The Impact of Climate Change on the Financial Sector

A study on the banks listed on the Nairobi Securities Exchange

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Submitted in partial fulfillment of the requirements for the Degree of

Bachelor of Business Sciences in Financial Engineering at Strathmore University

Strathmore Institute of Mathematical Sciences

Strathmore University

Nairobi, Kenya

August 2024

DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the Research Project contains no material previously published or written by another person except where due reference is made in the Research Project itself.

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ACKNOWLEDGEMENTS

First and foremost, I give praise and thanks to God Almighty for His blessings and favor upon me and for the grace and strength to start and complete this research project successfully.

I wish to express my sincere gratitude to Dr. Sebastian Kaweto for his wise counsel and academic guidance throughout the process.

I am extremely thankful to my mum and my siblings for their love, prayers, and sacrifices for my education. I am also deeply grateful to my friends and colleagues who have walked this journey with me until the end.

ABASTRACT

Climate change is reshaping the global financial landscape, presenting significant challenges and opportunities for Kenya's banking sector. This study investigates the financial performance and stability of the 10 banks listed on the Nairobi Securities Exchange, analyzing data from 2009–2023 using descriptive analysis and dynamic panel estimation through the Generalized Method of Moments (GMM). The findings reveal that larger banks are disproportionately exposed to credit defaults, stranded assets, and collateral devaluation due to their extensive lending portfolios and greater exposure to vulnerable sectors, while smaller banks face relatively lower risks. Limited investment in climate-smart practices across public and private sectors exacerbates these challenges, disrupting credit flows to high-risk industries and increasing credit risk. Despite these challenges, green finance emerges as a critical opportunity, offering banks a pathway to mitigate risks, improve financial performance, and drive sustainable development. This research underscores the urgent need for targeted resilience strategies, enhanced regulatory frameworks, and greater investment in climate-smart initiatives to safeguard Kenya's banking sector while capitalizing on emerging opportunities for sustainable growth and financial stability

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LIST OF ABREVIATIONS

ASALs: Arid and Semi-Arid Lands

BI: Bank for International Settlements

BOE: Bank of England

CAPM: Capital Asset Pricing Model

ESG: Environmental, Social, and Governance

GOK: Government of Kenya

GHG: Greenhouse Gas

IMF: International Monetary Fund

NDC: Nationally Determined Contribution

TCO2: Tons of Carbon Dioxide

UN: United Nations

WBG: World Bank Group

GMM: Generalized Methods of Moments

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CHAPTER ONE

INTRODUCTION

1.1 Background

In recent years, climate change risks have become a major concern for investors. Studies show that these risks play a crucial role in investment decisions for both private and institutional investors (Krueger, Sautner, & Starks, 2019; Reboredo & Otero, 2021) and influence the pricing of financial assets (Bolton & Kacperczyk, 2021; Ilhan, Sautner, & Vilkov, 2020; Monasterolo & De Angelis, 2020). Climate change risks come in two forms: natural disasters (physical risk) and changes in regulations, technology, or consumer preferences aimed at reducing carbon emissions (transition risk).

Physical risks, such as natural disasters, can impact firm values based on their exposure at the time of the disaster. Transition risks, on the other hand, are more complex as they depend on how firms manage the costs associated with climate change over time.

Research suggests that greenhouse gas (GHG) emissions are a significant driver of global temperature increases and the rise in extreme weather phenomena (Hansen, 1980; Hulmer, 1996; Adams et al, 1998). These environmental shifts negatively impact on the economy by reducing agricultural productivity, curtailing consumption, diminishing investments, and lowering overall economic output (Stern, 2007; Schlenker and Roberts, 2009; Dell et al., 2014; Ericksen, 2008). Reducing or eliminating GHG emissions requires comprehensive policy reform, innovative technology, and changes in consumer habits, which lead to alterations in production processes (Campiglio et al., 2018). These shifts can either boost economic growth or result in substantial financial losses for businesses (BIS, 2021a; Caldecott, 2018; Meinshausen). The resultant economic adjustments can undermine financial stability by increasing the likelihood of loan defaults and prompting the revaluation of asset portfolios (Monasterolo, 2020; Van der Ploeg and Rezai, 2020; Semieniuk et al., 2021).

1.2 The impact of Climate Change on Financial Institutions

Climate change poses a long-term threat to the global economy. Developing countries are most vulnerable to climate-related physical risks, yet they have limited strategies to mitigate and cope with these risks (Bank of International Settlements (BIS), 2021a; Eckstein, 2021; Grippa, Schmittmann, and Suntheim, 2019). The 2015 Paris Agreement aims to strengthen global responses to climate change by limiting global warming to below 2 degrees Celsius and transitioning to low or net-zero greenhouse gas emissions (GHG) by 2050 (United Nations, 2015). Financial institutions are expected to play a crucial role in this transition by providing sustainable climate financing and managing climate-related risks (Carney, 2015; Demakas and Grippa, 2021). Banks, in particular, are tasked with mobilizing and allocating capital for green initiatives (BIS, 2021a; Bank of England (BOE), 2013). However, banks are exposed to climate-related physical and transition risks either directly through the balance sheets of households and climate-sensitive sectors or indirectly through the effects of climate change on the broader economy and financial system (Grippa et al., 2019; Carney 2015). The rapidly evolving landscape of sustainable climate financing also poses financial stability risks (BIS, 2021a; 2021b).

The increase in extreme weather events negatively affects the stability of banks and insurers directly, given the specific nature of their businesses. Insurers are directly impacted because they cover losses on physical assets and property. A climate-induced disaster can lead to:

1. An exposure effect if banks or other financial firms are creditors or counterparties to the insurance companies for example.

2. An asset liquidation effect, where insurers might be forced to sell assets at low prices to pay large claims, causing a decline in asset values that negatively affects the portfolios of banks and other financial firms.

Banks are also directly exposed to physical risks, as these events reduce borrowers' ability to repay loans and decrease the value of damaged assets, affecting the banks' capacity to recover loan values if the assets are used as collateral. Extreme weather events may also cause liquidity issues by prompting banks' counterparties to withdraw deposits and draw on credit lines. The shock can spread from banks to insurers and other financial institutions through the exposure and asset liquidation effects.

Moreover, banks are exposed to climate change impacts on non-financial firms because they invest in securities issued by these firms, whose values might be affected by climate-induced disasters and climate policies. The performance of these financial contracts, mainly shares/stocks and bonds, can be influenced by extreme events and the design and implementation of climate policies, thereby affecting the value of banks and insurers' assets.

1.3 Overview of Climate-Related Risks in Kenya: Key Insights and Stylized Facts

Climate change is dramatically altering the landscape and livelihoods in Kenya. Regions like Western Kenya, Nyanza, and the Rift Valley have experienced severe flooding, displaced thousands and causing extensive property damage. The Kenya Red Cross Floods and Impact and Intervention 2024 report states that since the March-April-May rains began, over 101,132 households have been affected by floods. Meanwhile, other parts of Kenya are enduring prolonged droughts. The arid and semi-arid lands (ASALs) are particularly vulnerable, with water shortages impacting agriculture and livestock, which are crucial to local economies. The 2023 drought was especially harsh, with the International Rescue Committee projecting that about 5.4 million people would face severe food insecurity between March and June 2024, with 1.22 million likely to be in an emergency phase. This represents a 43% increase in people facing high levels of food insecurity compared to the same period in 2022.

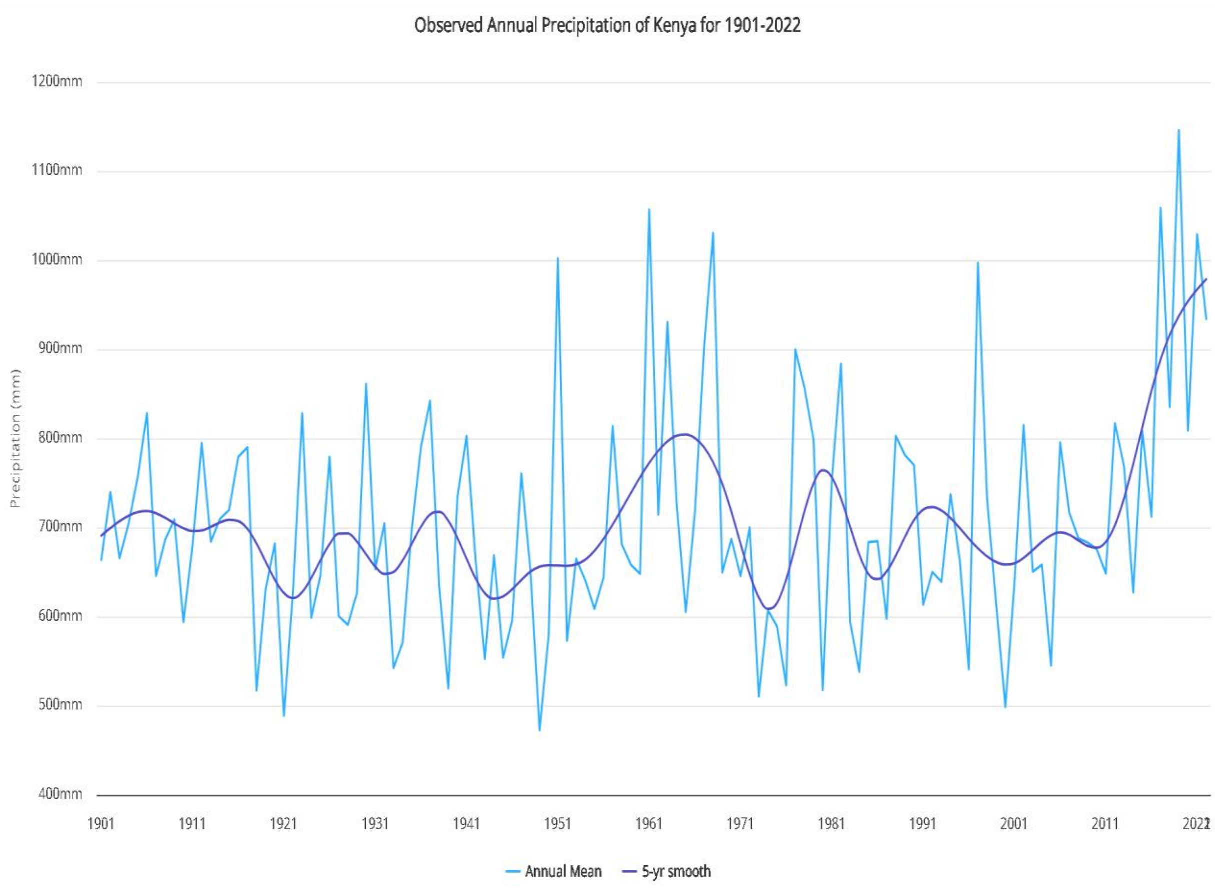
Global warming is causing more erratic weather patterns, making it difficult for farmers to plan their planting and harvesting seasons. This unpredictability has led to reduced crop yields and increased food insecurity, further straining the nation's resources.

1.3.1 Precipitations

Precipitation has been highly erratic with variable rainfall patterns and amounts. These changes have resulted in more frequent and extreme weather events ranging from droughts, floods and landslides, causing major socio-economic and developmental challenges to the economy (GOK,2021a; 2018; Mwangi and Mutua, 2015). These consequences are compounded by the widespread lack of supportive infrastructure and technology (GOK, 2010;2013).

According to the data from the World Bank, precipitation in Kenya is projected to remain highly variable and uncertain, however average rainfall is expected to increase by mid-century, particularly during the 'short rains', which occur between October and December. Extreme rainfall events are also expected to increase in frequency, duration and intensity and the proportion of heavy rainfall that occurs in heavy events will increase. However, the period between heavy rainfall events may increase. Importantly, the rainfall in the arid zones is generally projected to decrease. The chart below shows how the precipitation has been changing over the years, and why we should be alerted by rise in precipitations.

Figure 1. 1: **Annual Precipitation in Kenya**



Source: Climate Change Knowledge Portal for Development Practitioners and Policy Makers.

1.3.2 Temperature

According to numbers from the World Bank Group for Climate, the temperatures in Kenya are projected to continue rising by 1.7 degree Celsius by 2050s and by approximately 3.5 degree Celsius at the end of the century. Additionally, the number of hot days and nights will increase, with hot days projected to occur on 19%-45% of days by mid-century. Hot nights are expected to increase more quickly, projected to occur on 45%-75% of nights by mid-century and on 64%-93% of nights by end of century. Cold days and nights are expected to become increasingly rare. Across all emissions scenarios, temperature will continue to rise as it has been in the past years (Figures below).

Figure 1. 2 **: Average Temperature in Kenya**

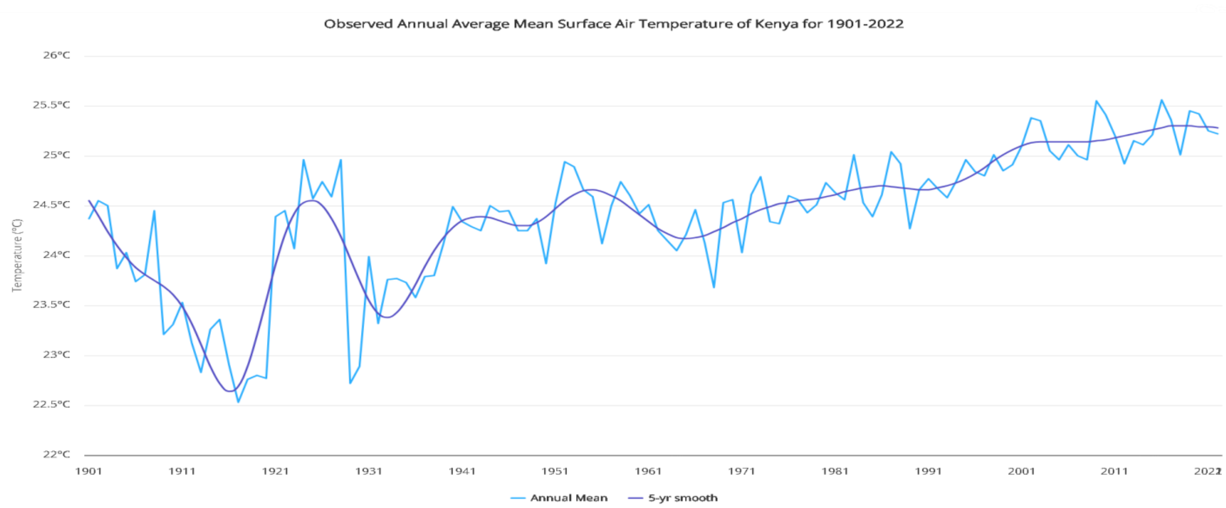
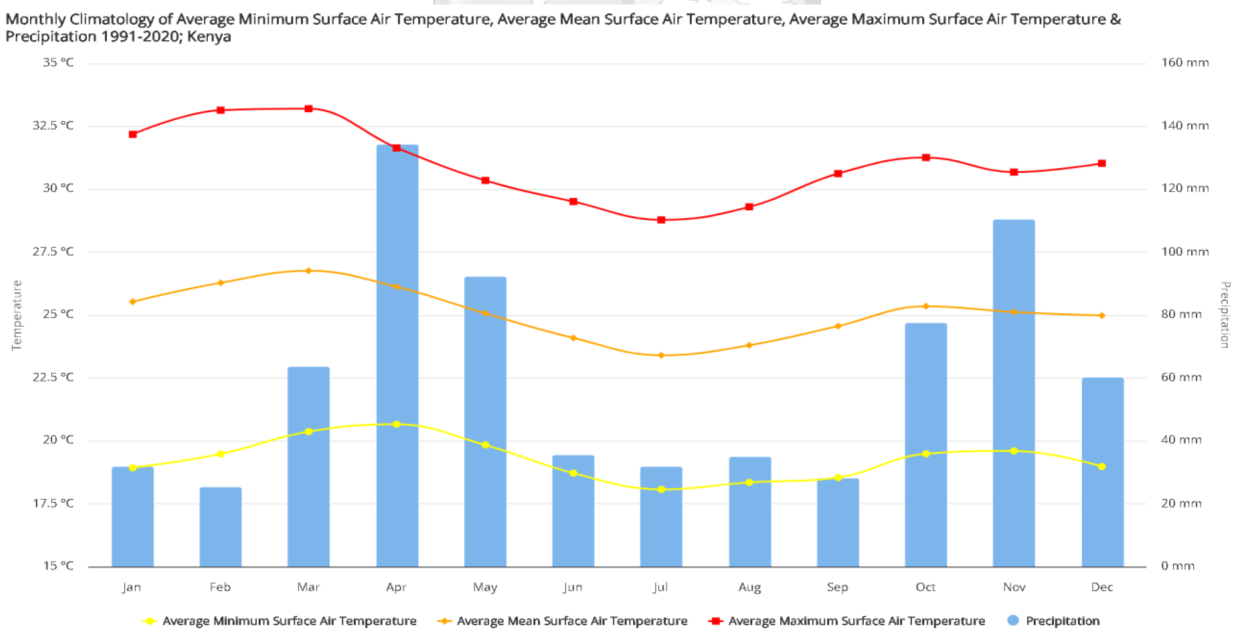


Figure 1. 3 **: Average Temperature and Precipitation in Kenya.**

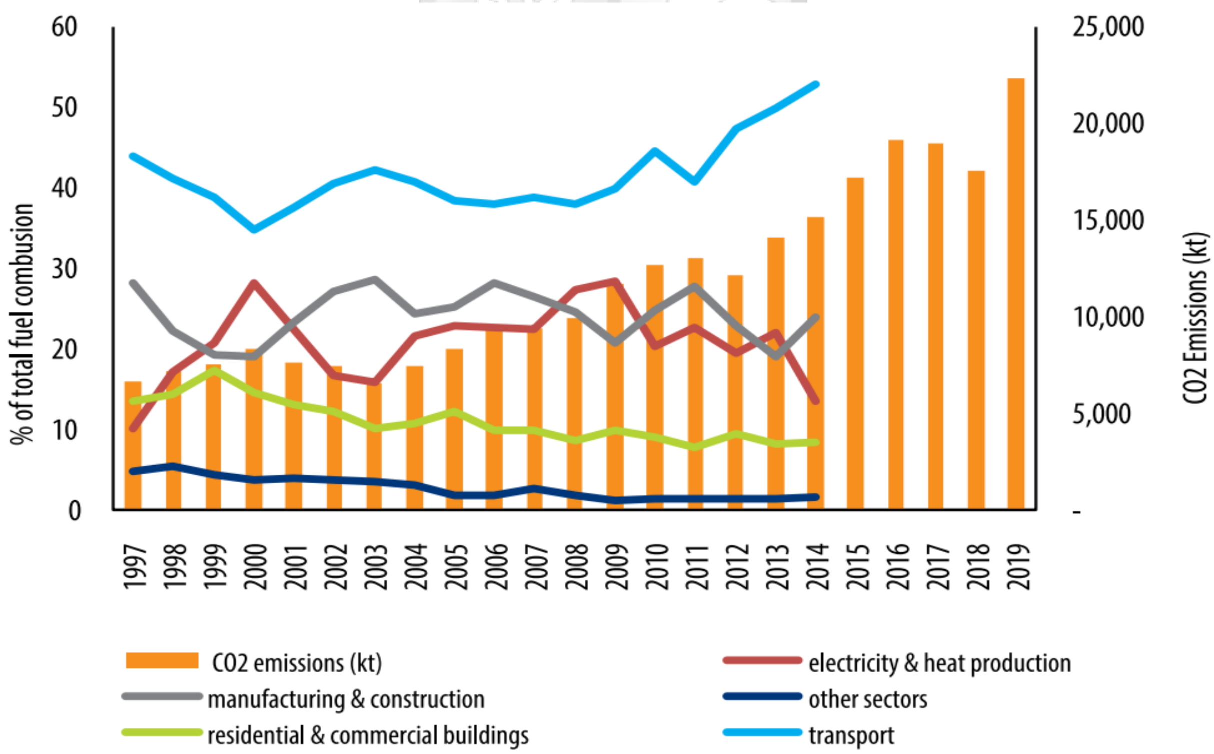


<u>Source:</u> Climate Change Knowledge Portal for Development Practitioners and Policy Makers.

1.3.3 Greenhouse Gas

Under the Paris Agreement, Kenya committed itself to tackling climate change. Its nationally determined contribution (NDC), which builds on the 2013 Kenya Climate Change Action Plan, pledges to reduce greenhouse gas (GHG) emissions by 30% by 2030. At the same time, Kenya's NDC recognizes the country's development aspirations of becoming a newly industrialized middle-income country by 2030. Although the above goals remain far off, some work have been done in that initiative, here we can cite e-mobility in the transport sector, where more than 50 startups entered the space and developed e-bikes, but there is still some work to be done in the transport sector as well as other sectors. The below illustration highlights the emissions of greenhouse gas emissions per sector in Kenya.

Figure 1. 4 **: Greenhouse Gas Emissions by Sector in Kenya**



Source: World Bank Database

1.3.4 Overview on Kenya's Vulnerability to Natural Hazards

Kenya is highly exposed to many natural hazards, the most common being floods and droughts. It is estimated that over 70% of natural disasters in Kenya are attributable to extreme climatic events. Typically, major droughts occur approximately every ten years, and moderate droughts or floods every three to four years. Repeating patterns of floods and droughts in the country have had large socio-economic impacts and high economic costs. For example, the 1998 to 2000 drought cost an estimated $2.8 billion, principally due to crops and livestock loss, as well as forest fires, damage to fisheries, reduced hydropower generation, reduced industrial production and reduced water supplies.30 Droughts have affected more people and had the greatest economic impact (8% of GDP every five years). As many as 28 droughts have been recorded in the past 100 years, and these appear to be increasing in frequency. Droughts are often nation-wide but normally have the most severe impacts in the country's highly arid zones.31 Drought also remains a significant concern to Kenya's agricultural sector. 32 Arid and semi-arid areas comprise 18 or the 20 poorest counties and are particularly at risk from increased aridity and periods of drought. While droughts affect the most people, floods have caused the greatest losses in terms of human lives. The districts of Baringo, West Pokot, Kisumu and Laikipia are some of the country's most disaster-prone areas and have required significant disaster risk investment.34 Vulnerability from these hazards poses major challenges for economic stability and fiscal sustainability and have had adverse social and fiscal consequences. Indeed, lower-income populations reside in more hazard prone locations, with high potential for significantly increased exposure to already vulnerable populations.

The data below form the Emergency Event Database: EM-Dat database shows the various natural hazards, including floods, landslides, wildfires, and storms that the country has been exposed to in the last 120 years.

Figure 1. 5 **: Natural Disasters in Kenya, 1900-2020**

Natural Hazard 1900–2020	Subtype	Events Count	Total Deaths	Total Affected	Total Damage ('000 USD)
Drought	Drought	16	196	52,911,500	1,500
Earthquake	Ground Movement	1	0	0	0
	Tsunami	1	1	0	100,000
Epidemic	Bacterial Disease	20	1,576	59,801	0
	Parasitic Disease	5	1,595	6,807,533	0
	Viral Disease	7	514	3,850	0
Flood	Flash Flood	8	245	193,500	500
	Riverine Flood	37	1,150	2,232,222	136,038
Landslide	Landslide	4	133	140	0
	Mudslide	1	20	6	0
Storm	Convective Storm	1	50	0	0

Source: World Bank database

1.4 Problem Statement

Climate change is increasingly recognized as a critical risk for the global financial sector, affecting both the stability and the performance of financial institutions. In Kenya, the impact of climate change is already visible, with severe flooding and prolonged droughts leading to significant economic disruptions. These environmental changes pose both physical risks, such as property damage and reduced agricultural productivity, and transition risks related to the shift towards a low-carbon economy. For banks listed on the Nairobi Securities Exchange, these risks translate into direct financial vulnerabilities through damaged assets, reduced loan payments, and increased claims, as well as indirect exposures via investment in affected sectors. Despite growing awareness of these issues, there is limited empirical research on how climate change specifically impacts the financial sector in Kenya. This study aims to fill this gap by examining the extent to which climate-related risks affect the financial performance and stability of banks in Kenya, as well how these institutions are adapting through climate financing strategies.

1.5 Research Objectives

1.5.1 General Objective

The primary objective of this research is to analyze the impact of climate change on the financial sector in Kenya, with a specific focus on banks listed on the Nairobi Securities Exchange.

1.5.2 Specific Objectives

1. To identify the specific climate-related physical and transition risks faced by banks in Kenya.

2. To assess how these climate-related risks affect the financial performance and stability of these banks.

3. To investigate the strategies and policies that banks in Kenya are adopting to manage and mitigate climate-related risks.

To achieve this, the study seeks to answer the following research questions:

1. What is the specific climate-related physical and transition risks faced by banks in Kenya?
2. How do these climate-related risks affect the financial performance and stability of these institutions?
3. What strategies and measure/policies are banks in Kenya are adopting to manage and mitigate climate-related risks?

1.6 Significance of the Study

This research is particularly significant given the context of Kenya as a developing country that faces considerable challenges in addressing climate change. Kenya's economy is highly dependent on climate-sensitive sectors such as agriculture, which is crucial for the livelihoods of a large portion of its population. The severe impacts of climate change, such as flooding and droughts, not only disrupt these primary economic activities but also pose significant risks to the stability of the financial sector. Financial institutions such as banks, which are vital to the country's financial infrastructure, are directly exposed to these risks through damage to assets, increased claims, and reduced loan repayments. Furthermore, these institutions are indirectly affected through their investments in sectors vulnerable to climate change.

The study provides empirical evidence on how climate-related risks impact the financial performance and stability of banks in Kenya. This insight is crucial for understanding the specific vulnerabilities within the financial sector and highlights the urgent need for effective risk management strategies. By examining the adaptation measures and climate financing mechanisms currently in place, the research offers valuable guidance on improving these strategies to better support the transition to a low-carbon economy.

In a country where resources allocated to combat climate change are limited, the findings of this study are pivotal for policymakers. They can inform the development of regulatory frameworks and policies that enhance the resilience of financial institutions to climate-related risks, ensuring financial stability and promoting sustainable economic growth. The study's insights can help banks to better allocate resources and capital towards sustainable investments, fostering a more resilient financial system capable of withstanding climate-induced shocks.

For an investor perspective, understanding the impact of climate change on the financial sector is essential for making informed investment decisions. Investors are increasingly considering environmental, social, and governance (ESG) factors in their investment strategies, and this research provides critical information on the climate-related risks and opportunities in Kenya's financial sector. By identifying the specific risks faced by banks, investors can better assess the sustainability and long-term viability of their investments. Additionally, the study highlights the role of climate financing in supporting green investments, offering insights into potential investment opportunities that contribute to a low-carbon economy.

Moreover, this research raises public awareness about the significant interconnectedness between climate change and financial stability. By highlighting these links, it underscores the importance of addressing climate-related risks and supports advocacy for greater investment in sustainable finance initiatives. This is crucial in a developing country like Kenya, where the impacts of climate change are felt acutely, and the need for effective climate action is pressing.

In sum, this study contributes to the existing body of knowledge on climate finance and risk management, particularly in the context of developing countries. It offers a multidisciplinary perspective that bridges environmental science and financial economics, providing actionable insights that can drive policy development, strategic planning, and public awareness. The research underscores the importance of building a resilient and sustainable financial sector capable of supporting Kenya's economic development in the face of climate change.

CHAPTER TWO

LITERATURE REVIEW

This chapter presents a review of the literature on the impact of climate change on the financial sector. Section 2.2 covers the theoretical frameworks that explain how climate change affects financial institutions. Section 2.3 discusses empirical studies that have investigated these impacts in various contexts.

2.1 The Theoretical Literature Review

Various theories have been used to explain the climate-related impacts to financial institutions. These theories include: The Climate Stress Testing, the Stranded assets in the context of climate change.

2.1.1 Climate Stress Testing

Developed by Jung and Engle et al. (2021), this climate stress testing methodology assesses banks' resilience to climate-related risks and gives insights into climate-related risk exposure of large global banks. They introduced a new measure, CRISK, which is the expected capital shortfall of a bank in a climate stress scenario (provided by the Network for Greening the Financial System). To estimate CRISK, they constructed climate risk factors and dynamically measured banks' stock return sensitivity (that is, climate beta) to the climate risk factor. This measure is useful in quantifying banks' climate-related risk exposure through market risk and the credit risk channels. The expected Capital Shortfall on a systemic climate change event, CRISK can then be defined as:

$$CRISK_{it}=E_t[CS_{i,t+h}|R^{CF}_{t+1,t+h}<\text{C}]$$

Where CS_{it} is the capital shortfall of bank I on day t. The capital shortfall is defined as capital reserves the bank needs to hold minus the firm's equity:

$$CS_{it} = k(D_{it} + W_{it}) - W_{it}$$

Where W_{it} is the market value of equity and D_{it} is the book value of debt, and k is the prudential ratio of equity to assets. The sum of D_{it} and W_{it} can be considered as the value of quasi assets. $\{R^{CF}_{t+1,t+h}< \text{C}\}$ is associated with a climate scenario.

2.1.2 Stranded Assets in the Context of Climate Change

Developed by Caldecott et al. (2021), this theory discusses the concept of stranded assets in the context of climate change. Contrary to stranded resources (a resource not used), stranded assets are defined as "assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities". Stranded assets are primarily a problem of countries, investors and consumers that have invested in a specific resource. Stranded assets can be investments, infrastructure, equipment, contracts, know-how and/or jobs. Thus, this theory discusses the transmission channels of climate related risks and the possible effects on societies, economies, and the financial system. It also reviews the growing central banks and supervisors' responses, including climate disclosure and stress testing.

2.2 Empirical Literature Review

The empirical literature review examines studies that have tried to quantify the impacts of climate change on financial institutions. This section explores various models and approaches that have been used to measure the financial sector's exposure to climate-related risks, including the profitability distribution of climate outcomes, the Dynamic Integrated Climate-Economy (DICE) model, and the macro-empirical approach. These empirical studies provide valuable insights into how climate change affects economic output, asset values, and the overall stability of financial institutions.

2.2.1 The profitability distribution of climate outcomes

In the profitability distribution of climate outcomes model, Pindyck (2021) highlights that climate change encompasses two major uncertainties: Climate sensitivity, and the relationship between economic outcomes (including asset values) and climate phenomena.

Climate sensitivity is the measure of how much temperatures will rise in response to a given amount of carbon dioxide in the atmosphere. This sensitivity is much harder to predict than the amount of carbon present, due to the intricate and potentially interconnected feedback mechanisms among numerous influencing factors.

In terms of the relationship between climate change and economic outcomes, the effects could potentially be either positive or negative, with the scale and nature of the changes being unprecedented. Climate change might necessitate adaptation, which could spur innovation and the modernization of infrastructure, buildings, and equipment. Migration might lead to a global redistribution of populations and the adoption of new, sustainable practices. However, these optimistic possibilities must be weighed against significant challenges, such as the destruction of capital, loss of homes, barriers to migration (both implicit and explicit), community stress, increased inequality, climate change denial, resistance to change, and GDP loss. Peters et al. (2017) propose a framework to integrate technological change and adaptation within a nested set of indicators to assess global emission pathways.

2.2.2 Dynamic Integrated Climate-Economy (DICE) Model

This intricate social, political, and economic process is captured by a damage function within the Dynamic Integrated Climate-Economy (DICE) model. The DICE model, an integrated assessment model (IAM) widely utilized by economists, quantifies the effects of climate change (refer to Nordhaus, 2017 [155], for the latest version). The damage function links temperature increases to decreased economic output through a specified function designed to be Hicks-neutral, maintaining the optimal balance of capital and labor. Essentially, the damage function operates as a tax on output:

$$Q(t) = \quad \Omega \cdot A(t)K(t)^{\alpha}L(t)^{1-\alpha}.$$

where $Q(t)$ is output at time t, $\Omega(t)$ is the damage function, or the fractionof output destroyed by climate damage at time t, $A(t)$ is technology, $K(t)$ is the capital stock, $L(t)$ is labor force, and α is the Cobb-Douglas production parameter (the share contribution of capital to output).

The damage function in the most recent iteration of the DICE model is given as:

$$\Omega(t) = [1 - D(t)] = 1 - \Psi_t T(1) - \Psi_2 T(t)^2.$$

where $D(t)$ is quadratic in $T(t)$, the globally averaged change in temperature, and the Ψ parameters are determined by fitting the quadratic to data from existing damage studies. Given that the damage function is arbitrary (polynomials of other degrees are not ruled out in principle) and that data are necessary limited, it is not surprising that the damage function is one of the most controversial aspects of the DICE model (see, e.g., Botzen and van den Bergh, 2012).

2.2.3 The Macro-Empirical Approach

An alternative method is to examine historical relationships between temperature changes (and other climate variables) and economic output. Schenkler and Roberts (2009) and Dell, Jones, and Olken (2014) estimate the effect of temperature on economic output to predict the likely impact of a two-degree Celsius temperature increase. Schenkler and Roberts analyze U.S. county-level yields for corn, soybeans, and cotton to explore the effects of temperature variations both within and across days. They find that crop yields rise with temperature up to a certain threshold, beyond which yields dramatically decrease. This method quantifies a specific microeconomic factor through which temperature directly affects GDP, contrasting with Dell et al.'s approach, which uses high-temperature years in less-developed countries as an identification strategy. Addoum, Ng, and Ortiz-Bobea (2019) use U.S. panel data to examine the impact of location-specific temporary temperature shocks on establishment sales and productivity, finding no average effect.

Kiley (2021) goes beyond average effects to analyze how temperature fluctuations impact the distribution of growth, including the tail risk of a significant GDP contraction. Using quantile regressions, Kiley discovers that the effect of temperature on the lower decile of the growth distribution is 50 percent larger (in absolute terms) than its effect on mean growth. He concludes that the growth-at-risk from climate-induced temperature increases is substantial.

2.2.4 The Agent Based Approaches

Another complication to quantification is that analysis of climate impact must also account for technological change and aggregation, heterogeneity and distributional implications, inter alia, as was discussed by Farmer et al. (2015). After reviewing the merits of dynamic stochastic general equilibrium models, Farmer et al. describe how agent-based modeling (ABM) can reconcile all the necessary requirements. An example of an early agent-based approach is Lamperti et al. (2017), who use an agent-based IAM composed of heterogeneous firms. They allow for increasing temperature to impact labor productivity, energy efficiency, the capital stock and firm inventories.

Lamperti et al. (2021) extends the model to account for the impact of three climate policies on financial stability. A key tenet economic policy is that n policy targets typically require n policy tools to achieve them. Following their analysis, Lamperti et al. (2021) imply three objective-tool pairs as follows:

1. **Objective:** Improve resilience of the banks to climate shocks – **Tool:** Capital buffer
2. **Objective:** Reduce risk of large price dislocations – **Tool:** Disclosure requirements/ credit rating adjustments
3. **Objective:** Promote economic growth by channeling financing towards strong climate-proof sectors – **Tool:** Partial credit guarantees.

Although all three policies combined are necessary and sufficient for achieving these goals, climate buffers alone are too blunt an instrument to effectively improve resilience without the introduction of disclosure.

2.2.5 Allowing for fat tailed distributions

Weitzman (2007) critiques the standard practice of truncating tails in climate risk distributions, arguing that it fails to capture the thick-tailed nature of potential climate outcomes. This concern is also echoed by Mastrandrea et al. (2011), who provided guidance on addressing uncertainty in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report. The inherent uncertainty in climate outcomes means that their probability distribution is itself subject to variability, complicating the estimation of default probabilities and potential losses.

Wagner and Weitzman (2018) emphasize the importance of the probability distribution's shape in climate impact analysis. They highlight that uncertainty about the expected value of global warming (Equilibrium Climate Sensitivity, or ECS) differs from the uncertainty about extreme events. Their review of Cox et al. (2018) shows that assuming a log-normal or Pareto distribution can drastically increase the likelihood of extreme temperature increases compared to a normal distribution.

Empirical determination of tail behavior is challenging due to the rarity of extreme events. However, many physical phenomena, including climate sensitivity, are better modeled by thick-tailed distributions. Studies by Baker and Roe (2009) and Roe and Baker (2007) suggest that ECS follows a thick-tailed distribution, indicating that future climate models should include robustness checks for sensitivity to different probability distributions.

The rarity of extreme climate events poses challenges for Bayesian analysis, which relies on updating priors based on accumulated data. Given the infrequency of extreme events, accumulating sufficient data to accurately update priorities within a reasonable timeframe is unlikely. This limitation makes it difficult to resolve the true shape of the climate outcome distribution using Bayesian methods alone.

2.2.6 Cost-Benefit Analysis and Policy Evaluation

Despite the inherent uncertainties in predicting climate change impacts, policymakers must still make informed decisions. This necessity has driven extensive research into the Social Cost of Carbon (SCC), which is vital for conducting cost-benefit analyses required by US climate policies. Daniel, Litterman, and Wagner (2018) address decision-making under uncertainty using Epstein-Zin (EZ) utility functions, which consider an agent's willingness to substitute across time and different states of nature. By simplifying their model to resolve uncertainty at discrete dates with binomial states, they find a high initial cost of carbon that declines gradually, emphasizing the need for urgent and bold policy actions rather than gradual adjustments.

Pindyck (2000) applies dynamic stochastic programming to global warming, identifying values for both waiting due to unrecoverable sunk costs and immediate action due to irreversible benefits. This approach clarifies the stakes involved in climate policy but also highlights the necessary simplifications, such as assuming efficient markets. Pindyck later acknowledges that the fundamental uncertainty in climate change challenges precise quantification, aligning with Kay and King (2020), who advocate for detailed scenario analysis over precise but potentially flawed quantitative models. Similarly, Pezzey (2018) suggests focusing on marginal abatement costs by modeling low-cost pathways to agreed climate targets, as endorsed by the IPCC's cost-effectiveness approach.

The choice of discount rates is critical in cost-benefit analysis, heavily influencing outcomes. Weitzman (1998, 2007) argues for using the lowest possible discount rate for far-distant outcomes, stressing the sensitivity of this choice to modeling details. Bauer and Rudebusch (2020) note the convergence of prescriptive (normative) and descriptive (market-based) discount rates, strengthening the argument for immediate action on greenhouse gas emissions. For the Kenyan financial sector, adopting these robust and adaptive approaches in policy evaluation is crucial to mitigate climate change impacts on banks listed on the Nairobi Securities Exchange.

CHAPTER THREE

DATA AND METHODOLOGY

3.1 Theoretical Framework

Climate change risks significantly amplify financial risks, while financial instability, in turn, hampers effective climate change mitigation and adaptation efforts. These risks are broadly categorized into physical risks, transition risks, and liquidity risks (Carney, 2015).

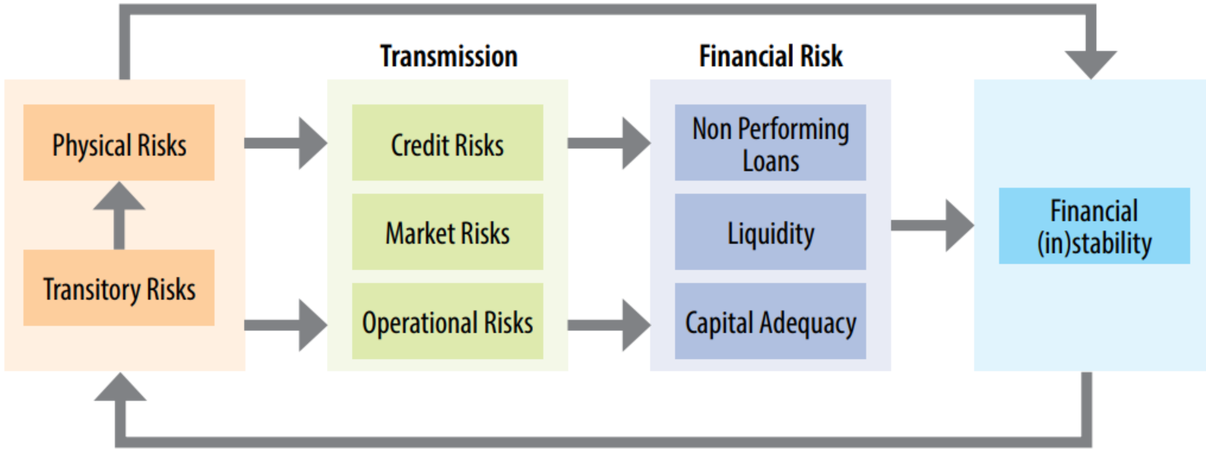
Physical risks arise from the direct impacts of climate change, such as temperature increases and changes in precipitation patterns. These changes lead to extreme weather events, including heatwaves, droughts, floods, and cyclones. These events can severely disrupt agricultural productivity, causing fluctuations in market supplies and prices, particularly in agriculture-dependent sectors. Additionally, physical risks can damage the infrastructure of households and firms, leading to a reduction in asset values. This reduction affects the creditworthiness of these entities, potentially increasing credit defaults and causing asset revaluations, thereby impacting banks' balance sheets. The destruction of physical capital also diminishes collateral value, limiting the borrowing capacity of firms and households. Furthermore, a significant disaster could disrupt bank operations, trigger large-scale withdrawals of deposits, and create liquidity risks (Gripper et al., 2021; BIS, 2021a).

Transition risks are associated with the process of moving toward a low-carbon economy. These risks stem from policy changes, technological advancements, and shifts in consumer preferences aimed at reducing carbon emissions. When transition risks materialize, they can affect the asset values of firms, either positively, through technological breakthroughs, or negatively, through asset stranding. These changes can alter production processes and affect firms' profitability. For instance, new regulations or a shift in consumer demand toward more sustainable products could render certain assets obsolete or less valuable. Conversely, firms that successfully adapt to these changes may see an increase in profitability. The overall effect on the financial system depends on the speed and effectiveness of the transition, as well as the exposure of financial institutions to affected sectors.

Liquidity risks can arise both directly and indirectly from climate change. A large-scale climate event, such as a natural disaster, could lead to sudden and substantial withdrawals of deposits from financial institutions, creating liquidity pressures. In addition, as physical and transition risks affect firms' profitability and households' financial stability, the demand for liquidity may increase, putting further strain on financial institutions. A liquidity crisis could occur if banks are unable to meet these demands, leading to broader financial instability.

In summary, climate change introduces a complex array of risks that can profoundly affect financial stability. Physical risks directly damage assets and reduce creditworthiness, transition risks challenge firms' profitability through economic shifts, and liquidity risks emerge from sudden demands on financial resources. The interplay between these risks requires careful management to ensure both climate resilience and financial stability. The chart below illustrates the relationship between climate risks and bank stability.

Figure 3. 1: **The Relationship Between Climate Risks and Bank Stability: A Theoretical Framework**



Source: KBA Centre for Research on Financial Markets and Polic

3.2 Data Sources and Selected Variables

The data for this research will be sourced from various reliable institutions. Specifically, financial data will be gathered from banks listed on the Nairobi Securities Exchange, with information being extracted from their financial statements. To capture macroeconomic factors, such as inflation and GDP, data will be drawn from the IMF World Economic Outlook database and the Kenya National Bureau of Statistics. Finally, climate indicators relevant to the study will be obtained from the World Bank's Climate Change Knowledge Portal. This comprehensive data collection approach will ensure a robust analysis of the impact of climate change on bank stability, particularly with a focus on the period before and after the 2015 Paris Agreement.

The data will be collected from the period of 2010-2023. The decision to use data from 2010 onward is driven by the need to capture a thorough understanding of the financial sector's performance and risk exposure both before and after the pivotal 2015 Paris Agreement. By including data from the years leading up to 2015, this study will establish a baseline for how banks managed risks and maintained stability prior to the introduction of global climate commitments. This allows for a clear comparison with the post-2015 period, where the Paris Agreement and other climate-related policies began to shape financial strategies. Analyzing this broader timeframe will enable us to identify significant shifts in risk management and financial stability, offering valuable insights into the evolving impact of climate change and international policy responses on the financial sector. The table below shows the sources of the data that will be used in this study.

Table 3. 1: **Variable description and data sources**

Variable abbreviation	Variable description and measurement	Data sources
ROA	Return on assets, measured as a ratio of net income to total assets	Balance sheets and profit and loss accounts of commercial banks
ROE	Return on equity, measured as a ratio of net income to total shareholder's equity	
CAR	Capital adequacy ratio is measured by total bank capital as a ratio to risk weighted assets of the bank.	
Z-Score	The bank Z-score captures the probability of default of a country's banking system. It is computed (ROA+(equity/assets))/standard deviation (ROA).	Computed based on data from balance sheets and profit and loss accounts of commercial banks
Bank size	Bank size is measured by total assets.	Balance sheets and profit and loss accounts of commercial banks
Credit risk	Measured by non-performing loans to total loans	
Liquidity	Defined as liquid assets/total assets	
RainVol	Variability in rainfall	Computed based on data from the World Bank's Climate Change Knowledge Portal
TempVol	Variability in temperature	
Inflation	Log of consumer price index	Kenya National Bureau of Statistics (KNBS)
GDP	Gross domestic product	
Mob_value	Value of mobile transactions	Central Bank of Kenya

Source: KBA Centre for Research on Financial Markets and Policy

3.3 Empirical Approach

This study employs a model that includes a lagged dependent variable as one of the regressors to account for time persistence in the dependent variable's structure. The dynamic panel data model is consistent with previous research, which has demonstrated that past levels of bank stability proxies influence their current levels (Jabra, 2020; Atoi, 2018):

$$BS_{it} = \alpha_0 + \delta_1 BS_{it-1} + \alpha_1 ClimateC_t + \delta_2 X_{it} + \mu_{it}$$

The dependent variable represents four distinct measures of bank stability that have been considered in prior studies. These four measures are the Z-score, capital adequacy, return on assets, and return on equity (Moreno et al., 2022; Pham et al., 2021; Ali and Puah, 2018; Diaconu and Oanea, 2015). $ClimateC_t$ denotes rainfall and temperature volatility, which are used as proxies for climate change. X_t represents control variables, including credit risk, inflation, GDP, bank size, and liquidity, while μ_{it} is the error term. The subscripts i = 1,… N and t = 1,…T refer to the cross-sectional and time series dimensions of the data, respectively.

Z score measures banking system stability and it is computed with three important soundness indicators. Equity/Assets ratio (R/E), the return on assets (ROA) and the standard deviation of return on assets (σ(ROA)) – a proxy for return volatility. Impliedly, Z score measures the distance from insolvency (Roy, 1952). As formalized by Mercieca et al., (2007):

$Z\_Score_{i,t} = (ROA_{i,t} + CAR_{i,t})/\sigma_i(ROA_{i,t})$; Where CAR: ratio of equity capital total assets

Simply put, Z_Score shows by how many standard deviations ROA could change to make the bank's total assets fall short of its total debts. The popularity of Z_Score is derived from the established inverse relationship it has with the probability of insolvency of financial institutions.

A higher value of Z_Score means lower bank risk, and more stability (Moreno et al., 2022; Pham et al., 2021). The table below shows the variables and data sources for the Z_Score calculation.

Table 3. 2 **: Variables description and data sources for the calculation of Z_Score**

Variable		Descriptions	Sources
	Bank stability proxy		
	Log Zscore	It is defined as the inverse of the probability of insolvency and is equal to the return on assets plus the capital asset ratio divided by the standard deviation of asset returns. The z-score measures the distance from insolvency (Roy, 1952). We use the natural logarithm of the Z-score which is less skewed and follows the normal distribution. A higher z-score indicates that the bank is more stable	Bankscope
	Bank specific variables		
	LnTA	Bank size : The natural logarithm of total assets	Bankscope
	BC	Bank capitalization ratio (%) =Total equity divided by total assets	Bankscope
	Macroeconomic variables		
	INF	The inflation rate	World Development Indicators
	GDP	The GDP growth rate	

Notes: Bank-level variables include bank capital and bank size. Macroeconomic variables include GDP growth rate and inflation rate. Domestic credit to the private sector and real interest rate. The macroeconomics data are obtained from the National Bureau of Statistics.

In existing research, climate change is typically gauged using indicators such as rainfall, temperature, and carbon emissions. This study specifically employs the quarterly changes in rainfall (measured in millimeters) and quarterly temperature variations (measured in Celsius) as proxies for climate change (Nahousse, 2019). Climate change, characterized by rising temperatures and unpredictable rainfall, leads to extreme weather events like floods, droughts, heatwaves, fires, rising sea levels, and hurricanes. These events result in capital losses, reduced profitability of firms, and a deterioration in their financial positions (Liu et al., 2021; Stern, 2007; Batten et al., 2016).

Theoretically, climate change impacts the financial system through physical risks and transition risks. The combined effects of these risks can result in market, credit, underwriting losses, and operational risks, depending on banks' exposure to households and corporations (Grippa et al., 2019). Lower asset values and increased debt defaults could emerge as a result of these risks, leading to systemic bank losses and negatively affecting investor confidence (Fabris, 2020; Batten et al., 2016; Dafermos et al., 2018; Bovari et al., 2018). The expected relationship between climate variability (temperature and rainfall) and bank stability is negative.

According to Pham et al. (2021), determinants of bank stability are generally categorized into three groups. This study considers bank-specific factors such as bank size, liquidity, and credit risk, along with macroeconomic variables like inflation and GDP (Pham et al., 2021; Diaconu and Oanea, 2015; 2014).

Bank size, which is measured by the natural logarithm of total assets, has a complex relationship with stability. The agency theory suggests that as firms grow, managerial decisions may become more self-serving, leading to instability. Conversely, the stewardship theory predicts a positive relationship, where managers align their actions with shareholders' interests (Adusei, 2015; Davis et al., 1997). Therefore, the expected relationship between bank size and stability is ambiguous.

Credit risk is measured by the ratio of non-performing loans to total loans. This ratio reflects the vulnerability of a bank to changes in the repayment behavior of its borrowers. A higher ratio indicates a greater likelihood of borrower default, which can lead to bank insolvency. Therefore, a negative relationship with stability is expected (Amara and Mabrouki, 2019; Adusei, 2015).

Bank liquidity is generally associated with higher asset quality, which directly contributes to stability by reducing balance sheet risks and facilitating asset liquidation during a crisis. However, the ease of asset liquidation in a crisis might encourage banks to take on additional risk, potentially offsetting the initial positive impact on stability (Wagner, 2007). Thus, the expected relationship between liquidity and bank stability is ambiguous.

In this model we also look at macroeconomic indicators such as a strong economic performance, indicated by high GDP growth, tends to reduce non-performing loans, improve credit quality, and enhance bank efficiency, all of which contribute to greater bank stability (Sifrain, 2021).This model will also capture inflation which affects bank stability by influencing bank performance. If inflation is anticipated, interest rates can be adjusted to maintain profitability, thereby positively impacting bank performance. However, if inflation is unanticipated, banks may struggle to adjust interest rates quickly enough, leading to rising costs and potentially negative impacts on performance (Sufian and Kamarudin, 2012).

Finally, the model looks at Mobile money services, which by expanding access to savings products, enable a broader population to engage with formal financial services, thereby diversifying and expanding banks' depositor bases. When mobile money is integrated with formal bank accounts, it can reduce the unit cost of financial services, helping banks expand their customer base and product offerings (Misati et al., 2022).

3.4 Empirical Estimation Approach

It's important to note that our model incorporates lagged dependent variables as regressors, a feature commonly associated with dynamic regressions. According to Baltagi (2002), dynamic regressions are characterized by two main aspects: autocorrelation due to the inclusion of a lagged dependent variable among the regressors, and unobserved heterogeneity in individual behavior.

However, panel datasets, which track the behavior of multiple cross-sectional units over time, provide a solution to address both the dynamic nature of the model and the unobserved individual heterogeneity (Giovanni, 2004).

Traditional methods like ordinary least squares (OLS), fixed effects, and random effects are inadequate when a lagged dependent variable is present. OLS may lead to biased results because it ignores unobservable heterogeneity, while fixed effects (FE) and random effects (RE) estimators can produce biased coefficients, particularly in small samples. The primary challenge with these methods is the correlation between the lagged dependent variable and the error term (Ledyaeva and Linden, 2008). To overcome these issues, this study employs the generalized method of moments (GMM), which offers asymptotically efficient estimators (Arellano and Bond, 1991). GMM is more efficient than other estimators because it addresses the bias seen in OLS when explanatory variables correlate with the error term, and it uses robust instruments to manage simultaneity and eliminate unobservable heterogeneity (Machasio, 2018). Therefore, GMM is chosen as the most suitable method for dynamic panel data, effectively resolving endogeneity issues and providing efficient estimators that are not achievable through OLS or FE methods.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 Descriptive Analysis

The summary of the variables used in the analysis of the impact of climate change on the financial sector: a study conducted on the banks listed on the Nairobi Securities Exchange is as follows

Table 3.3: Descriptive Statistics of variables in use

		Mean	St.deviation	Kurtosis	Skewness	Minimum	Maximum	Count
Dependent variables	ROA	0.02808578	0.033152392	89.2337	8.27923	-0.02939	0.383306	150
	ROE	0.18697132	0.181568983	99.7912	8.96227	-0.19034	2.185722	150
	CAR	0.14595861	0.072493727	3.5878	0.53573	0.000129	0.439779	150
	Z_Score	21.3641262	9.35292754	-0.2983	-0.66988	1.726647	39.92929	150
Independent Variables	Bank_Size	139781000	170070334.5	0.95855	1.26866	100678	7.35E+08	150
	Credit_Risk	0.10139154	0.773433948	149.373	12.2094	8.71E-05	9.501176	150
	Liquidity_Ratio	0.41404073	0.115103036	-0.2797	0.44028	0.207	0.7303	150
	RainVol	675.995333	157.5226084	-1.1095	-0.02261	423.31	947.91	150
	TempVol	25.6112078	0.498448453	1.4901	1.46233	24.98885	26.94858	150
	Inflation	7.12335199	2.387976241	2.2544	1.43817	3.961389	14.02249	150
	GDP	1.0172E+13	3.13634E+12	-1.3807	0.00544	5.51E+12	1.49E+13	150
	Mob_Value	3618521.77	2384395.199	-0.8052	0.56692	473411.5	7953930	150

The primary dependent variables examined include Return on Assets (ROA), Return on Equity (ROE), Capital Adequacy Ratio (CAR), and Z-Score. These variables serve as indicators of financial health and operational effectiveness.

Starting with Return on Assets (ROA), the average value observed is 0.0281, suggesting that, on average, the 10 banks analyzed in this study generate approximately 2.81% profit from their total assets. The standard deviation of 0.0332 indicates variability in performance among the banks, revealing differences in how effectively assets are utilized. A higher kurtosis value of 89.23 indicates a heavy-tailed distribution, pointing towards the presence of outliers that significantly impact the average performance metrics. Moreover, a skewness of 8.28 reveals substantial right-skewing; thus, it can be inferred that a few banks perform remarkably well, elevating the overall average ROA. The range of ROA values extends from -0.0294, highlighting instances of losses, to 0.3833, which denotes substantial gains, further illustrating the performance disparities across these institutions.

Following ROA, the analysis of Return on Equity (ROE) reveals an average of 18.70%, indicating a reasonable return on shareholder investments. With a standard deviation of 0.1816, there exists diverse performance within the equity management practices of the banks. Both the elevated kurtosis of 99.79 and skewness values reflect a distribution with significant outliers, where certain banks demonstrate eccentrically high returns, further emphasizing the variation in performance.

The Capital Adequacy Ratio (CAR) averages at 0.1460, which indicates that these banks maintain a healthy capital buffer above the minimum requirements. The standard deviation of 0.0725 shows moderate variability in capital judiciousness among the banks, underscoring differing strategies in capital management and risk mitigation. Furthermore, the Z-score, averaging 21.3641, suggests a high capacity for resilience against financial shocks, indicating a low risk of insolvency among these banks.

In addition to the dependent variables, the analysis incorporates independent variables that can potentially influence bank performance. Notable among these are Bank Size, Credit Risk, Liquidity Ratio, and environmental factors such as RainVol, TempVol, Inflation, GDP, and Mob_Value.

The average bank size is reported at 139.78 billion, illustrating that these institutions are substantial entities within the market, equipped with significant resources and market shares. The wide standard deviation of 170.07 billion points to considerable variability, indicating differing levels of asset accumulation among the banks.

Regarding Credit Risk, an average of 0.1014 signifies that a relatively small proportion of total loans are non-performing, which underscores effective credit risk management practices across the sector. The high standard deviation of 0.7734 reveals significant differences in risk exposure among the banks, potentially impacting overall operational health.

The average liquidity ratio, at 0.4140, coupled with a standard deviation of 0.1151, highlights that while some banks maintain solid liquidity positions, others might face challenges in meeting short-term financial obligations. Moreover, environmental factors like inflation rate, which averages approximately 7.12%, can significantly affect interest rates and overall profitability. The GDP means, being exceptionally high, signifies substantive economic activity that creates a favorable backdrop for banking operations.

4.2 Pre-estimation tests

Before conducting a unit root test, a cross-sectional dependence test needs to be done to identify which unit root test suits the data in use.

H_0: Cross-sectional independence (no dependence)

Conducting this test gave the following result:

Pesaran's test of cross-sectional dependence = -0.048, Pr = 0.878

Since the probability (p-value) is greater than 0.05, we fail to reject the null hypothesis of cross-sectional independence. This indicates that there is no evidence of cross-sectional dependence on the panel data.

As there is no cross-sectional dependence, it is appropriate to proceed with first-generation unit root tests, which assume cross-sectional independence. Since the dataset is unbalanced, the Fisher unit root test was conducted.

The following two tables highlight the values obtained for the Fisher unit root test for both the independent and dependent variables used in this research.

Unit Root Test for Dependent Variables

Variable	Test Statistics		P-Value	Level of integration	P-Value
	P	57.2297	0.0000	0	0
	Z	-3.7497	0.0001	0	0.0001
	L*	-4.2707	0.0000	0	0
ROA	Pm	5.8865	0.0000	0	0
	P	72.0759	0.0000	0	0
	Z	-4.5378	0.0000	0	0
	L*	-5.8167	0.0000	0	0
ROE	Pm	8.2339	0.0000	0	0
	P	29.3803	0.0805	1	0
	Z	-1.6576	0.0487	0	0.0487
	L*	-1.7047	0.0470	0	0.047
CAR	Pm	1.4832	0.0690	1	0
	P	37.6981	0.0096	0	0.0096
	Z	-2.3747	0.0088	0	0.0088
	L*	-2.5927	0.0061	0	0.0061
Z_Score	Pm	2.7983	0.0026	0	0.0026

Key

- Inverse chi-squared (20)- (P), - Inverse normal- (Z) , - Inverse logit t (54) - (L *) - Modified inv. chi-squared- (Pm)

As reported in the above table, all the dependent variables in the analysis were found to be stationary at the 5% level of significance as they all had a P-value less than 0.05. The same can also be observed for independent variables as it is shown in the table below. These two findings reinforce the idea that these variables are suitable for models that assume stationarity.

Unit Root Test for Independent Variables					
Variable	Test Statistics		P-Value	Level of integration	P-Value
	P	3.0222	1.0000	1	0
	Z	2.8991	0.9981	1	0
	L*	2.8491	0.9965	1	0
Bank_Size	Pm	-2.6844	0.9964	1	0
	P	41.3495	0.0034	0	0.0034
	Z	-2.1848	0.0145	0	0.0145
	L*	-2.498	0.0078	0	0.0078
Credit_Size	Pm	3.3757	0.0004	0	0.0004
	P	19.8605	0.4667	0	0.4667
	Z	0.0005	0.5002	1	0
	L*	0.0087	0.5035	1	0
quidity_Rat	Pm	-0.0221	0.5088	1	0
	P	20.2461	0.4426	0	0.4426
	Z	-1.0545	0.1458	1	0
	L*	-0.9439	0.1747	1	0
RainVol	Pm	0.0389	0.4845	0	0.4845
	P	10.2011	0.9644	1	0
	Z	0.8383	0.7991	1	0
	L*	0.7509	0.7720	1	0
TempVol	Pm	-1.5493	0.9393	1	0
	P	97.2863	0.0000	0	0
	Z	-7.6404	0.0000	0	0
	L*	-8.5456	0.0000	0	0
Inflation	Pm	12.22	0.0000	0	0
	P	11.499	0.9322	1	0
	Z	0.5033	0.6926	1	0
	L*	0.4478	0.6720	1	0
GDP	Pm	-1.3441	0.9105	1	0
	P	1.8699	1.0000	1	0
	Z	4.2632	1.0000	1	0
	L*	4.1001	0.9999	1	0
Mob_Value	Pm	-2.8666	0.9979	1	0

4.3 Empirical Results

		Dependent variables					
		Return on Assets: ROA	Return on Equity: ROE	Capital Adequacy Ratio: CAR	Z_Score		
		Model 1	Model 2	Model 3	Model 4 with TempVol	Model 5 with RainVol	Model 6 with TempVol
	Intercepts	0.030221 (-0.154538)	0.488804 (-0.856886)	-0.27635 (-0.312763)	-4.2011 (-44.05003)	25.8167 (-8.08719)	-15.01 (-39.21392)
Independent Variables	Bank_Size	-5.90E-11 (-1.86E -11)**	-1.80E-10 (-1.03E-10)**	-2.20E-10 (-3.76 E-11)**	1.59E-08 (-5.3E-09)*	1.59E-08 (-5.29E09)***	1.58E-08 (5.29 E-09)
	Credit_Risk	0.00036 -0.003457	0.000733 (-0.019169)	0.002261 (-0.006997)	0.610785 (-0.985444)	0.578896 (-0.982568)***	0.612876 (-0.98299)
	Liquidity_Rati	0.061015 (-0.027844)	0.333337 (-0.154392)	0.048871 (-0.056353)**	-7.29733 (-7.936873)	-7.27578 (-7.922284)	-7.3369 (-7.916835)
	RainVol	-2.20E-05 (2.83 E-05)	-9.40E-05 (-0.000157)	-1.80E-05 (-0.000057)	-0.00439 (-0.008076)***	-0.00684 (-0.007249)	-
	TempVol	0.000581 (-0.006085)	-0.00692 (-0.033742)	0.01523 (-0.012316)	1.202538 (-1.734575)	-	1.615044 (-1.556074)
	Inflation	-0.00056 (-0.001349)	-0.00196 (-0.00748)	-0.00066 (-0.00273)	-0.25398 (-0.38452)	-0.23237 (-0.382553)	-0.25135 (-0.383535)
	GDP	-1.50E-15 (5.02 E- 15)*	-1.90E-14 (2.78 E-15)***	7.13E-15 (1.02 E-14)***	5.65E-13 (1.43 E-12)***	9.81E-13 (1.3E- 12)***	2.04E-14 (1.02 E- 12)**
	Mob_Value	7.70E-11 (6.74 E-09)***	8.17E-09 (3.73 E-08)	-3.50E-09 (1.36 E -08)	-1.50E-06 (1.92 E-06)	-2.10E-06 (1.75 E- 06)	-7.30E-07 (1.27 E-06)
	No.Obs	1200	1200	1200	1200	1050	1050
	R_Squared	0.097403	0.074842	0.226815	0.078595	0.075454	0.076662

The above regressions reveal various relationships between independent variables and banking performance. Notably, Bank Size consistently showed a negative correlation across the dependent variables. This finding highlights the possibility that larger banks may face unique challenges in adapting to climate change, potentially leading to diminished performance relative to their smaller counterparts. As climate-related risks become more pronounced, it appears that larger institutions might struggle to effectively manage these challenges, necessitating further investigation into their operational strategies and capital planning.

Credit Risk emerged as another critical factor, presenting a positive correlation with ROA, ROE, and CAR in specific models. This relationship suggests that banks with heightened credit risk are possibly navigating the challenges of climate impact through robust risk management practices, allowing them to maintain acceptable performance levels. This resilience may be especially relevant given the broader economic uncertainties stemming from environmental disruptions.

The Liquidity Ratio also demonstrated divergent effects across models, showing positive impacts on ROA and ROE but negatively influencing CAR. This inconsistency could imply that while banks are managing their liquidity effectively in the face of climate pressures, the resultant capital implications may not align favorably, particularly as sustainability measures become integral to banking strategy.

Environmental factors, particularly RainVol and TempVol, displayed a complex influence on banking performance. RainVol's negative coefficients across multiple models underscore the importance of adapting to environmental changes, suggesting that fluctuations in rainfall patterns can adversely affect bank performance. Conversely, TempVol showed a positive relationship with ROA, suggesting that under certain conditions, temperature changes may present opportunities for growth. However, this requires further scrutiny to clarify the underlying mechanisms at play.

The results regarding Inflation and GDP also warrant attention. The persistent negative impact of inflation across all performance metrics signifies the potential for economic volatility exacerbated by climate change influences. Meanwhile, GDP's negligible role indicates that broader economic growth might not directly correlate with bank performance in this climate-sensitive environment, hinting at the need for financial institutions to prioritize environmental resilience alongside standard financial measures.

Finally, the inconsistent effects of Mob_Value on performance measures signal the complex interplay between market expectations and environmental accountability. This variability suggests that banks may need to strategically align their environmental initiatives with market demands, seeking to enhance reputation and performance in a landscape increasingly influenced by climate factors.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Summary and conclusion

While previous studies have shown the impact of regulatory, institutional, as well as economic factors on financial performance, little focus has been allocated to climate change risks. This research assesses the impact of climate change risks and bank stability indicators and analyzes the climate physical risks on bank performance in Kenya. This study applies descriptive analysis and the GMM panel estimation on 10 banks listed on the Nairobi Securities Exchange using yearly data from 2009-2023.

The descriptive analysis through different tables highlighted in this study indicates climate change risks in Kenya. While Kenya has pledged to mitigate climate risks by reducing the levels of greenhouse gas emissions, and adopting climate-smart practices in different sectors, this study has highlighted that no significant investment has been allocated in that perspective in both the private and the public sector. For the banking sector, this analysis shows that credit flow to sectors vulnerable to climate change risks and those target for low carbon emission, therefore having implications on credit risk default and stranded assets used as collateral for bank loans.

The quantitative analysis provided valuable insights into the factors influencing bank stability and performance, with larger banks may face greater challenges from climate change compared to smaller ones due to their broader exposure, stranded asset risks. It also shows that Climate change impacts performance both negatively, through physical and transition risks, and positively, via different opportunities such as green finance.

5.2 Recommendations

Banks should enrich their risk appetite frameworks by incorporating climate-related indicators. Climate risks act as amplifiers of existing financial risks, particularly in credit, market, and liquidity domains. For instance, physical risks like extreme weather events or prolonged droughts can degrade the value of collateral, increase loan defaults, and strain banks' capital buffers. Transition risks arising from policy changes, technological innovations, or shifting consumer preferences can also lead to stranded assets, reduced profitability, and reputational challenges.

To build resilience, banks must extend their stress-testing frameworks to include comprehensive climate-related scenarios. These scenarios should address both physical and transition risks, encompassing factors such as rising temperatures, regulatory reforms, technological breakthroughs, and changes in customer behavior toward more sustainable practices. Such forward-looking approaches enable banks to anticipate and mitigate shocks, ensuring financial stability while supporting the transition to a low-carbon economy.

Integrating climate considerations into risk management is not just a regulatory compliance measure but also a strategic imperative for banks to safeguard their portfolios and maintain stakeholder trust in an increasingly sustainability-focused financial landscape.

5.3 Limitations to the study

While this study provides valuable insights into the impact of climate change on banks listed on the Nairobi Securities Exchange, it is important to recognize certain boundaries within its scope. The analysis focuses on temperature and rainfall variability as key climate factors, given their significant relevance to Kenya's financial and environmental context. However, other climate variables, such as extreme weather events, carbon emissions data, and land-use changes, were not included due to the unavailability of reliable, region-specific data. These additional factors could offer a broader perspective on climate risks, but their exclusion does not detract from the robustness of the current findings. Instead, it highlights opportunities for future research to build upon this foundational work.

Additionally, this study operates within the context of Kenya, where climate-related financial disclosures are still evolving. Banks in the region are progressively adopting frameworks to assess and report climate risks, but standardized methodologies and regulatory requirements remain in development. While this study effectively leverages the available data and aligns with global trends in sustainable finance, it also reflects the unique challenges of studying climate risks in an emerging market. This focus not only strengthens the relevance of the findings to Kenya but also underscores the importance of continued advancements in data availability and regulatory support to further enhance research in this area.

5.4 Suggestions for further research

Future research could build on this study by incorporating additional climate variables and examining their broader implications for financial institutions. While this research focused on temperature and rainfall variability, other factors such as the frequency and intensity of extreme weather events, carbon emissions, and sea-level changes could also explore how these risks interact with socio-economic conditions, such as agricultural dependency, access to resources, to influence bank's exposure to climate risks. Furthermore, sector-specific studies could investigate how banks' lending portfolios in industries like agriculture, real estate, or energy are uniquely affected by physical and transition risks, providing granular insights for targeted risk management strategies.

Another critical avenue for future research is the role of policy and regulatory frameworks in addressing climate risks in the financial sector. Studies could analyze the effectiveness of current climate-related policies in Kenya and explore how regulatory requirements, such as mandatory climate risk disclosures or stress testing, impact banks' risk management practices. Comparative research could also evaluate how Kenya's financial institutions measure up against their counterparts in other emerging and developed markets. Additionally, future research could focus on innovative solutions, such as green financing instruments, sustainability-linked loans, or public-private partnerships, to enhance resilience and sustainability within the financial institutions. By addressing these areas, future research can provide actionable insights for policy makers and financial institutions to better navigate the complexities of climate-related risks.

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