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May 2023

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66

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Climate Change and Banking Sector (In)Stability in Kenya: A Vulnerability Assessment

Gillian Kimundi* and Reuben Wambui**

Abstract

This paper offers a climate change vulnerability assessment of the Kenyan banking sector by examining the time-varying linkages of climate risk drivers, economic sectors that get impacted by a disorderly low-carbon transition (climate policy relevant sectors (CPRSs)), and banking sector stability. We use temperature and precipitation climate data, identify 5 CPRSs and their quarterly outputs, construct a banking sector stability index, and examine the time-varying linkages of these variables. Effectively, we assess the response of banking sector stability to sectoral output shocks arising from physical and transition risks. Three important findings emerge: First, the agriculture sector is the sole channel of physical climate risk transmission. Second, manufacturing and utilities sectors are becoming increasingly critical/significant channels for transmitting transition risks. Third, during the COVID-19 era, all CPRSs have become increasingly linked to banking sector stability, effectively exacerbating the transmission of climate risks to the banking sector.

Keywords: *climate change, climate risk drivers, climate policy relevant sectors (CPRS), banking sector, stability*

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1.0 Introduction

In December 2015, during the annual UN climate change conference (COP21) held in Paris, 196 parties entered a legally binding international treaty on climate change (the Paris Agreement or Paris Accords) – to limit global warming to well below 2 °C, preferably to 1.5 °C, compared to pre-industrial levels. This would be achieved through a substantial reduction in greenhouse gas (GHG) emissions for each of the parties, with a 5-year review of the commitments and progress.

COP21 also addressed financing concerns for developing economies through developed countries committing to provide USD 100 billion of climate finance annually to developing countries. This was founded on the fact that developing countries have contributed the least to climate change and yet they are disproportionately affected. The move by countries to reducing emissions towards reaching net-zero emissions means these economies will need to cut GHG emissions to as close to zero as possible, with the residual emissions absorbed by natural carbon sinks such as oceans and forests. According to the UN (2021) [37], the lead up to 2021's COP26 climate talks in Glasgow meant that countries needed to revise their Nationally Determined Contributions (NDCs) commitments and this highlighted *"a shrinking window of opportunity"* in the plans to reach net zero by 2050, given the current level of emissions.

In a 2021 report on climate-related risk and financial stability, the European Central Bank (ECB)/European Systemic Risk Board Project Team [18] on climate risk monitoring highlights that there is a crucial policy debate on the impacts of climate change on financial stability which is going to be further informed by better measurement and modelling of climate change impacts. The ECB has adopted a granular mapping of climate drivers (both physical and transition risks) to *economic and financial risks.* The results suggesting spatial risk concentration in specific geographic and sectoral dimensions. As such, a crucial objective for individual banks globally is the translation of climate-related risk drivers into financial and operational risks. The Basel Committee on Banking Supervision (April 2021) [6] states that climate-related financial risks could affect the stability of individual financial institutions and financial sectors, **with broader implications for the banking sector.** They define climate risk drivers as ***"climate-related changes that could give rise to financial risks".***

Physical risks are those that classically arise from weather changes. These include acute risks (event-driven) such as wildfires, floods, and storms, to more severe/chronic risks (longer-term shifts) such as sustained higher temperatures, variability in rainfall patterns and sea level rises[1]. Physical climate events could lead to declining property/asset values, damaged infrastructure, declining agricultural yields, with more severe consequences on the ecosystem that lead to increased migration and an increased risk of humanitarian crises.

Transition risks arise from action taken to transition the economy from a system that is reliant on fossil fuels to a low-carbon economy. **Transition risks are the most likely apply to climate-policy relevant sectors (henceforth CPRSs), which are economic activities that could be impacted, either positively or negatively (including "stranded assets") by a disorderly transition to a low-carbon transition (Battiston, et al., 2017) [7].** These risks include introduction or revision of pollution control and energy transition policies, transition to energy saving, low-carbon, non-fossil fuel technologies and shifts in investor and consumer sentiment. Transition risks will possibly involve adjustments to basic energy prices (including electricity, carbon and fuel prices) which increase the costs of doing business[2]. Transition risks will most likely materialize in the event of a disorderly transition from the existing energy infrastructure, given the Nationally Determined Contributions[3]. These are set in line with the climate resilient development pathway and, for Kenya, include abating greenhouse gases emissions by 32% by year 2030, bearing 21% of these mitigation costs from domestic sources, increasing reliance on renewable energy and promoting energy efficiency in different sectors.

1.1 Motivation and Purpose of Paper

Figure 1 shows sectoral distributions of loans to climate policy relevant sectors (CPRSs) in Kenya as of December 2021, together with their contribution to total non-performing loans (NPLs) (Central Bank of Kenya (2021) [11]):

- Real Estate – 14.1% of gross loans (accounting for 16.3% of total NPLs)
- Manufacturing – 14.3% (16.2% of NPLs)
- Transport and Communication – 7.8% (9.2% of NPLs)
- Energy – 3 .7% (3.6% of NPLs)
- Agriculture – 3.3% (4.2% of NPLs)

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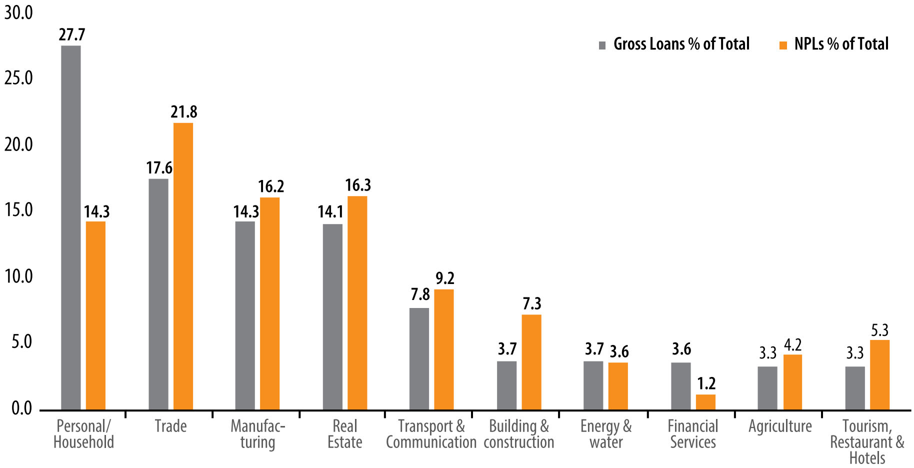
1. McKinsey Global Institute (January 2020) report [26] on the nature and extent of physical risk, especially since it forms the basis of transition risks. The report succinctly characterizes physical climate risk as: increasing, spatial (locally manifests), non-stationary (ever-changing), having non-linear effects (with thresholds beyond which living, food, service, asset and capital systems etc. are affected differently), systemic (with effects that cut across regions and sectors), regressive (bringing inequality concerns in some areas compared to others) and highlighting the general under-preparedness of companies and communities globally.

2. According to the Bank of England (2019) [2], if national and global policies are to change in line with the Paris Agreement, it is expected that two thirds of global fossil fuel reserves will go unused, leading to a decline in the value of investments in energy and energy intensive sectors.

3. Nationally determined contributions are non-binding commitments made by countries during COP15 to target climate change including reduction of GHG emissions, adoption of renewable energy, etc. These contributions are regularly updated and revised give the evolving climate change situation

Figure 1: **Sectoral Loan and NPL Distributions in Kenya**



Source: Central Bank of Kenya

These loan distributions are a good initial proxy to characterize banks' exposure to physical and transition risk, and thus provide a useful starting point for an assessment of climate risk transmission to banks. We can therefore run an assessment on whether (and to what extent) sectoral performance can be predicted by physical climate risk drivers and further assess effect on banking sector stability from sectoral output shocks arising from climate risks drivers. Effectively, the latter is an assessment of the transmission of climate risks.

In terms of Kenya's energy supply, according to the International Energy Agency (IEA)[4], 67% of the country's energy currently comes from bioenergy, as shown in **Figure 2** and **3**. Over time, there is a decreasing reliance on biofuels as oil and wind/solar sources gain traction. Oil usage remains relatively untouched in the past three decades, at an average of 16.7% usage. Projections of primary energy demand in Kenya to 2040 are shown in Figure 4. The projections are based on "The Africa Case", an IEA outlook of Africa guided by Agenda 2063. Agenda 2063 is the continentally agreed development blueprint adopted by heads of state and government in 2013. The already declining proportion of biofuel usage in the country is projected to worsen and likely narrow down to almost 15% by 2040 due to an increase in energy use from geothermal (other low carbon sources), coal, and oil.

The existing and potentially increasing reliance on brown energy sources presents a vulnerability for energy intensive sectors in the country in the global transition to low carbon economies. According to the Ministry of Energy (2020)[6], the 2025 energy savings targets for the combined industrial (includes manufacturing)

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[4] (International Energy Agency (IEA), 2019)

Figure 2: Total energy supply (TES) by source, Kenya 1990 - 2019 (TJ Units)

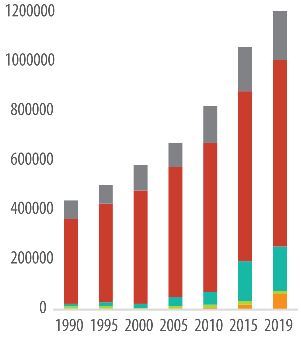


Figure 2: Total energy supply (TES) by source, Kenya 1990 - 2019 (Propotions)

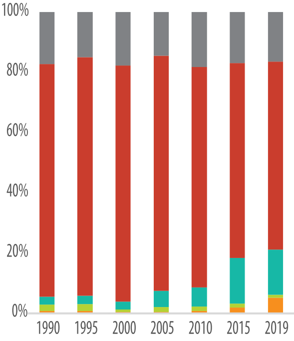
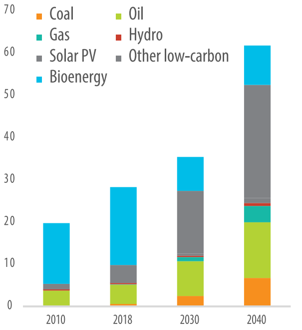


Figure 2: Kenya - Primary energy demand in the Africa Case (millions tns of oil equivalent)



Coal ▪ Hydro ▪ Wind, solar, etc. ▪ Biofuels and waste ▪ Oil

Data Source: International Energy Agency, Kenya Energy Outlook[5]

and agriculture sectors in an effort to improve energy efficiency in the country is set to 885,000 MWh/100MW demand or 250m litres heavy fuel oil or 9.0m litres industrial fuel. The transport sector consumes about 72% of all the petroleum products imported into Kenya. Energy saving targets for this sector as set at a reduced average fuel consumption (for light duty vehicles) of 6.5 litres per 100 km travelled by 2025, from 7.5 litres in 2019. For utilities, as much as there has been significant strides in the country to sustain renewable electricity production, about 1,200 GWh of electricity production is still reliant on Oil, versus 3,200 GWh from Hydro and 4,800 GWh from Geothermal sources. As such, for all these sectors, a rethinking of energy infrastructure will be inevitable in the wake of increasing climate change risks. Hence there is a strong need for the assessment of the transmission of climate risk within Kenya's banking industry, both within the most affected and relevant sectors, and to the industry's stability as a whole.

Overall, climate-induced banking sector instability has the potential to have far-reaching consequences on the state of the economy. Given the Kenyan banking sector's significant loan exposure to key CPRSs, and the country's energy needs, **one important consideration of this paper is the evolution of banking sector stability through the lens of these sectors. The purpose of this study is to examine the time-varying nexus of climate risk drivers, climate policy relevant sectors, and banking sector stability. The study does this by first analysing whether outputs from sectors**

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5. (International Energy Agency, 2022)

6. (Ministry of Energy (Kenya), 2020)

that present significant exposures for banks are granger-caused/predictable by physical climate risks.

Secondly, we examine whether banking sector stability is predicted by CPRS output, and further investigate the response of banking sector stability to sectoral output shocks that arise from physical and transition risks (posited effects for the latter). In this way, the paper examines sectoral transmission of climate risks to the banking sector.

1.2 Climate Policy Relevant Sectors and Transmission Channels

The design and implementation of climate policies that target the reduction of GHG emissions needs a national identification of CPRSs. An assessment of such transition risks is typically expected to start with sectors responsible for majority of recorded national emissions. Ritchie & Roser (2020) [32] analyse and visualize the total GHG produced **globally** by sector. The analysis shows the following breakdown of GHG emissions:

- Energy i.e., electricity, heat, and transport – 73 % (includes energy use in industry, energy use in commercial and residential buildings and energy use in transport)
- Agriculture, Forestry and Land Use – 18%
- Direct Industrial Processes – 5%
- Waste – 3%

As aforementioned in Battiston et al (2017), the identification of CPRSs is based on economic activities, first divided into three categories including: (1) the suppliers of fossil fuels, (2) the suppliers of electricity and (3) the users of fossil fuels or electricity. The authors finally remap these 3 economic activities into 5 CPRSs**: fossil, utilities, transport, energy-intensive and housing/real estate**[7]**.**

According to Network for Greening the Financial System (June 2020) [29], a first step in understanding the impact of climate change would be to understand the *"specific short-term impacts of climate risk drivers on sectors, geographies and asset classes",* and the eventual ramifications for macroeconomic and financial stability indicators. The former are ideally transmission channels through which physical and transition risk drivers impact banks, either directly and/or indirectly (through counterparties, asset positions and sectoral exposures, and the economy). BCBS (April 2021) [6] analyses two types of transmission channels: Microeconomic and Macroeconomic.

Microeconomic transmission channels are more direct causal pathways that involve how climate risk drivers (both physical and transition) affect the banks themselves (operational concerns, funding decisions, etc.) and their counterparties (impacts on household, corporate, or sovereign cashflows, income and wealth levels, potentially significant impacts on the value of financial assets). From a microeconomics perspective, it is clear that **real estate/ housing and agricultural sector** are almost immediately exposed to physical climate risk drivers, which translates to both the asset

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[7] Real estate is defined to include both land and buildings (amongst other dwellings)

and liabilities sides of banks' balance sheets and credit risk assessments for both households and firms. In addition, premium increases on the insurer's side may lead to declines in coverage for households and firms, increase in uninsured assets and losses, and ultimately spill overs that lead to a decline in the value of collateral for banks, thus feeding credit risk.

Additionally, both physical and transition risks will have consequences for expected economic conditions leading to the manifestation of market risk through declines in the value of real and financial investments. This may lead to adjustments to basic energy prices which increase the cost of business. As such, transition risks are expected to have compelling adverse effects on energy-intensive sectors – energy, such as manufacturing, utilities, transport, and real estate. Climate risk drivers (both physical and transition) also contribute to liquidity risk build ups, with possible impact on the banking sector's ability to raise deposits (due to compromised household and business incomes) or even liquidate asset positions. Moreover, there are also effects of climate risk drivers on operational risks for banks due to new compliance requirements, litigation risks, and reputational risks due to non-conformity.

2.0 Literature Review

Globally, banks and their regulators remain at an early stage of quantifying climate risk exposures and impacts. Most of the present assessments and methodologies have focused on credit risk (loan portfolio composition to corporates and real estate), and less on market risk, liquidity risk and operational risks. Thus, this literature review section also includes an overview of the methodological approaches taken by banks and regulators globally to understand the [potential] ramifications of climate risk drivers on financial institutions. It also highlights related econometric studies that seek to assess and/or quantify the effect of climate-related risks, both physical and transition, on the economy and on financial stability.

The wider the scope of risk assessment, the more granular and/or qualitative the data needs to become. According to BCBS (2021), risk assessments by banks and other financial institutions will be guided by their transactions with counterparties and the "level of exposure granularity" that is determined by factors such as the specific climate risk drivers, data availability and the capacity for computational complexity. All these will affect the approach selected for risk identification, measurement and utility in management. A higher level of granularity may not be applicable in all spheres, but specifically in aspects such as valuation and pricing. At an elementary level, BIS identifies three types of data that can be useful for such assessments – climate risk driver descriptives ***(useful to map risk drivers into economic risk factors)***, vulnerability to exposures ***(mapping economic risk factors to bank exposures including geospatial data for physical risk assessments, how sensitive counterparties are to energy prices for transition risk)***, and financial exposure data that translates these economic risks to banking sector financial risks including loan portfolio holdings and compositions.

In terms of measurement, at a bank level, the common practice when it comes to mapping transition risks is to analyze the degree to which climate policy relevant sectors are going to be affected by low carbon economy policies. Banks measure the loan distribution to these sectors, typically assessed as "carbon related assets." According to the ECB (2019) [17], such sectoral analysis allows for a comprehensive view of risk, since data availability at the sectoral level is easily available as compared to granular firm level data – therefore coming in handy for a top-down scenario analysis. Risk metrics are also used to estimate the sensitivity to physical risks, including geospatial/location-based risk metrics (such as exposure to heat stress, wild-fires, floods, and sea level rises). Scenario and stress testing analyses then follow, to try and determine the impact of these transition and physical risks on banks' credit and market risk metrics.

Sensitivity to transition risks can be assessed by looking at how different CPRSs respond to changes in energy prices, for example. The impact of severe physical risks can also be translated into sectoral output changes and the associated effects on firm revenue. For example, a study by Acclimatise Group Ltd & UNEP FI (2018) [1] sought to determine the evolution in probability of default of an overall agricultural portfolio due to climate change and an increasing frequency and severity of climate related events. A similar analysis in the same report sought to determine whether such extreme climate related events have an impact on real estate collateral value, affecting the loan-to-value ratio for banks.

2.1 Econometric Analysis of Climate Change Effects

The econometric analysis of climate change effects has been widely published in the past decade, with studies that use climate data to analyse climate impacts on economic outcomes. The studies highlighted below assess impacts of both physical and transition risks.

Strobl (2011) [36] estimates the impact of physical climate risks, specifically hurricane strikes, on local economic growth rates of US coastal counties. Using a panel data set of growth rates over the period 1970-2005, the author constructs a novel hurricane destruction index that is based on indicators such as monetary loss equation, local wind speed estimates, and local exposure characteristics. The panel analysis results suggest that a county's annual economic growth rate will initially fall by 0.8 percentage points following an initial hurricane strike but then partially recover by 0.2 percentage points. However, the author concludes that the net effect of a hurricane strike over the long term is negligible and as such may not be economically significant to be reflected in national economic growth rates.

An analysis by Carleton & Hsiang (2016) [10] quantifies climatic influence and finds that warming depressed US maize yields by approximately 48% and that conflict risk in African countries increased by 11% since 1980. Overall, their study finds evidence that increases in temperature have an adverse impact on agricultural yields, mortality, labour supply, and productivity. **Such effects are easily linked to banks balance sheet and income positions.** Hsiang, et al. (2017) [20] estimated the economic damage expected in the United States from climate change. The spatial, empirical, and probabilistic estimates point to damage across dimensions such as agriculture, crime, energy, human mortality, and labour – and show that the damage increases quadratically in global mean temperature, costing approximately 1.2% GDP for every +1 degree Celsius on average.

Noth & Schüwer (2018) [30] explored whether weather-related disasters such as hurricanes affect bank stability, highlighting that the effect may not be logically obvious. The authors find that natural disasters significantly weaken the financial stability of banks with business activities in the affected regions. According to the results, this is reflected in lower z-scores, higher probabilities of default, higher NPL ratios and foreclosure ratios, lower earnings ratios (returns on assets), and lower bank equity ratios. Overall, this reveals that natural disasters affect the borrowers' financial solvency and thus decreases bank stability. However, on a more optimistic note, the authors find that these banks tend to recover from adverse shocks from weather-related disasters (though they do not recover from geological disasters) after some years.

Buhr, et al. (2018) [8] analyse the impact of climate change on the cost of debt capital for climate-vulnerable countries through an analysis of potential impacts on sovereign credit ratings. Seemingly, credit rating agencies perceive a relationship between climate change and a country's cost of sovereign borrowing. Their econometric analysis finds that climate vulnerability, after controlling for a range of potentially confounding variables, has a positive and significant impact on sovereign yield. Climate vulnerability increases the cost of debt, on average, by 117 basis points. Such an increase in borrowing costs could lead to higher tax rates and depressed government spending, with consequences for economic productivity which translates to banks stability indicators.

Looking at the effect of climate policies and related transition risks, Dunz, Monasterolo, & Raberto (2018) [15] analyse how real and financial markets could react to climate physical and transition risks. The authors use an extended version of the EIRIN Stock-Flow Consistent behavioural model which allows them to track agents' reactions to climate policies imposed plus any idiosyncratic shocks based on their initial expectations of these climate risks. The authors find that the design of climate policies – especially imposition of carbon taxes – really matters to prevent a situation with winners and losers. The results show that if the cost of a carbon tax (mostly on fossil fuel energy and electricity companies) is passed through to the households (the consumers), incomes reduce, overall consumption in the economy reduces, and there are negative repercussions on the financial sector, investments, and GDP.

Similarly, Comerford & Spiganti (2020) [13] model the consequences of the implementation of a climate policy limiting the probability of a greater than 2 °C warming. This ultimately comes with near term cessation of all coal use in energy intensive industries ***("unburnable carbon")*** and a reduced exploitation of proven oil and gas reserves. This popular phenomenon has commonly been referred to by the Carbon Tracker (2011) as the Carbon Bubble [9] ***(as these assets are overpriced relative to their zero value in a 2-degree target)***. The authors show that naively imposing this carbon budget has detrimental effects on balance sheets of entrepreneurs and has macroeconomic implications in the presence of financial frictions. With worsening economic activity, the carbon price drop may fuel a downward spiral in forward looking financial markets.

A closely related analysis to our own study is by Zhonglu, Haibo, & Songlin (2021) [40] who examine and explore the impact of climate change on financial stability in China. The paper mainly applies a Non-

Linear Autoregressive Distributed Lag (ARDL) model, using monthly data from 2002 to 2018, to assess the nonlinear asymmetric effect (of temperature increases and decreases) on China's financial stability. Their results show that the response of financial stability to both positive and negative climate shocks is harmful. However, in the short term, the effect of positive climate shocks (increase in temperature) on the financial stability index is greater than the negative climate shocks (temperature decreases) in the current period, but lower in the lag period. They show that in the long term, negative climate shocks bring larger effect to the financial stability index in China.

Zhang, Zhang, & Lu (2022) [39] examine the effect of low carbon transition on banking sector stability using a parsimonious network analysis that depicts the dependence between the banking sector (using data on 25 listed banks) and the energy sector (106 firms) based on realized stock volatility data in the 2 sectors. The basis is that realized volatility characterizes systemic instability that could lead to a crisis. The authors use a dataset from China for the period 2009–2019 and find that a low-carbon transition increases the dependence of the banking sector risk on the evolved energy sector ***(60% and 46% increments of the energy sector's predictive and contemporaneous components)*** while it depends less on the traditional energy sector. According to the authors, this increased risk dependence can act as a measure of transition climate risk.

3.0 Data and Methodology

The study will use quarterly data on climate related variables and banking sector stability indicators from March (Q1) 2006 to December (Q4) 2021. Quarterly gross value-added data from the five CPRS is available from March (Q1) 2009. To capture banking sector stability, an index is constructed using commonly used quantitative indicators of the sector's health based on regulation and empirical literature.

3.1 Banking Sector Stability Index

To build the stability index, the study selects 6 indicators informed by the IMF Financial Soundness Indicators (FSIs) Guide (IMF, 2006) [23] and a review of measures of financial stability by the Bank of International Settlements (BIS, 2008) [4]. The indicators have become widely used for their information about the current health of financial institutions. The selected indicators for this study's index span across core capital-based FSIs, core asset-based FSIs, and income-based FSIs.

Table 1: Core IMF Financial Soundness Indicators for Depository Institutions

Capital Adequacy	▪ Regulatory Tier 1 capital to risk-weighted assets ▪ Net Non-Performing Loans (NPLs) as a % of Capital
Asset Quality	▪ Net Non-Performing Loans (NPLs) as a % of total gross loans
Liquidity	▪ Customer Deposits to Total Loans
Earnings/Income based	▪ Return on Assets (ROA) ▪ Return on Equity (ROE)

According to the IMF Financial Soundness Guide, asset quality of the bank loan portfolio refers to the timeliness in borrowers meeting their contractual obligations. This can be captured by the ratio of NPLs (net of provisions) to total gross loans; the NPLs are facilities which payments of principal and interest are past due by three months or more.

Capital adequacy is measured by 1) taking the value of NPLs (net of provisions) as a ratio of total capital and 2) taking core Tier I capital divided by risk-weighted assets (RWA). Capital is measured as total capital and reserves in the sectoral balance sheet. The first indicator using NPLs is a measure of the capacity of bank capital to withstand losses from defaults and bad debts. The second indicator uses core capital (which is the sum of equity capital and disclosed reserves that are freely available to meet/cushion against claims against the bank) as a ratio of the total weighted assets based on the credit risk exposure (default). These assets include loans, financial instruments, off balance sheet items, deposits, etc. The ratio once again measures the bank's ability to withstand credit shocks without going insolvent

Return on equity (net income divided by average capital) is a measure of how efficiently capital is being used. As a prominent measure of profitability, the measure needs to be used in conjunction with capital adequacy measures as a high ROE might indicate either high profitability or low capitalization (higher exposure to shocks). The return on assets (net income divided by average assets) is a measure of how efficient asset utilization is and is often used alongside ROE. Finally, the measure of liquidity used is the ratio of customer deposits to total loans (excluding interbank loans). If the loan book is funded with larger, more stable depository base, then the bank remains resilient in the face of liquidity stresses.

The banking stability index will be created from the above input variables using a Principal Component Analysis (PCA). This is a method of extracting important variables (in the form of components) from a larger set of variables. The methodology extracts a low dimensional set of features with a motive to capture as much information as possible and creates linearly independent principal components (PCs) which are normalised linear combinations of the original inputs in a data set. Each component captures some level of variance in the input data set (financial stability indicators), with the first one capturing the most. As a rule of thumb, Eigenvalues can be used to determine the number of principal components to retain after PCA (Kaiser 1961). An eigenvalue > 1 indicates that the PCs account for more variance than is accounted by one of the original financial stability indicators. The proportion of variance contributed by each component will be used as a weight for the final stability index.

3.2 Climate Change Measures

This paper uses quarterly temperature and precipitation levels from 2006 - 2020 in the country to capture climate-related changes. The data is sourced from the World Bank Climate Change Knowledge Portal (CCKP).[8] Summary statistics are shown in the table below, where TEMP and PREC are monthly average temperature and average precipitation respectively.

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[8] The Climate Change Knowledge Portal (CCKP) is a one stop shop portal that provides development practitioners with global data on historical and future climate related variables (World Bank, 2021)

Different sub-samples (2006 - 2010, 2011 - 2015, 2016 - 2020) highlight how high and increasingly volatile temperature and precipitation levels have become in the past two decades, with a 0.3 °C average temperature increases in the last five-year window. The maximum temperature has also increased by over a degree in the same time span. Precipitation levels have become more volatile with much lower minimums and higher maximums.

Table 2: Summary Statistics – Temperature and Precipitation (Monthly)

	Mean	Std Dev	Min	Max	Range
	2006	**2007**	**2008**	**2009**	**2010**
TEMP (°C)	25.2	1.2	23.6	27.2	3.6
PREC (mm)	49.1	25.8	19.6	109.8	90.2
	2011	**2012**	**2013**	**2014**	**2015**
TEMP (°C)	25.1	1.0	23.8	26.8	3.1
PREC (mm)	53.6	27.9	26.9	128.3	101.4
	2016	**2017**	**2018**	**2019**	**2020**
TEMP (°C)	25.4	1.1	23.9	28.0	4.1
PREC (mm)	51.6	30.8	14.4	135.8	121.4

Source: World Bank Group, Climate Change Knowledge Portal [38].

3.3 Climate Policy Relevant Sector Variables

As aforementioned, climate policy relevant sectors represent **transmission channels through which both physical and transition risk drivers impact banks' balance sheets and income outlooks.** Following Battiston et al (2017) identification of CPRSs, the paper considers the following main sectors whose productivity will likely be affected by climate related changes (both physical and transition risks): agriculture, utilities, energy-intensive (manufacturing), transport and real estate. These sectors also have significant proportions of loan distribution in the country, after trade and personal & household loans. Variables to capture each of these sectors and the expected effect of physical and transition risks is summarised below.

Table 3: **Climate Policy Relevant Sectors – Value Added[9] (Net Output)**

CPRS	Variable/ Measure	Expected Physical and/or Transition Risk Effect
Utilities	Utilities (electricity, water) Value Added	Transition to energy saving, low-carbon, non-fossil fuel technologies may lead to increased costs of energy and thus costs of doing business and lower value add/productivity
Transport	Transport Value Added	Transition to energy saving, low-carbon, non-fossil fuel technologies will possibly involve adjustments to fossil fuel energy prices, leading to increased costs of doing business and lower value add/productivity from transport sectors.
Agriculture	Agricultural Value Added	Physical risks (drought, floods, etc.) will have an adverse impact on agricultural yields/ output.
Energy Intensive	Manufacturing Value Added	Transition to energy saving, low-carbon, non-fossil fuel technologies may lead to increased costs of doing business and lower value add/productivity from energy intensive sectors.
Housing/ Real Estate	Real Estate Value Added	Physical risks may lead to declines in value of real estate/housing

Source: World Bank National Accounts Data

3.4 Other Variables

Additional variables used to explain the financial stability index will include a measure of the financial cycle (the Credit to GDP Gap), the average intermediation spread and inflation. Fluctuations in the credit-to-GDP ratio are a good indication of the financial cycle in play. Borio (2014) defines the financial cycle as "self-reinforcing interactions between perceptions of value and risk, attitudes towards risk and financing constraints, which translate into booms followed by busts." The credit to GDP gap (also referred to as the "Basel gap") is defined as the difference between the ratio of Private Sector Credit to GDP and its long-run statistical trend, as extracted from the Christiano-Fitzgerald (2003) filter.

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[9] Value added is the measure of output less the intermediate inputs used in production. The sum of value added from all producers is GDP

This filter is a band-pass type which seeks to separate the stochastic cycles from the trend. The assumption is that the underlying variable follows a random-walk process. The analysis specifies a 1-year (4 quarters) to 8-year (32 quarters) range to extract short-term cycles. This filter has been empirically applied in the estimation and analysis of financial cycles (including Drehmann, Borio, & Tsatsaronis (2012), Aikman, et al (2015), Oman (2019)).

There is also empirical evidence to support the link between the interest rates charged/ the intermediation spread and bank stability, including Sinkey & Greenawalt (1991) [35] (who find that loan loss rates are positively affected by loan rates and volumes) and Motelle & Biekpe (2014) (who find a Granger causal relationship between the financial intermediation spread and financial instability in the Southern African Customs Union). The link between higher inflation and bank instability could be argued from the perspective that borrowers face a harder time servicing their debts if their income does not match commensurate increases in consumption and expenditure due to inflationary pressures (Mosk & Welz, ECB (2022) [27]). Empirical evidence from Alhassan, Kyereboah-Coleman, & Andoh (2014) [2] suggests that the inflation rate has a negative impact on bank asset quality in Ghana.

However, it is also likely that if banks anticipate inflationary pressures, they may adjust their prices for their services to include an inflationary premium (Perry (1992) [31]) and as such, benefit from higher margins, hence stability. Dwumfour (2017) [16] provides evidence to support this in Sub-Saharan African countries

3.5 Data Analysis

Time Varying Granger Causality

As already stated, we seek to investigate the time-varying nexus of climate risk drivers (physical and transition), climate policy relevant sectors (CPRSs), and banking sector stability. We do this by first analysing whether output from CPRSs is granger-caused by physical climate risks. Where granger-causality is *"predictive-causality"* implying temporal relationships, rather than true causation (Granger (1969) [19]). We then proceed to examine whether banking stability is granger-caused by output from

Average Intermediation Spread	▪ Gap between the average commercial bank lending and deposit rates
Financial Cycle (Private Sector Credit to GDP Gap)	▪ Excessive credit growth measured by the Basel Gap (Credit to GDP gap) – extracted from the Credit to GDP ratio using the Christiano Fitzgerald Filter
Inflation Rate	▪ Change in CPI

these sectors. The two-tiered analysis allows us to 1) determine whether physical risks lead output from sectors (what is the intensity of lead-lag effects from climate related variables to the sectors?) and how/ to what extent this can translate to banking stability and 2) determine through which sectors transition risks can be prominently or significantly transmitted to the banking sector.

The popularity of Granger causality analysis stems from the fact that it is not reliant of a structural model of the variables at hand but simply focuses on the stochasticity of the variables to determine the lead-lag effects. However, Granger causality tests are well known to depend on the estimation window considered. In light of this, Shi, Phillips, & Hurn (2018, 2020)[10] [33] [34] develop a time-varying Granger causal analysis that involves a recursive rolling algorithm. They test the performance of the algorithm on the causal relationship between US yield curve data and economic activity from 1980 to 2015. The algorithm recursively calculates the Wald test statistic over varying window lengths **(with a specified minimum window length)** from every observation and produces the supremum from the sequence of test statistics. This procedure is found to perform better compared to a typical recursive estimation (estimation window expands forward) and rolling window algorithms. Their study reveals evidence that the impact of the yield curve on macroeconomic performance changes over time and is sensitive to the estimation window considered, ushering in a new facet of lead-lag modelling.

Impulse Responses

Following from the causality tests, the analysis further determines how a shock to climate related variables – physical risks – affects sectoral outputs **(specifically for sectors where the aforementioned Granger causality is found to be significant).** Additionally, we also examine the response of banking stability to sectoral output shocks. Both responses are obtained from an impulse response analysis (IRA) that follows the estimation of a multivariate vector autoregressive (VAR) model whose lag structure is pre-determined using the Akaike and Bayesian Information Criterion. The general model specification takes the following form:

$$Y_t=\sum_k \beta'_k \, Y_{t-k}+\varepsilon_t$$

Y_t denotes a vector of endogenous VAR variables including the banking stability index constructed using PCA, climate related variables, the output/GDP contribution of 5 CPRSs (Agriculture, Manufacturing, Utilities, Transport and Real Estate respectively) and control variables.

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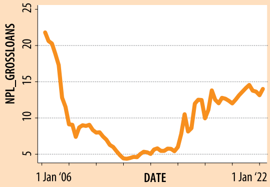
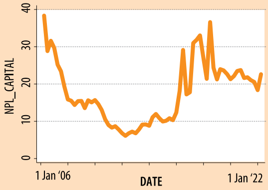
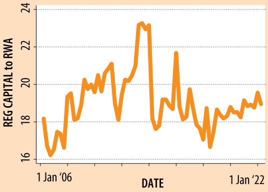
[10] Shi, Phillips, & Hurn (2018), Shi, Phillips, & Hurn (2020)

4.0 Results

4.1 Principal Component Analysis – Banking Sector Stability Index

To identify the effect of climate change on banking sector stability in Kenya, the paper starts by using a selection of variables to construct a stability index using principal component analysis. Summary statistics for the 6 variables capturing 4 dimensions on Financial Soundness are provided in Table 4

Table 4: **Banking Sector - Financial Soundness Indicators – Summary Statistics (Quarterly from 2006 to 2021)**

Dimension	Indicator	Mean	Std. dev	Min	Max	Chart
Asset Quality	Net NPL, % of Gross Loans and Advances	9.8	4.3	4.4	21.8	
Capital Adequacy	Net NPL, % of Capital	17.8	8.2	6.1	38.4	
Capital Adequacy	Regulatory Tier 1 Capital to Risk-Weighted Assets	19.1	1.6	16.2	23.3	

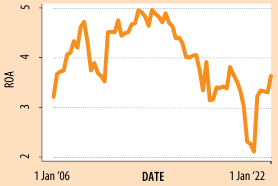
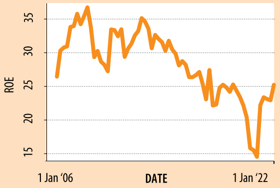
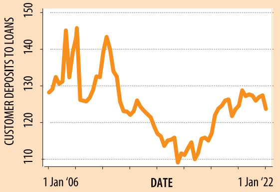
Dimension	Indicator	Mean	Std. dev	Min	Max	Chart
Earnings	ROA - Return on Assets	4.0	0.7	2.1	5.0	
Earnings	ROE - Return on Equity	28.3	5.0	14.5	36.7	
Liquidity	Customer Deposits to Total Loans	124.9	8.8	109.1	145.8	

Table 5 reports the eigenvalues, the proportion of variance contributed and the cumulative variance contribution for each principal component. The analysis relies on PC1 with a variance contribution of approximately 58%,

Table 5: Results from Component Extraction

Component	Eigenvalue	Proportion	Cumulative
Comp1	3.465	57.8%	57.8%
Comp2	1.322	22.0%	79.8%
Comp3	0.776	12.9%	92.7%
Comp4	0.321	5.3%	98.1%
Comp5	0.085	1.4%	99.5%
Comp6	0.032	0.5%	100.0%

The output from the PCA in **Table 6** below is loadings /scores for each variable in Component 1. A variable with a positive loading is associated with higher index value (positive correlation) and conversely a variable with a negative loading is associated with lower index value.

Table 6: Component Loadings for each Financial Soundness Indicator

Variable	Comp1
Net NPL, % of Gross Loans and Advances	-0.4755
Net NPL, % of Capital	-0.4928
Regulatory Tier 1 Capital to Risk-Weighted Assets	0.3697
ROA - Return on Assets	0.4851
ROE - Return on Equity	0.3982
Customer Deposits to Total Loans	0.0233

This implies that higher NPL-based ratios (capturing capital adequacy and asset quality) reduce the value of the index due to the negative loading. All other ratios/percentages with positive loadings increase the index, with the highest positive loadings recorded for profitability ratios.

Figures 5 and **6** respectively depict the stability index and the decomposed index (into trend and cyclical components using a Christiano-Fitzgerald Filter). Notable declines are seen and recently in 2020 (COVID-19). The decomposed index shows a general declining trend in from the main index between 2008 to 2010 between 2016 and 2019 (interest rate capping) recent years (since 2012).

Figure 5: Financial Stability Index

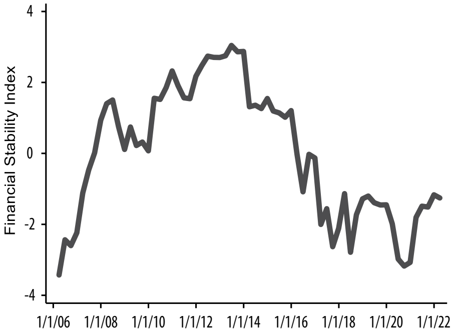
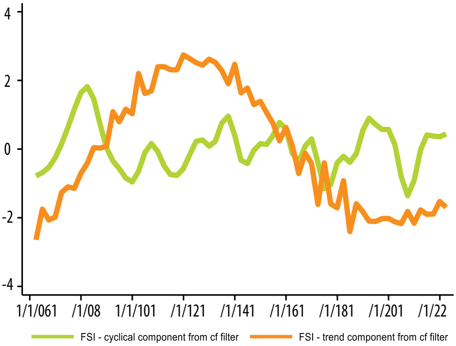


Figure 6: Cyclical and Trend Component of Financial Stability Index



4.2 Testing for Unit Root

Before proceeding to the main estimation, the variables are tested for unit root using the Augmented Dickey Fuller Test to avoid spurious regressions. As shown in Table 7 below, all variables, excpet the Average Intermediation Spread are integrated of order zero (stationary). The intermediation spread is differenced and becomes stationary with a test statistics of -6.1782 against a 5% critical value of -1.670.

Table 7: Results from ADF test for Unit Root

Variable	ADF test statistic	Critical Value 95%	
Banking Stability Index	-2.001	-1.670	Stationary
% Change in Agricultural GDP	-9.564	-1.677	Stationary
% Change in Utilities GDP	-6.949	-1.677	Stationary
% Change in Manufacturing GDP	-7.756	-1.677	Stationary
% Change in Transport GDP	-13.001	-1.677	Stationary
% Change in Real Estate GDP	-2.578	-1.677	Stationary
Average Intermediation Spread	-0.796	-1.670	Non-Stationary
Credit to GDP Gap	-2.143	-1.670	Stationary

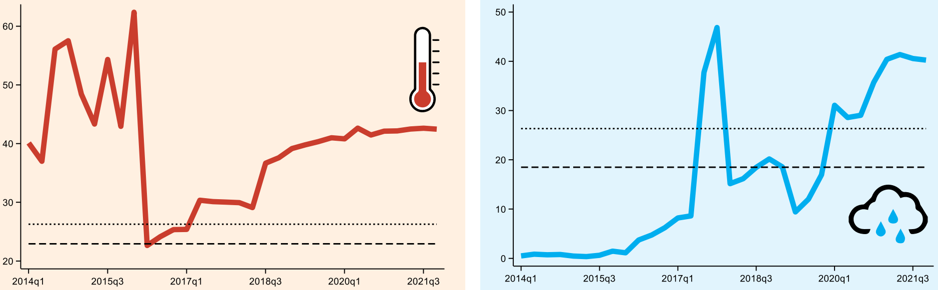
4.5 Physical Risks, Sectoral Output and Banking Sector Stability

Time Varying Granger Causality

Is the percentage change in CPRSs output granger-caused by physical risks? As aforementioned, the analysis here seeks to determines whether temperature and precipitation levels granger-cause/predict output from the 5 CPRSs. The plots from the recursive rolling algorithm are shown in **Figure 7a** and **7b** for each sector. From a microeconomics perspective, it is expected that both the agricultural and real estate sector would be the most exposed to physical risks. However, the results show that real estate consistently remains unpredicted by the variation in temperature and precipitation levels in the country. The most critical observation from the plots in **Figure 7a** and **7b** is that in recent years, both temperature (from 2017) and precipitation (from 2019) are becoming increasingly significant in predicting the percentage change in agricultural output. This result identifies with the significantly higher average temperature and higher variability in precipitation levels seen in the 2016 to 2020 sub-period **(Table 2 Climate Change Measures)**.

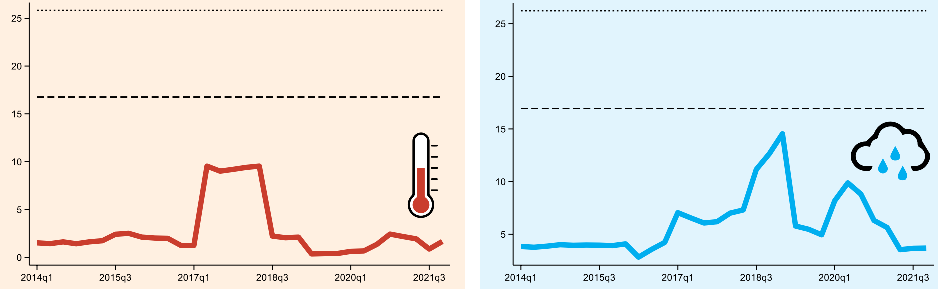
The next section determines the magnitude of response of agricultural output to physical shocks. The utilities sector was predictable by weather patterns around 2014 but this has since died down to statistically insignificant levels of granger causality.

Figure 7a: **Is the percentage change in CPRSs output Granger-caused by physical risks? Minimum Window Size = 20 quarters, Lag structure of underlying VAR = 1**



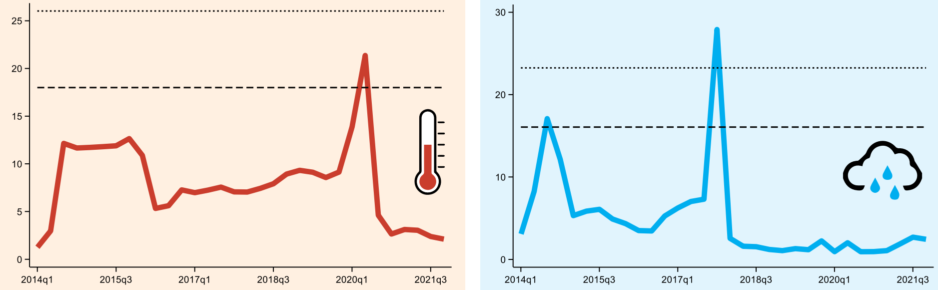
Recursive expanding Wald test for AGRICULTURE output growth G caused by TEMPERATURE, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.

Recursive expanding Wald test for AGRICULTURE output growth G caused by PRECIPITATION, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.



Recursive expanding Wald test for MANUFACTURING output growth G caused by TEMPERATURE, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.

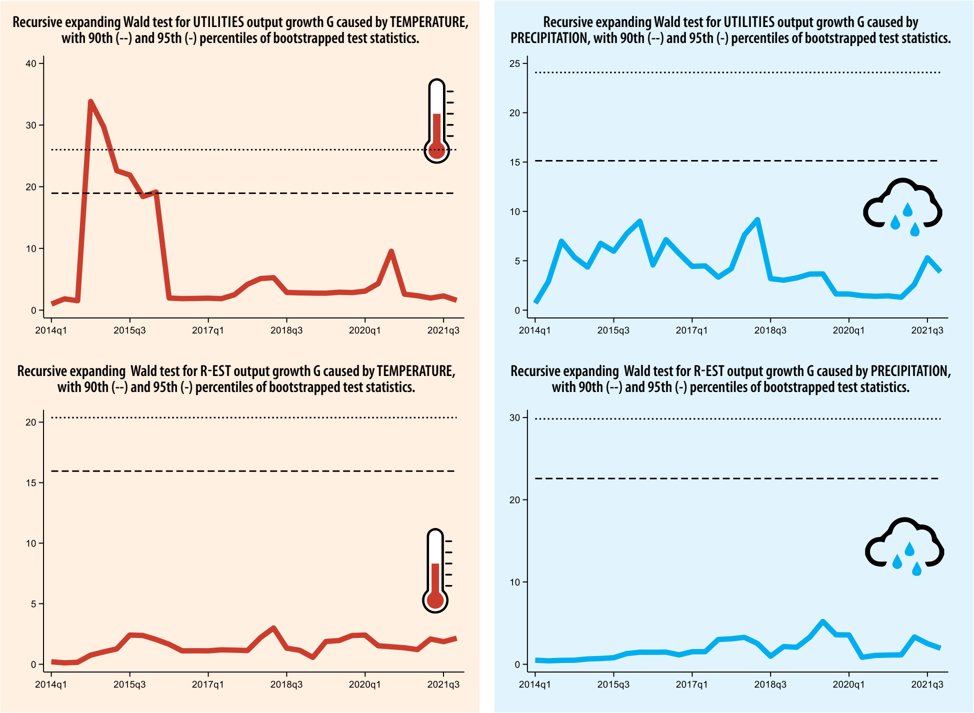
Recursive expanding Wald test for MANUFACTURING output growth G caused by PRECIPITATION, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.



Recursive expanding Wald test for TRANSPORT output growth G caused by TEMPERATURE, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.

Recursive expanding Wald test for TRANSPORT output growth G caused by PRECIPITATION, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.

Figure 7b: **Is the percentage change in CPRSs output Granger-caused by physical risks? Minimum Window Size = 20 Quarters, Lag structure of underlying VAR = 1**



Recursive expanding Wald test for UTILITIES output growth G caused by TEMPERATURE, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.

Recursive expanding Wald test for UTILITIES output growth G caused by PRECIPITATION, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.

Recursive expanding Wald test for R-EST output growth G caused by TEMPERATURE, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.

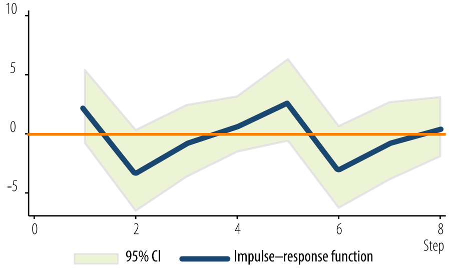
Recursive expanding Wald test for R-EST output growth G caused by PRECIPITATION, with 90th (--) and 95th (-) percentiles of bootstrapped test statistics.

Impulse Responses

Following the above results, this section goes further to examine the response of agricultural output to weather related shocks, and more importantly to examine the indirect effect of physical risks on banking sector stability through the Agricultural sector. A VAR model with 2 lags is first estimated (based on Schwarz Bayesian Criterion). Figures 8 and 9 present the impulse response of agricultural output growth to temperature and precipitation levels, showing a mixed response to both shocks.

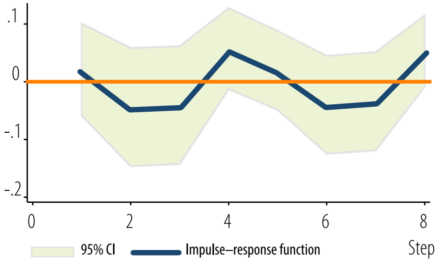
Specifically, agricultural output growth has a delayed (but economically significant) negative response to a unit positive shock in temperature and precipitation in quarters 2 to 3, and further ahead in quarters 6 to 7. The temperature shock (1 unit shock ~ 1.1 degrees) causes a negative response of almost 2.5 percentage points in quarter 2. A similar negative response to positive precipitation shocks implies that the % change in agricultural output is adversely affected by increasingly wet weather conditions (where, a unit precipitation shock amounts to a 30mm increase in the

Figure 8: **Temperature to % Change in Agricultural Output**



Graphs by irfname, Impulse variable, and Response variable

Figure 9: **Precipitation to % Change in Agricultural Output**

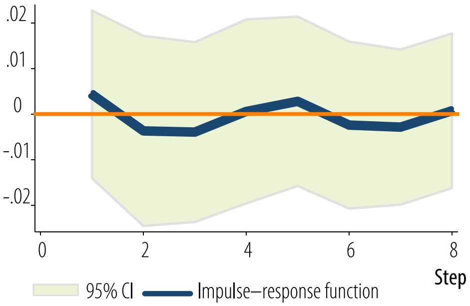


Graphs by irfname, Impulse variable, and Response variable

quarterly average, according to the standard deviation in the 2016-2020 window. This is economically significant given the mean of 51mm observed in the same window).

Figure 10 shows how agricultural output growth affects banking sector stability. A negative shock to agricultural output growth sees a delayed negative response from the stability index 2 to 4 quarters later. This plot provides evidence of the indirect effect that physical risk drivers (both temperature and precipitation levels) have on banking sector stability. As seen in the previous impulse responses, higher temperature and precipitation levels lead to a negative agricultural response within the first year (Q2 to Q3), with similar [adverse] implications for banking sector stability in the subsequent quarters.

Figure 10: **% Change in Agricultural Output to Banking Sector Stability**



Graphs by irfname, Impulse variable, and Response variable

Transition Risks via Sectoral Output and Banking Sector Stability

The preceding sections highlight the implications physical risks have on banking sector stability through the agricultural sector. However, to understand how transition risks present concerns for banking sector stability, it is important to highlight the transmittal effects from other CPRSs (manufacturing, transport, utilities and housing/real estate). We highlight 1) predictability of banks' stability by sectoral output (granger analysis) and 2) further examine the direction of the effect of a shock to sectoral output on stability.

In doing so, this paper adopts key postulations on how transition risk *(especially from a disorderly transition)* would affect Climate Policy Relevant Sectors. In using this broad approach, we hold that as much as specific transition risk effects to the sectors are not quantified, it remains critical for policy makers and sectoral authorities to dissect how vulnerable the banking sector is to these sectoral outputs. From this, proper design and careful implementation of appropriate transition policy actions in line with the country's NDCs can be done to mitigate possible output declines. Simply, is Banking Sector Stability Granger-caused/systematically predicted by Sectoral Output Growth? If so, what is the response of banking sector stability to negative sectoral output shocks? As aforementioned, transition risk is hinged on the fact that the push towards low carbon economies will likely result in energy price adjustments (increasing the cost of doing business), declining values of investment and collateral in energy intensive sectors, and lower liquidity levels for climate policy relevant sectors. These present output-related channels that transmit to the banking sector, increasing the credit risk, market risk and liquidity risk profiles of banks.

The results presented in Figure 10 (granger causality and impulse responses) gauge the exposure of the banking sector to transition risk based on this sectoral analysis, as a first step to approximating the potential impact on stability. As we discuss the results, we also seek to separate the effects from the COVID-19 pandemic.

Figure 11 presents the granger causal effects. Manufacturing has increasingly become statistically significant predictors of banking stability and the upward trajectory in the Wald Statistic has been consistent since 2016 ***(this is seen since before the COVID-19 period, but is magnified in this period, where we see a spike in the causality statistic).*** For the utilities sector, we see a similar pattern of causality, increasing especially in the COVID-19 period. However, the Wald statistic trajectory in the few years prior to the pandemic shows that the utilities sector was enroute to significance, and this was accelerated by the health crisis.

The transition risk in Kenya's utilities sector might however be lowered by the fact that most energy use in electricity production in Kenya is largely low-carbon at present (geothermal and hydropower). Nonetheless, as of 2019, data from the International Energy Agency shows that there is still about 1,200 GWh produced using oil as a source of energy (compared to 3,200 GWh from Hydropower and 4,800 GWh from Geothermal[11]), thus presenting a vulnerability to low carbon transition policies. The transport sector has specifically become increasingly important, only since COVID-19, however. The Wald statistics before the pandemic era were all insignificant. This implies that banking sector stability (outside of the COVID-19 period) is ordinarily not granger-caused by output growth from the transport sector. We see the same insignificance for the housing/real estate sector.

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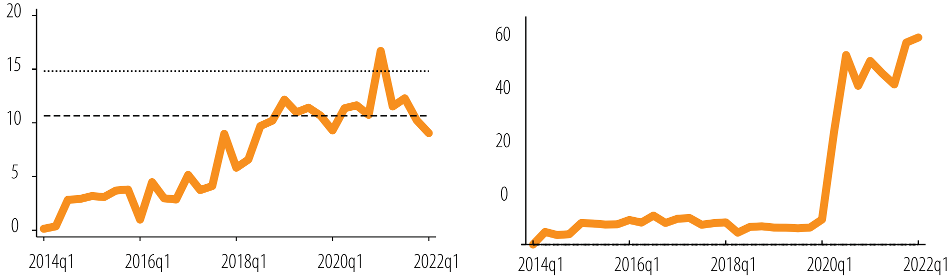
[11] https://www.iea.org/data-and-statistics/data-product/electricity-information

Should the trend continue, the two sectors' output growth [decline] will become significant predictors of banking sector stability [instability].

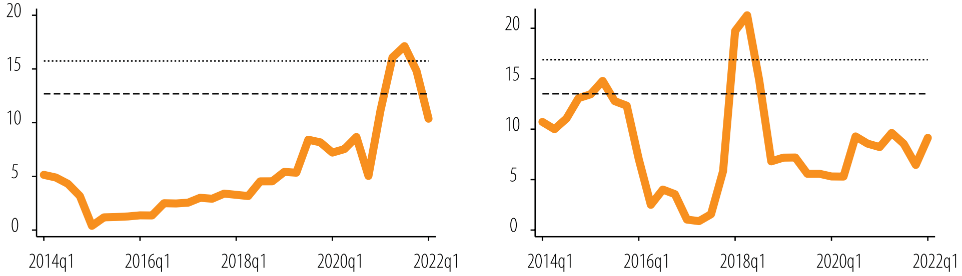
These results have important implications for banking sector stability: 1) Manufacturing and utilities sectors -- given the trajectory/trend in Wald Statistics well before the pandemic – are becoming increasingly critical/significant in leading/predicting banking sector stability and as such present important channels for transition risks to the sector 2) the Wald spikes seen during the pandemic from all four sectors (manufacturing, transport, utilities and real estate) significant or otherwise, shows how the banking sector is presently intertwined with these CPRSs, sans further climate related policies that may link these sectors even further.

Figure 11: Is Banking Sector Stability Ganger Caused by % Change in Sectoral Output?
(Recursive expanding Wald test for Banking Stability G-caused by SECTOR Output Growth, 2009q2 - 2022q1 with 90th (--) and 95th (-) percentiles of bootstrapped test statistics)

Maufacturing **Utilities**

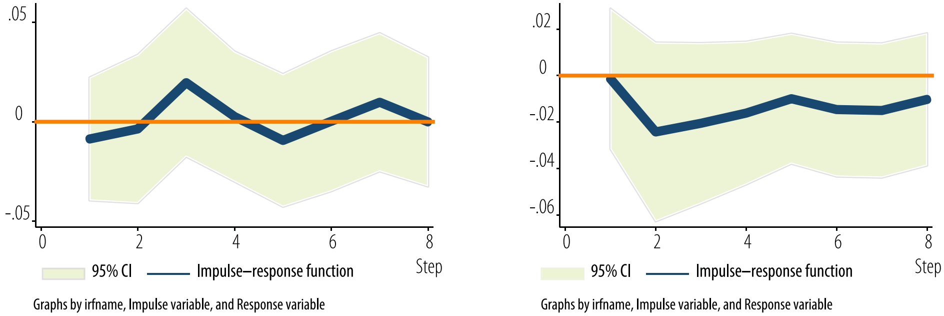


Transport & Communication **Real Estate**



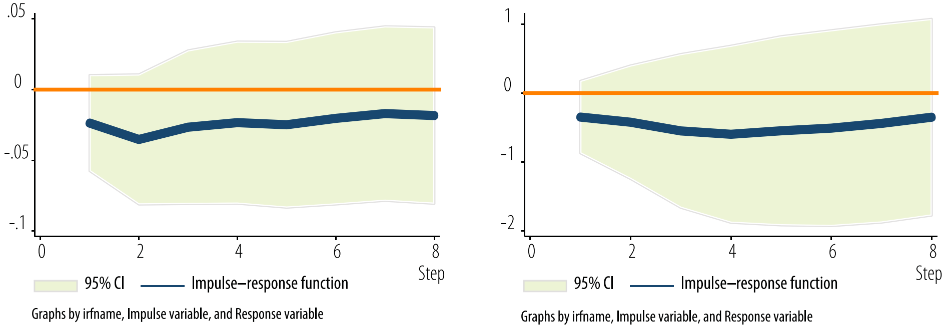
The impulse response plots in **Figure 12** shows the direction of the effect of a negative shock on each of the sectoral output growth levels. With the exception of manufacturing, which presents a rather erratic response from stability, the response to shocks in all other sectors is consistently negative. The response of the stability index to real estate is especially economically significant.

Figure 12: How does Banking Sector Stability Respond to Sectoral Output Growth Shocks? Impulse Responses – Lag Strcture of underlying VAR = 2



Maufacturing

Utilities



Transport & Communication

Real Estate

5.0 Conclusions and Policy Recommendations

The purpose of this paper was to examine the time-varying nexus of climate risk drivers, climate policy relevant sectors (CPRSs), and banking sector stability. We first analysed whether outputs from 5 different sectors (agriculture, manufacturing, utilities, transport, and real estate) are granger-caused/predictable by physical climate risks.

We find that physical risks significantly manifest through the agricultural sector alone, as seen by the significant granger causality test that examines the connectivity between temperature, precipitation, and the respective sectoral output growths. This is a key empirical finding that demystifies the primary channel through which physical risks can translate to the banking sector (in Kenya), where theoretical microeconomic perspectives argue that both the agricultural and real estate sector are exposed. The 23% agricultural contribution to GDP in the country spotlights the sector even further in the wake of climate change and related policies.

This evidence carries critical considerations for policymakers in this arena. Foremost, a "business as usual" approach to climate change with no relevant climate policies put in place to curb warming is clearly a detriment to banking sector stability. It is apparent that temperature and precipitation rises destabilize the banking sector. Such warming and the consequent rise of physical risks to the agricultural sector translate to an increased risk profile for banks. As a result, climate related policies that encourage a transition to a low-carbon economy (e.g., carbon taxes and subsidies on investment/consumption of renewable energy) will be critical in reducing the size and frequency of shocks arising from climate risks. That said, instruments such as carbon taxes and renewable subsidies should be considered for use to the extent that they are not market-distorting and are welfare-enhancing.

Secondly, the paper assessed the vulnerability of banks to transition risks by examining the response of the stability index to negative shocks on CPRS outputs. We find that the manufacturing and utilities sectors are becoming increasingly critical/significant in predicting banking sector stability (even prior to COVID-19) and as such they present critical channels for transition risks to the banking sector. Also, seeing that the climate change conversation has played alongside COVID-19, it is key to note that during this period, all CPRSs have become increasingly linked to the banking sector. This shows that the banking sector is already intertwined with these CPRSs and the transmission channel between the sectors and banking sector stability is therefore stronger (sans further climate related policies that may affect these sectors more).

Consequently, this calls to attention the need for cautious design and implementation of climate related policies and targets, to avoid significantly contracted sectoral performance and banking sector instability as a result. A disorderly transition to a low-carbon economy not only exacerbates the effects of the pandemic and slows down the recovery, but it also amplifies the climate risk transmission channel from climate policy relevant sectors to banking sector stability. Between physical and transition risks, it is clear that both present daunting outlooks for the banking sector – As much as the loan exposure to agricultural sector is ~3%, it is crucial to point out that this sector accounts for 54% of the country's employment (as at 2019), and this translates to the significant loan exposure to personal/household. There is an economically significant loan exposure to the manufacturing sector (14% as at 2021), making this sector a focal point in light of climate change and climate related policies. There is a place for sector-specific policymakers, central banks, and other financial regulators to ensure that firms in these sectors are resilient to climate-induced economic shocks given the ultimate effect this has on banking sector stability. As such, in the interest of maintaining such stability, it is crucial for policymakers (monetary, fiscal, or otherwise) to be proactive and find synergistic approaches to greening of the economy and the financial system, while identifying risks and challenges that come with such a transition.

Works Cited

1. Acclimatise Group Ltd; UNEP Finance Initiative. (2018). *Navingating a New Climate: Assessing credit risk and opportunity in a changing climate - Outputs of a working group of 16 banks piloting the TCFD Recommendations.*

2. Alhassan, A. L., Kyereboah-Coleman, A., & Andoh, C. (2014). Asset quality in a crisis period: An empirical examination of Ghanaian banks. *Review of Development Finance, Volume 4, Issue 1, 50-62.*

3. Bank of England. (2019). *Climate change: what are the risks to financial stability?* Retrieved from Bank of England Knowledge Bank: https://www.bankofengland.co.uk/knowledgebank/climate-change-what-are-the-risks-to-financial-stability

4. Bank for International Settlements. (26-27 August 2008). Measures of financial stability - a review. Proceedings of the IFC Conference on *"Measuring financial innovation and its impact", (pp. 365-380). Basel.*

5. Basel Committee on Banking Supervision (Bank for International Settlements). (2021). *Climate-related financial risks - measurement methodologies. Bank for International Settlements.*

6. Basel Committee on Banking Supervision. (April 2021). *Climate-related risk drivers and their transmission channels. Bank for International Settlements.*

7. Battiston, S., Mandel, A., Monasterolo, I., Schuetze, F., & Visentin, G. (2017). A Climate stress-test of the financial system. *Nature Climate Change, 7, 283-288.*

8. Buhr, B., Volz, U., Donovan, C., Kling, G., Lo, Y., Murinde, V., & & Pullin, N. (2018). *Climate Change and the Cost of Capital in Developing Countries.* https://unepinquiry.org/publication/climate-change-and-the-cost-of-capital-in-developing-countries/: Imperial College London; SOAS University of London; UN Environment.

9. Carbon Tracker. (2011). *Unburnable Carbon: Are the World's Financial Markets Carrying a Carbon Bubble?* Carbon Tracker.

10. Carleton, T., & Hsiang, S. (2016). Social and economic impacts of climate. *Science, Vol 353, Issue 6304.*

11. Central Bank of Kenya. (2021). *Bank Supervision Annual Report. Nairobi: Central Bank of Kenya.*

12. Christiano, L. J., & Fitzgerald, T. J. (2003). The band pass filter. *International Economic Review 44 (2), 435-465.*

13. Comerford, D., & Spiganti, A. (2020). The Carbon Bubble: Climate Policy in a Fire-Sale Model of Deleveraging. *European University Institute, Max Weber Programme .*

14. Drehmann, M., Borio, C., & Tsatsaronis, K. (2012). Characterising the Financial Cycle: Don't Lose Sight of the Medium Term! *Macroeconomics: Monetary & Fiscal Policies eJournal.*

15. Dunz, N., Monasterolo, I., & Raberto, M. (2018). Don't forget climate sentiments: real and financial markets' reactions to climate risks. *https://papers.ssrn.com/sol3/%20papers.cfm?abstract_id=3264181.*

16. Dwumfour, R. A. (2017). Explaining banking stability in Sub-Saharan Africa. *Research in International Business and Finance, 260-279.*

17. European Central Bank. (2019). *Climate change and financial stability.* Financial Stability Review.

18. European Central Bank/European Systemic Risk Board Project Team on climate risk monitoring. (July 2021). *Climate-related risk and financial stability. European Central Ban*k.

19. Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral method. *Econometrica, Vol 37, 424-438.*

20. Hsiang, S., Kopp, R., Rising, J., Delgado, M., Rasmussen, D., & Muir-Wood, R. (2017). Estimating economic damage from climate change in the United States. *Science 356 (6345), 1362-1369.*

21. International Energy Agency (IEA). (2019). *Africa Energy Outlook.* International Energy Agency .

22. International Energy Agency. (2022, Last Updated, September). *Energy Statistics Data Browser.* Retrieved from https://www.iea.org/data-and-statistics

23. International Monetary Fund. (2006). *Financial Soundness Indicators Compilation Guide.* Washington, D.C.: International Monetary Fund, Publication Services.

24. Keeton, W., & Morris, C. (1987). Why Do Banks' Loan Losses Differ? *Economic Review.*

25. Liu, Z., Sun, H., & Tang, S. (2021). Assessing the impacts of climate change to financial stability: evidence from China. *International Journal of Climate Change Strategies and Management Vol 13, No 3, 375 - 393.*

26. McKinsey Global Institute. (January 2020). *Climate risk and response: Physical hazards and socioeconomic impacts.*

27. Mosk, Benjamin; Welz, Peter (European Central Bank). (2022). Financial stability implications of higher than expected inflation. *Financial Stability Review.*

28. Motelle, S. I., & Biekpe, N. (2014). Financial intermediation spread and stability of the

banking system in the Southern Africa Customs Union. *Managerial Finance, Vol. 40 No. 3, 276-299.*

29. Network for Greening the Financial System. (June 2020). *The Macroeconomic and Financial Stability Impacts of Climate Change Research Priorities.* NGFS Secretariat/Banque de France.

30. Noth, F., & Schüwer, U. (2018). Natural Disaster and Bank Stability: Evidence from the U.S. Financial System . *SAFE (Sustainable Architecture for Finance in Europe) Working Paper No. 167. Available at SSRN: https://ssrn.com/abstract=2921000 or http://dx.doi.org/10.2139/s.*

31. Perry, P. (1992). Do banks gain or lose from inflation? *Journal of Retail Banking, Vol. 14, Issue 2.*

32. Ritchie, H., & Roser, M. (2020). *CO_2 and Greenhouse Gas Emissions.* Retrieved from OurWorldInData.org: https://ourworldindata.org/emissions-by-sector

33. Shi, S., Phillips, P. C., & Hurn, S. (2018). Change Detection and the Causal Impact of the Yield Curve. *Journal of Time Series Analysis, Vol 39, 966-987.*

34. Shi, S., Phillips, P. C., & Hurn, S. (2020). Causal Change Detection in Possibly Integrated Systems - Revisiting the Money-Income Relationship. *Journal of Financial Econometrics, Vol 18 (1),* 58-180.

35. Sinkey, J. F., & Greenawalt, M. B. (1991). Loan-loss experience and risk-taking behavior at large commercial banks. *Journal of Financial Services Research Volume 5, 43–59.*

36. Strobl, E. (2011). The Economic Growth Impact of Hurricanes: Evidence from US Coastal counties. *Review of Economics and Statistics, Volume 93, 575-589.*

37. United Nations. (2021). *United Nations Climate Action.* Retrieved from https://www.un.org/en/climatechange/net-zero-coalition

38. World Bank. (2021). *The Climate Change Knowledge Portal (CCKP).* Retrieved from https://climateknowledgeportal.worldbank.org/

39. Zhang, X., Zhang, S., & Lu, L. (2022). The banking instability and climate change: Evidence from China. *Energy Economics Vol 106.*

40. Zhonglu, L., Haibo, S., & Songlin, T. (2021). Assessing the impacts of climate change to financial stability: evidence from China. *International Journal of Climate Change* Strategies *and Management Vol. 13 No. 3, 375-393.*

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