The impact of climate change on the performance of banks in Southern Africa

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ABSTRACT

Using a sample of 12 countries from the SADC region, the study investigates the impact of climate change on the performance of commercial banks. The study this paper uses temperature and rainfall levels to measure climate change. Secondary data gathered through extraction of historical databases obtained from World Bank Development Indicators is used to deduce the relationship of these variables.

The results suggest that climate change matters. The study finds that although there is a positive relationship between bank profitability and climate change, there is a threshold beyond which further increases in temperature and rainfall will adversely affect bank profitability.

Also, banking sector concentration has a positive effect on banking profitability, while loan loss provisions and costs can erode profits if not managed properly. We also discover that there is no difference in how South Africa is affected by climate change compared to the rest of the SADC countries.

A number of policy recommendations emanate from the study. First, it imperative for banks to begin to take into account climate change in the operational activities. Second, there is no country immune from the ravages of climate change. All countries in the SADC region must cooperate to address the serious challenges emanating from climate change. For example, the impact of climate for South African banks is not different to the banking sectors in other countries in the SADC region. Indeed, across most countries in the region natural disasters, such as droughts and floods, are becoming more frequent and also more devastating.

Third, to address some of the challenges there is need to address the problems of, data scarcity and to use technology innovation to prevent natural disasters. These recommendations will equip the SADC region to be able to tackle the anticipated consequences of climate change on the financial institutions.

DECLARATION

I, Phumudzo Ralebona, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in Energy Leadership at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: Phumudzo Ralebona Signature: Ralebona P.C

Signed at Midrand, Johannesburg

On the 28th day of February 2023

DEDICATION

I dedicate this research to my husband, Rendani Sidogi. This journey looked easy when I started but things got tough, and you were there, never leaving my side at any point. I am honoured to have someone who believes in me like you do.

To my little sisters, Denzhe and Zwoluga Ralebona, I pass the baton to the both of you. I have crawled so that you can walk, this is evidence that if you dream it then you can achieve it.

To my loving parents, I dedicate this to you too because you allowed me to carve my own path for as long as I can remember. Carry this as your legacy for this is the results of your hard-work and discipline.

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A special thanks to my husband Rendani Sidogi who supported me throughout. To my whole family, thank you for the continuous encouragement, prayers and understanding when I had little family time.

I kept my faith in God through all the difficult times and He is the reason why I am here today. Ebenezer Father!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

CO2- Carbon dioxide

ECB-European Central Bank

EKC- Environmental Kuznets Curve

GFD- Global Financial Data

GHGs- Greenhouse Gases

IEA- International Energy Agency

IFC- International Finance Corporation

NGFS- Network for Greening the Financial System

NIM- Net Interest Margin

ROA- Return on Assets

SADC- Southern African Development Community

WEF- World Economic Forum

CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

Climate change is increasingly becoming a crucial part for the survival of the African economies (Abidoye & Odusola, 2015). The role of banks as stakeholders towards energy transition is inevitable, a successful energy transition requires a deployment of new and cleaner technology that must be financed by different institutions including banks (Geddes, Schmidt, & Steffen, 2018).

This quantitative study investigates how climate change affects the performance of banks in the SADC region. More specifically, the main question we seek to answer is: What are the implications of climate change on bank profitability on a country level? Answers to such a question may help bank management in these countries to come up with better green strategies without suffering hefty financial losses. This is especially important given that more countries are considering strategies to rebuild economies after the COVID-19 pandemic crisis. Indeed, there is a need for all stakeholders, including banks, to push for a rebuilding strategy that considers the environment and climate change.

Adaptation and mitigation of climate change risks will result in notable structural changes in the financial system (Scott, Van Huizen, & Jung, 2017). This paper assesses the implications of these changes for banks in South Africa and SADC countries using publicly available information from sources such as the World Bank.

1.2 Context of the study

Climate change was once viewed as an environmental hazard however all that has changed as risks associated with climate change are now affecting the economic players(Debelle, 2019). The gradual increase in energy demand has influenced how the global economy interacts with the energy industry ecosystem. Issues such as climate change, decarbonization and energy access have

sparked global debates for the past decades to try and understand the risks and opportunities they come with.

The emissions of greenhouse gases contribute largely to the current global warming that is affecting the global society and businesses negatively (Ritchie & Roser, 2020). Low carbon economies are likely to attract reputational risks, increased taxes and regulatory risks for companies that are high emitters (Maaloul, 2018). Energy transition refers to the shift from systems that are dominated by fossil resources in energy production to renewable energy sources such as solar, wind and hydro(Smil, 2010). Renewable energy generation only forms a partial solution to energy transition, infrastructure and storage facilities are also critical to drive this change (IEA, 2019).

Currently, environmental concerns are dominantly driving the energy transition as climate change is becoming a global issue that requires cooperation from countries all over the world (Del Granado et al., 2020). However, environmental sustainability cannot be achieved single handedly. According to the World Economic Forum, a successful energy transition will require a multi-stakeholder model approach(WEF, 2018). Different industry players will be impacted significantly by climate change as energy usage is a big part of any economy. Figure 1 depicts the WEF energy triangle balance, the energy transition system needs to provide gain for both society and business.

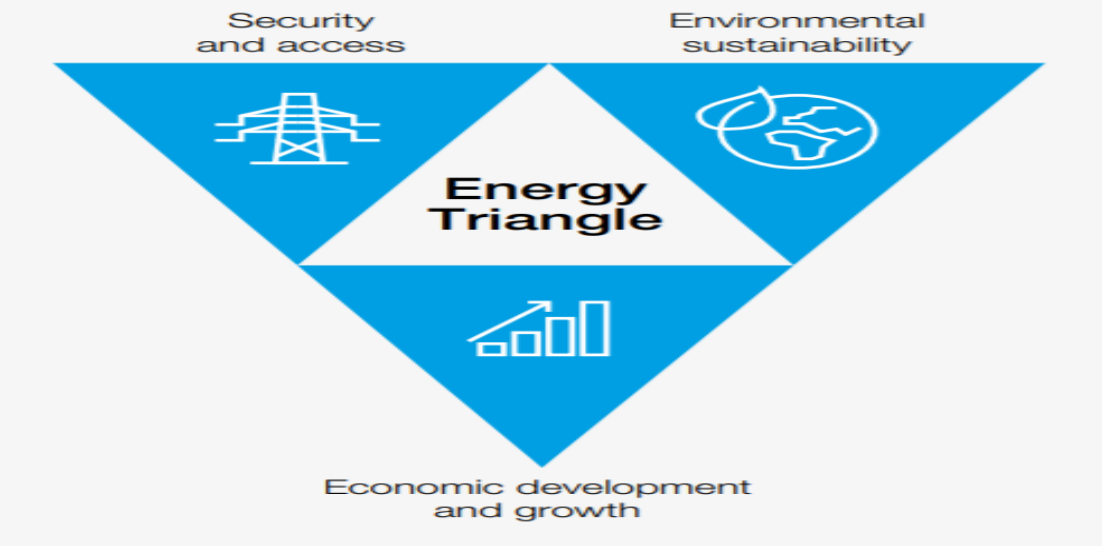

Figure 1: WEF Energy Triangle(WEF, 2020)

The promotion of economic growth and development is evidenced through providing access to reliable energy and security within reasonable cost of production (Nhamo et al., 2019). This is important because it will promote productivity for economic growth purposes which must be achieved in environmentally sustainable way. The combination of the two will result in better and improved energy access and security for society (Bompard et al., 2020).

1.3 Research problem

There are consistent concerns around the impact that climate change will have on the financial system (Battiston, 2017). Risk mitigation by various industry players including banks is one of the most important subjects right now for both researchers, regulators as well as business (Chenet, 2021).

Currently, most African countries do not have strict and clear regulation that governs the lending policies of banks regarding climate change risks, however, banks have increased anticipation of their supervisory expectations mainly for identifying and managing financial risks that are related to climate change (Feridun & Güngör, 2020). Some banks have taken it upon themselves to include initiatives in their forward-looking strategies as a way of being proactive on the issue(Krupa & Burch, 2011). This study seeks to establish impact of climate change on banking profitability in the SADC countries.

1.4 Research questions and objectives

The research questions are as follows:

1. What is the impact of climate change on bank performance?
2. Is there a difference on the impact of climate in South Africa compared to other SADC member states?

The research objectives are as follows:

1. To investigate the impact of climate change on bank performance
2. To investigate whether there is a big difference between the impact of climate change in South Africa compared to other SADC countries.

1.5 Significance of the study

Banks can assist in curbing the associated risks to climate change and sustainability, mitigating the risk impact and adapting to climate change and support recovery by reallocation of funding to sectors that are sensitive to climate change (Park & Kim, 2020).

By providing funding for projects that drive economic growth, banks have a role in driving the climate change ambitions (Gwatiringa, 2020). The type of projects they fund may improve or worsen the situation, it is important that banks acknowledge the impact that energy transition will have on their performance, for example, banks' profitability, may help to better understand why banks may behave the way they do when it comes to their high-carbon energy sources portfolio concentrations (Bowman, 2010). However, information of actual portfolio concentration and industry trends remains restricted to date, probably due to lack of binding regulatory requirements for their disclosures.

Bank specific factors are not the only factors that affect performance but external factors as well, such as macroeconomic environment(Gwatiringa, 2020). Abel and Le Roux (2016) investigated the profitability determinants of banking sector in Zimbabwe between 2009 and 2014. Their results showed that profitability of the banking sector profitability in Zimbabwe is substantially determined by bank-specific factors such as bank-level management. The reasoning by the authors is that efficient management of profitability factors such as liquidity, non-performing loans and capital amounts improves the performance of the banking sector.

Correlation between bank-specific factors and macroeconomic indicators were found in a survey performed for commercial banks in Latvian between 2006 and 2011(Erina & Lace, 2013). Regression analyses was used to analyse these indicators.

Due to the banks having a significant environmental impact indirectly through their lending, investing, and procurement processes, there is a sense of urgency for them to incorporate climate change initiatives in their strategies including their lending actions(H. Park & Kim, 2020). Banks are faced with reputational risks when it comes to project-financing decisions on whether they should continue financing companies that are still operating in the fossil fuel space(Bowman, 2010). The potential regulatory changes will also have an impact on how the banks make financing decisions for their clients in the energy industry.

The IFC estimates that there is $23 trillion worth of investment opportunities in developing countries that are climate friendly between 2016 and 2030 (Kludovacz, Stein, & Rooprai, 2018). The private sector has proved interest in investing in low carbon energy sources mainly because they are aware of the business disruption this energy transition will have on their current business models. Energy business enablers such as financial institutions have also come through with revised financing strategies in the energy sector to keep up with the changes in the industry.

Energy transition is gaining momentum for the banking sector in such a way that the strategic focus is being revised by most banks as strategic players in the economy(Bowman, 2010). Sustainable finance and banking have become a fundamental part of global banking systems. Banks are complex businesses that offer several financial products and services to a range of customers which makes them important stakeholders in energy transition

In 2015, the Paris Agreement was adopted by approximately 195 countries as a climate change framework to address the global climate change issue (Nangombe et al., 2018).The Paris Agreement seeks to cap the average global temperature below 2°C with the ultimate level being 1.5°C by 2030. The World Economic Forum predicts that global annual business infrastructure investments of US$5 trillion need to be environmentally friendly from 2020 in order to meet the targets in the Paris Agreement (Horstink, 2019)

The Equator Principles (Abidoye & Odusola) is a risk management framework being adopted by different financial institutions, especially in South Africa. The

principles are used to identify, assess, and manage environmental and social risk in projects that they finance. The purpose of the framework is to encourage responsible decision making within the institutions. The 80 EP requires project related loans, advisory and lending to be consistent in meeting international standards from an environmental and social viewpoint (Principles, 2020).

Currently, 35 countries have endorsed and adopted the 80 EP which applies globally to five financial products, namely; 1) Project Finance Advisory Services, 2) Project Finance, 3) Project-Related Corporate Loans, and 4) Bridge Loans and 5) Project-Related Refinance, and Project-Related Acquisition Finance (Principles, 2020).

Banks should not perceive climate change as a threat to the financial system however they need to start being proactive in planning for potential business disruption. It makes business sense for commercial banks to grab the opportunities that the energy transition comes with while playing an important role of supporting a sustainable environment through their business deals. The risks associated with climate change for the banking sector are depicted below in Table 1.

Table 1:Climate change risks for banks (Treasury, 2020)

Bank-Specific Climate-Related Risks	**Credit**	**Market**	**Operations**
Physical	The rise of flood risk mortgage portfolios	Severe weather events lead to re-pricing of sovereign debt	Alarming weather-change affect business continuity (banks and clients)
	The default rate in the agricultural sector output decline	Worldwide supply chain disturbance	

	Water associated issues affecting manufacturing and tourism industry		
Transition	Regulatory changes affect client margins	Companies revalued due to policy and consumer changes	Stakeholder pressure on banks leads to reputational risks
	New technology or consumer preferences result in stranded assets and impaired portfolios		
	New technology leads to client forfeiture		Liability and transparency issues
	Stricter regulations around energy efficiencies and building standards affect portfolios		

Some parts of the banks' assets are invested in highly exposed sectors that may pose risks to the climate (Battiston, Guth, Monasterolo, Neudorfer, & Pointner, 2020). Banks need to prepare themselves by considering disclosing their concentration of assets in exposed sector and having plans on how they are going to reduce exposure going forward. High carbon-emitting companies bear both transitional and physical risks that could flow into the banks as consequence. Information disclosure will encourage pro-active risk management frameworks that is important in systemic risk avoidance (Battiston, Mandel, Monasterolo, Schütze, & Visentin, 2017).

There are several reasons why African countries should take climate change seriously and begin to take proactive measures to mitigate its ravaging effects. First, most African countries depend on agriculture and climate change is associated with catastrophes like droughts and flooding, which can seriously

affect the agriculture sector and ultimately the entire economy. The countries are therefore more prone to the ravaging effects of climate change. Second, high concentrations of greenhouse gas emissions are associated with bad health outcomes – e.g., respiratory diseases. Third, consumers are increasingly getting environmentally conscious and may punish countries that continue to produce goods with high corban content. This implies that industries that produce such goods may – if they do not change - see a significant decline in the demand for their goods. There is therefore a need to change and stop supplying good whose demand is falling, as the profits may also be falling. Fourth, countries that do not reduce carbon content may also face internal penal codes whereby they may be forced to pay carbon tax for producing such goods. Given the above, African countries must therefore reorient their financial systems and industrial sectors with a view to ensure sustainable economic growth and development (Gwatidzo & Simbanegavi, 2021)

1.6 Delimitations of the study

I. The study only focuses on the banking sector of the SADC member countries, any other countries are be delimited from this research.
II. The climate change variables are be sourced from the World Bank data agencies and Reserve Bank/Prudential Authority of each country to maintain data consistency.
III. The secondary data was collected from a country level therefore bank-specific data was delimited from this research.

1.7 Definition of terms

I. Bank performance is defined as the ability of a bank to accomplish set objectives by their shareholders and regulatory bodies; a set of indicators is used as measure to these objectives (García-Meca, García-Sánchez, & Martínez-Ferrero, 2015)

II. Climate change - it is defined as the shifting of global climate patterns in the long-term period (National Geographic Society, 2019)

III. Decarbonisation is the reducing or eliminating of carbon dioxide from energy sources to achieve zero net emissions of carbon dioxide (Esso & Keho), as well as the stabilizing of emissions of short-lived greenhouse gases (GHGs)

IV. Energy transition refers to the change in production and consumption of energy sources that emits high levels of CO2 emissions to renewable energy sources (IEA, 2019).

1.8 Assumptions

I. All banks in different countries have clients in sectors that are vulnerable to climate change

The complex link between transitional and physical risks inevitably has effects on operational ecosystems of banks. This assumption is important for this study because to measure the impact, the banks must have sectors that possess credit risk as a result of climate change.

- **Climate change will affect the banks in different countries at an asset level**

The transitional risks that come through climate change could give rise to a re-evaluation of various asset classes if the banks are not proactively aligned to the energy transition and that may potentially oppress their earnings (Park, 2020).

- **The collected data from the world bank is an accurate reflection of how the climate has been affected over the selected period**

The World Bank's Climate Change Knowledge Portal collects historical climate related data, developing patterns and understanding of how the climate has evolved over the years. The data is important for the study because it shows the direct factors contributing to climate change that ultimately drives the energy transition.

1.9 Structure of the report

Chapter 1: Briefly outlines the general overview of the study. We discuss the context of climate change and its effect on the SADC economies, particularly the banking sector in those countries. The significance of the study is discussed as well to articulate the value add this report will have on the subject.

Chapter 2: This is the literature review component where we look at the work that has been done by other authors. We focus on the key terms and concepts of the report, looking at the different techniques and approaches that were used by various authors.

Chapter 3: This is the methodology section where we outline how we conducted the study. We explain about which research design, approaches, data collection methods and analysis we used to achieve the objectives of the research.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

Profitability of the banking sector is important because the wellbeing of the industry is crucially associated with the economic performance. Generally, an efficient and productive banking sector is capable of withstanding tough economic times without a financial system collapse(Athanasoglou, Brissimis, & Delis, 2008).

The literature review focuses on themes regarding the banking sector and climate change. The role that banks play by financing energy projects is a key role in the economic performance system of any country. This paper reviews the literature under the following subsections:

- Banks' profitability drivers
- Climate change on banks profitability
- Carbon emissions and economic growth

Most businesses receive loans and credit facilities from banks which makes it important for banks to be characterized by adaptability to different transitions. Credit risk management for banks should accommodate environmental factors that come with climate change, enabling them to allocate mitigation factors for any risks posed on their business (Wynman, 2021).

2.2 Definition of topic or background discussion

The 2008-09 financial crisis taught us the importance of credit risk management and loan book quality on banks' profitability(Dietrich & Wanzenried, 2011). The banking industry globally has also been competitive and embracing technological innovation as part of strengthening their credit risk management systems. The capital buffers that are required by the Basel regulation ensures that banks manage risks adequately due to their systematic importance.

The banks are already incurring costs because of climate change, it is evident that climate change is no longer a future scenario (Scott et al., 2017). For example, some farmers have not been yielding the best crop due to extreme weather conditions and that inevitably affects their loans from the banks in cases where hedging products were not purchased (Caldecott et al., 2016). Another example would be the producers of plastic material, they are affected by the new era of anti-environmental pollution which results in gaps in business efficiency. Lastly, water-shortage crisis due to extreme weather conditions also affects productivity of water intensive industries.

The few above-mentioned examples show that climate change is a financial risk source for the banking sector. The Network for Greening the Financial System report (NGFS, 2019), recommends the climate-related risks integration into monitoring and supervision of financial stability of banks and their contribution to the economy. This can be done through assessment of the financial risks posed by climate change on the financial system, risk indicators such as non-performing loans ratio can be used to monitor the risks. The NGFS report also recommends scenario analysis of specific climate risks, integrating them into the forecasting of the future supervisory standards.

Nedbank is one of the first South African banks to countersign the United Nations Framework Convention on Climate Change's objectives, committing to contribute to driving the below 2 ˚C target. All the African countries where Nedbank is present, have endorsed the Paris Agreement as signatories(Nedbank, 2020). The bank has approached their climate change's strategy to align with the Sustainable Development Goals formed by the United Nations(Nedbank, 2020). The strategy includes not financing any new coal-powered plants or related technologies, formulating a thermal coal policy that is available to the public and managing their climate change resolutions through shareholders involvement at AGMs.

Standard Bank has also committed to reducing its fossil fuel lending as a result of the growing concerns around banks financing unclean energy sources. As much as climate change poses a risk on the banks, it also initiates investment opportunities in the renewable energy space, energy storage technologies and

efficient energy projects. Microfinance and small businesses are also emerging in the space, to participate in the transition to a global low-carbon economy. This means that the poor population will also get to benefit by getting access to clean energy in their communities.

From a profitability perspective, we see that SADC countries were generally profitable between 2000-2018 as all of them recorded positive return on assets and equity. This is an indication of stability and soundness of the SADC Banks financial system.

Table *2*: SADC Banks Profitability

	2000-2010		2011-2018	
Country	**ROA%**	**ROE%**	**ROA%**	**ROE%**
Angola	2.82	29.08	2	18.5
Botswana	2.75	49.23	2	22.2
Lesotho	2.38	28.45	2.9	27.4
Malawi	5.14	31.72	6	36
Mauritius	1.9	14.29	1.3	8.12
Mozambique	3.13	31.44	0.4	7.40
Namibia	2.25	15.67	2.5	19
South Africa	1.13	18.82	1.5	15.49
Swaziland	2.27	15.48	2.8	19.91
Tanzania	2.29	22.21	1.2	9.95
Zambia	1.43	13.62	2.2	15.49

Source: Global Financial Development Database

2.3 What is the impact of climate change on bank performance?

Research states that the adoption of different climate change objectives from initiatives such as Equator Principles and Paris Agreement is mostly used to manage reputational risks by most financial institutions (Scholtens, 2007). There was not significant improvement found from a financial performance perspective between those that adopted the objectives and those that didn't in their performance management.

Conversely, the Global Alliance for Banking on Values conducted research comparing return on assets and return on equity of their member banks. The

findings showed that higher return on assets and return on equity was achieved by member banks in the years 2007 to 2016 (Seyfang & Gilbert-Squires, 2019).

2.3.1 *Climate Change*

The past decade sparked many anti-fossil fuel campaigns against financial institutions such as banks, insurers, and financial policy makers. Financing and investing in fossil fuels by banks has been seen to be carbon-heavy for many years and the awareness created by environmental lobbyists gained momentum around the globe, making it almost impossible for banks to ignore climate change.

The current and possible policy changes surrounding the energy transition era comes with credit risks to be faced by banks. Financial projections will also be impacted as carbon market prices of products such as coal, gas and oil may be volatile in the long run (Dellink, Jamet, Chateau, & Duval, 2014).

Popov (2019) found that economies that prioritize equity financing over ordinary banking finance tend to have lower carbon emissions per capita depending on their economic development.

Minetti (2011) states that new technology is instrumental for fighting the increase of carbon emissions while protecting the climate. Banks in this regard, must play a role of being less conservative in small and medium business lending criteria. Banks seem to be more conservative when coming to lending new and cleaner energy producers mainly because there is a risk that the value of the current collateral, they hold for existing loans representing non-environmentally friendly technologies may deteriorate (Minetti, 2011).

2.3.2 *Bank Performance*

Arias (2011) states that the studies on bank's performance determinants in the United States have produced mixed results in the past, some researchers have found that increasing the size of the bank results a little is cost saving while others found large economies of scale for banks that have asset size in the billion range.

Bikker and Bos (2008) says that the performance of banks can be expressed in terms of concentration, competition, productivity, profitability, and efficiency. Profitability ratios that are commonly used to determine banking sectors performance are: Return on Assets, return on equity, commission income as a percentage of total assets, net interest margin as well as net fees (Titko, Skvarciany, & Jurevičienė, 2015).

According to European Central Bank (2010), other approaches for banks' performance measurement would need an extensive analysis of the banks' operations utilizing stress-testing methods. This will eventually lead to some sort of transparency from the industry on how their profitability structures are formed.

The hypothesis regarding the negative relationship between profitability and operational efficiency of banks is expressed by cost-to-income-ratio (Titko et al., 2015). The banks' profitability drivers can be classified in the following three aspects:

i) Internal factors

Internal drivers of the banks' profitability are variables such as size, risk management, capital and management of expenses(Athanasoglou et al., 2008). The value of the total assets is used to measure the size of the bank. According to Smirlock (1985), a positive relationship exists between the size of the banks and its profitability. The higher the market share the bank possesses, the more likely it is to obtain higher profitability results. Short (1979), discovered that capital adequacy of a bank is significantly linked to the size of the bank mainly because it is cheaper to raise capital for larger banks compared to smaller banks.

ii) Industry Factors

The changes that can happen within the industry such as new entrants, mergers, acquisitions, and regulatory requirements may affect market share and industry concentration.

Ozili and Uadiale (2017) found that banks with high ownership concentration are more likely to deliver higher returns on assets, net interest margin and higher recurring earning power compared to banks with low ownership concentration.

This could be because there are fewer parties involved in decision-making that ultimately.

iii) Macroeconomic factors

Macroeconomic factors that affect banks' profitability generally are broad and inclusive to all the economy's participants. Inflation rate, unemployment levels, GDP and interest rates are amongst the several factors.

Ifeacho and Ngalawa (2014) found that the performance of banks is negatively related to unemployment rates and interest rates. Unfavourable macroeconomic factors affect the bank by contributing to spiked non-performing loans. A recent practical example being the Covid-19 pandemic, some industries were hit harder than others because of the lockdown restrictions in different countries. Covid-19 contributed to unemployment levels which may possibly lead to defaults in the financial obligations that customers had such as bond, vehicle, personal and business loans repayments. The banks' general costs of funds are indicated by real interest rates, higher interest rates result in unfavourable bank performance due to loan defaults.

2.3.3 Hypothesis 1

Climate change significantly impacts bank performance

2.4 Is there a difference on the impact of climate in South Africa compared to other SADC member states?

Prevention of global warming and its repercussions requires global unity from across the world. The main cause of global is greenhouse gas emissions more especially the CO2 emissions. About 75% of Sub-Saharan Africa's population and their economies depend on fossil fuel energy sources which are the main causes of global warming (Oji, Soumonni, & Ojah, 2016).

The bulk of most African countries are vulnerable to climate change because they have insufficient resources and capabilities to cope with the transition (Pressend, 2011). The largest emitters of greenhouse gases are mostly industrialized

countries however the impact of these emissions is experienced by most if not all in the global society (Modi, McDade, Lallement & Saghir, 2006).

This section will explore the theory of the Environmental Kuznets Curve that is used by different authors to study the relationship between economic growth and carbon emissions for developed and developing countries.

2.4.1 *Environmental Kuznets Curve*

The environmental Kuznets curve hypothesis has been commonly used for decades in applied research; it states that economic growth causes environmental degradation in the early stage of economic development following which economic growth reduces environmental degradation (Esso & Keho, 2016).

Below is an illustration of the EKC curve from the pre-industrial economy stage to post-industrial economy stage.

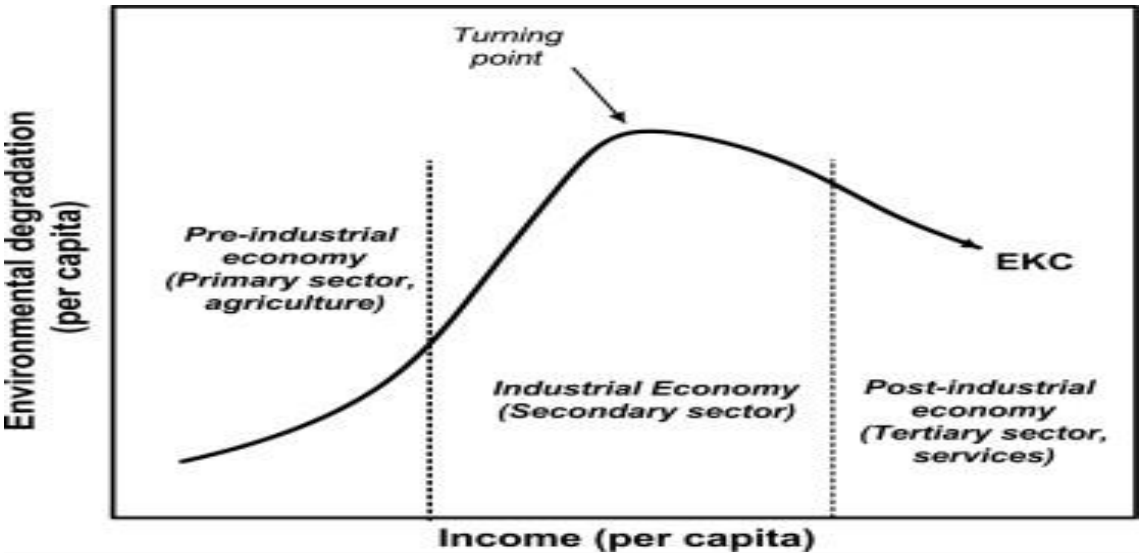

Figure 2: An Environmental Kuznets Curve

The environmental degradation is the dependent variable on the y-axis, the common indicators being air pollution emitters, deforestation or soil and land pollution(Kaika & Zervas, 2013). Environmental quality initially deteriorates at the beginning and improves with time when economic development is realized.

Narayan, Saboori, and Soleymani (2016) found that 21 out of 181 of the countries they sampled, only 12% supported the environmental Kuznets curve hypothesis. Furthermore, 49 (about 27%) of the 181 countries' results indicated that they would experience emissions' reduction as a result of a rise in income.

Olubusoye and Musa (2019) also used the environmental Kuznets for 20 African countries, the countries were classified into three sections without including the regions but using income category such as low, middle, and upper-middle African economies. The result from the study was that environmental degradation worsened, carbon emissions in this case, as income increased in the 14 countries out of the 20 sampled countries, the remaining 6 countries indicated that as country income increases, the carbon emissions declined(Olubusoye & Musa, 2019).

Esso and Keho (2016) studied a sample of 12 Sub-Saharan countries, examining the relationship between economic growth, energy consumption and CO2 emissions. The empirical results obtained were mixed between the different countries, indicating that in the long-term, energy consumption and economic expansion were associated with increase in CO2 emissions. The Granger causality tests showed strong evidence of economic growth resulting into CO2 emissions in the short run in Benin, DRC, Nigeria, Senegal and Ghana implying that economic expansion cannot be achieved without affecting the environment(Esso & Keho, 2016).

2.4.2 *Hypothesis 2*

There is significant difference on the impact of climate in South Africa compared to other SADC member states.

2.5 Conclusion of Literature Review

The pressure on the banking sector and other sectors by the climate change and energy transition in increasingly becoming unavoidable. Environmental sustainability as a concept includes several drivers that have an impact on the banking sector. The drivers such as reputational risks, credit risks, regulatory

changes, and performance management. It is important for banks to re-visit the drawing board to incorporate environmental sustainability in their business strategies. The quality of the loan book is important for the profitability of the banks' therefore the impact energy transition on banks' energy portfolio is inevitable, credit risk management on those portfolios must be managed well.

The accounting approach to measuring bank performance uses financial ratios to convey the financial standing of a company which is banks in this case. The evaluation of banks performance is important because it influences policies, regulation, and market structures (Chenet, 2021). Return on Assets is commonly used as one of the measures because it is an indicator of the value of shareholders' interest. It is also easy to determine ROA as a profitability ratio using publicly available information instead of complex undisclosed factors hence its commonality is evidenced in the various literature. Studies on bank profitability determinants have focused on specific factors of the banks such as operational costs, credit risk, market concentration and other macro-economic factors performance except climate change (Unzi & Wu, 2019; Dafermos, Nikolaidi & Galanis, 2018)

Banks seem to be under pressure for reactions on climate change risks, adequate information is vital to help in allocation of capital so that banks are prepared to deal with the risks (Lawrence & Doorasamy, 2021). The existing literature proves that more focus is needed to research climate change risks within financial institutions from a performance perspective, hence the relevance of this report under the following propositions:

2.5.1 Climate change significantly impacts bank performance

2.5.2 There is significant difference on the impact of climate in South Africa compared to other SADC member states.

Table 3. Consistency table

RQ #	Research Objective	Hypothesis	Data collection Details	Data Analysis method
1. What is the impact of climate change on bank performance?	To investigate the impact of climate change on bank performance	Climate change significantly impacts bank performance	Secondary data	Panel Data Analysis
2. Is there a difference on the impact of climate in South Africa compared to other SADC member states?	To investigate whether there is a big difference between the impact of climate change in South Africa compared to other SADC countries.	There is insignificant difference on the impact of climate in South Africa compared to other SADC member states.	Secondary data	Panel Data Analysis

Theoretical framework

Our study looks at the impact of climate change on bank profitability. Our theoretical framework borrows from the literature on the environmental Kuznets hypothesis. A number of studies have been conducted testing the environmental Kuznets hypothesis. These include the following Ulucak and Bilgili (2018), Akbostancı, Türüt-a sık and Tunc (2009), Ozokcu and Ozdemir (2017) and Ahmad et al (2017). According to the environmental Kuznets (1955) in the early stages of development, economic growth is detrimental to the environmental. That is, as economies growth they emit a lot greenhouse gases, for example, which damages the environment, but after a certain point (perhaps due to awareness and better technology) further growth may begin to be less damaging. This implies that most developing countries, particularly African countries, are still developing and are on the left side of the Kuznets Curve. They may therefore be doing massive damage to the environment as they develop. Indeed, as they continue damaging the environment a point may be reached whereby any further damage may be catastrophic – such that the drought and flooding (among other catastrophes) may become more frequent and more devastating. This may affect the financial systems and ultimately the banks.

From a theoretical point of view climate change has the potential to significantly impose some systemic risk on the banks and the financial system in general.

Low carbon emissions transition stimulates new investments in energy projects which are risky at the moment due to the fact that there is still uncertainties around their returns (Caldecott & Robins 2014). Also, we see a possible profitability impairment from the conventional fossil fuel intensive companies due to the replacement of energy sources in the market. At this stage, banks have to anticipate long waiting periods in order to yield results from their investments,

Because of government support, significant capital flows into the new energy sector will be realized. However, these may result in asset bubbles. Once the

energy transition fails to produce expected outcomes, investors including banks in this case may suffer financial losses, which may lead to a financial crisis.

Flori et al., 2021, explored empirically the interactions between commodity prices, climate-related variables (like rainfall and temperature) and an index that measures the degree of financial distress in capital markets. This is done by using a combination of a multi-dimensional graph-theoretical approach with standard econometric models. Their results suggest that climate change-related variables affect financial stability through the impact that they have on commodity prices as well as asset returns.

This is because climate change is associated with droughts, flooding, hurricanes, respiratory diseases, etc. All these can harm infrastructure (some of which may have been funded by banks), destroy production (especially in the agriculture sector). Such catastrophes affect bank borrowers who may be forced to default on the debt obligations and therefore affecting the profitability of banks. Our hypothesis is therefore that there is a negative relationship between climate change and bank profitability. Indeed, if climate change affects entire economies, this may affect the entire financial system.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Research approach

The research approach used in this study is an inductive method utilizing secondary data collected from different databases. The study does not provide any final and conclusive results but rather provides further insights as contribution to existing literature. The research is based on the following assumptions:

- **All banks in different countries have clients in sectors that are vulnerable to climate change**

The complex link between transitional and physical risks inevitably has effects on operational ecosystems of banks. This assumption is important for this study because to measure the impact, the banks must have sectors that possess credit risk as a result of climate change.

- **Climate change will affect the banks in different countries at an asset level**

The transitional risks that are coming through climate change could give rise to a re-evaluation of various asset classes if the banks are not proactively aligned to the energy transition and that may potentially oppress their earnings.

- **The collected data from the World Bank is an accurate reflection of how the climate has been affected over the selected period**

The World Bank's Climate Change Knowledge Portal collects historical climate related data, developing patterns and understanding of how the climate has evolved over the years. The data is important for the study because it shows the direct factors contributing to climate change that ultimately drives the energy transition.

3.2 Research design

The study, which seeks to investigate the impact of climate change on bank profitability, is conducted using a quantitative with correlation research design. Quantitative research design seeks to study the relationship between dependent and independent variables while analysing the findings against the objectives (Lowhorn, 2007). Additionally, quantitative correlation design does not allow control or data manipulation (Lowhorn, 2007). The quantitative design is appropriate for this study because a mathematical model is utilised to test the impact of climate change on banks profitability in the different countries.

The study employs regression using secondary data to determine the relationship between climate change and banking profitability determinants. We focus on the countries that are members of the SADC countries, mainly because we also seek to determine if there is significant impact on South Africa compared to the other member countries.

We use the Hausmann test to decide on the model to use, which is the fixed model. The correlations between variables as selected in the model tells us the extent to which the correlation of the independent variables is.

3.3 Data collection methods

Secondary data was gathered through extraction of historical databases obtained from World Bank Development Indicators. The secondary data method is appropriate for analysing data that is not necessarily available directly to a researcher (Hox & Boeije, 2005). Statistical applications sometimes require specific secondary data to function; however, it may not always be possible to find a perfect data set. Sources such as research institutes, government and regulators have existing data that they collect overtime.

The data for this research paper is sourced from existing reputable and reliable sources such as the World Bank database. The impact of climate change is measured using rainfall, CO2 emissions and temperature data covering the time from 2003 – 2018.

3.4 Population and sample

3.4.1 *Population*

The population of the study is the SADC region countries banking sector, SADC was formed with the aim of advancing sustainable socio-economic development as well as promoting economic growth amongst Southern African countries.

3.4.2 *Population method*

In total, the population covers banks from twelve countries that are member states of the Southern African Development Community as listed below, subject to data availability hence the other four countries were excluded from the study.

- Angola
- Botswana
- Democratic Republic of Congo
- Eswatini
- Lesotho
- Madagascar
- Malawi
- Mauritius
- Mozambique
- South Africa
- Tanzania
- Zambia

3.5 The research instrument

Our research instrument is desktop data that is collected from the various databases. The panel data approach is relevant in this case as we are combining all countries in one sample and following them from year to another. It also increases the number of observations in the study, which helps us to produce more precise parameter estimates.

In terms of the actual panel data models used, we will use both the fixed effects model and the random effects model. The Haussmann test was then used to select the more appropriate between the two models, the fixed effects model. We interpret the results based on the selected model.

The model to be estimated for the study is as follows:

$$ROA_{it} = \beta_0 + \beta_1 Climate_{it} + \beta_2 LIQ_{it} + \beta_3 LLOSS_{it} + \beta_4 COSTING_{it} + \beta_5 CONC_{it} + \beta_6 GDP_{it} + \beta_7 CPI_{it} + \beta_8 Country \times Climate_{it} + \varepsilon_{it}$$

$$NIM_{it} = \beta_0 + \beta_1 Climate_{it} + \beta_2 LIQ_{it} + \beta_3 LLOSS_{it} + \beta_4 COSTING_{it} + \beta_5 CONC_{it} + \beta_6 GDP_{it} + \beta_7 CPI_{it} + \beta_8 Country \times Climate_{it} + \varepsilon_{it}$$

The definitions of the variables in the above equation are explained below:

Table 4: Variables Table

Variable Name	**Variable description**	**Source of Data**
ROA	Return on assets and is measured Net Income over average total assets. It measures average bank profitability in a given country.	Global Financial Development database
Climate	Climate stands for climate change variables which will be measured using rainfall, and temperature. Monthly	Global Financial Development database

	rainfall/temperature variables will be converted to annual figures.	
LIQ	LIQ, a measure of liquidity using loan to assets ratio	Global Financial Development database/ Reserve Bank/Prudential Authority
LLOSS	LLOSS as loan loss provisions to loans ratio measured by dividing loan loss reserves by gross loans	Global Financial Development database/ Reserve Bank/Prudential Authority
COSTING	Costing measures bank efficiency using cost to income ratio	Global Financial Development database/ Reserve Bank/Prudential Authority
CONC	CONC, measuring banking sector concentration	Global Financial Development database/ Reserve Bank/Prudential Authority
GDP	GDP stands for the Gross Domestic Production of each country in the sampled population	Global Financial Development database/ Reserve Bank/Prudential Authority

CPI	CPI measuring Consumer Price Index	Global Financial Development database/ Reserve Bank/Prudential Authority

β_0 is a constant variable, ε is a well-behaved error term. It is assumed too normally distributed. The variables will be changing by country over time.

3.6 Procedure for data collection

The data is sourced from the different databases. Firstly, the SADC database was used to gather the macro-economic indicators variables such as GDP and inflation for all the twelve countries. Secondly, the data that was used to measure climate change variables was obtained from the World Bank Development Indicators and GFD data platform, the data was extracted through excel files. The banking sector data was obtained from each country's Reserve Bank/Prudential Authority to ensure accuracy. Once all the data has been extracted in different files, it was populated in one excel file which was loaded on to Stata ensuring that the structure is in the correct format of panel data.

3.7 Data analysis and interpretation

The regression analysis was used for this study because it explores the relationship amongst variables (Sykes, 1993). In this paper, we seek to establish the relationship between banking profitability drivers and climate change for the SADC countries. We assess the estimated statistical significance of the different variables on the banking profitability variables, determining the extent to which the estimated relationship is true.

The data is sorted by examining consistency and reliability in its measure which is important to improve efficiency (H. M. Park, 2011). We use the Hausmann test to decide on the model to use between fixed and random effects model. The Hausman specification test is used to weigh between models of fixed and random

effect (H. M. Park, 2011). Hausman specification test runs the comparison under the null hypothesis that of the model.

For this study, we examine bank performance at a country level using panel data following studies such as Lee and Lee (2019),Hesse and Poghosyan (2016) and Fu, Lin, & Molyneux(2014).The parameter of interest is β_1.Our hypothesis is that climate change is bad for bank profitability, we therefore expect a negative relationship between profitability and climate change $(\beta_1 \text{ is expected to be negative})$. We also test whether there is a non-linear relationship between bank profitability and climate change, this is measured by β_8.

The two panel data models are explained as follows:

- **Fixed effects Model**

The panel data set is called a fixed panel if the same subjects, countries in this case, are observed for each period (Greene, 2008). The null hypothesis rejection which means the statistic is statistically significant implies an adoption of the fixed effects model (H. M. Park, 2011).

- **Random effects Model**

The panel data is called a random panel if the subjects change with periods. When using the Hausman model, non-rejection of the null hypothesis is regarded as an adoption of the random effects model (H. M. Park, 2011).

Interpretation

$$ROA_{it} = \beta_0 + \beta_1 Climate_{it} + \beta_2 LIQ_{it} + \beta_3 LLOSS_{it} + \beta_4 SIZE_{it} + \beta_5 COSTING_{it} + \beta_6 CONC_{it} + \beta_7 GDP_{it} + \beta_8 CPI_{it} + \beta_9 Country \times Climate_{it} + \varepsilon_{it}$$

$$NIM_{it} = \beta_0 + \beta_1 Climate_{it} + \beta_2 LIQ_{it} + \beta_3 LLOSS_{it} + \beta_4 SIZE_{it} + \beta_5 COSTING_{it} + \beta_6 CONC_{it} + \beta_7 GDP_{it} + \beta_8 CPI_{it} + \beta_9 Country \times Climate_{it} + \varepsilon_{it}$$

A unit change in the explanatory variables (Climate, LIQ, LLOSS etc) for a particular country over time will lead to change in the coefficient(β_1..etc)

generating a unit increase in ROA and NIM. The correlations between variables as selected in the model tells us the extent to which the correlation of the independent variables is.

Secondly, the dummy variable helps answer the second research question comparing South Africa to the other SADC countries in terms of impact of climate change on bank performance. When the dummy variable is = 1, the country will be South Africa. When the dummy variable is =0, it will be any of the SADC countries. For example, if ROA=0,5 then South Africa's banking performance is positively affected by climate change compared to the other SADC countries and vice versa.

3.8 Limitations of the study

- Profitability data of banks is focused on industry level therefore the factors do not account for specific internal discrepancies
- Some countries that are SADC members may not have all the information pertaining the required variables which may cause an imbalance in the model
- The study assumes homogeneity among banks with no consideration of the endowment of fossil assets in SADC countries
- Banks are not being mandated by the same prudential authorities in the SADC countries, some of their risk methodologies may differ

3.9 Validity and reliability

3.9.1 *External validity*

The study focuses on the SADC region countries only therefore it cannot be easily generalized to other countries outside the SADC region.

3.9.2 *Internal validity*

The model we used for the study is well specified, mainly because it has been used before for similar studies and has produced desired results. We believe that the estimated parameters in the model will measure the required impact or effect of climate change0

3.9.3 *Reliability*

In order to enhance reliability, the study is based on a sample of SADC countries. The time frame or sample period chosen may affect the reliability and replicability of the results, especially if one chooses an abnormal period and fails to factor this in the estimation. Stability is tested using the research instrument with repeated testing abilities, Heale (2015) defines stability as the ability to a research instrument repeatedly while testing the consistency of the results.

In the study, periods when we had the global financial crisis and other shocks will be accounted for using appropriate dummies. This ensures that if our study finds that climate change is bad for bank profitability, other studies that will follow are more likely to find the same, even when using different time periods. This will meet the reliability criteria for the study as the consistency of measure will be evidenced (Heale,2015).

3.10 Ethical considerations

The study uses secondary data. We ensure that the data collected from the different databases is accurate and reliable. This is done through the utilization of reputable and authorized financial databases. There is acknowledgement of ownership of the original data by using the correct references in the paper.

CHAPTER 4. PRESENTATION OF RESULTS

4.1 Introduction

In order to achieve our objective of investigating the impact of climate change on bank performance we run a number of panel data regression models. These include: the fixed effects models, random effects model, FGLS and pooled regression models. We also conducted a number of diagnostic tests. These included the tests for joint validity of cross-sectional individual effects, Breusch Pagan (1980: 239) Lagrange Multiplier test for random effects and Hausman (1978: 1251) specification test for heteroscedasticity. We also used two measures of climate change, as done in the literature. These are: climate change1 (measured using average annual temperature in degrees Celsius) and climate change2 (measured using average annual rainfall in millimeters). As mentioned previously, bank performance is measured using returns on assets (ROA), returns on equity (ROE) and net interest margin (NIM). These have also been used in the extant literature.

The results of the study are shown in Tables 6-17. Tables 6-9 use ROA as the dependent variable, Tables 10-13 use NIM as the dependent variable, and Tables 14-17 use ROE as the dependent variable. In this section we discuss the results from these tables. We conclude the section by looking at a few diagnostic tests that were conducted to confirm the validity of our results. Given that we covered only 12 African countries our results do not necessarily apply to the rest of the continent but are especially applicable to the countries covered.

Looking at the overall results from all the tables, we find that there is a positive and significant relationship between climate change and bank profitability when using temperature and ROA as measures of climate change. There is a possibility of a turning point on this ROA positive relationship meaning there is a threshold that at some point the relationship becomes negative.

From an NIM perspective, we find that there is no relationship between climate change and bank profitability when using temperature as a measure. However, we also find that rainfall as a measure of climate change has a positive relationship on NIM but there is a threshold that at some point the relationship becomes negative.

From an ROE perspective, we find that there is no relationship between climate change and bank profitability when using temperature as a measure. However, we also find that rainfall as a measure of climate change has a negative relationship on ROE.

4.2 Results pertaining to Hypothesis 2: There is significant difference on the impact of climate in South Africa compared to other SADC member states.

South Africa is linked to the Southern African Development Community countries in several ways. The trade of goods between the countries is fundamental for the region to remain interconnected. SADC countries are considered not climate resilient due to unavailability of resources, inadequate infrastructure as well as different economic development (Pressend, 2011).

Tadesse (2010) argues that analysts are exaggerating the effect that climate change will have in Africa. This is because the African continent is considered a light polluter. The paper further argues that the current climate change science has not benefitted Africa yet because there isn't adequate information for policy decision making that is specific for Africa's conditions.

Table 6-17 displays the estimation results of the effect of climate change in South Africa compared to other SADC member states.

The coefficient of dummy_SA shows that there is no difference in how South Africa is affected by climate change compared to the rest of the SADC countries.

Zhang et al. (2022) concluded that high-income countries' bank performance is affected significantly by climate change via natural disasters compared to low-income countries. This in line with the Olubusoye and Musa (2019) and Kaika & Zervas (2013) who used the environmental Kuznets curve and discovered that that environmental degradation worsened.

4.3 Summary of the results/findings

Table 6 displays the estimation results of the effect of climate change on bank profitability when using ROA as dependent variable through the Fixed Effects Model.

The results indicate that there was no significant relationship between climate change and bank profitability. This is the case when using both temperature and rainfall as measures of climate change. Climate change squared was also used to check for a turning point (threshold) in the relationship, we also find that there is no turning point.

When it comes to the relationship between bank profitability and control variables, we find the following results: First, there was a positive relationship between concentration (CONCE) and bank profitability, with a coefficient of 0.022 at a 5% level of significance. This is an indication that banks that dominate the market are likely to be more profitable than smaller banks.

The significant coefficient of *LLOSS* in model 1 to 4 is -0.058 and significant at 5% level, showing a negative effect of loan loss provisions to bank performance. *COST* indicates a strong negative effect with a coefficient of -0.053 at 1% level of significance, showing a strong negative effect. In addition,

Table 7 displays the estimation results of the effect of climate change on bank profitability when using ROA as dependent variable through Random Effects Model.

The results indicate that there is a significant and positive relationship between climate change and bank profitability when using temperature as a measure, however, $CLIM1^2$ as an additional explanatory variable enlightens us to the possibility of a turning point on this ROA positive relationship. This means there is a threshold to the positive relationship.

We see rainfall as measures of climate change indicating a significant and positive relationship. Climate change squared was also used to check for a turning point (threshold) in the relationship, we also find that there is no turning point.

When it comes to the relationship between bank profitability and control variables, we find the following results:
LIQ shows a strong positive effect on bank profitability with a coefficient of 0.021 that is significant at 1% level, showing a strong positive effect on bank profitability. The coefficient of *LLOSS* in model -0.052, with 5% level of significance. *COST* indicates a coefficient of -0.057 which is significant at 1% level showing a strong negative effect. *CREDIT* coefficient is -0.057 with 1% level of significance indicating a strong negative effect to banking profitability. The coefficient of LDS is -0.020 at 5% significance level.

Banking sector concentration (CONCE) has a positive effect on banking profitability with a coefficient of 0.038 at a 1% level of significance indicating a strong positive relationship.

Table 8 displays the estimation results of the effect of climate change on bank profitability when using ROA as dependent variable though FGLS Model.

The results indicate that there is a significant and positive relationship between climate change and bank profitability when using temperature as a measure, however, $CLIM1^2$ as an additional explanatory variable enlightens us to the possibility of a turning point on this ROA positive relationship. This means there is a threshold to the positive relationship.

We see rainfall as measures of climate change indicating a significant and positive relationship. Climate change squared was also used to check for a turning point (threshold) in the relationship, we also find that there is no turning point.

When it comes to the relationship between bank profitability and control variables, we find the following results:

The coefficient of *LIQ* is 0.021 and significant at 1% level, showing a strong positive effect on bank profitability. *COST* indicates a coefficient of -0.064 which is significant at 1% level showing a strong negative effect. *CREDIT* coefficient is -0.093 with 1% level of significance indicating a strong negative effect to banking profitability. The coefficient of LDS is -0.020 at 5% significance level.

Banking sector concentration (CONCE) has a positive effect on banking profitability with a coefficient of 0.038 at a 1% level of significance indicating a strong positive relationship.

Table 9 displays the estimation results of the effect of climate change on bank profitability when using ROA as dependent variable through Pooled Regression Model.

The results indicate that there is a significant and positive relationship between climate change and bank profitability when using temperature as a measure, however, $CLIM1^2$ as an additional explanatory variable enlightens us to the possibility of a turning point on this ROA positive relationship. This means there is a threshold to the positive relationship.

We see rainfall as measures of climate change indicating a significant and positive relationship. Climate change squared was also used to check for a turning point (threshold) in the relationship, we also find that there is no turning point.

When it comes to the relationship between bank profitability and control variables, we find the following results:

The coefficient of *LIQ* is 0.021 and significant at 1% level, showing a strong positive effect on bank profitability. The coefficient of *LLOSS* in model -0.052, with 5% level of significance. *COST* indicates a coefficient of -0.064 which is significant at 1% level showing a strong negative effect. *CREDIT* coefficient is -0.085 with 1% level of significance indicating a strong negative effect to banking profitability. The coefficient of LDS is -0.020 at 5% significance level.

Banking sector concentration (CONCE) has a positive effect on banking profitability with a coefficient of 0.038 at a 1% level of significance indicating a strong positive relationship.

Table 10 displays the estimation results of the effect of climate change on bank profitability when using NIM as dependent variable through Fixed Effects Model.

The results indicate that there is no significant relationship between climate change and bank profitability when using both temperature and rainfall as a measure, however, $CLIM1^2$ as an additional explanatory variable enlightens us to the possibility no turning point on this NIM relationship.

When it comes to the relationship between bank profitability and control variables, we find the following results:

CREDIT coefficient is -0.083 with 10% level of significance indicating a positive effect to banking profitability. Banking sector concentration (CONCE) has a positive effect on banking profitability with a coefficient of 0.03 at a 10% level of significance indicating a strong positive relationship.

The Random Effects Model in table 11 displays the effect of climate change on bank profitability when using NIM as dependent variable.

The results indicate that there is no significant and relationship between climate change and bank profitability when using temperature as a measure, $CLIM1^2$ as an additional explanatory variable also enlightens us to no possibility of a turning point on this NIM relationship. This means there is no threshold in the relationship.

We see rainfall as measures of climate change indicating a significant and positive relationship. Climate change squared was also used to check for a turning point (threshold) in the relationship, we also find that there is no turning point.

When it comes to the relationship between bank profitability and control variables, we find the following results:

The coefficient of *LIQ* is 0.04 and significant at 1% level, showing a strong positive effect on bank profitability. The coefficient of *LLOSS* in model 0.14 with 1% level of significance. *CREDIT* coefficient is -0.13 with 1% level of significance indicating a strong negative effect to banking profitability.

Banking sector concentration (CONCE) has a positive effect on banking profitability with a coefficient of 0.05 at a 1% level of significance indicating a strong positive relationship. CPI also has a positive effect with a coefficient of 0.07 at 5% level of significance.

Table 12 displays the effect of climate change on bank profitability when using NIM as dependent variable through the FGLS model.

The results indicate that there is no significant and relationship between climate change and bank profitability when using temperature as a measure, $CLIM1^2$ as an additional explanatory variable also enlightens us to no possibility of a turning point on this NIM relationship. This means there is no threshold the relationship.

We see rainfall as measures of climate change indicating a significant and positive relationship. Climate change squared was also used to check for a

turning point (threshold) in the relationship, we also find that there is no turning point.

When it comes to the relationship between bank profitability and control variables, we find the following results:

The coefficient of *LIQ* is 0.04 and significant at 1% level, showing a strong positive effect on bank profitability. The coefficient of *LLOSS* in model 0.14 with 1% level of significance. *CREDIT* coefficient is -0.13 with 1% level of significance indicating a strong negative effect to banking profitability.

Banking sector concentration (CONCE) has a positive effect on banking profitability with a coefficient of 0.05 at a 1% level of significance indicating a strong positive relationship.
GDPG and *CPI* also indicates a positive relationship to NIM as a measure of banking profitability

Table 13 displays the effect of climate change on bank profitability when using NIM as dependent variable through the pooled regression model.

The results indicate that there is no significant and relationship between climate change and bank profitability when using temperature as a measure, $CLIM1^2$ as an additional explanatory variable also enlightens us to no possibility of a turning point on this NIM positive relationship. This means there is no threshold in the positive relationship.

We see rainfall as measures of climate change indicating a significant and positive relationship. Climate change squared was also used to check for a turning point (threshold) in the relationship, we also find that there is no turning point.

When it comes to the relationship between bank profitability and control variables, we find the following results:

The coefficient of *LIQ* is 0.04 and significant at 1% level, showing a strong positive effect on bank profitability. The coefficient of *LLOSS* in model 0.14 with 1% level of significance. *CREDIT* coefficient is -0.13 with 1% level of significance indicating a strong negative effect to banking profitability.

Banking sector concentration (CONCE) has a positive effect on banking profitability with a coefficient of 0.05 at a 1% level of significance indicating a strong positive relationship.
Table 14 displays the effect of climate change on bank profitability when using ROE as dependent variable through the pooled regression model.

The results indicate that there is no significant and relationship between climate change and bank profitability when using temperature and rainfall as a measure, $CLIM1^2$ as an additional explanatory variable also enlightens us to no possibility of a turning point on this ROE relationship. This means there is no threshold in the relationship.

When it comes to the relationship between bank profitability and control variables, we find the following results:

The coefficient of *LLOSS* in model 0.14 with 1% level of significance, loan provisions have a negative effect on banking profitability. *COST* coefficient is -0.13 with 1% level of significance indicating a strong negative effect to banking profitability. Large costs impact the overall profitability.

Banking sector concentration (*CONCE*) has a positive effect on banking profitability with a coefficient of 0.05 at a 1% level of significance indicating a strong positive relationship. This is an indication that larger banks are more likely to be profitable than smaller banks.

Table 15 displays the effect of climate change on bank profitability when using ROE as dependent variable through the random effects model.

The results indicate that there is no significant and relationship between climate change and bank profitability when using temperature, a measure, $CLIM1^2$ as an additional explanatory variable also enlightens us to no possibility of a turning point on this ROE relationship. This means there is no threshold the relationship. We find that rain has a positive relationship in this case with no possible threshold

When it comes to the relationship between bank profitability and control variables, we find the following results:

The coefficient of *LLOSS* in model 0.40 with 1% level of significance meaning loan provisions have a negative effect on banking profitability. *COST* coefficient is -0.13 with 1% level of significance indicating a strong negative effect to banking profitability. Large costs impact the overall profitability. CREDIT indicates a negative relationship as well, balance sheet extended to government and SOEs has a default risk due to ailing infrastructure.

Banking sector concentration (*CONCE*) has a positive effect on banking profitability with a coefficient of 0.05 at a 1% level of significance indicating a strong positive relationship. This is an indication that larger banks are more likely to be profitable than smaller banks

Table 16 displays the effect of climate change on bank profitability when using ROE as dependent variable through the random effects model.

The results indicate that there is no significant and relationship between climate change and bank profitability when using temperature, a measure, $CLIM1^2$ as an additional explanatory variable also enlightens us to no possibility of a turning point on this ROE relationship. This means there is no threshold the relationship. We find that rain has a positive relationship in this case with no possible threshold

When it comes to the relationship between bank profitability and control variables, we find the following results:

LIQ shows a strong positive effect on bank profitability that is significant at 1% level, showing a strong positive effect on bank profitability. The coefficient of *LLOSS* in model 0.40 with 1% level of significance meaning loan provisions have a negative effect on banking profitability. *COST* coefficient is -0.13 with 1% level of significance indicating a strong negative effect to banking profitability. Large costs impact the overall profitability. CREDIT indicates a negative relationship as well, balance sheet extended to government and SOEs has a default risk due to ailing infrastructure.

Banking sector concentration (*CONCE*) has a positive effect on banking profitability with a coefficient of 0.05 at a 1% level of significance indicating a strong positive relationship. This is an indication that larger banks are more likely to be profitable than smaller banks. Our results concur with findings by other literature authors ss Smirlock (1985) found a positive relationship exists between the size of the banks and its profitability. The higher the market share the bank possesses, the more likely it is to obtain higher profitability results.

Table 17 displays the effect of climate change on bank profitability when using ROE as dependent variable through the random effects model.

The results indicate that there is no significant and relationship between climate change and bank profitability when using temperature, a measure, $CLIM1^2$ as an additional explanatory variable also enlightens us to no possibility of a turning point on this ROE relationship. This means there is no threshold in the relationship.
We find that rain has a positive relationship in this case with no possible threshold

When it comes to the relationship between bank profitability and control variables, we find the following results:

The coefficient of *LLOSS* in model 0.40 with 1% level of significance meaning loan provisions have a negative effect on banking profitability. *COST* coefficient is -0.13 with 1% level of significance indicating a strong negative effect to banking profitability. Large costs impact the overall profitability. CREDIT indicates a negative relationship as well, balance sheet extended to government and SOEs has a default risk due to ailing infrastructure.

Banking sector concentration (*CONCE*) has a positive effect on banking profitability with a coefficient of 0.05 at a 1% level of significance indicating a strong positive relationship. This is an indication that larger banks are more likely to be profitable than smaller banks

4.4 Results pertaining to Hypothesis 1: Climate change significantly impacts bank performance

Table 5: The effect of climate change on bank profitability when using ROA as dependent variable (Fixed Effects Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	-0.000	0.002	-0.000	-0.000
	(0.01)	(0.01)	(0.01)	(0.01)
LLOSS	-0.057**	-0.056**	-0.058**	-0.058**
	(0.02)	(0.02)	(0.02)	(0.02)
COST	-0.053***	-0.052***	-0.053***	-0.053***
	(0.01)	(0.01)	(0.01)	(0.01)
CREDIT	-0.014	-0.014	-0.014	-0.014
	(0.02)	(0.02)	(0.02)	(0.02)
LDS	-0.011	-0.011	-0.011	-0.011
	(0.01)	(0.01)	(0.01)	(0.01)
CONCE	0.022**	0.021**	0.022**	0.021**
	(0.01)	(0.01)	(0.01)	(0.01)
GDPG	0.012	0.012	0.012	0.014
	(0.02)	(0.02)	(0.02)	(0.02)
CPI	-0.004	-0.003	-0.003	-0.004
	(0.01)	(0.01)	(0.01)	(0.01)
SA DUMMY x CPI interaction	-0.095	-0.091	-0.093	-0.093
	(0.11)	(0.11)	(0.11)	(0.11)
Climate change1	-0.079	1.411		
	(0.24)	(1.49)		
Climate change1 squared		-0.036		
		(0.04)		
Climate change2			0.000	-0.001
			(0.00)	(0.00)
Climate change2 squared				0.000
				(0.00)

Constant	5.801	-9.485	3.964***	4.406***
	(5.17)	(15.96)	(1.16)	(1.43)
Observations	191	191	191	191
R-squared	0.315	0.319	0.315	0.317
Number of Countries	12	12	12	12
F	7.779***	7.166***	7.788***	7.076***

Notes: Standard errors in parentheses. *, **, and ***stand for 10%, 5% and 1%, levels of significance. *Climate change1* stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall.

Table 6: The effect of climate change on bank profitability when using ROA as dependent variable (Random Effects Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	-0.000	0.021***	0.001	0.002
	(0.01)	(0.01)	(0.01)	(0.01)
LLOSS	-0.052**	-0.002	-0.025	-0.009
	(0.02)	(0.02)	(0.02)	(0.02)
COST	-0.054***	-0.059***	-0.054***	-0.064***
	(0.01)	(0.01)	(0.01)	(0.01)
CREDIT	-0.018	-0.052***	-0.057***	-0.085***
	(0.02)	(0.02)	(0.02)	(0.02)
LDS	-0.011	-0.016*	-0.012	-0.020**
	(0.01)	(0.01)	(0.01)	(0.01)
CONCE	0.023**	0.032***	0.031***	0.038***
	(0.01)	(0.01)	(0.01)	(0.01)
GDPG	0.012	0.002	0.004	0.002
	(0.02)	(0.03)	(0.02)	(0.03)
CPI	-0.003	0.013	0.005	0.017
	(0.01)	(0.01)	(0.01)	(0.01)
SA DUMMY	-1.280	-0.623	-0.790	-0.449
	(1.68)	(0.87)	(0.84)	(0.84)

SA DUMMY x CPI interaction	-0.095	-0.136	-0.105	-0.131
	(0.11)	(0.15)	(0.12)	(0.14)
Climate change1	-0.029	0.875*		
	(0.13)	(0.46)		
Climate change1 squared		-0.022*		
		(0.01)		
Climate change2			0.000	0.002**
			(0.00)	(0.00)
Climate change2 squared				-0.000
				(0.00)
Constant	4.733	-5.521	3.091***	2.526**
	(2.94)	(4.43)	(1.08)	(1.01)
Observations	191	191	191	191
Number of countries	12	12	12	12
Wald chi2	83.07***	185.5***	102.8***	194.2***

Notes: Standard errors in parentheses. *, **, and ***stand for 10%, 5% and 1%, levels of significance. *Climate change1* stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall.

Table 7: The effect of climate change on bank profitability when using ROA as dependent variable (FGLS Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	0.013**	0.021***	0.004	0.002
	(0.01)	(0.01)	(0.00)	(0.01)
LLOSS	0.013	-0.002	-0.001	-0.009
	(0.02)	(0.02)	(0.02)	(0.02)
COST	-0.064***	-0.059***	-0.061***	-0.064***
	(0.01)	(0.01)	(0.01)	(0.01)
CREDIT	-0.064***	-0.052***	-0.093***	-0.085***
	(0.01)	(0.02)	(0.02)	(0.02)
LDS	-0.014*	-0.016**	-0.020**	-0.020**

	(0.01)	(0.01)	(0.01)	(0.01)
CONCE	0.033***	0.032***	0.037***	0.038***
	(0.01)	(0.01)	(0.01)	(0.01)
GDPG	0.004	0.002	0.006	0.002
	(0.03)	(0.03)	(0.02)	(0.02)
CPI	0.015	0.013	0.023	0.017
	(0.01)	(0.01)	(0.01)	(0.01)
SA DUMMY	-0.297	-0.623	-0.332	-0.449
	(0.83)	(0.84)	(0.81)	(0.81)
SA DUMMY x CPI interaction	-0.140	-0.136	-0.133	-0.131
	(0.14)	(0.14)	(0.14)	(0.14)
Climate change1	0.043	0.875**		
	(0.03)	(0.44)		
Climate change1 squared		-0.022*		
		(0.01)		
Climate change2			0.001***	0.002***
			(0.00)	(0.00)
Climate change2 squared				-0.000
				(0.00)
Constant	2.241*	-5.521	2.595***	2.526***
	(1.23)	(4.28)	(0.98)	(0.97)
Observations	191	191	191	191
Number of countries	12	12	12	12
Wald chi2	191.9***	199.1***	203.6***	208.4***
Log-likelihood	-273.5	-271.7	-270.6	-269.4

Notes: Standard errors in parentheses. *, **, and ***stand for 10%, 5% and 1%, levels of significance. *Climate change1* stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall.

Table 8: The effect of climate change on bank profitability when using ROA as dependent variable (Pooled Regression Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	-0.000	0.021***	0.001	0.002
	(0.01)	(0.01)	(0.01)	(0.01)
LLOSS	-0.052**	-0.002	-0.025	-0.009
	(0.02)	(0.02)	(0.02)	(0.02)
COST	-0.054***	-0.059***	-0.054***	-0.064***
	(0.01)	(0.01)	(0.01)	(0.01)
CREDIT	-0.018	-0.052***	-0.057***	-0.085***
	(0.02)	(0.02)	(0.02)	(0.02)
LDS	-0.011	-0.016*	-0.012	-0.020**
	(0.01)	(0.01)	(0.01)	(0.01)
CONCE	0.023**	0.032***	0.031***	0.038***
	(0.01)	(0.01)	(0.01)	(0.01)
GDPG	0.012	0.002	0.004	0.002
	(0.02)	(0.03)	(0.02)	(0.03)
CPI	-0.003	0.013	0.005	0.017
	(0.01)	(0.01)	(0.01)	(0.01)
SA DUMMY	-1.280	-0.623	-0.790	-0.449
	(1.68)	(0.87)	(0.84)	(0.84)
SA DUMMY x CPI interaction	-0.095	-0.136	-0.105	-0.131
	(0.11)	(0.15)	(0.12)	(0.14)
Climate change1	-0.029	0.875*		
	(0.13)	(0.46)		
Climate change1 squared		-0.022*		
		(0.01)		
Climate change2			0.000	0.002**
			(0.00)	(0.00)
Climate change2 squared				-0.000
				(0.00)
Constant	4.733	-5.521	3.091***	2.526**

	(2.94)	(4.43)	(1.08)	(1.01)
Observations	191	191	191	191
Number of countries	12	12	12	12
Wald chi2	83.07***	185.5***	102.8***	194.2***

Notes: Standard errors in parentheses. *, **, and ***stand for 10%, 5% and 1%, levels of significance. *Climate change1* stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall.

Table 9: The effect of climate change on bank profitability when using NIM as dependent variable (Fixed Effects Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	-0.011	-0.008	-0.010	-0.009
	(0.01)	(0.01)	(0.01)	(0.01)
LLOSS	-0.061	-0.060	-0.056	-0.057
	(0.04)	(0.04)	(0.04)	(0.04)
COST	-0.022	-0.020	-0.021	-0.021
	(0.01)	(0.02)	(0.01)	(0.01)
CREDIT	0.083*	0.082*	0.078*	0.079*
	(0.04)	(0.04)	(0.04)	(0.04)
LDS	-0.001	-0.002	0.001	0.001
	(0.01)	(0.01)	(0.01)	(0.01)
CONCE	0.037*	0.037*	0.037*	0.037*
	(0.02)	(0.02)	(0.02)	(0.02)
GDPG	0.079*	0.079*	0.071*	0.068
	(0.04)	(0.04)	(0.04)	(0.04)
CPI	-0.012	-0.011	-0.013	-0.013
	(0.02)	(0.02)	(0.02)	(0.02)
SA DUMMY x CPI interaction	-0.031	-0.024	-0.039	-0.038
	(0.20)	(0.20)	(0.20)	(0.20)
Climate change1	0.424	3.121		

	(0.43)	(2.68)		
Climate change1 squared		-0.065		
		(0.06)		
Climate change2			0.000	0.002
			(0.00)	(0.00)
Climate change2 squared				-0.000
				(0.00)
Constant	-4.505	-32.168	4.326**	3.437
	(9.28)	(28.69)	(2.09)	(2.57)
Observations	191	191	191	191
R-squared	0.092	0.097	0.087	0.089
Number of Countries	12	12	12	12
F	1.71**	1.65**	1.60*	1.49*

Notes: Standard errors in parentheses. *, **, and ***stand for 10%, 5% and 1%, levels of significance. *Climate change1* stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall.

Table 10: The effect of climate change on bank profitability when using NIM as dependent variable (Random Effects Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	-0.008	0.041***	0.000	0.021**
	(0.01)	(0.01)	(0.01)	(0.01)
LLOSS	-0.037	0.148***	0.022	0.089*
	(0.04)	(0.05)	(0.04)	(0.05)
COST	-0.018	0.010	-0.008	-0.005
	(0.01)	(0.02)	(0.02)	(0.02)
CREDIT	0.051	-0.136***	-0.028	-0.112***
	(0.04)	(0.03)	(0.04)	(0.04)
LDS	-0.000	-0.018	-0.002	-0.022
	(0.01)	(0.02)	(0.02)	(0.02)

CONCE	0.041**	0.047***	0.047**	0.057***
	(0.02)	(0.02)	(0.02)	(0.02)
GDPG	0.068	0.112**	0.063	0.102**
	(0.04)	(0.06)	(0.05)	(0.05)
CPI	-0.009	0.075**	0.008	0.053*
	(0.02)	(0.03)	(0.02)	(0.03)
SA DUMMY	-4.141	-1.197	-3.492**	-2.141
	(2.84)	(1.82)	(1.76)	(1.69)
SA DUMMY x CPI interaction	-0.040	-0.114	-0.051	-0.095
	(0.20)	(0.31)	(0.23)	(0.29)
Climate change1	0.040	-0.214		
	(0.21)	(0.95)		
Climate change1 squared		0.008		
		(0.03)		
Climate change2			0.000	0.005***
			(0.00)	(0.00)
Climate change2 squared				-0.000***
				(0.00)
Constant	3.454	0.620	2.664	-1.288
	(5.11)	(9.23)	(2.14)	(2.02)
Observations	191	191	191	191
Number of countries	12	12	12	12
Wald chi2	15.62***	143.8***	22.10***	176.7**

Notes: Standard errors in parentheses. *, **, and ***stand for 10%, 5% and 1%, levels of significance. *Climate change1* stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall.

Table 11: The effect of climate change on bank profitability when using NIM as dependent variable (FGLS)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	0.043***	0.041***	0.032***	0.021**
	(0.01)	(0.01)	(0.01)	(0.01)
LLOSS	0.142***	0.148***	0.135***	0.089*
	(0.05)	(0.05)	(0.05)	(0.05)
COST	0.011	0.010	0.014	-0.005
	(0.02)	(0.02)	(0.02)	(0.02)
CREDIT	-0.132***	-0.136***	-0.153***	-0.112***
	(0.03)	(0.03)	(0.04)	(0.04)
LDS	-0.018	-0.018	-0.021	-0.022
	(0.02)	(0.02)	(0.02)	(0.02)
CONCE	0.046***	0.047***	0.049***	0.057***
	(0.02)	(0.02)	(0.02)	(0.02)
GDPG	0.111**	0.112**	0.123**	0.102**
	(0.05)	(0.05)	(0.05)	(0.05)
CPI	0.074**	0.075***	0.084***	0.053*
	(0.03)	(0.03)	(0.03)	(0.03)
SA DUMMY	-1.313	-1.197	-1.468	-2.141
	(1.72)	(1.76)	(1.71)	(1.63)
SA DUMMY x CPI interaction	-0.113	-0.114	-0.106	-0.095
	(0.29)	(0.29)	(0.29)	(0.28)
Climate change1	0.081	-0.214		
	(0.07)	(0.92)		
Climate change1 squared		0.008		
		(0.02)		
Climate change2			0.001	0.005***
			(0.00)	(0.00)
Climate change2 squared				-0.000***
				(0.00)
Constant	-2.138	0.620	-0.891	-1.288

	(2.54)	(8.91)	(2.04)	(1.95)
Observations	191	191	191	191
Number of countries	12	12	12	12
Wald chi2	154.2***	154.4***	154.6***	189.6***
Log-likelihood	-411.9	-411.9	-411.8	-402.6

Notes: Standard errors in parentheses. *, **, and ***stand for 10%, 5% and 1%, levels of significance. *Climate change1* stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall.

Table 12: The effect of climate change on bank profitability when using NIM as dependent variable (Pooled Regression Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	-0.008	0.041***	0.000	0.021**
	(0.01)	(0.01)	(0.01)	(0.01)
LLOSS	-0.037	0.148***	0.022	0.089*
	(0.04)	(0.05)	(0.04)	(0.05)
COST	-0.018	0.010	-0.008	-0.005
	(0.01)	(0.02)	(0.02)	(0.02)
CREDIT	0.051	-0.136***	-0.028	-0.112***
	(0.04)	(0.03)	(0.04)	(0.04)
LDS	-0.000	-0.018	-0.002	-0.022
	(0.01)	(0.02)	(0.02)	(0.02)
CONCE	0.041**	0.047***	0.047**	0.057***
	(0.02)	(0.02)	(0.02)	(0.02)
GDPG	0.068	0.112**	0.063	0.102**
	(0.04)	(0.06)	(0.05)	(0.05)
CPI	-0.009	0.075**	0.008	0.053*
	(0.02)	(0.03)	(0.02)	(0.03)
SA DUMMY	-4.141	-1.197	-3.492**	-2.141
	(2.84)	(1.82)	(1.76)	(1.69)
SA DUMMY x CPI interaction	-0.040	-0.114	-0.051	-0.095

	(0.20)	(0.31)	(0.23)	(0.29)
Climate change1	0.040	-0.214		
	(0.21)	(0.95)		
Climate change1 squared		0.008		
		(0.03)		
Climate change2			0.000	0.005***
			(0.00)	(0.00)
Climate change2 squared				-0.000***
				(0.00)
Constant	3.454	0.620	2.664	-1.288
	(5.11)	(9.23)	(2.14)	(2.02)
Observations	191	191	191	191
Number of countries	12	12	12	12

Notes: standard errors in parentheses. *, **, and ***stand for 10%, 5% and 1%, levels of significance. *Climate change1* stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall.

Table 13: The effect of climate change on bank profitability when using ROE as dependent variable (Fixed Effects Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	0.065	0.064	0.065	0.065
	(0.06)	(0.06)	(0.06)	(0.06)
LLOSS	-0.837***	-0.837***	-0.836***	-0.834***
	(0.23)	(0.23)	(0.23)	(0.23)
COST	-0.522***	-0.524***	-0.523***	-0.523***
	(0.08)	(0.08)	(0.08)	(0.08)
CREDIT	-0.063	-0.063	-0.060	-0.062
	(0.23)	(0.23)	(0.23)	(0.23)
LDS	-0.137*	-0.137*	-0.137*	-0.138*
	(0.08)	(0.08)	(0.08)	(0.08)

CONCE	0.275***	0.275***	0.276***	0.274***
	(0.10)	(0.10)	(0.10)	(0.10)
GDPG	0.284	0.284	0.287	0.293
	(0.22)	(0.23)	(0.22)	(0.22)
CPI	0.213*	0.213*	0.212*	0.212*
	(0.12)	(0.12)	(0.12)	(0.12)
SA DUMMY x CPI interaction	-1.325	-1.329	-1.326	-1.327
	(1.07)	(1.08)	(1.07)	(1.08)
CLIM1	0.001	-1.387		
	(2.28)	(14.29)		
CLIM1_squared		0.033		
		(0.34)		
CLIM2			-0.001	-0.004
			(0.01)	(0.01)
CLIM2_squared				0.000
				(0.00)
Constant	29.424	43.668	29.997***	32.045**
	(49.35)	(152.94)	(11.07)	(13.64)
Observations	191	191	191	191
R-squared	0.399	0.399	0.399	0.400
Number of countries	12	12	12	12
F	11.23***	10.15***	11.24***	10.17***

Climate change1 stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall.

Table 14: The effect of climate change on bank profitability when using ROE as dependent variable (Random Effects Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	0.075	0.090	0.069	0.130***
	(0.05)	(0.06)	(0.05)	(0.04)
LLOSS	-0.634***	-0.522***	-0.721***	-0.403**
	(0.21)	(0.20)	(0.21)	(0.20)
COST	-0.527***	-0.610***	-0.523***	-0.566***
	(0.07)	(0.07)	(0.08)	(0.07)
CREDIT	-0.458***	-0.868***	-0.239	-0.735***
	(0.17)	(0.13)	(0.21)	(0.16)
LDS	-0.129*	-0.115*	-0.130*	-0.068
	(0.07)	(0.07)	(0.07)	(0.07)
CONCE	0.287***	0.219***	0.287***	0.173***
	(0.08)	(0.06)	(0.09)	(0.06)
GDPG	0.173	0.007	0.244	0.164
	(0.21)	(0.22)	(0.22)	(0.21)
CPI	0.232**	0.227*	0.222*	0.272**
	(0.12)	(0.12)	(0.12)	(0.12)
SA DUMMY	2.790	8.589	0.608	6.766
	(7.70)	(7.02)	(9.59)	(6.85)
SA DUMMY x CPI interaction	-1.375	-1.529	-1.350	-1.545
	(1.09)	(1.18)	(1.06)	(1.18)
CLIM1	0.121	-3.095		
	(0.47)	(3.67)		
CLIM1_squared		0.095		
		(0.10)		
CLIM2			-0.002	-0.009*
			(0.00)	(0.00)
CLIM2_squared				0.000*

				(0.00)
Constant	27.419*	65.071*	30.266***	44.128***
	(14.39)	(35.64)	(10.47)	(8.18)
Observations	191	191	191	191
Number of countries	12	12	12	12
Wald Chi2	137.8***	245.6***	124.2***	246.3***

Climate change1 stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall

Table 15: The effect of climate change on bank profitability when using ROE as dependent variable (FGLS Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	0.125***	0.090*	0.111***	0.130***
	(0.04)	(0.05)	(0.04)	(0.04)
LLOSS	-0.588***	-0.522***	-0.476**	-0.403**
	(0.18)	(0.19)	(0.19)	(0.19)
COST	-0.591***	-0.610***	-0.598***	-0.566***
	(0.06)	(0.06)	(0.06)	(0.07)
CREDIT	-0.817***	-0.868***	-0.668***	-0.735***
	(0.11)	(0.13)	(0.15)	(0.15)
LDS	-0.121*	-0.115*	-0.070	-0.068
	(0.06)	(0.06)	(0.07)	(0.07)
CONCE	0.214***	0.219***	0.186***	0.173***
	(0.06)	(0.06)	(0.06)	(0.06)
GDPG	-0.004	0.007	0.130	0.164
	(0.21)	(0.21)	(0.20)	(0.20)
CPI	0.219*	0.227**	0.223**	0.272**
	(0.11)	(0.11)	(0.11)	(0.12)
SA DUMMY	7.211	8.589	5.671	6.766

	(6.65)	(6.78)	(6.64)	(6.61)
SA DUMMY x CPI interaction	-1.513	-1.529	-1.527	-1.545
	(1.14)	(1.14)	(1.15)	(1.14)
CLIM1	0.424	-3.095		
	(0.27)	(3.54)		
CLIM1_squared		0.095		
		(0.09)		
CLIM2			-0.002	-0.009*
			(0.00)	(0.00)
CLIM2_squared				0.000*
				(0.00)
Constant	32.220***	65.071*	43.483***	44.128***
	(9.84)	(34.41)	(7.95)	(7.89)
Observations	191	191	191	191
Number of countries	12	12	12	12
Wald Chi2	261.2***	263.6***	257.0***	264.3***
Log-likelihood	-670.4	-669.9	-671.3	-669.7

Climate change1 stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall

Table 16: The effect of climate change on bank profitability when using ROE as dependent variable (Pooled Regression Model)

VARIABLES	Model 1	Model 2	Model 3	Model 4
LIQ	0.075	0.090	0.069	0.130***
	(0.05)	(0.06)	(0.05)	(0.04)
LLOSS	-0.634***	-0.522***	-0.721***	-0.403**
	(0.21)	(0.20)	(0.21)	(0.20)
COST	-0.527***	-0.610***	-0.523***	-0.566***
	(0.07)	(0.07)	(0.08)	(0.07)
CREDIT	-0.458***	-0.868***	-0.239	-0.735***
	(0.17)	(0.13)	(0.21)	(0.16)
LDS	-0.129*	-0.115*	-0.130*	-0.068
	(0.07)	(0.07)	(0.07)	(0.07)
CONCE	0.287***	0.219***	0.287***	0.173***
	(0.08)	(0.06)	(0.09)	(0.06)
GDPG	0.173	0.007	0.244	0.164
	(0.21)	(0.22)	(0.22)	(0.21)
CPI	0.232**	0.227*	0.222*	0.272**
	(0.12)	(0.12)	(0.12)	(0.12)
SA DUMMY	2.790	8.589	0.608	6.766
	(7.70)	(7.02)	(9.59)	(6.85)
SA DUMMY x CPI interaction	-1.375	-1.529	-1.350	-1.545
	(1.09)	(1.18)	(1.06)	(1.18)
CLIM1	0.121	-3.095		
	(0.47)	(3.67)		
CLIM1_squared		0.095		
		(0.10)		
CLIM2			-0.002	-0.009*
			(0.00)	(0.00)
CLIM2_squared				0.000*

				(0.00)
Constant	27.419*	65.071*	30.266***	44.128***
	(14.39)	(35.64)	(10.47)	(8.18)
Observations	191	191	191	191
Number of Countries	12	12	12	12
Wald Chi2	137.8	245.6	124.2	246.3

Climate change1 stands for the climate change variable measured by temperature (in degrees Celsius), *Climate change2* stands for annual rainfall (measured in mm), LLOSS stands for loan loss provisions, *SA DUMMY* is a dummy variable taking a value of 1 when the country is South Africa and 0 otherwise, *SA DUMMY x CPI interaction* is an interaction between SA dummy and CPI stands for Consumer Price Index. *COST* stands for cost to income, *CREDIT* stands for credit to government and state-owned enterprises to GDP (%), *LDS* stands for lending deposit spread, *GDP* stands for Gross Domestic Product, $CLIM1^2$ stands for additional explanatory variable for temperature, $CLIM2^2$ stands for additional explanatory variable for rainfall

Diagnostic Tests

We conducted diagnostic tests to help confirm the validity of the results. Table 16 displays the summary of all variables. The results indicate that the standard deviations of most variables are small, except for the banking sector liquidity (LIQ) and rainfall (CLIM2).

The maximum and minimum of ROA are 6,78 and -4.45. The mean and standard deviation are 2.48 and 1.44 therefore the average ROA value in this dataset is 2.48 which is above the middle value of 2.33 indicating that the data distribution is skewed towards higher values.

The maximum and minimum of NIM is 14.95 and 1.98. Mean and standard deviation are 6.71 and 2.82, therefore the average NIM value in this dataset is 6.71 which is below the middle value of 12.97 indicating that the data distribution is skewed towards lower values. The standard deviations of plenty of the control variables are smaller than 10 except for just a few, showing that all variables are centralized.

Table 17: Descriptive analysis of all variables

Variables	Mean	Median	Maximum	Minimum	Std, Dev,	Skewness	Kurtosis	Jarque-Bera	Obs
ROA	2,48	2,46	6,78	- 4,45	1,44	0,27	6,43	95,94	191
NIM	6,71	6,57	14,95	1,98	2,82	0,73	3,28	17,35	191
EBTA	3,38	3,38	9,82	- 4,42	1,97	0,82	5,66	77,87	191
EBTE	30,53	28,30	77,66	- 0,39	16,16	0,47	2,86	7,04	191
OCTA	5,40	5,05	12,49	1,72	2,20	0,61	2,84	12,14	191
NIITI	42,01	42,15	78,20	17,27	8,71	0,51	4,88	36,22	191
LLOSS	5,86	4,68	25,83	1,00	3,89	1,41	6,93	185,61	191
LIQ	39,19	35,78	94,20	9,24	18,40	0,57	2,74	11,02	191
LDS	11,19	7,39	69,94	0,53	11,56	2,75	11,08	761,05	191
GDPG	4,61	4,56	15,03	- 7,65	3,16	- 0,25	4,99	33,49	191
CLIM1	21,34	22,29	24,92	12,30	3,00	-1,84	5,84	171,82	191
CLIM2	880,96	950,40	2 488,37	28,73	482,79	0,36	3,46	5,82	191
CIR	56,74	57,29	94,34	35,15	9,84	0,40	3,74	9,35	191
CONCE	90,23	96,32	100,00	48,09	12,06	- 1,27	4,09	61,16	191
COST	56,74	57,29	94,34	35,15	9,84	0,40	3,74	9,35	191
CPI	8,11	6,75	41,95	- 1,70	5,74	2,30	11,01	678,51	191
CREDIT	7,51	5,31	28,50	0,52	6,13	1,56	4,65	98,82	191

The table shows the observations, mean, SD (standard deviation), minimum value, median value, and maximum value of all variables.

Table 18: Correlation Analysis

Variable	ROE	ROA	NIM	EBTA	EBTE	OCTA	NIITI	LLOSS	LIQ	LDS	GDPG	CLIM1	CLIM2	CIR	CONCE	COST	CPI	CREDIT
ROA	0.75	1.00																
NIM	0.38	0.60	1.00															
EBTA	0.68	0.96	0.71	1.0														
EBTE	0.96	0.76	0.51	0.76	1.00													
OCTA	0.08	0.31	0.79	0.43	0.20	1.0												
NIITI	-0.06	0.13	-0.13	0.14	-0.03	0.19	1.00											
LLOSS	-0.16	0.04	0.30	0.10	-0.10	0.24	-0.00	1.00										
LIQ	0.22	0.27	0.41	0.33	0.30	0.27	0.01	0.18	1.00									
LDS	0.16	0.21	0.28	0.23	0.19	0.16	0.17	0.27	0.37	1.00								
GDPG	0.06	0.05	0.21	0.10	0.1206	0.21	-0.03	-0.06	0.11	0.06	1.00							
CLIM1	-0.17	-0.06	0.04	-0.08	-0.22	0.05	-0.09	0.26	-0.18	0.16	0.26	1.00						
CLIM2	-0.25	-0.01	0.07	-0.00	-0.23	0.06	0.17	0.34	0.39	0.29	0.08	0.36	1.00					
CIR	-0.54	-0.50	-0.03	-0.45	-0.52	0.40	0.09	0.06	-0.09	-0.15	0.03	0.04	-0.05	1.00				
CONCE	0.41	0.33	0.13	0.33	0.41	0.01	0.07	-0.24	0.03	0.21	-0.16	-0.34	-0.38	-0.19	1.00			
COST	-0.54	-0.50	-0.03	-0.45	-0.52	0.40	0.09	0.06	-0.09	-0.15	0.03	0.04	-0.05	1.00	-0.19	1.00		
CPI	0.14	0.18	0.28	0.21	0.15	0.18	0.04	0.33	0.12	0.23	-0.00	0.17	0.07	-0.14	-0.00	-0.14	1.00	
CREDIT	-0.46	-0.39	-0.4	-0.43	-0.5	-0.25	0.18	-0.06	-0.14	-0.23	-0.15	0.25	0.51	0.05	-0.31	0.05	-0.06	1.00

4.5 Comparison of literature review and own findings

Table 19. Comparison of literature review and findings

RQ #	State Research Question	Hypothesis #	State Hypothesis (literature review response to RQ)	Findings from own study
1	What is the impact of climate change on bank performance?	Climate change significantly impacts bank performance	Climate change is a financial risk source for the banking sector(Scott et al., 2017 & Dellink, Jamet, Chateau, & Duval, 2014)	Climate change and bank profitability have a slightly positive relationship when using ROA, NIM & ROE but there is a threshold that at some point the relationship becomes negative.
2	Is there a difference on the impact of climate in South Africa compared to other SADC member states?	There is significant difference on the impact of climate in South Africa compared to other SADC member states.	High-income countries are affected more by climate change compared to low-income countries, (Zhang et al, 2022 & Pressend, 2011)	There is no difference in how South Africa is affected by climate change compared to the rest of the SADC countries.

CHAPTER 5. CONCLUSIONS & RECOMMENDATIONS

5.1 Introduction

Given the importance of climate change, this study investigated the impact of climate change on bank performance. We use a sample of 12 SADC countries, covering the period 2003-2018. We ran a number of panel data regression models which include the fixed effects models, random effects model, FGLS and pooled regression models to study the effect of climate change on banking profitability.

The results from the study suggest that at low levels of temperature and rainfall, there is a positive relationship between climate change and bank performance, however beyond a certain point an increase in climate change (rainfall or temperature) adversely affects the performance of commercial banks in the sample countries covered. The implication here is that there is an urgent need for commercial banks to also start considering the effect of their activities on the environment. This is especially important when one considers the fact that the loans extended by banks to borrowers may be used to finance activities that adversely affect the environment. Indeed, while banks may not be harmed by climate change at low levels of temperature and rainfall, high and extreme temperatures and rainfall can be catastrophic for banks and their clients. Banks are therefore not immune to the adverse effects of climate change.

Our paper's conclusions can be helpful to improve climate change resulting in prevention of natural disasters and promoting profitable financial institutions. The key to maintaining the normal operations of banks is to preserve our climate through an effective ecology.

5.2 Conclusions regarding research question 1

The main conclusions are as follows:

First, climate change matters. Climate change and bank profitability have a positive relationship when using ROA, NIM & ROE but there is a threshold beyond which further increases in temperature and rainfall will adversely affect bank profitability.

Increased disasters that are climate change related result in infrastructure damage, industry disruptions and livelihood which leads distress in the financial systems (Guerreiro et al. 2018). We see our study aligning to part of this literature as we see that climate change ultimately has negative effect on banks.

Literature on determinants of bank profitability frequently use bank-specific factors such as macro-economics, market share, costs and loan loss provisions (Unzi & Wu, 2019; Dafermos, Nikolaidi & Galanis, 2018). Our study bridged the gap by introducing climate change variables into the equation and we learn that the effect is not straightforward.

5.3 Conclusions regarding research question 2

The South African economy is part of the African economy which is considered as low-income as Zhang et al (2022) found, therefore we can conclude that the results for the second hypothesis from our study is in line with both our empirical and theoretical literature. That is, as far as the climate change issues are concerned South Africa is not significantly different to other countries in the SADC region. This is demonstrated by the South African dummy variable which was found to be consistently insignificant.

Table 20: Consistency table: research questions, conclusions, and contribution to knowledge

RQ #	State Research Question or Objective	State literature-based proposition or hypothesis	State conclusion or answer based on own research	Highlight key differences between your initial propositions / hypotheses and your findings – this is your contribution to knowledge
1	What is the impact of climate change on bank performance?	Climate change significantly impacts bank performance	Climate change and bank profitability have a slightly positive relationship when but there is a threshold that at some point the relationship becomes negative.	Key difference identified was that in the early stages, climate change shows a positive relationship, however, a turning point is then realized, and we start seeing a negative relationship as predicted
2	Is there a difference on the impact of climate in South Africa compared to other SADC member states?	There is significant difference on the impact of climate in South Africa compared to other SADC member states.	There is no difference in how South Africa is affected by climate change compared to the rest of the SADC countries.	Key difference identified was that African economies are smaller compared to the first world countries therefore climate change doesn't affect them at the same pace

5.4 Recommendations

Inclusion of climate change factors in banking profitability

More banking sector development is required in the SADC region in terms embedding climate change into their guidelines for lending and their appetite for the risk that stems from climate change. Proactivity on this subject future of financial services and climate change may a competitive edge, this can be achieved through deployment of fitting expertise and strategic planning.

Data Scarcity

Relevant data scarcity is one the challenges facing decision makers in most spheres. We believe that there is not sufficient detailed data for the banking industry, this may be due to lack of strict reporting requirements.
Disclosure of much needed details would promote transparency and data led decisions.

Prevention natural disasters

Turning around climate change is a long-term journey that will need proper investment. This means that relevant regulations, proper infrastructure as well as technology innovation is critical in preventing natural disasters.

5.5 Suggestions for further research

Future research could investigate alternative methods for bank profitability such as profit margins to determine whether they produce the same conclusion regarding the effect of climate change on banks.
Furthermore, a study into the bank profitability data scarcity would be impactful for future studies.
Lastly, future studies should be able to take a micro approach and further unpack the relationship at specific banks levels which will be subjected to data transparency by banks.

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