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Sustainable Financing, Climate Change Risks and Bank Stability in Kenya

Maureen Odongo, Roseline Misati, Caren Kageha and Peter Wamalwa

Abstract

This study analyses the impact of climate risk indicators on bank stability in Kenya based on descriptive and quantitative approaches on quarterly data covering thirty-five banks over the period 2009 to 2021. The analysis reveals a distinct warming trend, variable rainfall pattern and an increasing trend in greenhouse gas emissions especially in the agriculture and transport sectors. Banks' climate financing for sustainable projects remains low. Empirical findings using dynamic panel estimation reveals adverse impact of temperature changes and rainfall variability on bank stability and credit risk arising from non-performing loans. The stress testing results reveal vulnerability of the banking sector to climate change as the probability of defaulting increases in moderate, severe, and extreme temperature changes. The results affirm banks' important role in managing financial stability risks while providing sustainable climate financing and the need to strengthen synergies between private and public sustainable financing for target priority sectors.

1.0 Introduction

Climate change continues to dominate the global risk landscape and poses long-term threat to the global economy. The severity of climate change is evident in the persistent occurrences of natural disasters, increasing temperatures and unpredictable weather patterns, which have intensified in the recent past (World Economic Forum (WEF), 2022). Developing countries are most vulnerable to climate-related physical risks, yet mitigation and coping strategies remain limited (Bank of International Settlement (BIS), 2021a; Eckstein, 2021; Grippa, Schmittmann and Suntheim, 2019). The implementation of the 2015 Paris Agreement calls for strengthening global responses to climate change by limiting global warming to below 2 degrees Celsius and transition to a low or net-zero greenhouse gas emissions (GHG) by 2050 (United Nations (UN), 2015).

Financial institutions are expected to play a fundamental role of transitioning to a low carbon economy by providing sustainable climate financing and managing climate-related risks (Carney, 2015; Demekas and Grippa, 2021). Specifically, banks are expected to play the intermediating role of mobilizing and allocating capital for the green agenda (BIS, 2021a; Bank of England (BOE), 2018). However, banks are exposed to climate-related physical and transitory risks either directly, through balance sheet of households and climate sensitive sectors or indirectly, through the effects of climate change on the wider economy and financial system (Grippa et al., 2019; Carney 2015). The rapidly evolving sustainable climate financing landscape also poses financial stability risks (BIS, 2021a; 2021b;).

With the increasing scale of climate change risks financial authorities globally have set prudential guidelines for monitoring and managing potential bank risks (Network for Greening the Financial System (NGFS), 2020a; 2020b). Advanced economies have entrenched climate risk assessment frameworks in their operations (European Central Bank (ECB) and European Systemic Risk Board (ESRB), 2021; BOE, 2021; 2018). While this progress provides global best practices, applicability to developing economies is limited because of differential climate-risk profiles and outcomes arising from geographical heterogeneity, sectoral peculiarities, and different mitigants (BIS, 2021a; Koetter et al., 2020). Climate-finance risks literature offer diverse outcomes. Some studies find positive financial stability impacts attributed in part to financial mitigants which buttress banks' stability by moderating their exposure to climate-related financial risks (Blickle et al., 2022; Koetter et al., 2020; OECD, 2018; Chavaz, 2016), other studies find negative stability impact due to either financial amplifiers (FSB, 2020; BIS, 2021a) and/or negative feedback loops from the economic sectors (Liu et al., 2021; Dafermos et al., 2018; Klomp, 2014). This therefore calls for localized assessment of climate change risks impact of financial stability.

In Kenya, climate-related risks affect not only agricultural sector but also the Agri-based industries and household incomes. According to World Bank (2021) drought in Kenya occurs every 3-5 years at an estimated cost of 8 percent of GDP. Given that financial assets are ultimately backed by economic activities, it follows that climate-related risks may affect financial system (Wambui, 2020; Dietz et al., 2016). Despite the multi-led industry initiatives (Government of Kenya (GOK), 2021a; 2016; KBA, 2015), there is limited empirical literature yet a quantitative understanding of the climate risks impact on the banking sector is imperative to facilitate efficient adjustment of business models, policy adaption and mitigation strategies. This is especially critical in the context of the Guidance on Climate Risks Management Frameworks which require banks to embed financial risks in their prudential regulations; develop approaches for monitoring climate risk and promote disclosures on financial risks arising from climate change (CBK, 2021a).

Against this background, this study seeks to: (1) examine the trend of climate-related risk indicators and climate financing in Kenya; (2) analyze the impact of climate change physical risks on bank stability, and (3) assess the vulnerability of bank credit to projected change in climate physical risk profile.

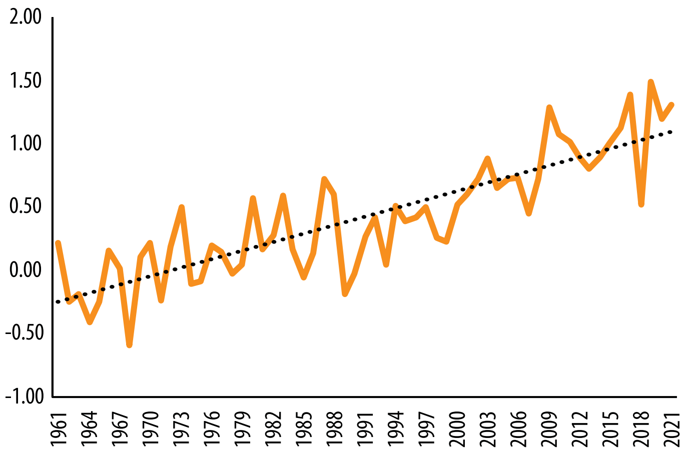
This study contributes to the ongoing literature on climate-finance risks and the efforts by financial sector regulators and policymakers in enforcing financial stability while at the same time encouraging sustainable climate financing. Unlike previous empirical studies, this study analyses climate change physical risks on various financial stability indicators, while paying special attention to long-term climate change risk profile using the stress testing scenario analysis.

2.0 Stylized facts on Climate-Related Risks and Climate Financing in Kenya

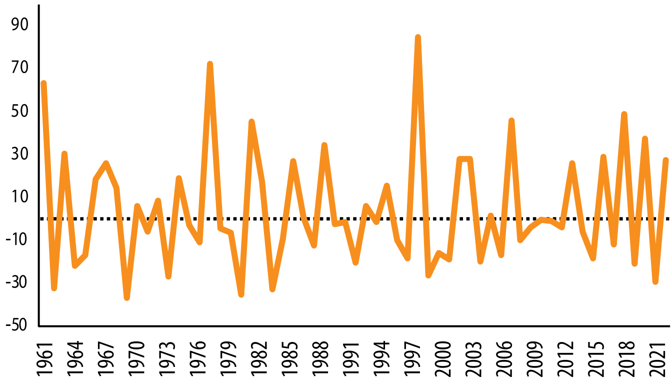
Climate change in Kenya exhibits a distinct warming trend and variable rainfall pattern (Figure 1). The annual temperature change averaged 1.3° C in 2021 having increased by an estimated rate of 0.21° C per decade and projected to reach 1.5° C in 2030 under business-as-usual scenario (World Bank, 2021; GOK, 2021a). Precipitation has been highly erratic with variable rainfall pattern and amounts. These changes have resulted in more frequent and extreme weather events ranging from droughts, floods, and landslides, causing major socio-economic and developmental challenges to the economy (GOK, 2021a; 2018; Mwangi and Mutua, 2015). The consequences are compounded by the widespread lack of supportive infrastructure and technology (GOK, 2010; 2013).

Figure 1:
Climate Change Indicators: Temperature and Rainfall in Kenya

1 (a) Temperature Change



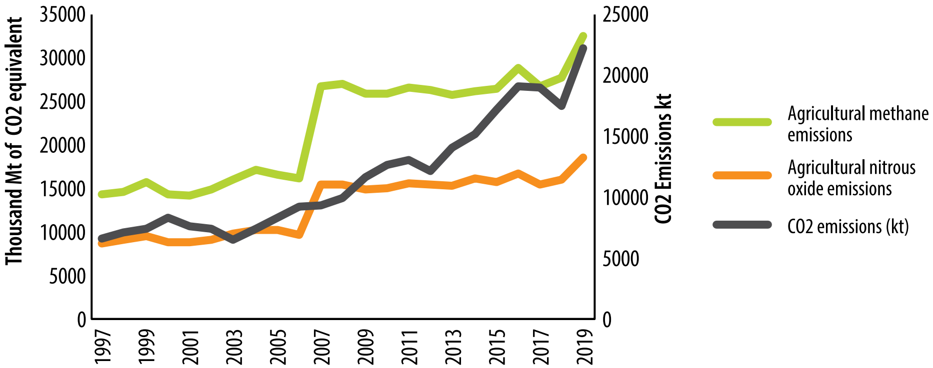
1 (b) Rainfall Annual Percent Change



Source: FAOSTAT and World Bank, World Bank Group's Climate Change Knowledge Portal

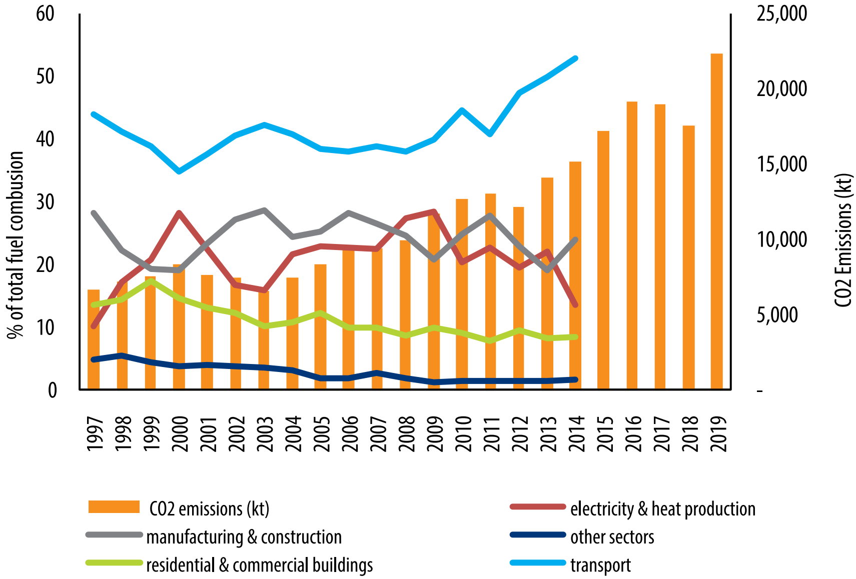
Kenya's total GHG emissions in 2019 were 81 million metric tons of carbon dioxide equivalent (MtCO2e) accounting for 0.18 percent of global the GHG emissions. While the emissions are relatively lower in comparison to the global levels, they are however increasing and are estimated to reach 143 MtCO2e by 2030 (GOK, 2021a). The leading emission sector is agriculture accounting for about 40 percent of total national emissions, attributed to fertilizer use, fossils, animal waste management, and burning agriculture waste, followed by energy and transport sectors at 38 percent (**Figure 2**). Aligning with the Paris

Figure 2: Greenhouse Gas Emissions by Sector in Kenya



Source: World Bank Database

Figure 2: Greenhouse Gas Emissions by Sector in Kenya



Source: World Bank Database

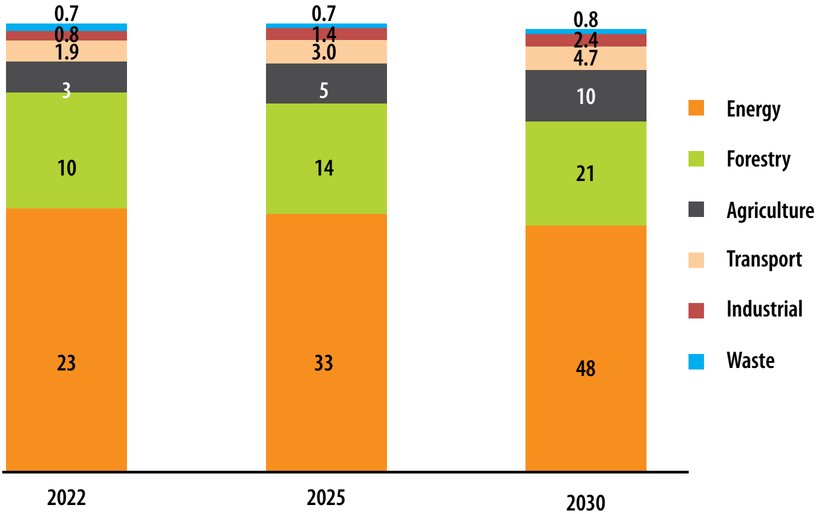
Agreement, the National Climate Change Action Plan I and II commits to mitigation strategies for energy, transport, industrial processing, agriculture, forestry, and waste management, while at the same time adopting climate-smart agricultural technologies (GOK, 2021a).

Despite Kenya's low levels of greenhouse gas emissions, the country commits to emission reduction potential of 86 MtCO2e by 2030 (GOK, 2021a).

In particular, the energy sector is expected to abate 48 MtCO2e followed by forestry (21 MtCO2e), agriculture (10 MtCO2e), and transport sector (10 MtCO2e) (Figure 3). The main targeted sectoral activities include increasing use of renewable energy, sustainable energy and waste management technologies, use of low-carbon transport systems and adoption of climate smart agriculture (GOK, 2021a).

Formal bank lending concentration is mainly

Figure 3: Kenya's Emission Reduction Targets, 2022-2030 (MtCO2e)



Source: GOK, 2021a

to the households (18.3 percent), Trade (17.2), Manufacturing (15.2), real estate (13.4) and transport sectors (7.9) (**Table 1**). Bank credit to agriculture sector has declined over the years from an average of 9.8 percent in the period 2000-2004 to 3.7 percent in the period 2012-2021. Despite the low credit allocation, agriculture remains the dominant source of staple food and the foundation of livelihoods for the rural poor. The sector contribution to Kenya's Gross Domestic Product (GDP) is about 23-25 percent, and is considered the backbone of the Agri-based industries providing backward-forward linkages to other important sectors such as manufacturing, trade, tourism, and transport (GOK, 2007; 2013).

Table 1: Bank Lending in Kenya by Sector (Percent share)

	2000-2004	2005-2009	2010-2014	2015-2019	2020	2021
Private households	9.85	21.51	24.26	19.48	18.42	18.31
Trade	18.1	14.8	16.6	17.0	17.3	17.2
Manufacturing	21.0	14.7	12.6	13.2	14.6	15.2
Real estate	7.9	6.0	12.5	14.8	14.5	13.4
Consumer durables	2.1	4.5	6.2	8.0	10.4	11.0

	2000-2004	2005-2009	2010-2014	2015-2019	2020	2021
Transport& communication	5.5	8.8	6.6	7.9	7.5	7.9
Business services	9.7	9.9	8.3	7.0	5.7	5.7
Building & construction	7.6	7.0	4.5	4.7	4.3	4.0
Finance and insurance	7.7	5.3	2.5	3.6	3.7	3.6
Agriculture	9.8	6.4	4.3	3.6	3.3	3.1
Mining & quarrying	0.8	1.1	1.8	0.7	0.4	0.6

Source: Central Bank of Kenya

Banks' exposure may arise from private households and the Agri-bases industries, since climate change physical risks suppress agriculture output, which affects affect households and firms' balance sheet either directly via reduced production and income levels or indirectly via reduced Gross Domestic Production. Exposures may be manifest through increased credit default, lower asset values, reduced funding, and draw-down on credit lines (CBK, 2021a). Elevated risks may also arise from collateralized lending since climate-related risks damage physical capital used as collateral security for bank credit (ECB/ESRB, 2021).

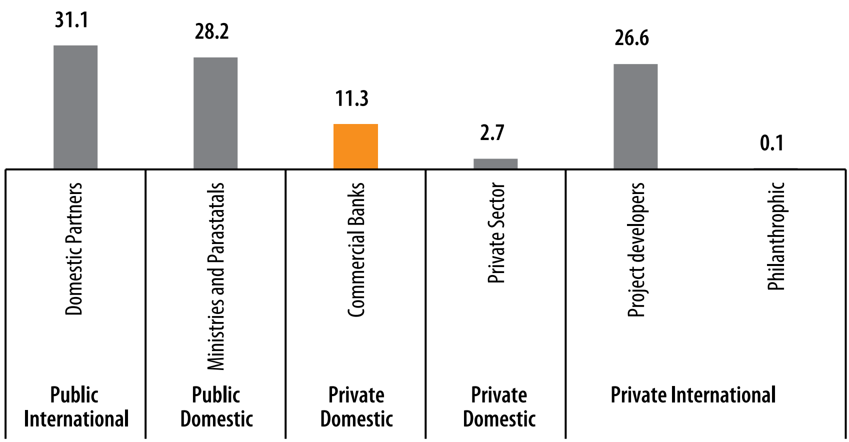
Sustainable climate financing in Kenya remains low estimated at USD 2.4 billion in 2018 and is mainly sourced from external loans and grants from international public institutions (GOK, 2021b). Public investment (from domestic and international providers) totaled USD 1.4 billion (59.4 percent) while investment from the private sector totaled USD 1.0 billion (40.7 percent). The contribution from the banking sector was USD 276 million, which was 11.3 percent of the total resource basket (**Figure 4**).

A larger share of commercial bank funding was towards the energy sector, specifically production of renewable and efficient energy. Despite Kenya's commitment to adoption of CSA a larger funding share was used for mitigation with minimal funding to agriculture and forestry sectors (**Figure 5**).

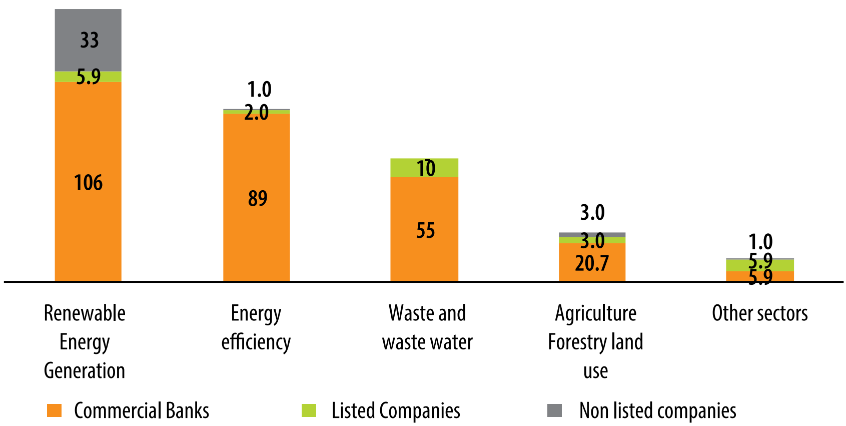
There is need to scale-up the public and private climate finance in order to meet the climate change targets outlined in the Nationally Determined Contributions (NDC). The financial sector is expected to play an important role in sourcing and aligning investments to sustainable financing. According to GOK (2021a) the estimated resource requirements during 2020-2030 is USD 17.7 billion of which USD 3.7 billion (21 percent) is to be sourced from the domestic economy, calling for increased financial sector support.

Figure 5: Climate Finance in Kenya in 2018

Climate Financing by source (% Share)



Sectors Funded by Domestic Private Sector (USD M)



Source: GOK, 2021b

3.0 Literature review

Theories of climate change posit that GHG emissions have caused rising global temperatures and induced extreme weather events (Hansen, 1980; Hulme, 1996; 1994; Adams et al, 1998) and affected the macro-economy through reduced crop yield, consumption, investment, and output (Stern, 2007; Schlenker and Roberts, 2009; Dell et al., 2014; Ericksen, 2008). Theoretical literature contends that attaining low or zero GHG emissions entails policy changes, technological innovations and consumer preferences and therefore shift in production patterns (Campiglio et al., 2018). However, this may have positive economy wide effects or cause extensive stranding of firm assets (BIS, 2021a; Caldecott, 2018; Meinshausen et al., 2009) with implications on financial stability through loan default, and portfolio revaluations (Monasterolo, 2020; van der Ploeg and Rezai, 2020; Semieniuk et al., 2021).

Empirical literature on climate-finance risks is very recent and findings are mixed. Studies have assessed transitory and physical risks impact on financial stability focusing mostly on developed economies, using varied methodologies, which include climate risk score (Weyzig et al., 2014; Battiston et al., 2017; Neito, 2019; Wambui, 2020) and climate scenario stress testing analysis (Ojea-Ferreiro, 2022; Allen et al., 2020; BOE, 2021) for transitory risk analysis. Empirical studies on physical risk assessment using scenario-based stress testing include (Batten et al., 2016; Bovari et al., 2018), global macro-ecological models (Dafermos, Nikolaidi, and Galanis, 2018; Dietz et al. 2016; Dell, 2014) and macro-econometrics models (Blickle et al., 2022; Koetter et al., 2020; Noth and Schuewer, 2018; Klomp, 2014; Liu et. al, 2021).

Empirical findings of physical risks impact on financial stability are mixed, with some studies showing positive impact (Blickle et al., 2022; Schüwer, Lambert, and Noth 2019; Koetter et al., 2020; Chavaz, 2016) and other studies revealing negative impact (Dafermos et al., 2018; Liu et al., 2020; Noth and Schuewer, 2018; Battiston et al., 2017; Dietz et al, 2016; Klomp, 2014). An increase in bank lending following weather shock is attributed to disaster aid flows to households (Blickle et al., 2022). Similarly bank location is important as it facilitates knowledge of local borrowers and the climate risk profiles (Blickle et al., 2022; Koetter et al., 2020; Chavaz, 2016; Berg and Schrader, 2012). Findings by Chavaz, (2016) revealed local knowledge on climate risk profile enables banks reduce lending from the unaffected regions to accommodate new lending to the affected region, while Schüwer, Lambert, and Noth (2019) showed that highly capitalized banks increase lending to affected firms.

Further, empirical studies show that climate change physical risks directly reduce financial sector credit expansion by reducing household and firm profitability, impair liquidity conditions and increase credit default (Noth and Schuewer, 2018; Klomp, 2014) for developed countries and (Liu et al., 2020; Dafermos et al., 2018; Dietz et al., 2016; Dell et al. (2014) for developing countries. According to this literature, the level of financial development, capital regulation, sectoral exposure of climate sensitive sector and bank supervision matters (Klomp, 2014). Dell et al. (2014) argued that temperature shocks are inevitably connected with consumption, agricultural, health and productivity outcome, and hence economic performance. Productivity shocks explain high variations of the cross-section equity returns, which eventually affects financial performance (Garlappi and Song, 2017). The study by Dietz et al (2016), consistent with Bovari et al., (2018) revealed that temperature volatility negatively affects financial stability, with a 2.5 percent increase in global mean surface temperatures affecting almost 2 percent of global financial assets.

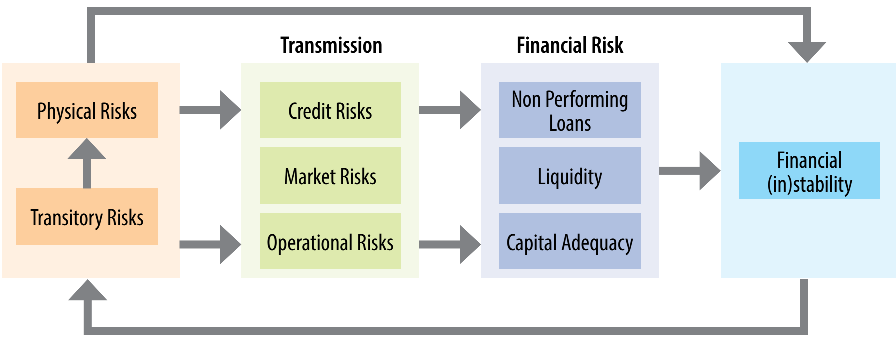
The reviewed literature reveals consistent theoretical argument on climate-finance risk in terms of causes, impact, and outcome on financial stability. However, empirical studies have considerable heterogeneity, arising from climate change risks, geolocation heterogeneity, and sectoral differences, and the course for policy action to mitigate climate change. Literature reveals that developed countries are cushioned in terms of regulation, capital adequacy, and asset portfolio and relationship lending, age, firm size, and alternative funding sources are important. However, there are gaps on climate-finance literature for developing countries. There is limited research on climate change risk assessment on bank stability, with existing studies focusing more on macroeconomic outcomes and agriculture productivity yet the brunt of erratic weather changes is evidently beyond the agriculture sectors (BIS, 2021a; IPCC, 2018; Carney, 2015; CBK, 2021a).

4.0 Research Methodology

4.1 Conceptual Framework

Climate change risks enhance financial risks while financial instability hinders the scope for effective climate change mitigation and adaptative measures (Figure 6). Three main climate change related risks are physical risks, transition risks and liquidity risks (Carney, 2015). Physical risks arise from the physical impact of climate change such as temperature increases and precipitation change, which lead to extreme weather events such as heatwaves, drought, flooding, and cyclones. When physical risks materialize, agricultural productivity is affected, and this has implications on market supplies and prices for the Agri-based sectors and households. Similarly, climate change physical risk damages infrastructure of households and firms and therefore the asset values. This affects firms' and households' creditworthiness, which in turn affects banks' balance sheets via credit default and asset revaluations. The destruction of physical capital reduces the value of collateral, which in turn limits the ability of firms and households to borrow (Gripper et al., 2021; BIS, 2021a). A large disaster could also affect bank operations, structures, and systems, and may triggers sizable withdrawal of customer deposits and thereby cause liquidity risk.

Figure 6: Conceptual Framework on Climate risks impact on Bank Stability



Source: Authors' Illustration

Transition risks arise from policy adjustments, technological innovations, and consumer preferences geared towards transitioning to low-carbon economy. Materialization of transition risks affect asset value of affected firms either positively via technology breakthrough or negatively via asset stranding thus affecting production processes, this in turn reduces firms' profitability. Technological changes may on the other hand spur transition to a low-carbon economy, positively affecting profitability of firms and thereby bank stability.

4.2 Data and data sources

This study used bank level quarterly data for the period spanning 2009 to 2021, for thirty-five commercial banks. The choice of data is informed by availability, uniformity, and consistency of the cross-sectional units. The start period of 2009 reflects the year when Kenya rebased GDP. Variable abbreviations, measurement and data sources are provided in **Table 2** below:

Table 2: Variable description and data sources

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

4.3 Empirical Model

The study used a model with a lagged dependent variable as one of the regressors to handle time persistence in the structure of the dependent variable. The study specifies a dynamic panel data model consistent with previous studies that have shown that previous levels of proxies of bank stability influence their current levels, (Jabra, 2020; Atoi, 2018).

$$BS_{it} = \propto_0 + \partial_1 BS_{it-1} + \propto_1 ClimC_t + \partial_2 X_{it} + \mu_{it}, \ldots, 1$$

Where the dependent variable, BS_{it} represents four different measures of bank stability that have been considered in previous studies. The four measures include, Z-score, capital adequacy, return on assets and return in equity, (Moreno et al., 2022; Pham et al., 2021; Ali and Puah, 2018; Diaconu and Oanea, 2015). ClimC represents rainfall and temperature volatility used as the two proxies for climate change. X represents control variables (Credit risk, inflation, GDP, bank size and liquidity) while μ is the error term. The subscripts i= 1 ,. . . ,N and t=1,. . . ,T refer to the cross-section and time series dimensions of the data, respectively

The bank Z-scores capture the probability of default of a country's banking system. The Z-score relates a firm's capital level to the variability in its return on assets (ROA), revealing how much variability in returns can be absorbed by capital without the firm becoming insolvent. A higher value of the z-score means lower bank risk, (Moreno et al., 2022; Pham et al., 2021). The computation of the Z-score is represented in equation 4.2 below:

$$\text{Z-score} = \frac{ROA + \frac{Equity}{Asset}}{\sigma ROA} \quad \ldots\ldots\ldots\ldots\ldots 2$$

In the literature, climate change is measured by rainfall, temperature, and carbon emission indicators. The study used quarterly change in the amount of rainfall in mm and quarterly variation in temperature in Celcius, (Nahousse, 2019). Climate change manifested in increases in temperature and volatility in rainfall leading to floods, drought, heatwaves, fire, rising sea levels and hurricanes cause capital losses reducing the profitability of firms and deterioration of their financial positions (Liu et al., 2021; Stern, 2007; Batten, et al, 2016). Theoretically, it affects the financial system through physical and transition risks. The combined effect of the physical and transition risk leads to market, credit, and underwriting losses as well as operational risks depending on the exposure of banks to households and corporations (Grippa et al., 2019). Consequently, lower asset values and debt defaults could arise which would lead to systemic bank losses and adverse effects on investor confidence, (Fabris, 2020; Batten, et al, 2016; Dafermos et al., 2018; Bovari et al., 2018) Apriori expectation between temperature and rainfall variability and bank stability is thus negative.

As indicated in Pham et al (2021), the literature categorizes determinants of bank stability into three categories. The bank-specific factors considered in this study include bank size, liquidity and credit risk while the macro variables constitute inflation and GDP, (Pham et al., 2021; Diaconu and Oanea, 2015; 2014). Bank size is measured by the natural log of total assets. The relationship between bank size and bank stability is entrenched in three theories. First is the agency theory of the firm which postulates that the goals of the owners and managers diverge with the manager inclined to make biased decisions geared toward personal gains over the owner's interests. Thus, increasing firm size is a consequence of managerial empire-building and such large firms are characterized by bad governance. In contrast, the stewardship theory predicts a positive relationship between bank size and stability in which case, managers are not motivated by individual goals, but rather are stewards whose motives are aligned with the objectives of their principal. In such cases, managers propel the shareholder's agenda, (Adusei, 2015; Davis et al, 1997). An ambiguous sign is thus expected apriori.

Credit risk is measured by non-performing loans to total loans. This variable indicates the extent to which a bank is vulnerable to variations in the repayment attitudes of its borrowers. Higher non- performing loans to total loans imply high borrower default and more likelihood of bank insolvency. Apriori a negative sign is expected, (Amara and Mabrouki, 2019; Adusei, 2015).

Bank liquidity is associated with higher asset quality which directly benefits stability by encouraging banks to reduce the risks on their balance sheets and by facilitating liquidation of assets in a crisis. However, improved possibilities for liquidating assets during a crisis makes a crisis less costly, which induces banks to take on an amount of risk that can counter the initial positive impact on stability, (Wagner, 2007). An ambiguous sign is thus expected between liquidity and bank stability.

Strong economic performance measured by high GDP growth minimizes non-performing loans, enhances credit quality and efficiency of banks and therefore bank stability, (Sifrain, 2021). Inflation affects bank stability through its effect on bank performance. The inflationary implications also depend on whether it is anticipated or not. In the anticipated case, the interest rates are adjusted accordingly, resulting in faster increase of bank revenues than costs and subsequently gives a positive impact on bank performance. In the unanticipated case, banks may be slow in adjusting their interest rates, resulting in a faster increase of bank costs than revenue with negative implications on bank performance, (Sufian and Kamarudin, 2012).

Mobile money by facilitating access to saving products to old and new customers, it enables more individuals to access formal financial services leading to diversification and expansion of banks' depositor base. In such cases, mobile money and commercial banking are complementary, with mobile money helping to mobilize deposits and enabling customers to eventually use more commercial bank services. In countries where mobile money products are linked to formal bank accounts, it may also reduce the unit cost of financial services, allowing banks to expand their customer base and product offering, (Misati et al., 2022).

4.4 Econometric Approach

Our model specification contains lagged dependent variables as regressors. Baltagi (2002) has identified two main characteristics of dynamic regressions. First, is the autocorrelation due to the presence of a lagged depended variable among the regressors and second, is the presence of unobserved heterogeneity in individual behavior. However, panel datasets, where the behavior of N-cross sectional units is observed over T-time periods, provide a solution to accommodate the joint presence of dynamics and unobserved individual heterogeneity (Giovanni, 2004).

Ordinary least squares (OLS), fixed effects and random effects are unsuitable when a lagged dependent variable is one of the regressors. OLS may be biased since it ignores unobservable heterogeneity while fixed effects (FE) and random effects (RE) estimators produce biased coefficient estimates with small samples. The basic problem of using least square methods is that the lagged dependent variable is correlated with the error term, (Ledyaeva and Linden, 2008). The generalized method of moments (GMM) provides a convenient framework for obtaining asymptotically efficient estimators, (Arellano and Bond, 1991). GMM is considered a more efficient estimator in comparison to other estimators because it can avoid the bias of ordinary least square methods when an explanatory variable in a regression is correlated with the regression's disturbance term. Moreover, GMM provides theoretically based and powerful instruments that accounts for simultaneity while eliminating any unobservable heterogeneity, (Machasio, 2018). In this study, we therefore used GMM which is the most appropriate for dynamic panel data since it solves problems of endogeneity and provides efficient estimators that are not obtainable from alternative methods such as OLS and FE.[1]

1. However, it should be noted that robustness of the models was confirmed by estimating fixed effects and random effects models with the same set of variables. The results were not very significantly different from the ones reported in this study

5.0 Empirical Results and Discussion

In Table 2, results from four models in columns 2-6 are reported, corresponding to four different indicators of bank stability. Results with return on assets, return on equity, capital adequacy and reciprocal of Z-score are reported in models 1-4, respectively. In the last two columns, we considered temperature and rainfall separately since these are two different variables, with the rainfall volatility capturing both floods and droughts while temperature volatility capturing extreme heat and cold. The effect of the volatility in the rainfall variable affects the agricultural sectors and associated sectors but extreme temperature does not only affect agriculture in case of drought but also affects sources of hydro energy with attendant effects on electricity of various economic activities with implications on costs of production and hence ability to finance and repay loans.

Generally, the results show that climate change, bank- specific factors and macro variables are significant in explaining bank stability. Specifically, the results show that rainfall volatility is significant in explaining bank instability in all the models reported in Table 2. This implies that rainfall variability affect productivity in some sectors such agriculture that are dependent on rainfall, which in turn also affect the sectors of the economy that are linked to agriculture. Rainfall variability also disrupts livelihoods especially when it involves landslides and internal migration thus interfering with economic activities of some economic agents holding loans with the banking sector. As a result, the profitability and financial positions of such sectors is affected with possible debt defaults, reduced cash at hand and collateral leading to negative implications on the banking sector. These results are consistent with previous studies, (Liu et al., 2021).

2. The significance of the temperature variable is also observed when it is separately entered in models where ROE and ROA are considered as measures of bank stability.

Table 3: Empirical results

	Dependent Variable					
	Return on Assets ROA	Return on Equity ROE	Capital Adequacy Ratio CAR	Z-Score Reciprical		
				With rain and temperature volatility	With temperature volatility	With rain volatility
Independent Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Liquidity	0.64(0.91)	0.65(0.76)	0.10(1.15)	0.41(0.46)	-0.65(-0.61)	0.18(0.20)
Inflation	0.006(0.08)	0.04(0.564)	0.005(1.83)*	0.03(1.09)	-0.05(-1.01)	0.03(1.07)
GDP	-0.18(-1.24)	-0.30(-1.37)	-0.06(-1.44)	-7.39E-13 (-2.49)***	-1.88E-12 (-3.21)***	-6.26E-13 (-2.10)**
Bank size	0.08(2.43)***	0.09(2.05)**	0.04(1.40)	0.61(2.09)**	0.53(2.08)**	006(0.31)
Credit risk	-0.22 (-3.26)***	-0.17(-1.76)*	-0002(-0.66)	0.37 (4.00)***	0.22 (2.46)***	0.30 (3.47)***
RainVol	-0.06(-2.24)**	-0.06 (-2.01)**	-005 (-2.68)***	0.002 (2.78)***		0.002 (2.89)***
TempVol	0.04(0.72)	-0.02(-0.77)	-0.01 (3.28)***	-0.03(-1.39)	0.21(2.21)**	
Mob_value	5.55E-06(1.82)*	5.26E-06(2.35)***	0.09(2.63)***	3.59E-07(0.20)	6.50E-06(2.15)***	2.00E-06(1.29)
Lag_BS	0.77(13.2)***	0.78 (12.5)***	0.70 (4.28)***	0.83 (16.4)***	0.80 (15.0)***	0.81 (16.5)***
No. Obs.	908	908	893	906	1136	906
R2	0.63	0.66	0.89	0.57	0.48	0.58
J-Statistic (Prob)	22.9(0.81)	21.3(0.87)	14.1(0.44)	31.03(0.41)	25.7(0.41)	36.1(0.24)

Note: The results are based on GMM Panel Data estimation. ***, **, * represent significance level at 1%, 5% and 10% respectively

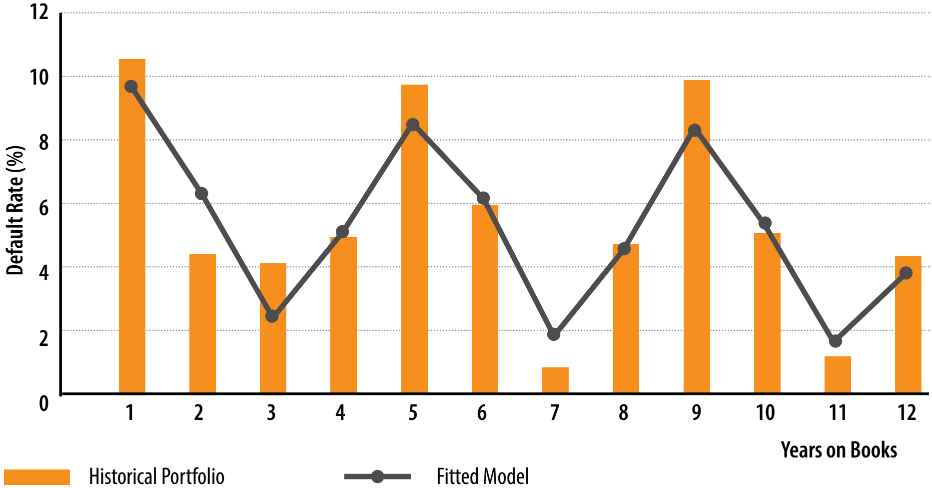
Temperature volatility is highly significant when it is separately considered as is the case in model 5, unlike where both rainfall and temperature variables are included in the same model.[2] This would imply that rainfall volatility is more important than temperature volatility when both variables are included in the same model. However, the significance of temperature is revealed when the variables are isolated, manifesting the different aspects of climate change that they capture. Investors also need to be sensitized on climate change risks in terms of identifying the estimated size and scope and attempt to price the climate related financial risk.

Besides climate change factors, bank size and credit risk also explain bank stability. The positive relationship between bank size and banking stability is consistent with the stewardship theory in which case, managers of firms/banks are stewards whose motives are aligned with the objectives of their principal. In such cases, managers propel the shareholder's agenda. Moreover, large banks are able to hedge and diversify risk, implying the need to build bank capital and asset base while ensuring optimal balance through establishments of bank size thresholds.. The results of this study are consistent with previous studies, (Adusei, 2015). Credit risk has a negative effect on bank stability and this finding could be attributed to the recent pick-up in gross loans amid weak economic growth, as non-performing loans compounded by the negative effects on productivity and employment due to the COVID-19 pandemic and erratic weather pattern.

Whereas inflation is not significant in any of the models reported in Table 2, the coefficient of GDP is significant implying that economic activities matter for bank stability. This is consistent with the notion that high GDP growth minimizes non-performing loans and enhances credit quality with possible efficiency gains for banks. The value of mobile transactions has a positive and significant effect on bank stability. This is consistent with the view that mobile money increases saving and enables more individuals to access formal financial services, and this would diversify and expand banks' depositor base implying possible complementarity of mobile financial services with commercial banks. However, it should be noted that the magnitudes of the coefficients of mobile transaction are too small to warrant much weight in our analysis.

The stress testing results show that the baseline increase in temperature of 0.2^{o}C leads to physical damages that undermine the ability to repay loans and increases the value of stranded assets. The probability of default estimated by the model is first compared with actual data to assess the fitness of the model based on the predictive power. The historical PD is plotted alongside the estimated PD in (**Figure 7**).

Figure 7: Probability of Default Using Historical and Estimated Values



Source: Authors Illustration

The PDs generated by the model fit the data well, hence the model can be used to simulate the impact of climate change on credit risk. The baseline average temperate of 1.3° C results in PD declining from 7.6 percent in the first year of the loan (2022) to 3.8 percent by 2030. However, an increase in mean temperature by 0.2°C from the baseline to 1.5° C results in an increase in the PD to 20.1 percent by the end of the first year (2022) and declines to 18.6 percent by 2030. This implies that an increase in average temperature to 1.5° C induces physical damages that undermine the ability to repay leading to a default of about 20 percent of the loan. The expected loss given default is estimated to be KSh 628 billion. In the severe scenario, whereby temperate increases by 0.4° C, the PD increases to 80 percent in the first year and declines to 69.7 percent by 2030. The banking sector would incur a loss of KSh 839.2 billion, which is about 11.1 percent of their core capital. In the extreme scenario, an increase in temperature by 1.0° C, increase PD to 96.7 percent in the first year, which declines to 75.4 percent. The expected loss given default due to elevated temperature is KSh 944.4 billion. As a result of the loss, 12.3 percent of the core capital for banks will be eroded. The tendency of banks and borrowers to adapt to elevated temperature mitigates the impact of temperature increase on banks. However, if borrowers and banks fail to adopt to severe temperature changes, elevated temperature will occasion capital erosion due to borrowers defaulting.

6.0 Conclusion and Policy Implications

Previous studies have documented the impact of regulatory, institutional, and economic factors on financial stability, with little focus on climate change risks. This study provides an assessment of the trend of climate change risks and bank stability indicators and analyzes the impact of climate change physical risks on bank stability in Kenya. The study applies descriptive analysis and dynamic GMM panel estimation on thirty-five banks using quarterly data from 2001-2021. In addition, the study uses stress testing to evaluate the vulnerability of the banking sector in Kenya to severe but plausible changes in temperature in the period 2022-2030.

The descriptive analysis covers climate change risk in Kenya. Physical risk indicators are captured by temperature changes and rainfall changes. The analysis revealed a distinct warming pattern in Kenya with the annual mean temperature increasing at 0.21°C per decade. Similarly, the analysis reveals variable rainfall patterns in terms of amounts and timings. The descriptive analysis of the climate change transitory risks reveals increasing tendencies of GHG in the agriculture and transport sectors. Emissions in agriculture are mostly methane and nitrogen oxide, while emissions in transport, forest, and industry are mostly carbon dioxide. While Kenya has pledged to mitigate climate change risks by reducing the levels of GHG and adopting climate-smart agriculture, funding from the public and private sector remains low. For the banking sector, the analysis reveals credit flow to sectors vulnerable to climate change risks and to those targeted for low carbon emission, therefore having implications on credit risk default and stranded assets used as collateral for bank loans. Similarly, credit allocation to the agriculture sector is low but has linkages to the agro-based industries and private households, whose credit share is relatively high, posing risks for bank stability.

The quantitative analysis reveals that size of banks and credit risk matters for bank stability. However, the climate change physical risks pose major challenges to bank stability, with temperature change and rainfall variability adversely impacting bank stability. suggesting the need for policy focus The negative impact of credit risk on bank stability arises from higher loans to allocations to climate-sensitive sectors.

The stress test results indicate that the Kenyan banking sector is vulnerable to climate change. In all the scenarios- moderate, severe, and extreme changes in temperature increase the probability of default. The transmission channel is the decline in output and ability to repay loans. This is consistent with the empirical results that indicate the positive impact of economic activity on bank stability. Climate change also reduces the value of the collateral which increases the expected loss from default. The expected loss from default erodes bank capital, thereby stability to other shocks and the capacity to intermediate.

The results imply that Kenyan banks have an important role to play in providing sustainable climate financing while managing financial stability risks. Climate change mitigation, and adaptation strategies should be entrenched, and risk assessment frameworks developed to facilitate the analysis of climate change risks. There is need to strengthen synergies between private and public sustainable financing of targeted priority projects.

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Appendix

Appendix 1: Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
ROA	1.000										
ROE	0.959	1.000									
CAR	0.038	-0.140	1.000								
Bank Size	0.371	0.429	-0.414	1.000							
Credit Risk	-0.417	-0.435	-0.022	-0.274	1.000						
Inflation	-0.060	-0.048	0.004	-0.058	-0.059	1.000					
GHC	-0.062	-0.074	-0.102	0.344	0.009	0.053	1.000				
GDP	-0.112	-0.136	-0.129	0.383	0.108	-0.157	0.878	1.000			
MOB_VAL	-0.103	-0.129	-0.116	0.360	0.132	-0.138	0.816	0.955	1.000		
RainVol	0.018	0.011	-0.060	0.093	-0.011	0.289	0.227	0.194	0.240	1.000	
TempVol	-0.114	-0.126	0.011	0.076	0.012	-0.195	0.227	0.185	0.161	0.081	1.000

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