and increased profits volatility in addition to profitability. Isshaq et al. (2019) and Park et al. (2019) suggested that non-interest income decreases or has little impact on bank risks and improves the return of banks. Nevertheless, Brei et al. (2019) indicated in their study that extreme weather events resulting from climate change cause a decline in transactions conducted by their clients, which leads to a reduction in their revenue from fees charged on these transactions. In this study, it was anticipated that non-interest revenue would have a favorable effect on bank performance.

The Net Interest Margin, indicated by NIM, was included in models one and two as a control variable. According to Curtis et al. (2013) and Puspitasari et al. (2021), higher levels of net interest margins increase the ROA and ROE of banks. This indicator was employed in the first two models because as the rate of default loans rises, banks are hindered from yielding profits

that are earned from interest on loans which contribute significantly to the overall profits of banks (Zhang et al., 2021). In this study, the NIM is anticipated to increase both ROA and ROE.

Bank size, denoted by *size*, was the most mentioned determinant of bank performance in the literature. Bank size in this study is measured by bank assets to GDP. The extent of financial intermediation in a country's financial system is determined by the size of its banking industry. With a strong regulatory structure in place, large banking industries are expected to be more stable as compared to smaller banking industries (Ozili, 2018). This is due to the belief of some scholars that huge banks enjoy economies of scale and can thus earn marginal cost savings, enhance profitability, and be less susceptible to shocks (Chand et al., 2021; Menicucci & Paolucci, 2016; Sufian & Habibullah, 2009). In examining the impact of climate change on firm performance, studies by Alvarez (2012), Ferrat (2021), Giang et al. (2021), Laskar et al. (2022), Lee et al. (2015), and Sun et al. (2020) identified that the size of firm matters to the firm's financial performance. According to Giang et al. (2021), large firms can invest in cutting-edge technology, diversify more, take advantage of economies of scale, and handle risks more effectively. Therefore, it is anticipated that climate change has less overall impact on large firms. It is expected that bank size has a positive impact on bank profitability and stability.

Bank deposits to GDP denoted by *bd* comprise the total value of demand, time, and saving deposits at domestic deposit money banks as a share of GDP deposit taking constitutes the core of every bank's business. Oleiwi (2020) and Menicucci and Paolucci (2016) discovered that bank deposits have a positive correlation with the profitability of banks. Additionally, a study by Brei et al. (2019) showed that following a hurricane, banks saw an increase in deposit withdrawals and a decrease in the frequency of financial transactions. A positive impact of bank deposits on both bank profitability and stability was expected in this study.

The liquid assets to deposits ratio, denoted by *latd*, measures the liquidity of banks. It shows the proportion of short-term commitments, that in the event of unexpected withdrawals, may be satisfied with the bank's liquid assets. Banks with higher liquidity are assumed to face the risks of low returns on investment, hence unprofitability and bankruptcy (Sahyouni and Wang, 2019). To counteract the negative funding shock caused by extreme weather occurrences, Brei et al. (2019) reported in their study that banks frequently resorted to their liquid assets. However, it was expected in this study that a percentage increase in liquidity may lead to a decrease in bank profitability and stability.

Bank asset concentration is an industry-specific indicator denoted by *bac*. The indicator measures the ratio of the assets of three of the largest commercial banks' total assets of all commercial banks. A study by Jeon and Miller (2011) showed that bank asset concentration positively impacted bank return on equity. On the other hand, a study by Gupta and Mahakud (2020) proved otherwise. Loans, securities, and reserves make up a bank's assets, all of which are subject to a decline in value when the bank encounters climate change issues. Some studies indicated banks experience a decline in their returns from loans or an increase in non-performing loans, a decline in the prices of securities and subsequently its returns, and a deterioration of their liquidity (Beatty & Shimshack, 2010; Brei et al., 2019; Campiglio et al., 2019; Pagnottoni et al., 2022; Zhang et al., 2021). A positive impact of bank asset concentration on bank profitability and stability was anticipated in this research work.

The cost-to-income ratio denoted by *cti* measures the efficiency of the banking industry. It indicates the amount spent by banks to generate revenue. The lower the ratio, the more profitable and productive the bank is deemed to be, and overhead costs denoted by *ohc* measure the value of the operating expenses of banks as a ratio of overall assets. Naceur and Goaied

(2011) indicated that the more overhead costs a bank has, the more profitable it is. Brei et al. (2019), U-din et al. (2021), and Sun et al. (2020) claimed that the losses brought on by climate change can increase the costs and expenses of banks and businesses. Both types of costs were expected to harm bank profitability and stability.

### 3.8 Moderating Variables

#### 3.8.1 Measuring Monetary Policy

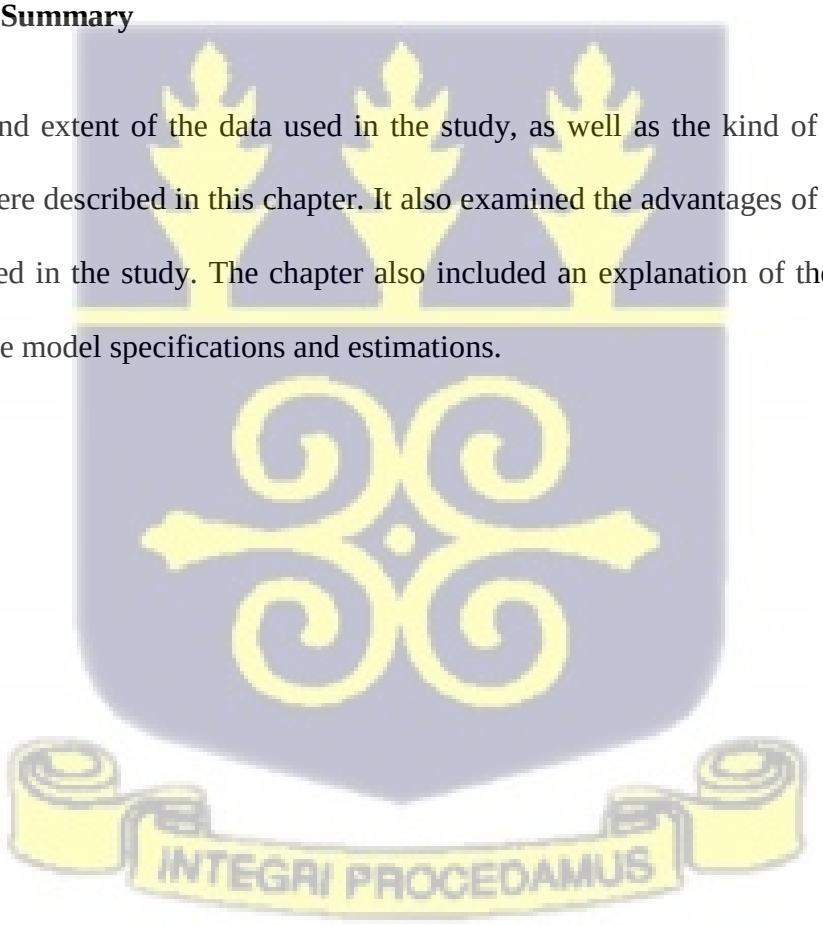
To achieve the third objective, country-level interest rates and broad money were employed based on studies by Qingquan et al. (2020), Bletsas et al. (2022) and Chishti et al. (2021). Real interest rate (lending rate adjusted for inflation) - central banks implement monetary policies by setting policy rates which usually feed into real interest rates (Mathai, 2020). Monetary policy rates were not employed in this study because of the limitation of data availability. Data on monetary policy rates for the sample size used in the study were not available, therefore real interest rates and broad money were employed because both measures are an outcome of monetary policies rates set. When central banks set expansionary monetary policies, it elicits a decrease in real interest rates causing people to borrow more since they can do it at a cost. Thereby increasing the amount of money made available to them. On the other hand, contractionary monetary policies elicit an increase in interest rates causing people to borrow less to avoid paying higher rates, hence reducing the amount of money made available to them. The increase and decrease of the real interest rate affect the spending and borrowing patterns of individuals and firms. Qingquan et al. (2020) and Chishti et al. (2021) found a long significant positive relationship between expansionary monetary policies and carbon dioxide

emissions- an indicator of climate change, and contractionary monetary policies are effective in reducing carbon dioxide emissions.

Broad money (M3) as a percentage of GDP indicates the supply of money in the economy. By setting contractionary monetary policies, central banks tend to decrease the supply of money in an economy. whereas expansionary monetary policies boost the supply of money available in an economy. Bletsas et al. (2022) assert that by carefully and effectively regulating the money supply, central banks may have an impact on greenhouse gas emissions.

### 3.9 Chapter Summary

The nature and extent of the data used in the study, as well as the kind of research design employed, were described in this chapter. It also examined the advantages of the econometric technique used in the study. The chapter also included an explanation of the variables used along with the model specifications and estimations.



# CHAPTER FOUR

# ANALYSIS AND DISCUSSION OF RESULTS

## 4.1 Introduction

The data analysis, findings, discussions, and interpretation of the findings are all included in this chapter. The chapter also provides descriptive statistics, which highlights an overview of the variables in the dataset used, and robustness tests to verify the authenticity and appropriateness of the data and model used. The section also shows the influence climate change can have on banks' performance in Africa, and how monetary policies moderates this impact.

## 4.2 Data Presentation and Analysis of Results

The research provides descriptive statistics, the correlation matrix, and the output from the regression. In this section, the assumptions test for the estimating technique is also covered.

### 4.2.1 Descriptive Statistics

**Table 4.1 Descriptive Statistics**

| Variables | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Return on Assets | 412 | 1.681 | 1.737 | -23.257 | 6.778 |
| Return on Equity | 405 | 16.574 | 10.432 | -18.072 | 78.84 |
| Net Interest Margin | 408 | 5.803 | 2.851 | .281 | 14.105 |
| Non-performing Loans | 238 | 9.863 | 8.958 | .525 | 49.342 |
| Annual Surface Temperature Change | 416 | 1.045 | .421 | -.336 | 2.34 |
| Log of Greenhouse Gases | 440 | 10.041 | 1.55 | 6.254 | 13.237 |
| Real Interest Rate | 332 | 7.237 | 10.818 | -34.743 | 52.437 |
| Broad Money | 426 | 41.923 | 27.247 | 8.483 | 132.069 |
| Non-interest Income to Total Income | 418 | 42.32 | 11.77 | 18.702 | 94.991 |
| Overhead Costs | 414 | 4.839 | 2.404 | .524 | 12.822 |
| Liquid Assets to Total Deposits | 418 | 36.82 | 18.274 | 11.769 | 101.56 |
| Bank size | 425 | 37.042 | 32.147 | 3.87 | 227.14 |
| Costs to Income | 418 | 58.842 | 15.175 | 24.753 | 202.041 |
| Bank Asset Concentration | 418 | 71.767 | 18.138 | 32.521 | 100 |

| | | | | | |
|---|---|---|---|---|---|
| Bank Deposits | 424 | 36.968 | 29.565 | 6.104 | 242.095 |
| Inflation | 434 | 7.359 | 10.577 | -24.847 | 95.409 |
| Unemployment | 429 | 8.607 | 7.364 | .32 | 28.76 |
| GDP growth | 434 | 4.54 | 6.365 | -50.339 | 86.827 |

Table 4.1 shows the descriptive statistics of the data employed in the study. The ROA for the period under study was 1.681 which surpassed the world average of 1.287 within the same period. The mean of ROA portrayed how banks in Africa may produce revenue using a relatively lesser proportion of assets and with policies to extend their services to the unbanked, to increase their income. Similarly, the mean of ROE was 16.574 which is higher than the global mean of 12.607 tells of the level of value banks in Africa create for their shareholders using their investments. Nevertheless, for both ROA and ROE, their standard deviations of 1.737 and 10.432 respectively were slightly less than the global standard deviation of 2.046 and 12.662. This implies that the banking industry in Africa is attractive since the profitability measures have fewer underlying risks.

NIM had a mean of 5.803 which is slightly higher than a global mean of 4.5 and paints a picture of the high demand for loans in Africa. But with a standard deviation of 2.851 slightly higher than that of the global of 2.837, which proves that banks in Africa face higher risks with respect to the payment of interest on loans and the principal amount. The high NIM could be a result of a high loan rate in the loan market. Thus, the banks offer lower interest rates to depositors and charge higher interest rates to borrowers. This confirms the high ROA and ROE reported by the bank during the study period. The high NIM and high standard deviations were the results of African banks investing in risky assets that offer high returns.

The NPL has an average of 9.863 and a standard deviation of 8.958 which are higher than the global mean of 7.064 and a standard deviation of 7.56 which provides evidence of the risks African banks face when it comes to non-performing loans. A high non-performing loan poses a threat to the stability of the banking industry. This is because having a high NPL in the bank's balance sheet hurts its cash flows, as well as its stock price. This is not so surprising since factors such as unemployment, inflation, and other economic issues that fuel NPLs are high in the region.

In terms of climate change variables, the mean annual surface temperature change *(ASTC)* in the region during the period was 1.045. During the period of study, Cape Verde recorded the highest temperature change of 2.34 because of the temperature of 41.5ºc recorded in the year 2017, while Zimbabwe had the least temperature change recorded in 2009. The mean of the log of greenhouse gases (LNGHG) was 10.041 for African countries. The greenhouse gases figure shows that the level of greenhouse gases in the region was relatively low to the global average of 48.9. The level of greenhouse gases in the region was driven by South Africa having the highest greenhouse gas emission of 13.237 in 2014. This is not surprising since South Africa has been a hub of manufacturing companies, with the manufacturing sector recording a growth of 9.5% in 2014. The manufacturing industry has been reported to significantly contribute to the level of greenhouse gas emissions (US Environmental Protection Agency, 2020).

Inflation attained an average of 7.359 and a standard deviation of 10.577 with Libya having the least inflation rate of -24.847 in 2009 and Zimbabwe having the highest inflation rate of 95.409 in 2009 because of a disruption in their economy and sanctions imposed on the country. GDP growth had an average of 4.54 and a standard deviation of 6.365. Libya recorded the least GDP growth rate of -50.339 in 2011. The disruption occurred because of the civil war that happened in the country during the year. This affected their production of oil which was their primary source of

revenue immensely. However, in the next year, the country recorded the highest GDP rate of 86.827. The overthrowing of their president brought some stability to the economy after the war in 2011. This caused oil production to bounce back faster than expected, improving their economy.

Non-interest income to total income averaged 42.32 with a standard deviation of 11.77 mainly driven by the ratio of 73.011 from Libya in 2014. The liquid assets to deposits ratio had a mean of 36.82 and a standard deviation of 18.274 with Libya having the highest ratio of 101.56 in 2014. In 2014, the country faced a renewed conflict situation which affected its economy and resulted in a lack of confidence in its banking system causing a liquidity crisis in the banking industry. The banking industry had to have high liquidity standing to pay off customers who wanted their funds immediately. Bank asset concentration had an average of 71.767 and a standard deviation of 18.138. Ghana recorded the least ratio of 32.52 in 2015, which indicates the competitiveness level amongst banks in the Ghanaian banking industry.

While Burundi, Djibouti, Egypt, Gabon, Guinea, Lesotho, Madagascar, Mozambique, Seychelles, Niger, South Africa, and Togo had the highest ratios of 100 indicating how their banking industries are characterized by monopoly, bank deposit to GDP had an average of 36.968 and a standard deviation of 29.565. Congo recorded the least ratio of 6.104 in 2008. This ratio was explained by the global financial crisis faced in 2008. DR Congo was severely affected during the period. One of the country's major industries, the mining industry, was severely affected because of the fall in global prices of the main commodity they trade, copper.

### 4.2.2 Multicollinearity

The absolute value of the correlation coefficient is used to determine the magnitude of the relationship, and the sign of the coefficient indicates its direction. This, however, fails to demonstrate causality. In this study, the Pearson correlation matrix was employed to identify multicollinearity-related problems. The problem of multicollinearity can have several implications in research. Firstly, multicollinearity inflates the variances of the OLS estimators making accurate estimations difficult. Secondly, multicollinearity elicits inaccurate conclusions due to the widening of confidence margins. In addition, multicollinearity can produce very high $R^2$ , although the t-ratio of coefficients in the model is statistically insignificant. Lastly, estimators and standard errors in a model can become more sensitive to changes as a result of multicollinearity (Gujarati & Porter, 2009).

#### 4.2.2.1 Correlation Matrix

Under Pearson's pairwise correlation, correlation coefficients higher than 0.8 indicate severe multicollinearity. Coefficients equal to or less than 0.5 are more considerable. Table 4.2 presents the correlation coefficients between the variables adopted for the study. From the correlation matrix, ROA and ROE had the highest correlation coefficient of 0.82. This indicates that both variables are highly associated and that they have similar parameters. Therefore, both variables are included in separate models. Followed by a net interest margin and overhead costs of 0.774. Although both variables are highly correlated, both have been included in the study because studies by Cruz-García and Fernández de Guevara (2020), Maudos and Solís (2009), Rjoub et al. (2021),

and Tarus et al. (2012) showed that overhead costs, which are mainly operating expenses, are a major determinant of banks' net interest margin.

Real interest rates and non-performing loans had a strong correlation value of 0.686; however, despite this, both variables were included in the same model since some research showed that when interest rates rise, borrowing costs rise, and those who have previously borrowed face higher repayment costs (Bahruddin & Masih, 2019; Matěj & Petr, 2020; Siddiqui et al., 2012).

***Table 4.2 Pairwise Correlations***

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) roa | 1.000 | | | | | | | | | | | | | | | | | |
| (2) roe | 0.820*** | 1.000 | | | | | | | | | | | | | | | | |
| (3) nim | 0.400*** | 0.286*** | 1.000 | | | | | | | | | | | | | | | |
| (4) npl | 0.074 | 0.113* | 0.310*** | 1.000 | | | | | | | | | | | | | | |
| (5) rir | 0.008 | -0.010 | 0.269*** | 0.686*** | 1.000 | | | | | | | | | | | | | |
| (6) bm | -0.146*** | -0.146*** | -0.548*** | -0.446*** | -0.162*** | 1.000 | | | | | | | | | | | | |
| (7) astc | -0.204*** | -0.240*** | -0.245*** | -0.036 | -0.123** | 0.218*** | 1.000 | | | | | | | | | | | |
| (8) lnghg | -0.134*** | -0.125** | -0.162*** | -0.037 | -0.036 | -0.012 | 0.002 | 1.000 | | | | | | | | | | |
| (9) nintinc | -0.051 | -0.020 | -0.216*** | 0.156** | -0.077 | -0.187*** | -0.132*** | 0.011 | 1.000 | | | | | | | | | |
| (10) size | -0.161*** | -0.232*** | -0.462*** | -0.326*** | -0.119** | 0.645*** | 0.204*** | 0.021 | -0.062 | 1.000 | | | | | | | | |
| (11) bd | -0.113** | -0.132*** | -0.397*** | -0.200*** | -0.004 | 0.637*** | 0.194*** | -0.036 | -0.041 | 0.577*** | 1.000 | | | | | | | |
| (12) latd | -0.077 | -0.045 | 0.012 | 0.200*** | 0.164*** | 0.154*** | -0.060 | -0.154*** | 0.152*** | -0.101** | 0.143*** | 1.000 | | | | | | |
| (13) bac | 0.037 | 0.166*** | -0.110** | 0.057 | 0.001 | 0.123** | 0.001 | -0.248*** | 0.069 | -0.008 | 0.130*** | 0.169*** | 1.000 | | | | | |
| (14) ohc | 0.152*** | 0.064 | 0.774*** | 0.319*** | 0.201*** | -0.635*** | -0.225*** | -0.180*** | 0.144*** | -0.472*** | -0.438*** | -0.031 | -0.114** | 1.000 | | | | |
| (15) cti | -0.121** | -0.284*** | 0.182*** | 0.168** | 0.076 | -0.286*** | -0.010 | -0.118** | 0.251*** | -0.169*** | -0.215*** | -0.072 | -0.053 | 0.500*** | 1.000 | | | |
| (16) inf | 0.220*** | 0.232*** | 0.299*** | 0.134** | -0.477*** | -0.191*** | -0.098** | 0.065 | 0.057 | -0.117** | -0.143*** | 0.131*** | -0.045 | 0.224*** | 0.011 | 1.000 | | |
| (17) unempl | -0.047 | -0.015 | -0.308*** | -0.376*** | -0.206*** | 0.443*** | 0.060 | -0.095** | -0.111** | 0.248*** | 0.324*** | 0.246*** | 0.280*** | -0.362*** | -0.182*** | -0.102** | 1.000 | |
| (18) gdp | 0.053 | 0.067 | 0.134*** | 0.004 | 0.033 | -0.140*** | -0.080* | 0.028 | 0.089* | -0.143*** | -0.103** | 0.000 | -0.100** | 0.155*** | 0.087* | 0.009 | -0.151*** | 1.000 |

**** p<0.01, ** p<0.05, * p<0.1*

*Notes: ASTC: Annual Surface Temperature Change; LNGHG: Log of Greenhouse gases; NINTINC: Non-interest Income to Total Income; SIZE: Bank Size; BD: Bank Deposits; LATD: Liquid Assets to Total Deposits; BAC: Bank Asset Concentration; OHC: Overhead Costs; CTI: Costs to Income; INF: Inflation; UNEMPL: Unemployment; GDP: Gross Domestic Product.*

Furthermore, bank deposits and the size of banks have a correlation value of 0.577. Kagecha (2014) asserted that bigger banks have more market power and are better able to draw bank deposits, which leads to profits. Lastly, the costs-to-income ratio and overhead costs had a correlation value of 0.50. Both variables had similar constituents and were therefore not included in the same model.

### 4.2.3 Diagnostic Tests

For Best Linear Unbiased Estimates (BLUE), it is of utmost importance to select the most appropriate estimation technique for the data employed in the study.

#### 4.2.3.1 Test for Autocorrelation

First, the Woolridge test was employed to test for the presence of autocorrelation in the dataset. The null hypothesis states that there is no first-order autocorrelation present. Therefore, the null tends to be rejected if the p-value of the output is equal to 0.05 or less. Results from Appendix 2 show a p-value of 0.0030 which is less than 0.05; therefore the null hypothesis was rejected as there is autocorrelation present.

#### 4.2.3.2 Test for Heteroscedasticity

The Breusch Pagan Godfrey test presents an indication of heteroscedasticity in the regression model. Heteroscedasticity is a problem that shows that the variance of the error term varies across the coefficients of the regressors. The assumption of homoscedasticity is very relevant in a regression analysis. If violated, it shows that the regression models produce estimates that are

biased and erroneous. From Appendix 3, the p-values of the models adopted were less than 0.05, therefore the null hypothesis is rejected. As a result of the presence of both autocorrelation and heteroscedasticity in the data, the study failed to use the Ordinary Least Square model (OLS) since the presence of the two violated its assumption of the error term having a constant variance, no serial correlation, and an error term uncorrelated to the dependent variable.

#### 4.2.3.3 Hausman Specification Test

To determine which model is more appropriate, the Hausman test was used to compare the fixed effects model and the random effects model. As opposed to the null hypothesis, which states that the preferred model is one with random effects, the alternative hypothesis states that the preferred model is one with fixed effects. The test investigated if the idiosyncratic errors and the regression coefficient of the model are related. There was no association between the two, according to the null hypothesis. A p-value lesser equal to or close to zero indicates that there is a substantial difference between estimators of the Random Effects Model and Fixed Effects Model and therefore the fixed effects model is more appropriate. For results shown in Appendix 3, the most appropriate model is the Fixed Effects since all p-values were less than 0.05. However, due to the presence of autocorrelation and heteroscedasticity, using the Fixed Effects model might produce biases in inaccurate estimates.

#### 4.2.3.4 Cross-Sectional Dependence Test

The final test conducted was the Cross-Sectional Dependence Test. The null hypothesis for the test states that there is no cross-sectional dependence. Therefore, a p-value less than or equal to 0.05 indicated that the null hypothesis should be rejected because data are correlated across panel units, which is the case of this study (see Appendix 4). Therefore, the Panel Corrected Standard Errors (PSCE) was adopted to deal with the issues of autocorrelation, heteroscedasticity, and cross-dependence existing in the data.

### 4.2.4 Analysis and Discussion of Regression Results

#### 4.2.4.1 Impact of Climate Change on Bank Profitability

Table 4.3 presents the regression results on the impact of climate change on bank profitability. In models 2 to 4, annual surface temperature change (ASTC) has a statistically negative significant impact on all indicators of bank profitability at a 1% significance level. In a similar vein, the log of greenhouse gas (LNGHG) had a negative significant impact on ROA and ROE at a 1% significance level and a significantly adverse influence on net interest margin *(NIM)* at a 5% significance level. This means that an increase in ASTC by $1^0$c would lead to a decrease of 0.632, 5.759, and 0.527 percentage points in ROA and ROE, and NIM respectively. An increase in the LNGHG by 1 metric ton leads to a decrease of 0.187, 1.137, and 0.117 percentage points in ROA, ROE, and NIM respectively. This finding confirms that climate change can reduce the profitability of banks. These findings are in line with the theoretical framework of the study, which explains that the disruption that climate change mostly affects bank performance indirectly in industries like manufacturing, agriculture, construction, and real estate.

These results are intuitive because businesses often collaborate with various banks financially to sustain and grow the effectiveness of their operations. These financial engagements include taking loans, depositing, and transferring funds to and from their bank accounts, and investing excess funds in financial instruments. All of which generate income and profit for banks (Gobat, 2017). Studies such as Alvarez (2012), Brei et al. (2019), Huang et al. (2018), Sun et al. (2020), and Zhang et al. (2021) also document that climate change has the ability to distort the financial performance and cash flow of businesses through the destruction of property and operational disruption. They allude to the fact that this can have a significant negative influence on their ability to repay debts, which increases the frequency of bank default loans. Thus, banks forfeit the interest revenue these loans generate. Additionally, businesses may be unable to conduct other non-interest financial operations with the banks, which will also affect their capacity to make money from non-interest-bearing activities.

***Table 4.3 Impact of Climate Change on Bank Profitability***

| | ***(Model 2)*** | ***(Model 3)*** | ***(Model 4)*** |
|---|---|---|---|
| ***Variable*** | ***ROA*** | ***ROE*** | ***NIM*** |
| *ASTC* | -0.632*** | -5.759*** | -0.527*** |
| | (0.195) | (1.106) | (0.203) |
| *LNGHG* | -0.187*** | -1.137*** | -0.117** |
| | (0.0571) | (0.312) | (0.0549) |
| *NINTINC* | 0.0305*** | 0.159*** | -0.0866*** |
| | (0.00973) | (0.0502) | (0.00648) |
| *NIM* | 0.501*** | 2.575*** | |
| | (0.0709) | (0.337) | |
| *SIZE* | -0.00258 | -0.0529*** | -0.00829*** |
| | (0.00449) | (0.0183) | (0.00318) |
| *BD* | 0.00319 | 0.0120 | 0.000156 |
| | (0.00390) | (0.0183) | (0.00305) |
| *LATD* | -0.0189*** | -0.119*** | 0.0102** |
| | (0.00529) | (0.0261) | (0.00458) |
| *BAC* | 0.00203 | 0.0759*** | -0.00313 |
| | (0.00437) | (0.0252) | (0.00442) |
| *OHC* | -0.423*** | -3.002*** | 0.853*** |
| | (0.0879) | (0.394) | (0.0437) |
| *INF* | 0.0266* | 0.205*** | 0.0313*** |

| | | | |
|---|---|---|---|
| | (0.0149) | (0.0515) | (0.00948) |
| *GDP* | 0.00456 | 0.0966 | 0.00396 |
| | (0.00983) | (0.0589) | (0.0117) |
| *CONSTANT* | 2.399** | 25.33*** | 7.020*** |
| | (1.021) | (5.555) | (0.952) |
| *Observations* | 351 | 346 | 352 |
| *R-squared* | 0.308 | 0.369 | 0.746 |
| *Number of years* | 11 | 11 | 11 |

Notes: ***, **, * represent significance levels at 1%, 5%, and 10% respectively. Return on Assets (ROA), Return on Equity (ROE), and Net Interest Margin (NIM) are the dependent variables of this regression result, representing bank profitability. Whiles Annual Surface Temperature Change (ASTC) and log of greenhouse gases (LNGHG) represent the independent variables. Bank-specific control variables are non-interest income to total income (NINTINC), Net Interest Margin (NIM), Bank size (SIZE) measured by total assets to Gdp ratio, Bank deposits (BD), Liquid assets to deposits ratio (LATD), Bank asset concentration (BAC) measured by total assets of 3 largest commercial banks and Overhead costs (OHC). Inflation (INF) and Gross domestic product (GDP) represent macroeconomic variables relevant to the models.

Sutcliffe (2021) explains that extreme weather events caused by climate change may also have an immediate effect on banks by causing their operations to be disrupted, necessitating the suspension of business activities in their retail branches, reducing their revenue, and diminishing their overall profits. Finally trading in securities is another channel through which banks generate revenue. According to Campiglio et al., (2019) Collender et al. (2021), and Painter (2020), climate change increases the costs associated with managing these securities while lowering the benefits received from them, particularly if these securities are owned by carbon-intensive companies that have suffered a decline in the value of their assets or are left with stranded assets. The findings are in support of studies by Batten et al. (2017), Battiston et al. (2021), Bowen and Dietz (2016), Carney, (2015), Dafermos et al. (2018), and Rudebusch (2021) who assert that climate poses risks to the banking industry that can affect its profitability.

Regarding the control variables, an increase in non-interest income to total income (NINTINC) by one percentage point led to an increase in ROA and ROE by 0.0305 and 0.159 respectively. This indicates that an improvement in the income banks earn from non-interest activities improves their profitability. This is consistent with the findings of Sufian and Habibullah (2009), Sufian and Noor Mohamad (2012), and Park et al. (2019) whose studies focused on the determinants of banks' risk

and performance. Nonetheless, an increase in non-interest income to total income (NINTINC) elicited a reduction in NIM by 0.0866. This suggests that when banks charge higher fees for services rendered, it deters consumers from patronizing their services, especially taking loans. For some clients, these fees are a mirror image of interests that may be charged on loans. This finding is contrary to a study by Rahman et al., (2015).

The coefficients of net interest margin *(NIM)* in Models 1 and 2 show a significant positive impact on ROA and ROE. An increase in NIM by one percentage point increased ROA and ROE by 0.501 and 2.575 respectively. NIM served as a factor through which the loan deposit ratio can increase profitability (Puspitasari et al., 2021). Consistent with the finding of this study, Curtis et al. (2013) found a significant positive correlation between NIM and ROA. Furthermore, an increase in bank size (SIZE) by one percentage point leads to a significant decrease in ROE and NIM by 0.0529 and 0.00829 respectively, but an insignificant decrease in ROA by 0.00258. This means that when banks grow in size the costs and expenses accruing to banks increases. These costs and expenses, when not well managed, may harm the profit of banks. The finding of this study is contrary to the findings of studies by Menicucci and Paolucci (2016), Rahman et al. (2015), Sufian and Noor Mohamad, (2012), and Yakubu and Bunyaminu (2022),.

In models 1 and 2, the results show that an increase in liquid assets to deposits (LATD) by one percentage point led to a significant decrease in ROA and ROE by 0.0189 and 0.119 respectively, while significantly increasing NIM by 0.0102. Loans are part of the list of liquid assets, which exposes banks to more credit risk and lowers their profit. However, the rise in NIM shows the effect an increase in loans may have on interest-based profit margins. These findings are similar to the findings of Ali and Puah (2019), Saif-Alyousfi and Saha, (2021), as well as Sufian and Noor Mohamad, (2012). In model 2, bank asset concentration (BAC) is shown to have a significant

positive influence on ROE. An increase in bank asset concentration (BAC) by 1% led to an increase in ROE by 0.0759, an insignificant increase in ROA by 0.002, and an insignificant decrease in NIM by 0.003..

Additionally, the findings reveal that overhead expenses (OHC) significantly reduce the ROA, and ROE while substantially increasing NIM. This implies that banks with larger overhead costs pass on these expenses to clients, increasing their NIMs. According to Naceur and Goaied (2011), banks with high overhead costs (OHC) tend to have higher NIM. All three models provided evidence of the ability of inflation to improve bank profitability. As inflation increased by one percentage point ROA, ROE and NIM significantly increased by 0.03, 0.205, and 0.03 respectively.

This finding suggests that a rise in inflation elicits a rise in bank profitability since banks can adjust their interest rate and pass on any additional costs to their clients. On the contrary, studies by Rahman et al. (2015), as well as Sufian and Habibullah (2009) found a negative impact of inflation on bank profitability. They posited that inflation leads to higher costs than returns. However, the findings of this study are consistent with that of Aburime (2011), Adelopo et al. (2018), Flamini et al. (2009), as well as Naceur and Ghazouani, (2007).

#### 4.2.4.2 The Impact of Climate Change on Bank Stability

Additional findings regarding the effect of climate change on bank performance are shown in Table 4.4. The findings demonstrate that both climate change indicators have varyingly large effects on bank stability as assessed NPLs. An increase in annual surface temperature change (ASTC) by 1ºC led to a significant increase in NPLs by 1.212 percentage points at a 1% significance level, but an

increase in greenhouse gases (GHG) led to a significant decrease in NPLs by 0.217 percentage points at a 10% significance level.

***Table 4.4 The Impact of Climate Change on Bank Stability***

| ***Variables*** | ***(Model 5)*** |
|---|---|
| | ***NPL*** |
| ASTC | 1.212*** |
| | (0.454) |
| LNGHG | -0.217* |
| | (0.130) |
| NINTINC | -0.00491 |
| | (0.0233) |
| BAC | 0.000370 |
| | (0.0139) |
| LATD | 0.0236* |
| | (0.0122) |
| CTI | 0.0132 |
| | (0.0107) |
| RIR | 0.905*** |
| | (0.0250) |
| UNEMPL | 0.127*** |
| | (0.0399) |
| INF | 0.759*** |
| | (0.0394) |
| GDP | 0.00665 |
| | (0.0241) |
| CONSTANT | -5.935*** |
| | (1.998) |
| Observations | 208 |
| Number of years | 11 |
| R-squared | 0.913 |

*Notes: ***, **, * represent significance levels at 1%, 5%, and 10% respectively. Non-performing loans (NPL) are the dependent variable of this regression result representing bank stability. Whiles Annual Surface Temperature Change (ASTC) and log of greenhouse gases (LNGHG) represent the independent variables. Bank-specific control variables are Non-interest income to total income (NINTINC), Bank asset concentration (BAC) measured by the total assets of 3 largest commercial banks, Liquid assets to deposits ratio (LATD), Cost to income ratio (CTI), and Real interest rate (RIR). Unemployment (UNEMPL), Inflation (INF), and Gross domestic product (GDP) represent macroeconomic variables relevant to the model.*



Temperature change, according to Zhang et al. (2021), is the most sensitive feature of climate change and the main cause of extreme weather phenomena such as storms, floods, and droughts.

Based on this study's theoretical framework, studies by Denton and Perrella (2022), Giang et al. (2021), Huang et al. (2018), and Sun et al. (2020), it has been demonstrated that climate change risks caused by these extreme weather events impaired businesses' financial performance, decreasing their capacity and ability to repay loans, which in turn caused banks to deal with a higher proportion of defaulted and non-performing loans — a key sign of instability in the banking industry. This finding is consistent with studies by Chai (2004), Kamran et al. (2020), and Zhang et al. (2021).

But, results on the influence of greenhouse gases (GHG) on NPLs were not what was anticipated and contrary to the trend of this study. Per Ahmed et al. (2022), Qingquan et al. (2020), NASA (2021), and the United States Environmental Protection Agency (2020), a surge in industrialization and other human activities including agriculture, mining, and construction are key factors that contribute to the rise in greenhouse gases (GHG) emissions. Nevertheless, studies by Elfaki et al., (2021) and Ndiaya and Lv, (2018) found that in increase in industrialization can result in an increase in economic growth through job creation, innovation and increased productivity. Anita et al. (2022), Foglia (2022) and Stone (2017) also provide evidence of economic growth having a negative impact on non-performing loans. Therefore, as industries expand and human activities intensify, leading to an increase in economic output and revenue, corporations, industries, and individuals develop better capacities to pay back bank loans, reducing the risks of non- performing loans banks face (Anita et al., 2022; Donor Committee for Enterprise Development, 2021; Stone, 2017).

Concerning the control variables, an increase in real interest rates (RIR) by 1% led to a significant increase in NPLs by 0.905 percentage points at a 1% significance level. A rise in real interest rates raised borrowing costs, making it more challenging for borrowers to repay loans, consequently

increasing the percentage of NPLs. Khemraj and Pasha (2013) as well as Siddiqui (2017) reported that an increase in real interest rates increased the risks of NPLs, which is consistent with the findings of this study. Additionally, a 1% increase in liquid assets to deposits (LATD) led to a 0.0236 increase in NPLs at a 10% significance level. This is due to the higher credit risks associated with NPLs in highly liquid institutions. This result is consistent with research by Abdelaziz et al. (2022).

Furthermore, an increase in inflation (INF) by 1% led to a significant increase in NPLs by 0.759 at a 1% significance level. High inflation rates in an economy increase expenses, lower consumers' purchasing power, and make it more difficult for borrowers to repay bank loans, which increases the number of NPLs. This finding is consistent with the findings of Alnabulsi et al. (2022). Similarly, an increase in unemployment (UNEMPL) by 1% led to a significant increase in NPL by 0.127 at a 1% significance level. This suggests that higher unemployment rates reduce cash flows while raising household debt loads and lowering consumers' purchasing power. This, ultimately, decreases the incentive to produce more goods and services and lowers overall business income, increasing the likelihood of businesses defaulting on loans, and eliciting a rise in NPLs. This finding is consistent with the findings of Alnabulsi et al. (2022), Messai and Jouini (2013), and Ozili (2018).

#### 4.2.4.3 The Moderating Role of Monetary Policy on The Impact of Climate Change on Bank Performance

##### 4.2.4.3.1 Real Interest Rates

Table 4.5 provides evidence of the moderation effect monetary policy has on climate change. After interacting real interest rate (RIR) with annual surface temperature change (ASTC), the results

showed that annual surface temperature change (ASTC) significantly decreased ROA and ROE by 0.0751 and 0.349 respectively at a 5% significance level. This indicates the reduction in the magnitude of impact annual surface temperature change (ASTC) has on both indicators of bank profitability. The interaction, however, led to an increase in NIM by 0.0196, although this effect is insignificant.

An interaction with greenhouse gases (LNGHG) also goes further to prove that real interest rate (RIR) can indeed have a role to play in the impact climate change has on bank profitability. After the interaction, greenhouse gases (LNGHG) reduced the ROA by 0.0184 but increased the ROE and NIM by 0.120 and 0.00463, respectively. The effect of the interaction on ROA and NIM was, however, insignificant but significant for ROE at a 10% significance level. The table also shows that the impact of the interaction of annual surface temperature change (ASTC) with a real interest rate (RIR) on NPLs is insignificant. While interaction with greenhouse gases (LNGHG) caused a significant reduction of 0.0526 in NPL at a 5% significance level.

These results are apparent because, as real interest rates rise, it is generally believed that the return on interest margins between interest on loans and interest on deposits tends to grow. Based on the results of this study, its influence is estimated to be subdued because a rise in real interest rates can lead to a decrease in the maximum volume of loans issued in the banking industry while simultaneously managing an increase in costs spent to minimize the impact of annual surface temperature change (ASTC). Due to this, banks' profitability and stability typically suffer even as interest rates rise because of growing costs brought on by climate change and the rate of NPLs, which is not considerably influenced. As a result, utilizing real interest rates as a tool to counteract the impact that annual surface temperature change (ASTC) would have on bank stability and profitability becomes difficult (Pérez & Pérez, 2018).

***Table 4.5 The Role Real Interest Rate (Monetary Policy) Plays in Moderating the Impact of Climate Change on Bank Performance***

| *Variables* | *Model (6)* | *Model (7)* | *Model (8)* | *Model (9)* | *Model (10)* | *Model (11)* | *Model(12)* | *Model(13)* |
|---|---|---|---|---|---|---|---|---|
| | *ROA* | *ROA* | *ROE* | *ROE* | *NIM* | *NIM* | *NPL* | *NPL* |
| ASTC | -0.171 | | -3.848** | | -0.802*** | | 0.850* | |
| | (0.282) | | (1.605) | | (0.277) | | (0.511) | |
| RIR | 0.0633** | 0.191 | 0.367** | -1.147* | 0.0219 | -0.000852 | 0.839*** | 1.451*** |
| | (0.0295) | (0.135) | (0.148) | (0.595) | (0.0251) | (0.0918) | (0.0558) | (0.247) |
| ASTC× RIR | -0.0751** | | -0.349** | | 0.0196 | | 0.0728 | |
| | (0.0316) | | (0.157) | | (0.0271) | | (0.0534) | |
| NINTINC | 0.0351*** | 0.0433*** | 0.220*** | 0.246*** | -0.0839*** | -0.0872*** | -0.00826 | 0.000 |
| | (0.0122) | (0.0120) | (0.0620) | (0.0607) | (0.00752) | (0.00706) | (0.0234) | (0.0228) |
| NIM | 0.568*** | 0.557*** | 3.027*** | 2.958*** | | | | |
| | (0.0934) | (0.0878) | (0.420) | (0.411) | | | | |
| SIZE | -0.000655 | -0.00384 | -0.0434** | -0.0571*** | -0.00505 | -0.00568* | | |
| | (0.00523) | (0.00497) | (0.0208) | (0.0217) | (0.00347) | (0.00335) | | |
| BD | 0.00300 | 0.00354 | 0.0150 | 0.0178 | -0.00379 | -0.00463 | | |
| | (0.00500) | (0.00494) | (0.0227) | (0.0238) | (0.00369) | (0.00360) | | |
| LATD | -0.0179*** | -0.0206*** | -0.124*** | -0.132*** | 0.00166 | 0.000951 | 0.0282** | 0.0253** |
| | (0.00634) | (0.00653) | (0.0299) | (0.0304) | (0.00519) | (0.00515) | (0.0117) | (0.0118) |
| BAC | 0.00763 | 0.00266 | 0.133*** | 0.105*** | 0.00354 | 0.00150 | 0.00414 | -0.00213 |
| | (0.00540) | (0.00518) | (0.0284) | (0.0297) | (0.00480) | (0.00481) | (0.0141) | (0.0136) |
| OHC | -0.447*** | -0.477*** | -3.432*** | -3.734*** | 0.809*** | 0.790*** | | |
| | (0.108) | (0.101) | (0.469) | (0.470) | (0.0478) | (0.0473) | | |
| CTI | | | | | | | 0.0157 | 0.0154 |
| | | | | | | | (0.0106) | (0.0103) |
| UNEMPL | | | | | | | 0.127*** | 0.135*** |
| | | | | | | | (0.0398) | (0.0375) |
| INF | 0.00979 | 0.0254 | 0.164** | 0.284*** | 0.0497*** | 0.0578*** | 0.763*** | 0.751*** |
| | (0.0246) | (0.0232) | (0.0802) | (0.0822) | (0.0147) | (0.0138) | (0.0399) | (0.0370) |
| GDP | 0.00289 | 0.00439 | 0.0819 | 0.103* | -0.000131 | 0.00328 | 0.00618 | 0.00310 |
| | (0.0110) | (0.0101) | (0.0601) | (0.0580) | (0.0113) | (0.0111) | (0.0239) | (0.0230) |
| LNGHG | | -0.0549 | | -1.716*** | | -0.169** | | 0.101 |
| | | (0.0915) | | (0.498) | | (0.0767) | | (0.173) |
| LNGHG×RIR | | -0.0184 | | 0.120** | | 0.00463 | | -0.0526** |
| | | (0.0133) | | (0.0578) | | (0.00892) | | (0.0236) |
| CONSTANT | -0.776 | -0.198 | 4.328 | 20.19*** | 5.609*** | 6.815*** | -8.360*** | -8.342*** |
| | (0.802) | (1.402) | (4.148) | (7.225) | (0.634) | (1.093) | (1.165) | (2.217) |
| Observations | 282 | 304 | 278 | 300 | 283 | 305 | 208 | 220 |
| R-squared | 0.285 | 0.277 | 0.387 | 0.337 | 0.743 | 0.756 | 0.912 | 0.911 |
| Number of year | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |

Nevertheless, results on the interaction between greenhouse gases (GHG) and real interest rate (RIR) indicated that real interest rate (RIR) played a more significant role in moderating the impact of greenhouse gases (GHG) on NPL. Per Chishti et al. (2021) and Qingquan et al. (2020), an increase in real interest rates (RIR) owing to contractionary policies implemented by central banks first reduces the income of businesses and individuals as a result of a decrease in lending and consumption power. This reduces the incentive of industries to produce goods (leading to a reduction in the use of fossil fuels and greenhouse gas (GHG) emissions) and to borrow from banks (Bletsas et al., 2022; Isiksal et al., 2019). As a result, there will be fewer bank loans, which tend to lower the banks' credit risks and maintain the stability of the banking industry. This finding is specifically consistent with the findings of Chishti et al. (2021) and Qingquan et al. (2020).

Nonetheless, studies provide evidence of a significant inverse relationship between NPLs and ROE. The more NPLs banks hold in their books, the higher their liquidity risks and the more they run at a risk of bankruptcy leaving them incapable to pay-back their shareholders. Therefore, the lower the NPLs hold, the higher their return on shareholders' equity (Jolevski, 2017; Khan et al., 2020; Ozurumba, 2016; Vellanita et al., 2019).

#### 4.2.4.3.2 Broad Money

Table 4.6 presents further clarity on how expansionary or contractionary monetary policies by central banks moderate the impact of climate change on bank performance. An increase in the interaction between annual surface temperature change (ASTC) and broad money (BM) by 1% led to 0.00149, 0.00112, and 0.00599 percentage points increase in ROA, ROE, and NIM respectively. Unexpectedly, it also increases NPL by 0.0278 percentage points. However, these

are all insignificant. This finding shows that even though the supply of money may mitigate the effects of annual surface temperature change (ASTC) on bank performance, its role may, ultimately, prove ineffective due to the weak transmission channels through which monetary policies in Africa can mitigate climate change risks. This is a result of the region's underdeveloped financial markets and institutional constraints. These transmission mechanisms may only continue to deteriorate over time with unchecked climate concerns (Boneva et al., 2022; Modugu & Dempere, 2022; Schnabel, 2021).

Furthermore, a 1% increase in the interaction between greenhouse gases (LNGHG) and broad money (BM) led to an insignificant increase of 0.00314 and 0.00990 in ROA and ROE respectively but caused NIM to significantly increase by 0.00552 at a 1% significance level and an insignificant decrease in NPL by 0.00235. This suggests that when a central bank adopts policies that increase the supply of money in an economy, it increases total lending and purchasing power. This encourages industries to produce more to satisfy the rise in demand, which raises their income and improves their capacity to repay borrowed money. Banks receive larger returns on their loans as a result (Winarso et al., 2020).

***Table 4.6 The Role Broad Money (Monetary Policy) Plays in Moderating the Impact of Climate Change on Bank Performance***

| *Variables* | *Model (6)* | *Model (7)* | *Model (8)* | *Model (9)* | *Model (10)* | *Model (11)* | *Model(12)* | *Model(13)* |
|---|---|---|---|---|---|---|---|---|
| | *ROA* | *ROA* | *ROE* | *ROE* | *NIM* | *NIM* | *NPL* | *NPL* |
| ASTC | -0.657* | | -5.464** | | -0.805** | | -0.170 | |
| | (0.369) | | (2.224) | | (0.395) | | (1.045) | |
| BM | 0.00659 | -0.0233 | 0.0261 | -0.0685 | -0.0223** | -0.0712*** | -0.0333 | 0.0205 |
| | (0.0103) | (0.0202) | (0.0542) | (0.118) | (0.00898) | (0.0178) | (0.0216) | (0.0446) |
| ASTC×BM | 0.00149 | | 0.00112 | | 0.00599 | | 0.0278 | |
| | (0.00590) | | (0.0366) | | (0.00638) | | (0.0176) | |
| NINTINC | 0.0359*** | 0.0375*** | 0.182*** | 0.228*** | -0.0907*** | -0.0947*** | 0.000913 | -0.00913 |
| | (0.0102) | (0.00963) | (0.0538) | (0.0527) | (0.00652) | (0.00593) | (0.0265) | (0.0240) |
| NIM | 0.536*** | 0.519*** | 2.725*** | 2.693*** | | | | |
| | (0.0706) | (0.0677) | (0.347) | (0.345) | | | | |
| SIZE | -0.00342 | -0.00577 | -0.0517** | -0.0681*** | -0.00246 | -0.00336 | | |
| | (0.00519) | (0.00484) | (0.0208) | (0.0210) | (0.00362) | (0.00345) | | |
| BD | 0.00115 | 0.000671 | 0.00575 | -0.00122 | 0.00312 | 0.00284 | | |
| | (0.00413) | (0.00386) | (0.0193) | (0.0195) | (0.00322) | (0.00306) | | |
| LATD | -0.0195*** | -0.0206*** | -0.118*** | -0.125*** | 0.0138*** | 0.0146*** | 0.0255** | 0.0260** |
| | (0.00564) | (0.00554) | (0.0275) | (0.0278) | (0.00465) | (0.00444) | (0.0121) | (0.0123) |
| BAC | 0.00617 | 0.000444 | 0.104*** | 0.0758*** | 0.000666 | -0.00468 | 0.000468 | 0.00262 |
| | (0.00436) | (0.00439) | (0.0243) | (0.0265) | (0.00413) | (0.00430) | (0.0142) | (0.0143) |
| OHC | -0.394*** | -0.397*** | -2.820*** | -2.900*** | 0.819*** | 0.828*** | | |
| | (0.0908) | (0.0846) | (0.403) | (0.401) | (0.0458) | (0.0429) | | |
| INF | 0.0233 | 0.0256* | 0.182*** | 0.196*** | 0.0274*** | 0.0276*** | 0.751*** | 0.755*** |
| | (0.0148) | (0.0145) | (0.0518) | (0.0536) | (0.00918) | (0.00892) | (0.0430) | (0.0420) |
| GDP | 0.00562 | 0.00781 | 0.103* | 0.111* | 0.00195 | 0.00465 | 0.00161 | -0.000607 |
| | (0.0102) | (0.00977) | (0.0613) | (0.0605) | (0.0113) | (0.0111) | (0.0245) | (0.0238) |
| LNGHG | | -0.353*** | | -1.495* | | -0.433*** | | -0.0927 |
| | | (0.133) | | (0.774) | | (0.118) | | (0.311) |
| LNGHG×BM | | 0.00314 | | 0.00990 | | 0.00552*** | | -0.00235 |
| | | (0.00191) | | (0.0112) | | (0.00170) | | (0.00466) |
| CTI | | | | | | | 0.0158 | 0.0136 |
| | | | | | | | (0.0112) | (0.0120) |
| RIR | | | | | | | 0.900*** | 0.895*** |
| | | | | | | | (0.0274) | (0.0266) |
| UNEMPL | | | | | | | 0.136*** | 0.133*** |
| | | | | | | | (0.0406) | (0.0394) |
| CONSTANT | -0.548 | 2.896* | 7.865* | 18.75* | 6.401*** | 10.42*** | -7.068*** | -5.848* |
| | (0.784) | (1.644) | (4.427) | (9.699) | (0.696) | (1.452) | (1.632) | (3.320) |
| Observations | 351 | 374 | 346 | 369 | 352 | 375 | 207 | 219 |
| R-squared | 0.293 | 0.293 | 0.346 | 0.299 | 0.752 | 0.769 | 0.912 | 0.909 |
| Number of years | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |

Notes: ***, **, * *represent significance levels at 1%, 5%, and 10% respectively. ASTC× BM and LNGHG × BM measure how broad money (BM) can moderate the impact of annual surface temperature change (ASTC) and greenhouse gases (GHG) on bank performance.*

# CHAPTER FIVE

# SUMMARY, CONCLUSION, AND RECOMMENDATIONS

## 5.1 Introduction

The final chapter of the study presents a summary of findings drawn from the results of the study. It also provides a conclusion obtained from the summary of findings, recommendations, and recommendations for further research.

## 5.2 Summary

The aim of this research was to first evaluate the outcome of climate change on bank profitability in Africa, which according to studies, is the most susceptible region in the world to climate change. The study sought to ascertain further the influence of climate change on bank stability in Africa, and finally ascertain the role monetary policy by central banks plays on the impact of climate change on bank performance. The study adopted the Panel Corrected Standard Errors to analyze data from forty (40) African countries over an eleven (11) year period.

First, the study's findings showed that climate change proxied by greenhouse gas and annual surface temperature change has the potential to have a substantial detrimental influence on bank profits in Africa. This implies that as more greenhouse gases are released causing extreme temperature changes and extreme weather events, the profitability of banks, as measured by ROA, ROE, and NIM, may be adversely affected. This, according to reports and studies, is mostly indirect, happening mostly through the impact of climate change on customers of banks.

However, depending on the sort of proxy employed for climate change, the influence of climate change on bank stability, as measured by non-performing loans, yielded varied outcomes. The results showed that the probability of non-performing loans for banks increased because of climate change as measured by yearly surface temperature change. Conversely, a rise in greenhouse gases lowered the risks associated with non-performing loans. This indicates that the more firms and individuals participate in productive activities that create more greenhouse gases, the more they may make money and pay back bank loans.

Furthermore, the findings indicated that monetary policy by the central bank can regulate the impact climate change may have on the performance of banks. Incorporating monetary policy proxied by real interest rate into the models reduced the magnitude of impact climate change proxied by annual surface temperature change had on ROA and ROE significantly, as long as the magnitude of impact on Non-performing Loans insignificantly. Nevertheless, the study indicates that the interaction term increased the Net Interest Margin, but insignificantly.

Finally, additional proof of the moderating influence of climate change on bank performance was provided by the interaction between greenhouse gases and real interest rates. The results showed that the negative impact of climate change on ROA fails to be significantly moderated by real interest rates. Net Interest Margin does, however, barely increase because of the real interest rate. Real interest rates did, however, result in a significantly higher Return on Equity and a significantly lower number of Non-Performing Loans. Also, the study provides additional evidence of broad money having the ability to significantly moderate the impact of greenhouse gases on only net interest margin.

The financial distress caused to the banking sector happening because of climate change not only makes it less resilient but can lead to a credit crunch, reducing the availability of credit for businesses and individuals, and increase the cost of borrowing for businesses. This can hamper economic growth and job creation. The credit crunch can also limit investment in critical sectors of the economy, such as infrastructure, manufacturing and services, agriculture, energy, transport, health, private enterprises, and education. If banks face substantial losses due to climate change, they may require government support or bailout packages. This can strain government finances, potentially leading to increased deficits or reduced spending in other critical areas. Climate change impacts often disproportionately affect vulnerable populations. If banks reduce lending or insurance availability in high-risk areas, it can exacerbate economic inequalities within a country, as those with fewer resources may find it even more challenging to access financial services and recover from climate-related events.

### 5.3 Conclusion

Several studies provide evidence of the harm climate change (which occurs because of an increase in greenhouse gas emissions), annual surface temperature change, and global warming can have on several sectors in African economies. Additionally, numerous studies have delved into the various risks banks face and the elements that result in the banks' performance in Africa.

However, the impact climate change may have on the performance of banks in Africa is barely investigated. The study showed that as the risks associated with climate change continue to increase, the profitability of banks in Africa indicated by ROA, ROE, and NIM can be negatively affected, while instability in the banking industry represented by non-performing loans increases. Nonetheless, a relevant monetary policy implemented by central banks can control the emissions

of greenhouse gases that result in climate change and the magnitude of impact climate change can have on banks in Africa. But it is of utmost importance that central banks utilize more useful and appropriate transmission mechanisms to ensure the effectiveness of these policies.

## 5.4 Recommendations

### 5.4.1 Policy Recommendations

Based on the results and findings drawn, the study recommends that banks must perform a thorough assessment of how physical risks (for example damage of assets and properties as a result of extreme weather events), transitional risks (for example financial losses from high exposure to high-carbon industries in a low-carbon economy), and losses from reputational risks, credit risks, market risks and operational risks emanating from climate change can affect their operations. Consequently, central banks must require banks to conduct climate risk assessments and disclose their exposure to climate-related risks. Disclosure should be standardized to facility comparability. Central banks need to make it a must for banks to perform climate stress tests and scenario analyses to help them evaluate how resilient their portfolios and operations can be in various climate scenarios. Central banks can also work with relevant authorities and standard-setting bodies to develop and promote climate-related reporting standards that will guide banks in how to resilient systems. Additionally, central banks can encourage banks to invest in environmentally friendly and sustainable financial ventures, such as renewable energy projects, energy-efficient infrastructure, and sustainable bonds, and give incentives to businesses to go green. Central banks can offer preferential conditions for banks taking part in these initiatives. Furthermore, the systemic effects of climate change should be studied and analyzed by central banks, and the financial industry should be informed of their results. This can aid banks in managing and better

understanding climatic risk. Finally, Central banks can provide guidance and training to banks on green finance practices and sustainable lending and investment strategies.

### 5.4.2 Future Research Recommendation

Future research can be conducted to ascertain whether other indicators of climate change like the number of disasters can lead to the same results achieved in this study. Other forms of monetary policies may be adopted to determine other means through which the central banks can moderate the effect of climate change on bank performance.

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## APPENDIXES

### *APPENDIX 1: DESCRIPTION OF DATA AND SOURCES*

| Variables | Definition | Source |
|---|---|---|

| | | |
|---|---|---|
| **Bank Profitability** | | |
| Return on Assets | Percentage of commercial banks' net income to annual average total assets | Global Financial Development Database |
| Return on Equity | Percentage of commercial banks' net income to annual average equity | Global Financial Development Database |
| Net Interest Margin | The value of commercial banks' net interest as a percentage of their average interest-bearing assets | Global Financial Development Database |
| **Bank Stability** | | |
| Non-performing loans | Percentage of defaulting loans to total gross loans | Global Financial Development Database |
| **Climate Change** | | |
| Greenhouse gas emissions | Total greenhouse gas emissions measured in kilotons (kt) | World Bank Indicators |
| Annual surface temperature change | Mean surface temperature change for each year | IMF Climate Change Dashboard |
| **Monetary Policy** | | |
| Real Interest Rates | The lending interest rate with which inflation has been accounted for | World Bank Indicators |

| | | |
|---|---|---|
| Broad Money (% of GDP) | The amount of money in circulation in an economy | World Bank Indicators |
| **Macroeconomic Variables** | | |
| GDP Growth | The sum of all finished goods and services produced in a country | World Bank Indicators |
| Inflation | A measure of the rate of increase in prices of goods and services | World Bank Indicators |
| Unemployment | Rate of the number of people who are employable and actively seeking employment but unable to find any | World Bank Indicators |
| **Bank Specific Variables** | | |
| Liquid assets to deposits ratio | Percentage of the value of liquid assets to short-term funds and total deposits | Global Financial Development Database |
| Non-Interest Income to Total Income | Income generated from banks' non-interest activities | Global Financial Development Database |
| Overhead Costs to total assets | Banks' operating expenses as a percentage of the value of all assets | Global Financial Development Database |
| Bank asset concentration | Assets of the three largest commercial banks as a percentage of total commercial banks' assets | Global Financial Development Database |

| | | |
|---|---|---|
| Bank deposits to GDP | Percentage of all types of deposits as a share of GDP | Global Financial Development Database |
| Costs to income ratio | Operating expense as a percentage of the total net-interest revenue and other income | Global Financial Development Database |

***APPENDIX 2:AUTO CORRELATION TEST***

Test For Autocorrelation

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
F( 1, 19) = 11.587
Prob > F = 0.0030

***APPENDIX 3: TEST FOR HETEROSCEDASTICITY***

Breuschâ€“Pagan/Cookâ€“Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of roa
H0: Constant variance
chi2(1) = 837.55
Prob > chi2 = 0.0000

Breuschâ€“Pagan/Cookâ€“Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of roe
H0: Constant variance
chi2(1) = 7.01
Prob > chi2 = 0.0081

Breuschâ€“Pagan/Cookâ€“Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of nim

H0: Constant variance
chi2(1) = 91.88
Prob > chi2 = 0.0000

Breuschâ€“Pagan/Cookâ€“Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of npl
H0: Constant variance
chi2(1) = 62.35
Prob > chi2 = 0.0000

## *APPENDIX 4: TEST FOR FIXED EFFECT OR RANDOM EFFECT*

**Hausman (1978) specification test**

| | Coef. |
|---|---|
| Chi-square test value | 29.001 |
| P-value | .002 |

**Hausman (1978) specification test**

| | Coef. |
|---|---|
| Chi-square test value | 23.016 |
| P-value | .018 |

**Hausman (1978) specification test**

| | Coef. |
|---|---|
| Chi-square test value | 71.601 |
| P-value | 0 |

**Hausman (1978) specification test**

| | Coef. |
|---|---|

| | |
|---|---|
| Chi-square test value | 22.658 |
| P-value | .031 |

***APPENDIX 5: CROSS-SECTIONAL DEPENDENCE TEST***

| Variable | CD-test | p-value | average joint T | mean ρ | mean abs(ρ) |
|---|---|---|---|---|---|
| roa | 4.529 | 0.000 | 9.65 | 0.05 | 0.34 |

| Variable | CD-test | p-value | average joint T | mean ρ | mean abs(ρ) |
|---|---|---|---|---|---|
| roe | 10.899 | 0.000 | 9.32 | 0.13 | 0.38 |

| Variable | CD-test | p-value | average joint T | mean ρ | mean abs(ρ) |
|---|---|---|---|---|---|
| roe | 10.899 | 0.000 | 9.32 | 0.13 | 0.38 |

| Variable | CD-test | p-value | average joint T | mean ρ | mean abs(ρ) |
|---|---|---|---|---|---|
| npl | -.838 | 0.402 | 10.55 | -0.01 | 0.09 |