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Impact of Climate Risk on Financial Sector Stability of the Selected SADC Countries

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ABSTRACT

The study investigates the impact of climate risk on the financial sector stability of the selected SADC countries in the context of Angola, Malawi, Mozambique, Madagascar, Namibia, Tanzania, Eswatini, the Democratic Republic of Congo, South Africa, and Zambia. Countries chosen for this study face similar climate-related shocks, such as rising annual carbon dioxide emissions, affecting their agro-based economies and the real sector. The study employed Panel Ordinary Least Squares (POLS), Panel-Corrected Standard Errors (PCSE) and Feasible Generalised Least Squares (FGLS) models to estimate the long-run parameters of climate risks' impact on the region's financial sector stability. The results show that climate risk negatively affects financial stability while positively increasing lending activities. The study recommends that SADC countries expand government-guaranteed bank credit schemes targeting capital projects needed to facilitate the transition to green energy sources and incentivise targeted green investments, particularly green bonds, carbon credits, and green banking, to enhance green growth and financial sector resilience.

Keywords: Financial Sector Stability, Non-Performing Loans, Climate Risk, Southern Africa Development Community
JEL Classifications: G01; Q54; E44

1. INTRODUCTION

The world is confronting a grappling complex, increasing uncertainty, frequency and severity of climate-related shocks, and the same narrative is evident in the Southern Africa Development Community (SADC). Climate change poses one of the global catastrophic risks to humanity, and the future might even hold more unimaginable catastrophes. A collective effort to fight these symptoms of calamity must be genuine and robust. Given that climate change creates both climate risks and opportunities for the globe, this study probes climate risk and financial stability and excludes the opportunities brought by climate change. The study investigates the impact of climate risks on the financial sector stability of the selected SADC countries in the context of Angola, Malawi, Mozambique, Madagascar, Tanzania, Eswatini, Democratic Republic of Congo, Tanzania, South Africa, Madagascar, Zambia. The researcher based the selection of eleven countries out of sixteen SADC countries on the availability of data for the primary independent variable of the study: Climate risk index. The study concludes that climate risk and carbon emissions negatively and statistically significantly affect SADC's financial sector stability. The study was motivated by debates opined by the Governor of the Bank of England Carney (2016), who openly advocated for integrating climate risk into financial and risk management (Löyttyniemi, 2021). His speech "Tragedy of Horizons" became a wake-up call to governments, the insurance industry, and the banking sector about the risks drawing near stemming from the horizons. The talk provided three main broad channels through which climate change can affect financial stability: the physical risks -insurance liabilities, and the value of financial assets that arise from climate and weather-related events, such as floods and storms that damage property or disrupt trade. Secondly, liability risks are compensation made by those responsible in case of eventualities caused by climate change.

Thirdly, transitional risks are policy changes and technology costs towards a low carbon dioxide economy (Carney, 2016; Dunz et al., 2019).

Climate-induced physical and transitional risks are interconnected and destabilize the financial markets and institutions (Vioto et al., 2022). Climate-related financial risks can strongly jeopardize the soundness of global or regional financial systems (Diallo et al., 2023). Therefore, financial risk and climate fragility reinforce each other (Aglietta and Espagne, 2016; Vioto et al., 2022). Financial sector stability is essential for climate resilience and adaptability (Tang and Zhang, 2024). To date, no known technology can reverse climate catastrophes (Fabris, 2020). On novelty: The paper sheds light on a relevant and timely question by providing a meaningful contribution to a burgeoning literature on climate economics and financial stability. It informs the ongoing discussions on the economic consequences of climate risk in a previously overlooked region.

The study documents two channels through which climate change affects the stability of the financial sector: The climate → real sector and climate → financial sector in the region (Bilal and Känzig, 2024; Dantas et al., 2023; Silva, 2021). The study comes when research themes worldwide hover around providing tailored policy recommendations to enhance the region's financial sector's adaptability, mitigation, and resilience when faced with complicated climate shocks. Among the studies presented by the literature and to the researcher's best knowledge, none quantified the transmission mechanisms of climate, financial sector and the real sector using the climate risk index in SADC (Aloui et al., 2023; Aslan et al., 2022; Brunetti et al., 2021; Campiglio et al., 2018; Chabot and Bertrand, 2023; Conlon et al., 2024; Debels-Lamblin and Jacolin, 2020; Diallo et al., 2023; Liu et al., 2024; Mandel et al., 2021; Wu et al., 2023). The research ignites debate on SADC's sustainable climate financing policy as a workhorse for a smooth transition to a green climate (Meng et al., 2023; Tang and Zhang, 2024). Apart from that, if the climate risk effect is quantified, bankers and insurers can delineate supervisory frameworks (Fabris, 2020). The study proceeds as follows: Section 1: Introduction and Background, Section 2: Literature Review, Section 3: Materials and Methods, Section 4: Results Discussion and Empirical Results Analysis, and lastly, Section 5: Conclusion and Policy Recommendations.

No region can ignore climate change's devastating effects and risks. According to the Climate Risk Index 2025 report, 765 500 people lost their lives worldwide and approximately USD4.2 trillion (inflation-adjusted) losses from 9400 extreme weather events (Adil, 2025). Back in Africa, the risks of climate change also pose unique challenges. Africa is particularly vulnerable to the impacts of climate change due to its dependence on rain-fed agriculture, limited adaptive capacity, and high poverty levels (Debels-Lamblin and Jacolin, 2020; Pereira, 2017). The countries chosen for the study are all agrarian economies currently battling food shortages, food inflation, malnutrition crisis, and water shortages because of the El Niño weather phenomenon (Mugiyo et al., 2023). The region underwent tremendously dry conditions during the 2023/24 El Niño season, including one of the driest Februarys in over 40 years, resulting in widespread crop failure across central parts of the region reported by the (OCHA, 2024). These impacts can disrupt economic activities and strain financial systems, potentially leading to financial instability (Cashin et al., 2017). Apart from that, Central Banks from developing countries have a more significant scope to deal with than just price stability compared to Central Banks from the developed world. Even worse, Central Banks from developing countries lack independence from government policies and political pressures, a limiting factor. That leaves central banks from the developing world with a limited mandate to venture into low-carbon transition goals and invest in a sustainable climate (Campiglio et al., 2018). The African Development Bank (AfDB) has emphasized integrating climate-related considerations into financial sector policies and practices to ensure financial institutions' long-term stability and sustainability (Abor and Ofori-Sasu, 2024). African countries have been addressing climate risks, such as developing national climate change strategies and implementing climate adaptation and mitigation measures. However, not all central banks in SADC are members of the Network for Greening Financial Systems (NGFS) launched in 2017 (Robins et al., 2021). As of October 2024, only six of the sixteen states in SADC were members of the NGFS. Hence, it has given challenges in compilation and access to data needed for climate stress tests from Sub-Saharan Africa. The mandate of NGFS is to conscientize all central banks and all stakeholders on how they can incorporate climate change dynamics into their balance sheets.

The SADC region is highly vulnerable to the impacts of climate change, with sectors such as agriculture, water resources, energy, and the financial sector at particular risk. According to the Global Climate Index ranking 2016, of the ten most affected countries between 1997 and 2016, nine were from low-income countries, and only one was an upper middle income. Among the nine, Haiti, Fiji, and Zimbabwe were in the top ten, with Mozambique and Madagascar falling in the top twenty most affected, pointing to extreme vulnerabilities of the region and its financial sector (Eckstein et al., 2021). Mozambique has experienced severe flooding in recent years, which has led to significant damage to infrastructure and agriculture production. The country's financial sector can be negatively affected by the increased reconstruction costs and the decline in agricultural output (Eckstein et al., 2021). Similarly, Zimbabwe has faced recurring droughts, adversely affecting its agricultural sector and overall economic stability. Reduced crop yields and increased food prices can lead to inflationary pressures and strain the financial sector's stability to support affected communities adequately. Malawi was brutally hit by cyclone Freddy 2023, which destroyed significant roads, farmlands and residential infrastructure. Of late, these vast water bodies have threatened the survival of SADC countries. In most cases, they are sources of severe weather hazards, such as rampant tropical cyclones in the continent. Table 1 shows a timeline of tropical cyclones that have generally affected some SADCs over the last 20 years and their origins.

These hazards are, by and large, the product of climate shocks that triggered very high temperatures, strong winds, heavy rains and storms, and subsequent flooding. DeMenno (2023) pointed out that catastrophes such as cyclones cascade to financial services through bank credit, market, liquidity, and operational risks in several ways. Most SADC countries have always been on the path of these weather hazards. The impact has been severe on the already vulnerable SADC. Figure 1 shows the carbon dioxide emissions, a standard indicator of climate change.

The upward trend noticed across the regions in the world can also be seen in the SADC region between 1884 and 2022. In 2022, South Africa, more of an outlier, had the most significant emissions, followed by Botswana and Namibia. The least emitters in SADC are the Democratic Republic of Congo and Malawi. As such, the share of emissions in the SADC region is relatively trivial, accounting for approximately 1.3% of global emissions (Gütschow et al., 2021; Lesolle, 2012). Nevertheless, the region remains susceptible to climate change and related risk effects. The probability of climate change events and associated risks is not dependent on the level of economic development, whether from the global north or south. Nevertheless, regardless of their contribution to global carbon emissions, it affects all regions. The following section delineates financial sector challenges.

Table 1: Timeline of tropical cyclones that have affected SADC and their source of origin

Cyclone	Source	Year
Cyclone Eline	Indian Ocean	2000
Cyclone Japhet	Indian Ocean	2003
Cyclone Galifo	Indian Ocean	2003
Cyclone Dineo	Indian Ocean	2016
Cyclone Dineo	Indian Ocean	2017
Cyclone Idai	Indian Ocean	2019
Cyclone Eloise	Indian Ocean	2021
Cyclone Chalane	Indian Ocean	2021
Cyclone Gombe	Indian Ocean	2021
Cyclone Batsirai	Indian Ocean	2022
Cyclone Hermine	Atlantic Ocean	2022
Cyclone Freddy	Indian Ocean	2023
Cyclone Cheneso	Indian Ocean	2023

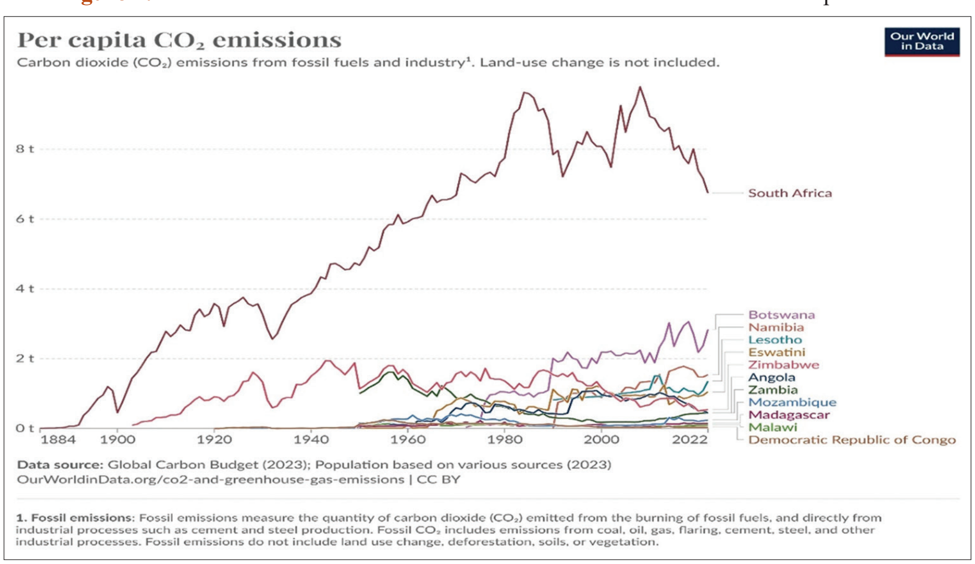
Source: Author's compilation

SADC is among the regions that have not actively driven their financial sector systems into climate risk through regulatory requirements. Integrating climate-related risk into prudential, financial, and regulatory supervisory framework remains weak despite membership to the SADC-Development Finance Resource Centre (Oman et al., 2024). SADC countries are lagging in joining international climate-related initiatives, where very few countries are members of the Network for Greening Financial Systems (NGFS), Sustainable Banking and Finance Network (SBFN), and Net-Zero Banking Alliance (NZBA) among others (Canton, 2021). The financial sector of SADC countries is not immune to these climate-related risks. Also, the fact that only South Africa in SADC is a member of the Financial Stability Board leaves the region unconnected to international institutions that provide expertise in addressing vulnerabilities of global financial systems (FSB, 2023).

Financial institutions face challenges in assessing and managing climate risks, including the potential for loan defaults due to climate-related disruptions, devaluation of assets, and increased insurance claims. Climate-related metrics for compensation basis are still evolving, and the study calls for concerted efforts to develop standard and transparent compensation schemes (Campiglio et al., 2023). After realizing the importance of addressing climate risks, SADC countries have started incorporating climate change considerations into their national development plans and policies. Given this background, studying the impact of climate physical risks on financial sector stability in selected SADC countries becomes crucial. Such studies can help to quantify the impacts of climate risks on the financial systems of the selected SADC countries. Besides, it encourages the assessment of SADC's vulnerability and resilience, informing the development of appropriate policies and strategies to promote financial sector stability in the face of climate physical risks (Lee et al., 2023).

Climate change-related risks increasingly expose the SADC's financial sector, both physical and transitional. The extreme

Figure 1: Carbon dioxide emissions from fossil fuel combustion and industrial processes



Sources: Our world in data

weather conditions perennially affecting the region are a cause of concern; these include tropical cyclones, which have a record of excessive flooding, destruction of infrastructure, crops and other agricultural products, and stagnating mining production. A perfect example is El Nino weather conditions experienced in SADC season 2023/2024, which led to drought in most parts of SADC. EL Niño affected the financial system via key economic sectors such as agriculture: The food and water shortages both affected the value chain and the energy crisis. Common phenomenal outcomes were inflationary pressures, exchange rate volatilities and financial market instabilities experienced in the region. Again, risks associated with economic restructuring towards carbon neutrality cannot be underestimated (Aloui et al., 2023). The risks directly affect the financial sector via liquidity, credit availability, price changes, and exchange rate volatilities, thus affecting strategic industries. Central banks and other financial institutions in SADC have made limited progress in curbing climate-related risks. Therefore, regional financial institutions lack adequate assessment models and frameworks to measure, manage and mitigate climate risks (CPI, 2024).

Moreover, investors are sceptical about investing in climate risk-induced catastrophes, and hence, investor confidence remains very low because of the uncertainty in climate change and its impacts; the only way to boost confidence is through developing climate risk models that help evaluate and assess investment decisions. According to Baarsch et al. (2020) concur that quantitative integration of climate risks in economic and financial development planning is a requirement. The empirical findings highlight that the region has yet to integrate climate risks into investment, which is against the backdrop of inadequate international climate finance that developed countries promised to offer developing countries (Egenhofer & Georgiev, 2009). Also, global financial flows for adaptation are lacking, affecting adaptation options in developing countries (Lee et al., 2023). Again, weak financial development has constrained financial inclusion and depth (Émilie and Luc, 2020).

If policymakers do not pursue efforts to control climate risk, it may lead to financial sector instabilities that destabilize trade, mining, agriculture, and energy sectors and the overall performance of the economies under study. In addition, the region lacks risk management strategies and resilience mechanisms in the face of climate shocks. The literature on climate physical and transitional risk on financial stability is still scant in SADC, and hence, the paper opines and ignites the debate in the respective areas. The primary goal of the research is to provide an in-depth analysis of the impact of climate risk on the financial sector stability in the context of SADC and to uncover climate-to-real sector and climate-to-financial sector transmission mechanisms.

The study builds on the externality theory propounded by Coase (1960) and (Pigou, 2017original work published 1920) that gave the first- and second-best solution to global problems, that is, the notion that climate change is a negative externality resolved by imposing a price on emissions through tax, cap and trade system. However, the second-best solution incorporates social, technical, political or economic elements found to be suboptimal, especially under complex political economy to climate policy. Again, we consider the climate fragility hypothesis (Aglietta and Espagne, 2016), which posits that climate fragility aggravates financial fragility. The hypothesis connects physical risk, liability, and transitional risk as the crucial mechanisms through which climate systemic risk stimulates financial crises. The key submissions were that climate systemic risks are non-idiosyncratic shocks, and as such, they call for a collective insurance approach that targets the financial sector. The hypothesis contends that isolated measures to mitigate climate risks are futile and counterproductive. Alternatively, the study is also informed by the theoretical foundations of the dismal theorem Weitzman (2009), which states that the impact of climate change is highly uncertain on actual timing. The theorem considers fat-tailed risks as risks that have a low probability of occurring but can have severe consequences when they do occur. However, the 21st century has seen fast-increasing frequency and extreme climate catastrophes; hence, ignoring the probabilities of such disasters is unsustainable. The theory emphasizes the importance of proactive global climate policies. As a result, delaying action against climate change makes the tail flatter, which means it could be more devastating and irreversible. Just like the climate fragility hypothesis drifts away from traditional cost-benefit analysis, so does the Weitzman theorem depart from externality theories and conventional cost-benefit analysis, citing that the value of damages from an event may be infinite and difficult to account for.

The study acknowledges that global climate and economic activities have complex relationships (Burke et al., 2015b). The complexities result primarily from climate uncertainties and risks associated with climate change. The study explores the pathways through which climate change impacts the financial sector and the real world. Several studies have concluded that climate change risks result in output losses, which drives up prices (Batten, 2018; Byrne and Vitenu-Sackey, 2024; Millard, 2023). These effects are linked to supply-side and demand-side shocks, respectively. Remarkably, Bilal and Känzig (2024) document that the macroeconomic damages from climate change are several times larger than previously imagined: a 1°C increase in average temperatures associated with a decline of 12% in the world's GDP. The results of Bilal and Känzig (2024) can be construed as indicative of a channel Climate→Real Sector. Also, Fan et al. (2024) recognized the climate→real sector transmission mechanism that linked the climate change→labour→income→NPL ratio. According to the researchers, high temperatures lower labour productivity, negatively affecting company profits and preventing economic agents from honouring their loan obligations. Gradual warming, seasonal rainfalls and rising sea levels (physical risk) affect the macro-economy via inflationary pressures from disrupted value chains local or internationally, productivity shocks because of drought, flooding, and closure of businesses due to infrastructure damages (Batten et al., 2020; Moore and Diaz, 2015). Critically, these events eventually result in financial losses and a plunge in the GDP. In another dimension, Burke et al. (2015a) argues that climate risk and events increase the risk of violence and conflicts in communities at local and regional levels: a 1% increase in climate risk is associated with a 14% increase in the risk of intergroup conflict. The conclusion by Burke et al. (2015a) points to the climate risk-real sector-financial sector channel, originating from resource conflicts and climate-induced displacement, thus affecting foreign trade, manufacturing, and labour markets. While we have discussed the physical risk dynamics in transmission mechanisms, we note that even transitional risks have similar channels. Trade-off costs are incurred as industries abruptly switch to matching green technology policies (Batten, 2018). A climate policy adversely affects the industry's profits, productivity, employment and GDP. For instance, the closure of coal mining industries in South Africa resulted in substantial job losses, declining profits, and reduced income that cascades to the financial service via increased default rates and, if left unchecked, can spread into the financial system (Semieniuk et al., 2021). However, the opposite is true for firms that are greening the economy.

Critically, it is well known that the state of the macroeconomy and public finances affect financial stability (Dantas et al., 2023; Silva, 2021). That means that the financial sector, non-financial sector, and the government's finances are naturally intertwined: Real sector↔Financial sector ↔Government fiscal space (Dantas et al., 2023). Moreover, based on the premise that banks' financial conditions depend on governments' financial conditions and other macroeconomic conditions (Dantas et al., 2023; Silva, 2021), the two channels may operate concomitantly, leading to a spiral effect: Climate risk leads to a deterioration of the macro-economy, which in turn forces governments to engage in expansionary fiscal policies (widening deficits), which in turn undermines the stability of the banking sector, which in turn deteriorates the state of the macroeconomy and leads to wider deficits, so on.

Distinctively, climate change affects either the financial or real sectors directly or concurrently, confirming two channels: Climate→Financial→Real sector: Climate→Real sector→financial sector channels. The study explored whether climate change affects the financial sector first and then the macroeconomy (real sector) or vice versa. However, it is virtually impossible to separate the two channels and attribute economic values empirically, so it remains an area for further research as present research focuses on the channels through which climate change risks affect the real economy, the financial sector, and the government.

Numerous studies have been undertaken in Sub-Saharan Africa and on a global scale. Diallo et al. (2023) examine climate risk and financial stress of the Economic Community of West Africa (ECOWAS). The study reflected climate risk and financial stress to display a non-linear relationship, and a multivariate threshold autoregressive vector model was employed. While the current research considers linear relationships, it acknowledges that the data set used is small, which justifies the reliability of the results. The key takeaway from the study is that a Pigouvian tax on emitters would ultimately reduce greenhouse gas emissions, climate stress testing and early warnings before the shocks could mitigate the extreme effects of climate shocks.

Evidence from Sub Sahara, according to Amo-Bediako et al. (2023), indicates that the banking system is resilient to temperature shocks in the long run, whilst the banking system is negatively affected by precipitation and greenhouse gas shocks in the long run. In contrast, the banking system is only resilient to precipitation shocks in the short run. The argument could be that SSA countries are slowly diversifying their economies, thus moving away from climate-sensitive sectors, such as agriculture. On the other hand, resilience to precipitation shocks in the short run is linked to informal economies that characterize the SSA. Hence, banks often finance properly documented farmers who already have access to irrigation, thus limiting exposure to precipitation shocks. In the same domain of SSA, Ayele and Fisseha (2024) concluded that a negative association exists between climate change and financial stability in the long run compared to the short run. However, the authors pointed out that physical risks are more devastating and could be abated by incorporating consistent climate policies and regulations. Investigating SADC is crucial as it will inform the region's policies and mitigation strategies.

Aloui et al. (2023) concluded that spillover effects of environmental degradation from a rise in consumption of non-renewable and renewable energy would increase the occurrence of systemic banking crises, thus confirming the climate fragility hypothesis in SSA. Another comprehensive bibliometric analysis of trends in climate change and organizations (Díaz Tautiva et al., 2024) identified several research gaps. However, this study embraced the notion that Africa is understudied and that the region lacks an understanding of the manifestation of climate risk. The authors also pointed out a shortage of research on how extreme weather events impact organizational performance. Therefore, the present study bridges the gap by focusing on the magnitude of severe climate-induced shocks on financial systems in the SADC region.

Shifting the focus from SSA, a study done in G20 countries (Nur et al., 2023) found no significant link between climate risk and financial fragility attributed to the resilience demonstrated by the advanced nations. Indeed, strong credit markets and risk insurance could contain the adverse effects of climate risks. However, climate risk had a minimal impact on financial access, an attribute that shows how G20 countries have managed to protect their economies from shocks of climate risks. G20 countries should harness climate change mitigation strategies to augment financial system efficiency.

Vioto et al. (2022) using quantile regression, researchers investigated how systemic risks of US banks and insurers relate to the performance of both green and brown markets. Again, the study concluded how quickly and to what extent the US banking sector responds to an enormous climate disaster using the Wilcoxon signed rank sum test. In essence, the study fosters the adoption of climate policies capable of countering the rise in frequency and severity of extreme weather events. The study confirmed that physical risks caused by climate catastrophes grossly threaten financial stability and, therefore, the need to design policies that significantly mitigate climate risk impact, thus confirming the climate fragility hypothesis.

Another similar investigation by Di Febo et al. (2024) used ordinary least squares with individual effects and fixed time. The broad objective of the study was to analyze the Non-Performing Exposures (NPEs), domestic banking groups and climate risks in Europe. The study disintegrated climate risk into physical and transitional risk—the present research combined physical and transitional risks due to the unavailability of data. Findings from the research pointed out that both physical and transitional risk adversely affect the financial stability of the European Banking institutions. Additionally, the study included macroeconomic variables such as GDP, Unemployment, and Voice of Accountability. The paper confirms that European banks are vulnerable to NPEs, and climate risk management still needs to be boosted to restrain financial instabilities.

Another relevant investigation assessed the impact of climate change on green finance and financial stability and found a negative effect of CO_2 emissions on financial stability and a positive impact of green finance on financial stability, most notably through green loans. Researchers used the Z-score index to measure the financial stability of both emerging and developed countries (Nabil, 2024). In this investigation, both emerging and developed countries exhibited an antagonistic relationship that climate change imposes on financial stability. However, the Z-score index for both emerging and developing countries could not vary, which implies that both emerging and developing countries had relatively sound financial systems.

A study by Fan et al. (2024) investigated whether climate change fuels commercial banks' non-performing loan (NPL) ratio in 31 provinces of China. The study used a System Generalized Methods of Moments (GMM) and concluded that climate change measured by a proxy temperature fluctuation and bank's asset quality measured by non-performing loans had a significant positive impact. An attractive insight from the paper was the transmission mechanisms of climate change to labour productivity per capita incomes and NPL. The dimension is critical in policy formulation, thus calling for labour policy to incorporate climate change effects and designing mitigation measures towards labour productivity challenges. However, green credit as a mitigation strategy for climate-related risks proved insignificant, which suggests that commercial banks in China have limited investment in green credit as a tool to curb financial instability. As for the SADC region, data on green credit is still scant, pointing to scepticism about implementing such mitigation strategies.

In another dimension, an investigation by Furukawa et al. (2020), the author emphasized that climate risk is a source of financial risk, and hence, the Central Banks have the responsibility to oversee and supervise banks to attain financial stability. Sun et al. (2022) examine the role of financial stability on climate risk and mitigation of G-5 countries, and research findings advocate the integration of global warming concerns into policies and financial risk for greening economies. On the other hand, Ozili (2021) argues that it is not the responsibility of Central Banks to manage climate change risk and policy development; instead, politicians, the electorate, and international organizations should be held accountable for climate catastrophes. In that notion, the current study complements the ideas by building on quantifying the impact of climate risk on the financial system, which is helpful to stakeholders in resource allocation, risk assessment, management strategies, and policy evaluation.

Overall, research conducted in the SSA has predominantly emphasized climate change by analyzing precipitation and temperature changes as the key variables measuring climatic variations. The studies from Africa are largely confirming the climate fragility hypothesis. Climate risk negatively affects financial resilience; notably, the banking sector was more resilient to temperature than precipitation and greenhouse gases. Also, the association between climate change and financial sector stability is confirmed in the short and long run (Aloui et al., 2023; Amo-Bediako et al., 2023; Ayele and Fisseha, 2024; Diallo et al., 2023; Émilie and Luc, 2020). Nevertheless, the literature on SADC's financial resilience to climate shocks remains scant. The current study sought to include a climate risk index regarded as a more comprehensive measure of climate-induced risks to uncover the transmission channels that run from climate to the financial and real sectors and vice versa (Le et al., 2023; Nur et al., 2023; Wu et al., 2023). According to Díaz Tautiva et al. (2024), Africa is still understudied and lacks an understanding of climate risk. Therefore, the study bridges the gap by sparking the debate from a SADC regional perspective.

Hypothesis 1: H_0: Climate risk has no significant impact on the stability of the financial sector of SADC
Hypothesis 2: H_0: Climate risk has no significant impact on bank lending activities of SADC

2. MATERIALS AND METHODS

The study used country-based panel data models using data from 2010 to 2020. The availability of the leading independent variable-climate risk data determines the period and sample size under study. The Germanwatch has data for the climate risk index from 2010 to 2020. Hence, this limits our observations and keeps our sample size small. However, recent data could have also improved the narrative. The study sample comprises eleven SADC countries (Angola, Malawi, Mozambique, Madagascar, Namibia, Tanzania, Eswatini, Democratic Republic of Congo, Tanzania, South Africa, and Zambia). We employed panel-corrected standard errors (PCSE), pooled ordinary least squares (POLS) and feasible generalized least squares (FGLS) as our primary estimation method. According to Adeleye et al. (2023), when data exhibits cross-sectional dependence and cointegration among variables, a panel-corrected standard errors (PCSE) by the Prais Winsten regression model yields a reliable estimate. The method also controls heteroskedasticity and serial correlation. We used FGLS, system generalized methods of moments (GMM) and Driscoll-Kraay standard errors (DK-SEs) to ensure robust estimates in our analysis. The study follows the empirical models (Adeleye et al., 2023; Conlon et al., 2024; Fan and Gao, 2024; Liu et al., 2024). The models were used to assess how globalization and energy usage influence carbon emissions in South Asia, the impact of climate risk on financial access and sector stability in G20 countries and linkages between climate change and commercial banks' non-performing loan ratio in 31 provinces in China. The researcher modified the models to give us the following:

- Model of Z_score

$$Z\_score_{it} = \alpha_0 + \alpha_1 CRI_{it} + \sum_{n-1}^{6} \beta_n Control_{n,it} + \mu_i + \varphi_t + \varepsilon_{it} \quad (1)$$

Where financial sector stability (Z_score) is expressed as a linear function of climate risk index (CRI), carbon emissions (CO_2), agricultural output (AFF), Non-Performing Loans (NPL), Inflation, Exchange Rate (EXR)

- Model of Bank loans to Bank credit (bank stability)

$$LDR_{it} = \alpha_0 + \alpha_1 CRI_{it} + \sum_{n-1}^{6} \beta_n Control_{n,it} + \mu_i + \varphi_t + \varepsilon_{it} \quad (2)$$

LDR_{it} denotes bank lending activities (bank stability), CRI_{it} denote the global climate risk index and the $control_{;\,it}$ denotes variables that influence financial stability, those related to the financial sector and macroeconomic variables that

μ_i- is the country's individual effect, φ_t- fixed effects, $Control_{n,it}$- *control variables*

2.1. Dependent Variable

2.1.1. Z_score

The primary dependent variable that measures the financial sector's stability. Calculated as return on asset, ROA+(equity/assets))/sd (ROA); sd (ROA) is the standard deviation of ROA, calculated for country-years with no <5 bank-level observations. Several researchers used the Z-score to measure financial system stability (Battiston et al., 2021; Fan and Gao, 2024; Kamran et al., 2020; Klomp, 2014; Le et al., 2023; Liu et al., 2024; Machdar, 2020; Nabil, 2024; Nur et al., 2023; Wang and Luo, 2022). Whilst the research could have used recent measures of financial systemic risk, the study chose to use Z-score as a measure of financial stability solely due to data scarcity in the financial sector in the region. However, the author acknowledges that more recent systemic risk measures could have improved the narrative. According to Cortes et al. (2022); Gao et al. (2018), the literature unearthed several measures of systemic risk, for instance (Conditional Value at Risk Indicator) ΔCoVaR, Systemic Expected Shortfall (SES), Marginal Expected Shortfall (MES), and Systemic Risk Measure (SRISK) amongst others (Acharya et al., 2017; Brownlees and Engle, 2017; Tobias and Brunnermeier, 2016). In line with the authors, ΔCoVaR allows the measurement of systemic risk that captures (cross-sectional) tail dependency on the whole financial system and institutions and, again, can estimate forward-looking ΔCoVaR as well as monitoring of a build-up of the systemic risk on the contrary, Z-score depend on historical data and it is backward looking, may fail to detect a company's distress. Notably, unlike the CoVaR and MES, which face few data points given the rareness of extreme events, the Z-score is suitable for analyzing the long-term financial stability of all financial institutions. The researcher sourced from the global financial development database.

2.1.2. Bank credit ratio (LDR)

Financial resources banks provide to the private sector. It is measured by the ratio of total bank credit to deposit balance at the end of each year. It indicates the overall lending activities of the banking sector. The higher the value, the better. On the contrary, the lower the value, the better from the perspective of risk protection (Wu et al., 2023). The study used LDR as the dependent variable measuring bank stability. There is generally a positive relationship between bank lending activities and climate risk. Data sourced from the Financial Soundness Indicators Database (fsi.imf.org), international monetary fund (IMF)

2.2. Independent Variable

2.2.1. Climate risk index (CRI)

The major independent variable is the climate risk index, which measures the physical risks resulting from economic costs from extreme weather conditions. The climate risk index was sourced from Germanwatch's Global Climate Risk Index (CRI). The index is constructed using data from Munich Re NatCat SERVICE and four indicators, which include the number of deaths, number of deaths per 100000 inhabitants, the sum of losses in US$ in purchasing power parity (PPP) and losses per unit of gross domestic product (GDP). The country's annual CRI index is calculated from the average world ranking in losses of the four indicators, which are assigned weights that denote the proportion of the indicator in the final score (Adil, 2025). A high CRI score signifies minimum impact, whereas a lower CRI score indicates very high risk. Several research studies employed climate risk indexes such as (Le et al., 2023; Liu et al., 2024; Nur et al., 2023). However, the index suffers from backward-looking bias because it uses statistics from past events to generate current-year data, which undermines the predictive power of the CRI data period (Adil, 2025).

2.2.2. Control variables

2.2.2.1. Non-preforming loans to GDP(NPL)

Non-Performing Loan ratio has been widely used as a proxy of financial stability (Conlon et al., 2024; Fabris, 2020; Fan and Gao, 2024; Fan et al., 2024; Liu et al., 2024; Nieto, 2019; Pointner and Ritzberger-Grünwald, 2019). In the case of floods, storms, and natural disasters, the effects cascade to the financial sector through multiple channels, including erosion of assets capital value, loan defaulters, and regional lenders facing high concentration. In other words, credit risks increase in the financial sector. The study used bank non-performing loans to calculate total gross loans divided by the total value of the loan as a percentage—data sourced from world development indicators (WDI).

Capital adequacy ratio (CAR), also known as bank regulatory capital to risk, ensures the bank has enough capital to absorb losses. The minimum acceptable range is 8-10.5% (Budiyanto and Rusdiyanto, 2021). A higher CAR signifies stability and a stronger financial position. We anticipate a negative relationship between LDR and CAR. The rest of the explanatory and control variables are given in Table 2, and theoretical considerations and empirical evidence informed the selection of variables used in the models.

3. RESULTS DISCUSSION

Table 3 indicates statistical analysis of the whole data set, and critical importance are the dependent and major independent variables. The dependent variable Z_score, which measures the financial stability of SADC, shows that the average score for the period under investigation is 14.411, and the maximum is 27.018, with a minimum score of 4. 268. The standard deviation 6.355

Table 2: Data sources

Variable	Description	Source
Z_score	Z_score -A measure of financial stability usually calculated as (ROA+(equity/assets))/sd (ROA); sd (ROA) is the standard deviation of ROA, calculated for country-years with no less than five bank-level observations.	Bank scope (2000-2014) and Orbis (2015-2020), Bureau van Dijk (BvD)-Global financial development database
LDR	Bank credit to bank deposit is a financial resource provided to the private sector by domestic money banks as a share of total deposits calculated as %	International Financial Statistics (IFS), International Monetary Fund (IMF), (World Bank, 2022b)
CRI	Global climate risk index-The index is constructed using four indicators, which include the number of deaths, number of deaths per 100000 inhabitants, the sum of losses in US$ in purchasing power parity (PPP) and losses per unit of Gross Domestic Product (GDP) (Adil et al., 2025).[e.g. CRI score=1/6 death toll*country's rank+1/3 death/100000*rank+1/6 loss in PPP*rank+1/3 loss in GDP*rank]	German watch Global climate risk index, MunichRe Nat CatSERVICE (2006-2021)
CO_2	Carbon Emissions (metric tons per capita)	Available online at: https://www.climatewatchdata.org/ghg-emissions, (World Bank, 2023)
AFF	Agricultural Output-tones per hectare	(World Bank, 2022a, 2022b)
NPL	Non-performing Loans-Bank non-performing loans to gross loans (%)	Financial Soundness Indicators Database (fsi.imf.org), International Monetary Fund (IMF)
Infl	Inflation	International Monetary Fund, International Financial Statistics and data files
GDP_pc	Gross domestic product per capita constant 2015 US$)	(World Bank, 2023)
CAR	Bank regulatory capital to risk-weighted assets (%)	Financial Soundness Indicators Database (fsi.imf.org), International Monetary Fund (IMF)

Table 3: Summary of descriptive statistics

Variable	Obs	Mean	Standard deviation	Min	Max
Z_score	121	14.411	6.355	4.268	27.018
LDR	121	72.632	17.843	32.044	119.064
CRI	121	68.899	29.993	2.67	132.33
CO_2	121	1.339	2.184	0.03	8.218
Infl	121	8.407	7.492	−3.518	43.069
EXR	121	609.652	950.755	4.798	3787.754
GDP_pc	121	2781.446	2509.495	324.828	8737.041
NPL	121	7.214	4.934	0.964	25.836
CAR	121	34.792	14.323	12.301	75.434
AFF	121	14.468	9.156	1.82	29.078

Source: Author's computations

indicates a moderately high variability in the financial sector across SADC. More so, the climate risk index (CRI) shows that the average score is 68.899 and a maximum score of 132.33 with a minimum of 2.67. High values of the CRI score indicate less climate risk, whilst lower scores point to high climate risk. The standard deviation of 29.993 is high, signifying higher variabilities in the climate risk.

Table 4 depicts the results of the Pearson correlation test, with explanatory variables showing noncollinearity. A slightly higher and statistically significant positive correlation coefficients are depicted between carbon emissions (CO_2) and bank credit-to-deposit ratio (LDR) (0,768), GDP_pc and LDR (0.709), GDP_pc and CO_{2}(0.785). However, correlation coefficients are statistically significant at 5%. Z_score measuring financial stability is negatively affected by Inflation (Inf) and non-performing Loans (NPL) with a coefficient of −0.098 and −0.184 and is statistically significant. However, climate risk (CRI) and carbon emission (CO_2), though significant at 5%, all show a positive relationship with the dependent variable, which is against the theory and prompts further investigations. Alternatively, CO_2 is negatively related to agricultural productivity (AFF), non-performing loans (NPL), exchange rates (EXR), and Inflation (Infl) with the following statistically significant coefficients: 0.531, 0.301, 0.347 and 0.206, respectively. Table 5 depicts the cross-sectional dependence test results.

Table 5 exhibits cross-sectional dependence test results, and the null hypothesis of cross-sectional dependence is rejected for all variables with a significance level of <5%. Thus, we conclude that there is substantial cross-sectional dependence in the panels, meaning that standard shocks that arise can be easily transmitted throughout the region. A second-generation unit root test is employed once a data set indicates cross-sectional dependence (Adeleye et al., 2023). Therefore, Table 6 shows both first—and second-generation unit root tests.

Table 6 displays the unit root test results for all the variables used in the two research objectives. Pesaran and Shin is a second-generation unit root test that is necessary when running a model with cross-sectional dependency problems. The other two first-generation tests are used just for robustness checking. Overall, logZ_score and log non-performing accepted the null that the panel contains unit root in levels1(0), which got stationary after the first difference1(1). Whereas all other variables like climate risk(logCRI), carbon emissions (logCO_2), and bank credit to bank deposit (logLDR) among other variables, reject the null hypothesis that panels contain unit root in levels 1(0) and all are significant at <5% significance level.

Table 7 shows panel cointegration results using Kao and Westlund. Both statistics strongly reject the null hypothesis of no cointegration at a 1% significance level. Therefore, the study concludes that there is strong evidence of cointegration among Z_score, climate risk index, carbon dioxide emissions, agricultural output, bank credit to bank debt, exchange rate, and inflation. A long-run relationship exists among the variables (Mufandaedza, 2021).

Table 4: Pearson pairwise correlation results

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Z_score	1.000								
(2) LDR	0.480* (0.000)	1.000							
(3) CRI	0.155 (0.010)	0.001 (0.990)	1.000						
(4) NPL	−0.184* (0.043)	−0.499* (0.000)	0.009 (0.921)	1.000					
(5) CO_2	0.076 (0.406)	0.768* (0.000)	−0.079 (0.388)	−0.301* (0.001)	1.000				
(6) GDP_pc	0.222* (0.014)	0.709* (0.000)	0.202* (0.026)	−0.371* (0.000)	0.785* (0.000)	1.000			
(7) EXR	0.072 (0.434)	−0.174 (0.057)	−0.248* (0.006)	0.276* (0.002)	−0.347* (0.000)	−0.531* (0.000)	1.000		
(8) Infl	−0.098 (0.286)	−0.361* (0.000)	−0.098 (0.283)	0.281* (0.002)	−0.206* (0.023)	−0.237* (0.009)	0.019 (0.836)	1.000	
(9) AFF	−0.033 (0.723)	−0.363* (0.000)	−0.368* (0.000)	0.172 (0.060)	−0.531* (0.000)	−0.803* (0.000)	0.673* (0.000)	0.072 (0.434)	1.000

Source: Author's computations Standard errors in parentheses $P < 0.05$,*

Table 5: Cross-sectional dependence test

Variable	CD-test	P-value	Corr	Abs (corr)
logZ_score	−1.940	0.053	−0.07	0.33
logCRI	2.61	0.009	0.11	0.31
logCO_2	5.605	0.000	0.23	0.53
logAFF	3.362	0.001	0.14	0.49
logEXR	22.075	0.000	0.90	0.90
log NPL	2.495	0.013	0.10	0.47
logGDP_pc	6.757	0.000	0.27	0.52
Infl	2.965	0.003	0.12	0.29

Under the null hypothesis of cross-section: Independence CD~N (0,1)
Source: Author's computations

Tables 8 and 9 present the heteroskedasticity and endogeneity test, a Breusch Pagan test concluded that the data set had non-constant variance, and a modified Wald Test for a group-wise fixed effects model confirmed similar results, as shown in Table 8. The 2SLS instrumental variables were employed to detect endogeneity, and the test confirmed that a panel of ordinary least squares was more efficient than the 2SLS instrumental variable regression. A Sargan Basmann test of overidentifying restrictions fails to reject the instrumental validity null hypothesis and concludes that the instruments used are valid. Also, the Durbin Wu Hausman test accepts the null hypothesis of tests concluded that variables are exogenous; hence, estimated models are free from endogeneity, ruling out possibilities of bias, inconsistent estimates, and model misspecification, as shown in Table 9.

3.1. Analysis of Empirical Results

Table 10 represents the main model which answers hypothesis 1. The study rejects the null hypothesis that climate risk has no significant impact on the financial sector stability of SADC and accepts the alternative hypothesis at <10% significance level in all models (Gujarati, 2002). The results confirm a long run negative and statistically significant relationship between climate risk and financial stability. A 1% increase in climate risk negatively impacts financial stability by (−2.874%; −3.455%, −4.189%) from columns 1 to 4, thus confirming the climate fragility hypothesis. Several authors also made similar conclusions from different regions (Chabot and Bertrand, 2023; Le et al., 2023; Nur et al., 2023). The result approves a direct transmission mechanism that runs from the climate to the financial sector of SADC. The risks brought by perennial cyclones, hurricanes, high temperatures, and others are giving rise to property devaluation and reconstruction costs, which cascade into the finance houses, banks, and the stock market (Naseer et al., 2024).

In some cases, colossal infrastructure maintenance and reconstruction costs resulting in national budget deficits, for instance, damages caused by Cyclone Freddy in Malawi and Cyclone Idai in Zimbabwe and Mozambique, destroyed infrastructure, displaced people and caused loss of lives (Mugiyo et al., 2023). Such devastating losses (tail risks) confirm the dismal theorem, which explains that cost-benefit analysis can not be justified for a risk that may promise to destroy humanity. Instead, prevention is safe. Baarsch et al. (2020); Debels-Lamblin and Jacolin (2020); Liu et al. (2024); Mandel et al. (2021) confirmed similar empirical evidence internationally in the G20, Europe, and Asia, and Africa.

Table 6: First and Second-Generation Unit root tests results LLC, CIPS, Fisher

Variables	LLC		CIPS		Fisher	
	1 (0)	1 (1)	1 (0)	1 (1)	1 (0)	1 (1)
logZ_score	−5.3660***	−8.2678***	−0.4945	−1.6642**	12.7217	60.4187***
$logCO_2$	−2.1629***		−1.9827***		60.4957***	
logCRI	−3.3791***		−4.5253***		88.9748***	
logAFF	−4.1308***		−2.3279***		36.5061	
logGDP_pc	−6.7612***		−1.4825**		32.9765**	
logNPL	−2.9820***	−3.3300***	0.5465	−1.9163*	33.6102	17.5338
Infl	−8.6621***		−2.4669***		58.0166***	
logEXR	−6.9615***		−1.3093***		51.5747***	
LogCAR	−9.3178***		−2.8599***		89.9057***	
logBL_basst	−5.6998***		−1.9189***		80.8102***	
logLIRR	−8.1089***		−1.3780**		69.0240***	
logLDR	−1.4201**		−1.8162**		20.0369	117.4387***

***, **,*represent 1%, 5% and 10% significance level respectively
Source: Author's computations

Table 7: Cointegration test results [Kao and Westlund]

Cointegration test	MPP_t	PP_t	ADF-t	Variance ratio
Kao	−5.9457 (0.0000)***	−5.5933 (0.0000)***	−3.6597 (0.0001)***	
Westlund				3.0984 (0.0010)***

Source: Author's computations
***,**,*represent 1%, 5% and 10% significance level respectively
H_0: No cointegration

Table 8: Heteroskedasticity

Modified Wald Test Group Wise Heteroskedasticity	chi2(10) 97.50 Pro>chi2 =0.000	H_0: Constant variance
Bruesch Pagan test	chi2(1) 14,25 Pro>chi1(2) =0.002	H_0: Constant variance
Wooldridge test for autocorrelation in panel data	F (1; 9) = 41,095 P>F = 0.001	H_0: No first-order autocorelation

Table 9: Test of Endogeneity using 2SLS instrumental variable

Test	Scores	Hypothesis
Tests of overidentifying restrictions	a)Sargan (score) chi2(3)=.376693 (p=0.9450) b) Basmann chi2(3) =.351649 (p=0.9500)	H_0: Instruments are valid
Tests of endogeneity	a) Durbin (score) chi2(1) = .637402 (p = 0.4247) b) Wu-Hausman F (1,95) = .609416 (p = 0.4369)	H_0: Variables are exogenous

Source: Author's computations

The study also notes that carbon emission (CO_2) has a negative and statistically significant long run impact on financial stability. The study established that a 1% increase in carbon emissions correlates with a deterioration in financial stability by significant percentages (−8.424%, −9.402%, −10.22%) in columns 1-4, thus confirming the climate fragility hypothesis. From a transitional risk perspective, we can confirm climate to real sector transmission mechanism. A climate policy harms the brown industry's profits, productivity, employment and GDP. For instance, the slow migration to renewable energy resulted in the closure of SADC industries, mainly mining and manufacturing, resulting in substantial job losses, declining profits, and reduced income. That cascades to the financial service via increased default rates and, if left unchecked, can spread into the financial system (Semieniuk et al., 2021). The dismal theorem is more applicable in transitional risks, a paradigm shift that abandons industrial norms, and the system confronts industries as tail risks. Another dimension is that increasing CO_2 affects financial stability in various waves, such as credit, liquidity, market and operational risks, especially in the current climate adaptation drive. Imposing a carbon tax on high-emitting companies increases operational costs, which alone magnifies the probability of defaulting. Researchers in SSA, Asia, Europe, and other parts of the world (Amo-Bediako et al., 2023; Ayele and Fisseha, 2024; Chabot and Bertrand, 2023; Vioto et al., 2022) also confirm similar findings.

Non-performing loans show a statistically significant negative correlation with financial stability. An increase in NPL will erode the financial sector's stability through several channels: credit crunch, profitability, erosion of Tier 1 capital and failure of banks to absorb losses in times of climate and other macroeconomic shocks (Chabot and Bertrand, 2023). The analysis exposes that a 1% increase in NPL weakens financial sector stability by (−2.092-2.028%) in columns 1-4. The result confirms a bank balance sheet direct mechanism channel affecting financial stability. Hence, it is also confirmed empirically in (Aslan et al., 2022; Conlon et al., 2024; Zhang et al., 2024).

The control variables that the research utilized are theoretically and empirically significant in explaining financial stability. The results confirm that a 1% increase in agricultural productivity (AFF) improves the financial sector stability by 4.5%; however, it is not robust. The results confirm the financial sector to real sector channel; thus, as productivity in agriculture increases, the credit market stabilizes. Farmers and all stockholders can use financial services with limited risks by investing more in farming, saving for future farming seasons, reducing borrowing and improving banks' liquidity (Bekoe et al., 2025). A robust result confirmed that a1% increase in Gross Domestic Product per capita (GDP_pc) positively enhances financial stability by (20, 37%; 21, 82%); this means that a stable financial system promotes macroeconomic stability and gains are significant (Dar and Nain, 2024; Kurtoglu and Durusu-Ciftci, 2024; Silva, 2021). Hence, the study documents that financial sector stability is a vital determinant of the economic growth of SADC. Also, an Exchange rate (EXR) is positive and statically significant though not robust; a 1% depreciation in exchange rate boosts the stability of the financial sector by 1.28%, and this is accompanied by a positive and statistically insignificant Inflation (infl), and this implies that depreciation may trigger price volatilities especially given that all are net importing countries. However, it enhances the export market, stabilizing foreign currency flows and encouraging investments.

Table 11 represents model two, primarily designed to analyze the credit expansion mechanism in relation to climate risk. The second objective measures bank stability using a loan-to-deposit ratio and answers hypothesis 2. Results show that we reject the null hypothesis in all models at <5% significance level and accept the alternative hypothesis. Climate risk positively influences lending activities; a 1% increase in climate risk increases bank lending activities by (0.052%; 0.0370%) at 1% and 5% significance levels in all four models; however, it is not robust in DK-SEs. The result means that in extreme weather conditions like cyclones, hurricanes, high temperatures, droughts, and others, the banking sector credit of SADC expands by 0.05%, which can significantly destabilize the banking system. Thus, confirming a climate-to-financial sector transmission channel and a climate fragility hypothesis. A good example is the effects of Elnino experienced in some SADC countries in season 2023/2024, where rising food inflation aggravated food security in the whole region, leaving an estimated 18 million experiencing food shortages and that also led to fiscal expansion of countries that declared national disasters (Mugiyo et al., 2023).

Likewise, carbon emissions revealed a robust positive and statistically significant impact on bank stability. A 1% increase in carbon emissions will increase bank lending activities by (0.148%, 0.147%, and 0.173%) in columns 1-4, respectively, at 1% and 5% significance levels. The results indicate that climate change and the associated risks weaken financial sector stability because they increase banking sector lending activities, leaving banks with liquidity and operational risks, as suggested by DeMenno (2023). Similar findings were drawn from several studies in the global north and south (Aslan et al., 2022; Battiston et al., 2021; Le et al., 2023; Nieto, 2019). Other macroeconomic variables

Table 10: Main model: The impact of climate risk on financial sector stability of SADC

Variables	(Z_score) PCSE model 1	(Z_score) PCSE model 2	Robustness (Z_score) FGLS model	Robustness (Z_score) SYS-GMM
logCRI	−3.455* (1.770)	−3.455** (1.559)	−3.455** (1.434)	−4.189* (2.488)
$logCO_2$	−9.402*** (1.897)	−9.402*** (1.440)	−9.402*** (1.502)	−10.22*** (3.190)
logNPL	−2.092*** (0.712)	−2.092** (0.877)	−2.092*** (0.785)	−3.040 (2.040)
logGDP_pc	20.37*** (3.191)	20.37*** (2.511)	20.37*** (2.431)	21.82*** (4.653)
logAFF	4.547*** (0.990)	4.547*** (1.359)	4.547*** (1.570)	4.549 (4.599)
logEXR	1.284*** (0.456)	1.284** (0.519)	1.284** (0.505)	1.291 (1.603)
Infl	0.0208 (0.0726)	0.0208 (0.0867)	0.0208 (0.117)	0.0880 (0.141)
Constant	−161.0*** (21.07)	−161.0*** (18.86)	−161.0*** (18.64)	−170.0*** (39.29)
Year dummy	-	-	-	Yes
Observations	110	110	110	110
Number of C_ID	10	10	10	10
R-squared	0.423	0.423		

Source: Author's computations. Robust standard errors in parentheses
***P < 0.01, **P < 0.05, *P < 0.1

Table 11: Model 2: Impact of climate risk on bank lending activities of SADC

Variables	(LDR) POLS	(LDR) PCSE	(LDR) FGLS Model Robustness	(LDR) DK-SEs Robustness
logCRI	0.0520** (0.0255)	0.0520** (0.0246)	0.0517*** (0.000679)	0.0370 (0.0291)
$logCO_2$	0.148*** (0.0154)	0.148*** (0.00913)	0.147*** (0.000937)	0.173** (0.0652)
logNPL	−0.0914*** (0.0205)	−0.0914*** (0.0293)	−0.0921*** (0.000644)	−0.0436*** (0.0107)
logAFF	0.161*** (0.0315)	0.161*** (0.0214)	0.160*** (0.00208)	0.00626 (0.0500)
logEXR	−0.000271 (0.0100)	−0.000271 (0.00921)	−0.000807 (0.000699)	−0.138** (0.0496)
Infl	−0.00437** (0.00195)	−0.00437 (0.00271)	−0.00439*** (5.76e-05)	−0.000695 (0.00180)
Constant	3.978*** (0.146)	3.978*** (0.134)	3.987*** (0.0100)	4.928*** (0.218)
Observations	121	121	121	121
R-squared	0.639	0.639		
Number of C_ID		11	11	11
Number of groups				11

Source: Author's computations: Standard errors in parentheses
***P<0.01, **P<0.05, *P<0.1

concur with prior theoretical and empirical findings that inflation (Infl) negatively influences bank lending activities, meaning price increases in commodities directly reduce bank lending through several channels. In light of this, interest rates will discourage loan demand, and banks will adjust lending rates in response to the inflation outlook. A 1-unit increase in inflation decreases lending activities by (0.00107) % from column 4 in Table 11 and is not robust in Driscol-Kraay SEs.

Notably, non-performing loans (NPL) negatively impact bank stability, which has been confirmed in Hypothesis 1. NPL erodes the bank lending activities through liquidity risk. In the event of any catastrophe, banks switch from investments in fixed assets, long-term loans, and equity investments to increasing liquidity, which forces banks to contract credit on the greening of the economy. The result diverges from similar analyses done in G20 countries, where climate risk had a negligible effect on financial fragility owing to their advanced credit markets and well-designed insurance models (Nur et al., 2023). However, evidence from notable research confirmed that climate risk has a detrimental effect on banking stability and fragility (Aslan et al., 2022; Brik, 2024; Nehrebecka, 2021; Wang and Luo, 2022). Analysis of agricultural productivity indicates a positive and statistically significant relationship in the long run, meaning that as bank lending activities increase, so does agrarian productivity. In anticipation of a bumper harvest, the agriculture sector may push for more loans for inputs, a common phenomenon from the sample under investigation because the sector contributes significantly to the gross domestic product of the SADC countries to a tune of 10-20% (García-Villegas and Martorell, 2024; Pretorius). FGLS and DK-SEs were used to check the robustness of the models in Table 11. Again, the hypothesis that climate risk has no significant impact on bank lending activities of SADC is rejected at <10% significance level in all models columns 1-3 and fails to be robust using DK-SEs on climate risk variable however positive as indicated in columns 1-4 in Table 11.

4. CONCLUSION AND POLICY RECOMMENDATIONS

4.1. Conclusion

The paper investigated the impact of climate risk on SADC's financial sector stability and further explored the effect of climate risk on SADC's bank lending activities. The research used Z_score (dependent variable) to measure financial stability, and the main explanatory variables are climate risk index and carbon emissions using PSCE, where FGLS and system GMM were used as robustness checking models. The study confirmed a long-run negative and statistically significant relationship between climate risk and financial stability.

Considering the results from the first main model of this research, the study further investigated a second objective to see the transmission mechanism that runs from the climate risk to the financial sector using bank stability: Loan to deposit ratio. The study used POLS and PCSE, whereas FGLS and DK-SEs were robust checking results. The findings endorse the adverse effects of climate change risks on the banking sector through an expansion in lending activities. Notably, all models confirm that non-performing loans (NPL) negatively impact financial stability, models in hypotheses 1 and 2.NPL erodes the banking sector stability through credit market risk.

The study has shown that climate change makes the distributions of temperature and natural disasters inherently more ambiguous (Moore, 2024). Results confirm a channel climate→financial sector; Climate→real sector→ financial stability. Climate change risk expands bank lending activities and destabilizes the financial sector through increased credit risk, loan default, and liquidity risks. The study concludes that climate risk negatively affects financial stability while positively increasing lending activities.

The research suggests climate-induced financial instability worsens social inequalities, particularly for vulnerable low-income populations. These groups often encounter significant barriers in accessing credit, insurance, and other essential financial services. The agro-based economies in the SADC region are particularly susceptible to unpredictable extreme weather events. Droughts can result in job losses, livestock destruction, and the spread of diseases, which disproportionately affect rural livelihoods. Consequently, rural-urban migration has become a prevalent trend in SADC. If policymakers fail to establish a resilient financial system to climate risks, they risk perpetuating social injustices and leaving the most vulnerable populations without support.

4.2. Policy Recommendations

The study recommends that SADC countries expand government-guaranteed bank credit schemes targeting capital projects needed to facilitate the transition to green energy sources and incentivize targeted green investments, particularly green bonds, carbon credits, and green banking, to enhance green growth and financial sector resilience.

The study proposes critical interventions in creating climate risk insurance products to lessen financial losses during serious physical climate risks and availing incentives towards green investments to enhance financial sector resilience. The research findings encourage all SADC member countries to embrace the Network for Greening Financial Systems launched in 2017. This network allows collective efforts to compile climate risk data necessary for global financial stability statistics. The study also recommends that SADC's central banks prioritize investment in green bonds, carbon markets, and climate finance. Africa has 11 bonds, 1% of the world's green bonds (CPI, 2024).

4.3. Limitations of the Study

The study hereby acknowledges its main weaknesses. The use of climate risk index as a significant variable measuring climate risk, whereas the study could have split the climate risk into physical and transitional risk and having to run two models with separate measures of climate risk. However, the major obstacle was data availability on these climate risk variables. Notably, the dataset was small, which limited the research to a few panel data models that could accommodate a small T and N sample. As for climate risk index data, the German Watch has data from 2010 to 2020 and out of sixteen countries in SADC, only eleven countries had data for climate risk from the given period, limiting the study from extending its observations further than 2020. The study also acknowledges that using Z-scores can be problematic: suppose that banks' ROAs are high because bank spreads are high and banks have reported low levels of provisions (Silva, 2021). However, the high spread could indicate that banks' risk-taking is elevated (high spreads to compensate banks for taking such risks) and that lower provisions suggest that banks have weaker buffers for credit losses (Dantas et al., 2023).In this case, the high Z-score is masking the financial instability of the banking sector.

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