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Annual Review of Resource Economics

Climate Change and Sub-Saharan Africa: The Role of Central Banks

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Keywords

climate change, central banking, Sub-Saharan Africa, financial markets, financial risk

Abstract

Climate change is driving three transformations in the landscape of global finance, with implications for central banks in Sub-Saharan Africa (SSA). First, pressures on financial institutions related to climate-related physical risks are mounting, with potential to threaten price and financial stability. Second, global and domestic responses to climate change are creating risks and opportunities for SSA economies. Third, the ongoing shift in the global financial architecture toward sustainability could either crowd-out or crowd-in international investment flows to SSA. Uncertainties in each increase the challenges for central banks and supervisors. We find that, without action, the risks outweigh the opportunities. To fulfil their mandates, SSA's central banks are obliged to react; however, the paucity of peer-reviewed evidence hinders the development and execution of appropriate responses. Preparedness is crucial if actions by SSA central banks are to play their part in shifting the balance towards managing risks and grasping opportunities.

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1. INTRODUCTION

Climate change, along with broader environmental degradation, is profoundly transforming the physical world and leading to structural shifts in energy, food, water, ecosystems, trade, and finance. From an economic standpoint, the implications of climate change are threefold. First, production, especially in climate-sensitive sectors, must adapt to the physical impacts of climate change: higher average temperatures and their associated ramifications. Second, efforts to stabilize the climate through emission reductions and to adapt to current climate change will prompt changes in economic structures. Third, the aggregation of multiple domestic transitions at the global level, uneven paces of transition, and disjointed policy efforts will impact international markets with ripple effects across countries and value chains. For all nations and regions, this threefold set of implications for the real economy creates a complex web of uncertain economic risks and opportunities.

For Sub-Saharan Africa (SSA), temperatures are rising faster than global averages (IPCC 2021, WMO 2021) and extreme events are becoming more frequent and intense across much of the continent (Thomas et al. 2022, WMO 2023). Relative to the rest of the world, physical risks are high because SSA economies typically consist of large sectors that are vulnerable to climate-related risks, coupled with limited adaptation capacity due to relatively low levels of development, and (by and large) geographies predisposed to higher temperatures and climatic extremes (TCFD 2017, LSEG Afr. Advis. Group 2018). However, many forward-looking analyses find a firming of world prices for climate-sensitive sectors, notably agrifood, that creates incentives, on aggregate, to invest into, rather than away from, climate-sensitive sectors (Hertel 2018). The salience of climate-sensitive sectors, in terms of both production and consumption in the African context, highlights the importance of this implication. The elevated risk profiles in SSA call for careful risk management at the supervisory level in the short to medium term.

Further, while the pace of global transition to a low-emissions economy has almost surely been insufficient to restrain temperature rise to the 1.5°C target, substantial transition is taking place, notably in electricity generation and the electrification of transport. This transition is driven in part by policy and in part by rapid technological advances. African emissions, measured in terms of CO2eq, a unit used to aggregate the global warming potential of different greenhouse gases, represented less than 9% of global emissions in 2023 (Andrew & Peters 2024). Importantly, aggregate emissions in SSA differ substantially in composition from those of historically large emitters, as they originate principally from non-fossil fuel sources, notably agriculture, forestry, and other land use (AFOLU). The largest emitting sector in SSA is thus exposed to both transition risk and substantial physical risk. Fossil fuels also represent around 25% of African exports and imports (WITS 2024). These challenges, in addition to achieving broader development objectives, underline the need for a strengthened domestic financial sector that supports a multifaceted transition and the right enabling conditions for complementary external financing.

Sitting at the apex of financial systems, central banks are positioned to play a critical role in confronting these implications of climate change in SSA, alongside other public institutions. Most central banks in SSA operate under a dual mandate of (*a*) delivering price stability against an inflation target and (*b*) supporting financial stability, often with a subsidiary objective of market development. In practice, particularly in the low-income countries of SSA, central banks often find themselves supporting a broader developmental mandate around macroeconomic forecasting, monetary-fiscal policy, and sovereign debt management.

Climate change affects central banks' ability to deliver both arms of the mandate, albeit over different time horizons. This review aims to trace how three fundamental climate-induced changes are altering the economic and financial environments in which SSA central banks operate and their implications for the design of central bank operations and the delivery of their mandates.

While neither climate-related risks and opportunities nor broader macroeconomic conditions are homogeneous across countries, the climate-related challenges faced by all countries in the region are sufficiently common to allow this review to provide some general guidance.

Moreover, these exogenous risks compound with other persistent challenges facing SSA economies. Although there are pockets of more rapid economic growth and others of conflict-related stagnation, most countries in the region have experienced a modest economic recovery post-COVID-19, with growth averaging around 3.5% per annum (IMF 2024a). But with population growth still over 2% per annum, per capita growth remains low, and the pool of domestically generated savings capable of meeting the investment needs for climate change-induced structural transformation is low. Most countries are also constrained by limited fiscal space and high levels of public debt. Dependence on public and private external financing, therefore, will remain central to the region's continued growth over the coming decades.

The remainder of the review is organized as follows. Section 2 reviews the evidence on the changing landscape for SSA financial systems associated with climate change. In Sections 3 and 4, we turn our attention to central banks and supervisors in SSA and their role in managing the effects of climate change and supporting countries' efforts to navigate sustainable climate transitions. Section 3 focuses on the short-term price stability arm of central banks' mandate, emphasizing the extent to which, if at all, frameworks of monetary policy require moderation in the face of increased frequency and magnitude of climate-related shocks to prices and output. Section 4 considers the financial stability mandate with, once again, a focus on volatility. A final section summarizes and concludes.

2. THE CHANGING LANDSCAPE FOR FINANCIAL SYSTEMS IN SUB-SAHARAN AFRICA

Risk is the dominant framing through which the impacts of climate change and environmental degradation on the financial sector are typically analyzed and understood. **Figure 1** conceptualizes how climate-related risks are transmitted through the economy to the financial sector (NGFS 2022). These risks can materialize as credit, liquidity, or market risks, among others, on the balance sheets of financial institutions, both public and private. In turn, these financial risks drive investment behavior and affect, for example, access to capital in the real economy. The financial sector's risk profile is inherently international, due to its holdings in companies and governments globally and its dependencies on global trade, supply chains, and macroeconomic conditions. Risks can therefore transmit globally.

Although risk is the dominant framing, change also brings opportunities. Motivated by the threefold set of real-side implications of climate change outlined in Section 1 and by **Figure 1**, the rest of this section considers salient implications, both risks and opportunities, for financial institutions across SSA. The first subsection considers physical climate- and nature-related implications. The second considers mitigation, including carbon markets, and implications for international prices. The final subsection highlights financial flows and implications for the global financial architecture.

2.1. Physical Climate- and Nature-Related Risks

Physical risks are a function of the probability of a hazard occurring, the exposure of economic activities to that specific hazard, and the economic activities' capacity to withstand and recover from the hazard. At a global level, the impact of physical climate-related risks on financial portfolios has been widely explored (e.g., Mandel et al. 2021, BoE 2022, ECB 2022). The evidence for Africa is relatively sparse in comparison. In 2022, the South African Reserve Bank with the International Monetary Fund (IMF) conducted analyses of the potential implications of transition

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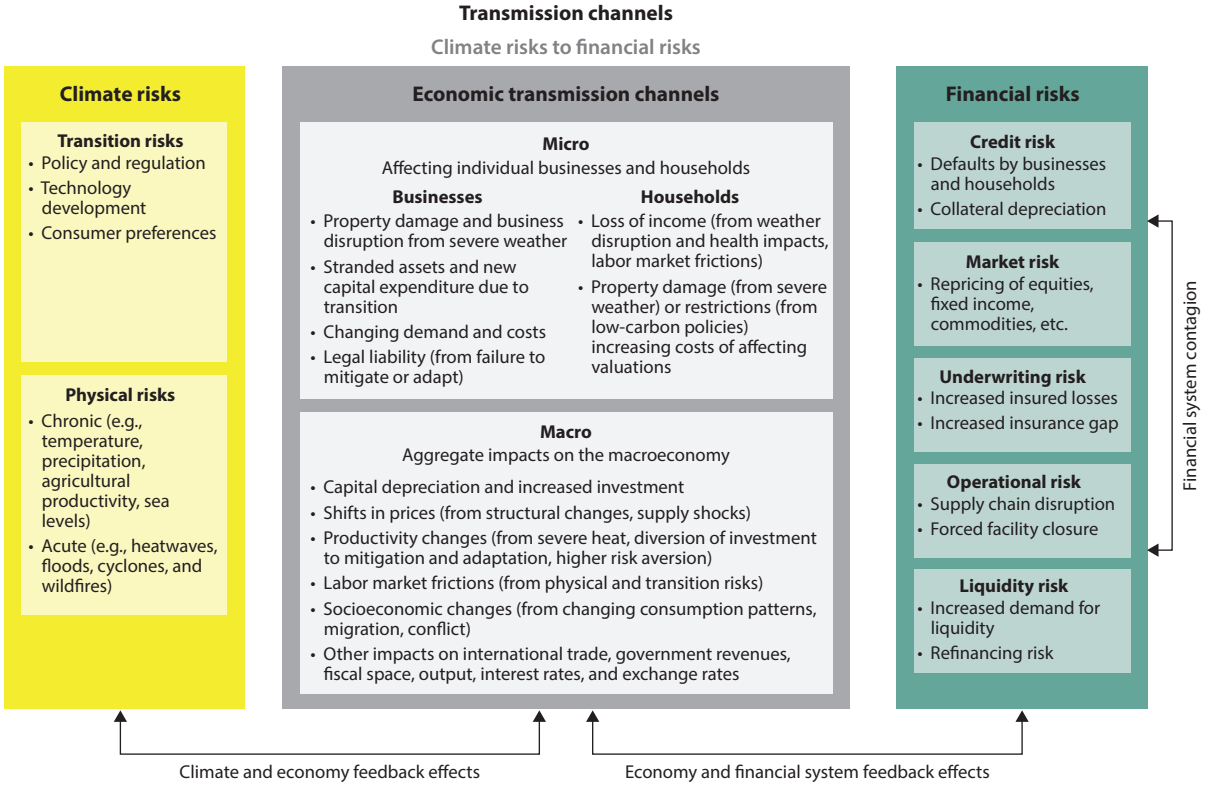


Figure 1

Transmission channels for climate-related risks. Figure adapted from NGFS (2022).

risks and drought for the financial sector. It concluded that "Analysis of stress testing of climate risks points to non-negligible implications for the financial sector. . .The country's arid climate, geographical position and high dependence on fossil fuel production and consumption renders it vulnerable to both physical and transition risks" (IMF 2022a, p. 20). It found notable risks in water-scarce provinces, though it concluded that some of those physical risks are to some extent already reflected in estimated default probabilities.

In Kenya, three consecutive droughts in 2009, 2010, and 2011 cost 11%, 7%, and 9% of gross domestic product (GDP), respectively (Rep. Kenya 2012). A more recent follow-up study by the Central Bank of Kenya (CBK 2021) finds that rainfall variability is correlated with lower bank performance due to banks' exposure to the agricultural sector. Elsewhere in Africa, the World Bank (2024) finds that Moroccan banks are exposed to flood and drought risk, also with unfavorable impacts on their nonperforming loan ratios. This handful of studies does not capture all the dimensions of financial risk implied through the scientific literature (e.g., Trisos et al. 2022). For example, for Malawi, Mozambique, and Madagascar, tropical cyclones such as Idai and Kenneth (both in 2019) demonstrated the outsized impacts climate shocks can have on price dynamics and financial stability (Arndt & Tarp 2015, Nhundu et al. 2021).

Several papers in recent years have attempted to capture the interlinkages between climate and nature risks (e.g., DNB 2020, Ranger et al. 2023, Ranger & Oliver 2024, Svartzman et al. 2021b) as well as water insecurity (e.g., Rudebeck 2022, Davies & Martini 2023). FSDA-Vivid (2022) completed the first analysis of nature-related financial risks in Africa, finding that 23% of African

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GDP is highly dependent on nature. Yet, evidence clearly shows that natural systems in Africa, as in other parts of the world, are currently in a state of crisis, with nature degrading at rates faster than humanity has previously experienced (IPBES 2019). The disruption of ecosystem services is a consequence of both climate change and other drivers and acts as an amplifier for climate-related physical risks. Given the strong interlinkages, there is growing consensus that climate- and nature-related risks be considered together (NGFS 2023).

Governments are similarly exposed (Agarwala et al. 2021). Studies suggest that climate change and nature loss are likely to adversely affect fiscal positions of SSA countries over the short to medium term (e.g., AfDB 2019, Kotz et al. 2024). Unplanned allocations for extreme weather event responses across SSA, for example, are already taking up between 2% and 9% of budgets and are likely to increase over time absent effective adaptation and/or global mitigation measures (Songwe & Adam 2023). However, the constrained fiscal space across many countries in SSA limits countries' capacity to respond to environment-related risks (UNCTAD 2023).

Sovereign borrowing may be further constrained if increased exposure to environmental risks leads to a repricing of sovereign assets, with reduced creditworthiness increasing borrowing costs. For example, Cevik & Tovar Jalles (2020) find that a 10% increase in climate vulnerability is associated with a 150-basis point (bp) increase in long-term government bond spreads for developing countries. By contrast, bond spreads and credit ratings in advanced economies are broadly invariant. Klusak et al. (2023) find that the economic impact of continued rising temperatures could result in sovereign credit rating downgrades for more than 60 countries, resulting in additional costs for sovereigns between US$35.8 and US$62.6 billion under RCP8.5, a high-emissions scenario. Agarwala et al. (2021) look at the impact of changes in fisheries, tropical timber, and wild pollination and find that 58% of sovereign credit ratings analyzed would suffer a downgrade of one notch or more under a partial ecosystem collapse scenario. These findings underline the materiality of environment-related risks for governments and other market actors. Whether or not due to climate change, the long-run decline in climate-dependent commodity prices (food and other agriculture) that characterized the twentieth century has come to a halt in the twenty-first century (FAO 2025). Because demand for food and agricultural products is inelastic, deleterious productivity implications due to climate change can be expected, ceteris paribus, to drive prices for food and agricultural products upward more than proportionately. Hence, SSA's dependence on climate-sensitive sectors in the context of climate change creates opportunities to capitalize on firmer commodity prices on average and occasional price spikes, as well as risks associated with climate-induced drags on productivity and occasional major production shortfalls.

2.2. Global, Regional, and National Responses to Climate Change

As of 2024, 195 countries have ratified the Paris Agreement and made commitments to take action to keep global warming below 2°C and as close to 1.5°C as possible. Since then, more than 140 countries have put in place net zero targets and climate policies to limit national emissions. Thirty-seven of 54 African countries have proposed, pledged, or adopted a national net zero target (**https://zerotracker.net/#companies-table**). Moreover, five countries in western Africa have explicitly indicated their intention to explore carbon taxes or emission trading systems (UNFCCC 2024). Ambitious policy changes in SSA, such as these, create so-called transition risks and opportunities for economies.

However, global policy action also has large-scale spillover effects for SSA economies, both directly, for example, through the introduction of international carbon pricing mechanisms such as carbon border tax adjustments (CBTAs), and indirectly, through shifts in global demand, prices, trade, and investment flows. CBTAs, such as the EU Carbon Border Adjustment Mechanism, will penalize CO_2-intensive imports into the European Union (EU) from Africa and elsewhere. While

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this is unlikely to severely affect agricultural exports from SSA, research suggests that nonagricultural exports are likely to face adverse price movements (Afr. Clim. Found. & LSE 2024, Clora et al. 2023, Dobranschi et al. 2024). Impacts depend on national export characteristics, including their emissions intensity. Countries such as Mozambique, for example, could see transition risks materialize in its emissions-intensive trade-exposed goods such as cement, aluminum, and steel, despite these being less emissions-intensive than goods from other countries (Eicke et al. 2021). Such effects are particularly severe for the continent given that the EU is a significant trading partner for SSA countries, accounting for 68% of Mozambique's aluminum exports and 13% of Zimbabwe's iron and steel exports, for example (Gergondet 2021).

Concerning shifts in demand, prices, trade, and investment flows, the oil market is highly relevant to SSA. According to the World Integrated Trade Solution database, petroleum oils represented about 25% of total exports from SSA in 2022 (WITS 2024). The most recent forecast of the International Energy Agency (IEA) predicts a decline in global oil demand in 2030 due to structural factors, notably the expansion of renewable electricity generation displacing oil-fired generation, the rapid growth in electric vehicles reducing gasoline demand, and ongoing efficiency gains in the use of fuels (IEA 2024a). These structural factors are expected to persist into the 2030s and may expand into other uses for crude oil, such as diesel and jet fuel markets.

Although other forecasters expect peak oil demand to occur much further into the future (OPEC 2024), the IEA forecast should not be discarded. A long-run decline in oil demand is essentially unprecedented. When it occurs (from 2029, earlier, or later), it must be accompanied by long-run compression of supply. How exactly this compression unfolds is unknown. Low-cost producers have incentives to force high-cost producers out of the market by allowing oil prices to drop low enough for long enough to induce a sufficient volume of permanent shutdown. This puts high-cost producers as prime candidates for relatively early shutdown.

For net importers of fuels in SSA, periods of low oil prices constitute significant terms of trade gains (Arndt et al. 2019b). However, many African net exporters of oil confront considerable risk. Prominent among these is Nigeria, which, despite decades of rhetoric about diversifying the economy, still counts on oil and derived products for about 90% of official export revenue. Further, Nigerian total export values are low and import values are concomitantly low at about 12% of GDP (compared with an average of more than 20% for lower-middle-income countries). Finally, while exact figures are not known, Nigeria is widely viewed as a relatively high-cost oil producer and is not renowned as an easy place to do business (ITA 2023, The Economist 2024). Nigeria could confront, in the not-too-distant future, a prolonged period of low oil prices that is designed specifically to force higher-cost producers permanently out of the market. This would likely oblige Nigeria to enter an intense period of structural adjustment as it seeks to raise non-oil exports from their current level of about 1% of GDP. Nigeria is also highly dependent on oil for government revenue (ITA 2023). Overall, Nigeria appears to be at significant risk should global oil production consolidate. Other African net exporters of oil and derived products would be subject to similar forces.

At the same time, in a world that is transitioning to a low-carbon economy, opportunities will arise that could be of significant benefit to SSA, such as carbon markets, and new nature-related financing, as well as opportunities in critical minerals and green hydrogen. Africa holds an estimated 30% of the world's supply of at least a dozen critical minerals that are essential for global value chains in low-carbon energy (Ouedraogo & Kilolo 2024) and is well-suited for production of green hydrogen (AbouSeada & Hatem 2022). Furthermore, SSA's vast carbon sequestering capabilities from existing natural resources provide a potentially effective way to finance and protect natural capital, both of which provide critical global ecosystem services and resilience. Today Africa accounts for only 25% of trading on voluntary carbon markets, which is valued at more than

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$500 million, despite being home to some of the world's largest reserves of natural capital in its forests, seas, and lands (EM 2024). The African Carbon Markets Initiative reports it has already secured $1 billion of intentions to invest in high-integrity African carbon credits. Such markets could scale with the agreement of Article VI at COP29 in Baku in 2024.

However, realizing the potential gains offered by carbon markets requires surmounting significant challenges. Carbon markets suffer from a lack of credibility, particularly around credits for avoided emissions (e.g., Greenfield 2023). This is relevant for recent African carbon credits, as 90% have financed cookstove projects and avoided deforestation (ACMI 2024). Equally, there have been some concerns in the SSA regions that without sufficient equity considerations, carbon credits enable a form of recolonization that allows other countries to continue emitting carbon (e.g., Navarro 2022). Sylvera (2023) estimates a 22% reduction in global demand for carbon credits as a result of these issues. Proponents argue that some fluctuations are expected while markets mature (ACMI 2024), and initiatives such as the Integrity Council for the Voluntary Carbon Market aim to increase credibility and transparency in these markets by addressing these issues.

The global adoption of biodiversity policies such as the Global Biodiversity Framework and growing demand for nature-positive investments provide a further opportunity for SSA. Innovations such as biodiversity credits and payment for ecosystem services programs are nascent but could come to the fore in the next decade and create a significant opportunity (UNEP 2023).

A common thread that emerges across each of these areas is the challenge of policy uncertainty. The speed, scale, and structure of the sustainability transition depend heavily on domestic and international policy, as well as the rate of technological progress. Vastly different outcomes could be seen, with varying winners and losers. Central banks need to navigate this growing uncertainty over the coming decade.

2.3. Financial Flows and Changing Global Financial Architecture

The world has seen substantial shifts in the global financial landscape over the past 10 years, including growth in sustainable investment flows. Global investment in clean energy has risen by 50% in the past five years, now representing around $1.8 trillion—nearly two-thirds more than global investments into fossil fuels (IEA 2024b). In parallel, flows of green and sustainability-linked bonds have increased fourfold, with issuance of such instruments reaching $870 billion in 2023 (CBI 2024). However, SSA economies have benefitted little from these financial flows. Still, only 1.3% and 4.1% of all financial flows from European institutional investors (insurers and pension funds, respectively), for example, are allocated to low- and middle-income economies overall, and much of this is in the form of hard-currency sovereign bonds, rather than direct investments (Eur. Comm. 2024). Investment flows into energy systems in Africa have hardly increased in the last five years, with the majority continuing to flow into fossil fuels, increasing the potential for stranded assets (IEA 2024b).

At the same time, international climate finance flows for adaptation and mitigation to SSA are still woefully limited, despite pledges by international actors. It is estimated that around US$2.8 trillion of climate finance in total will be needed for the implementation of African nationally determined contributions (NDCs) between 2020 and 2030 (Meattle et al. 2022). Adaptation needs by 2035 for the continent are also estimated to be eight times higher than current financing flows (CPI 2023). Over half of adaptation finance flowing into Africa is concentrated in 10 countries, with others receiving as little as 1% of total flows. Only 3% of adaptation finance stems from private sources, with the rest being funded primarily by domestic public sources, followed by international public finance. Importantly, these needs and flows are dwarfed by overall financing needs for achieving the UN Sustainable Development Goals (SDGs) in Africa, which are currently

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estimated at $1.3 trillion per year and expected to increase due to population growth and setbacks from COVID-19 (UNECA 2020).

SSA countries face significant constraints in mobilizing and absorbing the volumes of external capital flows required to finance investment in adaptation and transition (IFC 2023, IMF 2023, OECD 2023). These constraints are partly structural, reflecting the depth and maturity of domestic capital markets, particularly for private capital flows, and partly macroeconomic, reflecting concerns about fiscal space and debt sustainability.

The structural barriers to flows of sustainable finance in SSA are well-documented and mostly reflect general barriers to wider investment in African economies (e.g., Eur. Comm. 2024). However, the immaturity of sustainable finance frameworks, including a lack of guidance on or required disclosure, creates an additional major barrier to sustainable investment compared with other parts of the world. For example, research by the African Development Bank (AfDB 2021) showed mixed progress across the region in implementing the building blocks of green financial frameworks (**Figure 2**). There are also risks related to the emerging sustainable financial architecture at the international level. For example, the growing requirement for transition plans or other disclosure elements from international investors can raise the cost of capital of firms in SSA. This could unintentionally crowd-out investment into developing economies should counterparties be unable to meet these requirements.

These structural barriers are compounded by macroeconomic conditions. While the transformation of societies will be driven primarily by private capital flows financing private sector investment (World Bank 2023), public investment and hence public debt will play a catalytic role in driving this transformation, especially in the short term. But, unless governments can borrow at highly concessional rates, or indeed finance public investment from unrequited grants, the

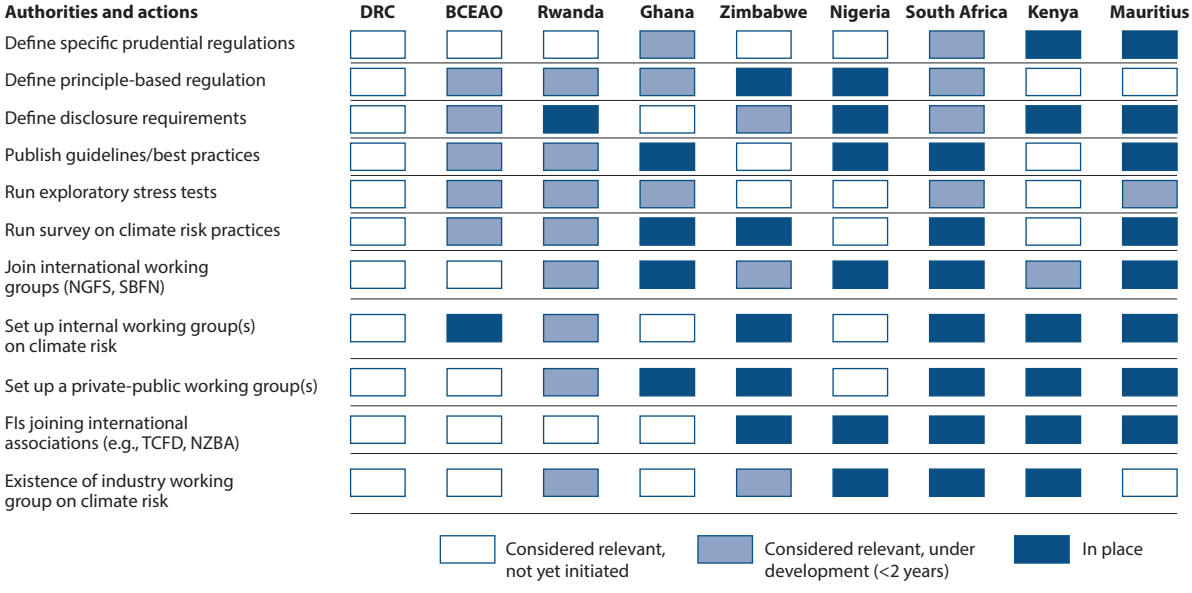


Figure 2

Overview of climate-related risk regulations and initiatives across selected Sub-Saharan African countries. Figure adapted with permission from AfDB (2021). Abbreviations: BCEAO, Central Bank of West African States; DRC, Democratic Republic of the Congo; FI, financial institution; NGFS, Network for Greening the Financial System; NZBA, Net-Zero Banking Alliance; SBFN, Sustainable Banking and Finance Network; TCFD, Taskforce on Climate-Related Financial Disclosures.

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capacity to scale-up public debt will remain highly limited, as many SSA countries are already operating close to the limits of public debt sustainability: As of September 2024, of the 37 low-income SSA countries eligible for concessional support from the IMF, 19 were either in or at high risk of debt distress (IMF 2024b). Even with access to concessional financing, the arithmetic of debt sustainability will remain challenging for many governments, primarily for reasons of liquidity rather than long-run solvency. These challenges are expected to magnify as the increased economic volatility resulting from climate change will incentivize central banks to accumulate higher short-term reserves, further restricting sovereign borrowing ability. In preparing markets to absorb greater external capital flows and mitigate some of the volatility through insurance, central banks can lessen the burden on sovereigns, thereby unlocking further capital.

3. CLIMATE CHANGE, PRICE STABILITY, AND MONETARY POLICY

In this section, we focus on the implications of climate change for the price stability leg of central banks' mandate. The last two decades have seen many African countries implement significant reforms to their monetary policy frameworks. These have shifted from regimes built around targets for the growth of the money supply toward those built around explicit targets for inflation, where the interest rate and a clear communications strategy aimed at anchoring inflation expectations have emerged as the principal instruments for anchoring domestic price inflation (Adam et al. 2018). Central banks are in the early stages of considering the implications of climate change for the operation of monetary policy in these new regimes, let alone other environmental changes.

Environment-related risks and shocks impact monetary policy operations in terms of how they impact the transmission mechanism from monetary policy actions (e.g., interest rate setting) to the level and volatility of prices and aggregate output, from both the supply side and the demand side. On the supply side, climate-induced volatility is most likely to transmit both through domestic food prices (which, in SSA, constitute a large share of the overall consumption basket) and, to the extent that environmental change induces greater volatility in globally traded food prices, through import prices and the exchange rate (Ndulu & Masawe 2015). On the demand side, environment-related shocks can create short-term demand pressures, for example, if households switch consumption from imported to domestic goods and services. These are relatively straightforward for central banks to respond to with policies, as output and inflation tend to move together, meaning the monetary policy response required to stabilize inflation is the same as that required to stabilize output relative to trend, at least directionally. Thus, in the face of a positive demand-side shock, tightening the monetary stance bears down on the interest-sensitive components of consumption and investment, slowing economic activity and reducing inflation. The same process of tightening may be expected to dampen import demand, appreciate the nominal exchange rate and ease pressure on imported inflation.

Supply-side shocks, on the other hand, present central banks with a classic policy trade-off that is particularly acute for flexible inflation targeting central banks armed with a single policy instrument (i.e., the interest rate). This is because their core mandate of price stability is accompanied by an explicit additional objective of seeking to smooth the path of output around its trend. In the face of adverse supply-side shocks, output will be below trend and inflation will rise above target. The imperative to deploy monetary instruments in the face of extreme events, to provide liquidity and other special lending facilities for affected firms, households, and financial institutions, and to lower the cost of finance to support reconstruction represent a loosening of the monetary stance, which may also be mirrored by (and supportive of) a similar loosening of the fiscal stance. In many cases, however, this may be occurring in the context of rising prices, for both non-core components of price indices, such as imported food and energy costs, and also core prices of

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domestically produced goods and services, which reflect labor market pressures. Together, these call forth a tightening of the monetary stance. Such situations are particularly prevalent in economies that are more susceptible to environment-related risks, which can materialize as extreme supply shocks, due to either the small size of the country or their significant exposure.

To date, work in this area has tended to focus on the impact of this form of one-off extreme weather events such as tropical storms or floods, which present themselves as classic supply-side shocks (e.g., Cantelmo et al. 2022). In many respects, such shocks are little different from those that SSA central banks have been responding to for much of their existence, and the policy trade-off described above applies and is well-understood. The standard prescription in modern monetary policy analysis is that, when faced with such a trade-off, the monetary authorities should lower interest rates in the short run to ease the compression of output but bear down on so-called second-round effects of inflation to ensure that the temporary rise in inflation does not get embedded in inflation expectations. In this context, the art of monetary policy lies in timing and scale of response: how aggressive the initial loosening of policy should be and how rapidly central banks should seek to return policy to its preshock stance.

In this respect, climate-induced shocks do not qualitatively alter central banks' approach to monetary policy. However, as climate-related shocks are often highly location specific, monetary policy, while necessary in aggregate, is often a very blunt tool to address immediate stabilization needs. Closer policy coordination with fiscal authorities that are able to deploy targeted responses thus becomes an essential element of the broader monetary-fiscal policy response to climate-related shocks.

What is likely to be different, however, is as the effects of global climate change become ever more frequent and more material, both in their own right and by amplifying existing sources of price volatility in agriculture and elsewhere, the policy challenge facing central banks becomes quantitatively more demanding. There has, to date, been much less analysis of these developments and how the broader class of environment-related risks impact the conduct of monetary policy. Three key parameters of monetary frameworks need to be revisited. First, at a fundamental level, for example, central banks need to take a view on whether, over the medium term, climate change and associated responses to it are likely to alter the long-run equilibrium real or natural rate of interest. This rate, which is ultimately governed by the long-run savings and investment balance, is the anchor around which a monetary framework is built. Conventional wisdom in the first quarter of this century anticipated the global natural rate to decline, partly reflecting aging populations. But recent analysis suggests that climate change works in the opposite direction and may be sufficiently strong to dominate demographic forces (Kara & Thakoor 2022). Second, just as a rising natural rate of interest may require recalibration of the monetary policy framework, so too may the prospect of the increased volatility of agricultural prices. One critical factor determining countries' choice of inflation target is the underlying degree of structural price volatility in the economy, with higher structural volatility arguing for a higher inflation target to allow more space for relative price adjustments when, for example, nominal wages or prices are sticky. This is why many developing countries maintain higher inflation targets (e.g., around 5% per annum) than their counterparts in the advanced economies, where targets are typically around 2% per annum. If climate change alters the underlying volatility of prices, this may argue for an upward adjustment to the inflation target. Third, the counterpart to this concerns inflation expectations. If increased climate-induced supply-side shocks draw central banks into more frequent accommodations of temporary inflation shocks, there is a risk that price and wage setters in the economy come to anticipate repeated overshoots of the stated inflation target and build this into their expectations and hence weaken the inflation anchor. To counter this, central banks need to continue to invest in their research and communication strategies.

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At present, there is relatively little disagreement that the broad contours of monetary policy frameworks across the economies of SSA remain appropriate to the environments of enhanced climate-related volatility. Thus, we are likely to continue to see central banks build policy regimes around a core commitment to anchor domestic prices, supported in most cases by a commitment to stabilize output around trend. Nonetheless, there remains some active debate on the most effective policy rules to guide monetary policy in this broader context. In their work on monetary policy in small open disaster-prone economies, Cantelmo et al. (2022) defend the use of conventional flexible inflation-targeting rules that place weight on both output and inflation while maintaining a broadly floating exchange rate, as these provide for temporary deviations from the inflation target in response to extreme weather and natural disaster shocks. They argue that this regime protects welfare better than a range of alternative policy rules, including strict inflation targeting and those based on more aggressive exchange rate targeting. On the other hand, McKibbin et al. (2020) advocate for a resurrection of a nominal income targeting approach, which, they argue, is much more attuned to managing the essential trade-off between inflation and output stabilization that arises in the face of supply-side shocks. Nominal income targeting has the property that, while the policy rule induces an equivalent response to demand shocks as a conventional inflation targeting rule, it responds to the net effect of positive inflation and negative output effects generated by aggregate supply shocks. These two contrasting policy definition approaches illustrate the need for further research and highlight the continued uncertainty surrounding monetary policy operations under increased frequency and/or intensity of environment-related risks. These uncertainties and corresponding research needs are compounded in SSA by shallow markets limiting the effectiveness of monetary policy (Adam et al. 2018) and the modelling constraints outlined in the section below on stress tests.

4. FINANCIAL SECTOR REGULATION, MARKET DEVELOPMENT, AND FINANCIAL FLOWS

In this section, we focus on the implications of climate change on the financial stability leg of central banks' mandates. The extent to which central banks are positioned to manage sustainable transformations is disputed in the literature, given the explicit and implicit variations of their financial stability mandate across jurisdictions (Baer et al. 2021, Dikau & Volz 2021, Arseneau & Osada 2023; see Oman et al. 2022 for an overview). However, the lack of consideration of environment-related risks across the corporate and financial sectors suggests a systemic buildup of unaccounted risk akin to the drivers of the 2008 financial crash, referred to as the green swan risks (Bolton et al. 2020, Svartzman et al. 2021a). This makes a central bank's responsibility for financial stability a compelling policy space for action.

Supervisory policy interventions within this mandate have already been introduced. More than 18 central banks worldwide have carried out climate stress tests, covering jurisdictions on all continents, and many more are considering improved disclosure (E-axes Forum 2024). Other micro- and macroprudential policy interventions have been designed to address this buildup of systemic risk and are under consideration, including sustainable-adjusted capital requirements (Dafermos & Nikolaidi 2021), lending limits, and liquidity ratios (D'Orazio & Popoyan 2019). Several micro- and macroprudential policy measures are already being implemented by central banks and regulators including green capital requirements in Hungary, credit guidance in India (E-Axes 2024), and the greening of collateral frameworks and asset purchasing programs as seen in China and the United Kingdom (e.g., Diluiso et al. 2021, McConnell et al. 2022, Aloui et al. 2023, E-axes Forum 2024).

These innovative but unconventional policy actions have attracted criticism that they violate the market neutrality principle lying at the heart of most central banks' mandates (e.g., Cochrane

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2020, Weidman 2020) and, as such, political economy constraints have meant not all central banks have moved in this direction. Across SSA, the focus of central banks' measures has remained on microprudential surveillance, regulation, and their role as lenders-of-last-resort instead of macroprudential measures, indicating scope for further development. Nonetheless, the large and growing membership of the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), including 14 central banks from SSA, indicates a commitment to engage on these issues. Indeed, across much of SSA, these moves are consistent with central banks' implicit developmental role that extends beyond their core mandate (Englama et al. 2016). For example, the Central Bank of Kenya has provided alternative investment vehicles to deepen domestic capital markets and also facilitated digital innovations targeting financially underserved populations. Actors in SSA will face their own unique challenges in managing sustainable transitions at the national and regional levels, but there are also common opportunities.

4.1. Maintaining Financial Stability Through Regulation

This section highlights three instruments regulators in SSA can leverage to maintain financial stability in the face of climate change: stress testing, disclosure, and investment taxonomies.

4.1.1. Stress testing. Stress testing via scenario analysis is a key tool used by central banks to manage risks as part of financial sector surveillance and regulation. As of November 2022, 35 countries had undertaken climate scenario exercises, with a similar number underway. In most cases, the central aim of such activities is to raise awareness and develop capabilities across the financial sector and central banks (FSB-NGFS 2022). The main purpose of scenario analysis to date has been macroprudential (assessing risks to the financial system as a whole) and microprudential (risks to individual financial institutions). Exercises have focused on transition and physical risks.

Very few central banks in SSA have conducted such assessments for environment-related risks to date. South Africa initiated its first climate stress test in March 2024, although a smaller climate risk component was added to its 2023/2024 macroprudential test of insurers, and climate risks have already been integrated into its common scenario stress test (SARB 2023). The 2022 Financial System Stability Assessment for the West African Economic and Monetary Union (WAEMU) included climate change (IMF 2022b) and concluded that WAEMU countries, particularly those in the Sahel region, are highly exposed to climate change. Importantly, they concluded that less than one-third of banks consider themselves capable of identifying assets that are directly exposed to climate risks. Elsewhere, the Bank of Mauritius and the Central Bank of Kenya have issued guidance to financial institutions on how to carry out stress tests and scenario analysis (CBK 2021, BoM 2022) but are yet to carry out their own exercises.

An important challenge facing central banks and governments in SSA is the identification of relevant scenarios. Forward-looking assessment approaches are crucial to adequately account for the connections between financial and environmental systems, given the lack of historical precedence for environment-related risks. Scenarios map out different futures of environment-related risks, policies, technological developments, macrofinancial trends, and behavioral changes that may influence the development of economies. These multiple plausible futures are then used to assess the sensitivity of regions, institutions, sectors, or economies to specific scenarios.

Most of the scenarios used by central banks globally to date, however, are based on those developed by the NGFS. The NGFS scenarios use a consistent methodology globally, bringing advantages in simplicity and comparability (including reducing the regulatory burden on firms operating across multiple jurisdictions), but with the disadvantage of resulting in scenarios that miss potentially important national or regional characteristics. For this reason, global scenarios are often applied with some modifications to meet the needs of specific jurisdictions. Several

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authors have pointed out challenges with the NGFS scenarios (Fiedler et al. 2021, Baer et al. 2023, IFA 2023, Ranger et al. 2023), including a poor representation of shocks and tail-risks and an overreliance on integrated assessment models (IAMs). Research institutions, financial institutions, and authorities themselves have noted that these deficiencies mean that, while current scenarios are useful, they could lead to a systematic underestimation of risk (FSB-NGFS 2022, Ranger et al. 2023).

For the SSA context, these risks are particularly salient. The IAMs on which NGFS scenarios are built have been argued to present an incomplete picture of the impacts of climate change (Farmer et al. 2015), including missing catastrophic weather shocks, such as droughts and floods and other tipping points and nonlinearities that are particularly important for SSA (Stern 2016). In addition, several phenomena induced by climate change such as global migration, crop yield–related shocks, and potential energy disruptions related to hydropower water shortages are not explicitly included in physical climate risk estimates of the NGFS. SSA economies can be particularly susceptible to global trade and supply shocks, which are also not represented (Aghion et al. 2019). The scenarios also do not capture the potential destabilizing responses to changing physical risks; for example, the potential for rapid adjustments in asset valuations in coastal areas as real estate investors perceive growing risks related to climate change, or changes in the provision of insurance (Keys & Mulder 2020, Kyum Kim & Peiser 2020). Some promising advances tailoring IAMs to the structural characteristics of SSA economies have been made (see, for example, the modeling suite described in Arndt & Tarp 2015), but more work needs to be done in this area.

Another key drawback of scenarios used to date for the SSA context is their lack of consideration of other environment-related financial risks. Many economies in SSA boast large contributions from the agricultural sector, which is one of the most exposed sectors to nature-related risks, as well as climate risks. Some important advances have been made recently on integrating nature into scenario analysis (see Ranger et al. 2023, Ranger & Oliver 2024), but additional work is needed to fully adjust these to the SSA context. Moreover, relevant scenarios for SSA should consider international transition risks from climate and nature.

4.1.2. Disclosure. Corporate disclosures on environment-related financial risks form the basis for the pricing and management of risks, both internally for the companies making the disclosures and externally for investors, lenders and others with financial exposures to those companies (TCFD 2017). Initiatives, such as the Taskforce on Climate-Related Financial Disclosures (TCFD) and the Task Force for Nature-Related Financial Disclosures (TNFD), have been established to standardize the volume and quality of corporate disclosures (Christensen et al. 2021). In many high-income countries, TCFD has already been implemented into national policy frameworks.

However, critics argue that the overemphasis on disclosure in sustainable finance policy discussions relies on the efficient market hypothesis, wherein financial actors adjust their behavior once sufficient information is available to factor into decision-making (Christophers 2017, Ameli et al. 2019). This relies on the assumption that information disclosed is decision-useful. Indeed, one strand of the literature is increasingly turning to automated methodologies to make sense of the swathes of unstructured nonpecuniary information being disclosed by firms currently (e.g., Bingler et al. 2024, Spacey Martín et al. 2024). While these criticisms are valid, disclosure is still a necessary step in being able to make more informed management decisions on environment-related financial risks (Goldstein et al. 2022, Ilhan et al. 2023). Although there is little empirical evidence to suggest that improved risk information is leading to better decision-making, the information made available through disclosure, provided it is of sufficient quality, has the potential to inform targeted policy interventions by central banks and government.

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To date, several countries in SSA have released guidance for voluntary sustainability disclosure, but there are no mandatory policies to date. Some countries, such as Nigeria, Kenya, and South Africa, are considering developing mandatory disclosure requirements (IFRS Found. 2024). Others have not outlined this as a priority, suggesting a lack of capacity or prioritization in governments and firms. However, reliable sustainability reporting can provide access to nascent sustainable finance flows, thus presenting an opportunity to leverage new forms of capital. The International Financial Reporting Standards (IFRS) Foundation and African Development Bank signed an agreement to build capacity in firms and regulators in effective sustainability reporting earlier this year; more initiatives are needed to challenge this capacity gap. Central banks and their networks can be key actors in this.

4.1.3. Investment taxonomies. An important tool to enhance disclosures are sustainable investment taxonomies. In classifying what economic activities constitute sustainable investment, taxonomies embedded in legislation serve as cornerstones of sustainable finance policy architecture, both in enhancing disclosure and in mobilizing sustainable investment. Interoperable taxonomies can also play an important role in aligning market expectations and thus mobilizing investment. Across SSA, four investment taxonomies are being developed (Ghana, Kenya, Rwanda, and Senegal), and one has already been launched (South Africa) (RSA Natl. Treas. Dep. 2022, C&C 2023, CBK 2024, Rep. Ghana Minist. Finance 2024). When tailored to national contexts, these frameworks provide clarity to the market on locally sustainable activities and can serve to signal where market opportunities lie (Schütze & Stede 2024). They can also help structure information flows arising from disclosure and used in stress tests. It is necessary, however, to ensure that taxonomies and associated disclosure regulations are aligned across jurisdictions to avoid duplication of the regulatory and reporting burden, which may act as a disincentive to investment. Interoperability is, therefore, crucial to avoid investment barriers (should taxonomies be implemented) or to encourage adoption—a lesson being learned in South Africa currently (Lötters-Viehof et al. 2023). Although the South Africa taxonomy was explicitly developed to align with the EU Sustainable Investment Taxonomy, the EU does not recognize the equivalence of the two respective taxonomies (Hilbrich et al. 2023). Common frameworks have been developed between the EU and China and between Latin American countries; however, no such frameworks exist with countries in SSA. This presents a dual opportunity for regulators to form common taxonomies either within SSA or between SSA and other jurisdictions.

4.2. Maintaining Financial Stability: Broader Market Developments

The second element of central banks' financial stability and market regulation mandate reflects the broader role that many SAA central banks have assumed in seeking to deepen local capital markets. To this end, central banks may trade corporate bonds, improve the regulatory structures for more complex financial instruments, including forward contracts and other derivative markets, and support market participation by a wider range of nonbank financial institutions, including insurance companies. In recent years, these initiatives have been accelerated—and increasingly framed—by two important developments, both of which have drawn central banks into new spheres of engagement.

The first development is the emergence of systems of climate risk insurance aimed at mitigating the fiscal and financial risks of climate- and nature-related shocks across SSA. Insurance coverage varies significantly from country to country, but even in the most advanced economies (e.g., Ghana, Nigeria, Kenya, South Africa), coverage is extremely low given countries' exposure to physical climate- and nature-related hazards. For example, only 7% of losses incurred from Cyclone Idai in Mozambique, Malawi, and Zimbabwe in 2019 were insured (Swiss Re Group

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2019). The development of robust insurance markets is a priority, with public-private facilities and regional risk-pooling facilities seen as key institutions for supporting the development of private markets. Though still at an early stage, developments in this area are promising. For example, the African Union's donor-funded African Risk Capacity (ARC) Group provides governments with financial and technical support to manage the fiscal implications of natural disasters. At the same time, a range of climate risk facilities are emerging, including the Africa Climate Risk Insurance Facility for Adaptation (ACRIFA) from the African Development Bank, as well as private-sector market initiatives [e.g., the proposed African Climate Risk Facility, led by 85 African-based insurers (Willard 2022)].

The second development relates to the range of global green-finance-led activities and initiatives aimed at strengthening climate-oriented and environmental, social, and governance (ESG)-oriented investment toward Africa (AfDB 2021). In 2021, for example, the Glasgow Financial Alliance for Net Zero (GFANZ), a network of more than 250 financial institutions, established a hub in Africa to support the mobilization of international resources into Africa. In 2024, the European Commission's High-Level Expert Group on Scaling Sustainable Finance in Low- and Middle-Income Economies published its initial recommendations, among which was a recommendation to build stronger public-private collaboration platforms to mobilize investment, such as the Climate Finance Leadership Initiatives (CFLIs) and Just Economic Transition Partnerships (JETPs). It also proposed new facilities to manage currency risks, provide technical assistance to support the development of sustainable financial markets, deepen capital markets, and support the issuance of green and sustainability-linked bonds, including through the use of guarantees (Eur. Comm. 2024). The African Development Bank has also launched several major initiatives to support the development of green financial markets, including through its Sustainable Bond Program exploration of a Green Bank for Africa and capacity-building initiatives (AfDB 2024). Central banks in SSA, as well as other public actors, have been drawn into these initiatives given the overlap with their mandates and their technical leadership locally.

Both developments present an opportunity for SSA central banks to enhance their ongoing initiatives to deepen the capacity of domestic capital markets. These partnerships also need to be leveraged to integrate SSA central banks more closely in the development of consistent global disclosure requirements, regulations or transition plan requirements, for example. The NGFS in June 2023 had its first regional outreach session hosted by the National Bank of Rwanda for NGFS members locally to be introduced to the work program. Though important, these types of engagements need to be more consistent and include stronger technical assistance components. Central banks should, therefore, use these and other networks (e.g., International Platform on Sustainable Finance or the G20 Sustainable Finance Working Group) to ensure continued policy relevance and that adequate support is received.

5. SUMMARY OF FINDINGS AND RECOMMENDATIONS

The physical, environmental, and economic changes being wrought by climate change and environmental degradation are profound and demand action from a whole array of national and international actors, public and private. This review has sought to identify the principal challenges facing SSA central banks and financial regulators as they in turn seek to identify and shape their role in this new environment. While the challenges are very substantial, opportunities and benefits are also within reach. The greening of the financial system at large offers the prospect of greater resilience to climate-induced economic volatility while national and international cooperation can help unlock substantial public and private financial flows required to support a green transition and to minimize the costs of adaptation and mitigation.

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Perhaps the clearest finding of this review is that despite the explosion of work on these issues from many quarters, the evidence base on which central banks can reliably draw is highly fragmented and lacks a solid foundation of peer-reviewed evidence on the implications of environment-related risks for central banks and financial sector regulators in SSA. The literature on the physical risks posed by climate change to countries in SSA is best developed. However, both here and across the broader central bank mandate encompassing supervision, monetary policy, debt management, and financial market development, the lessons from the literature remain partial at best and often quite generic. The evolving geopolitics of climate action creates additional challenges by adding policy uncertainty, increasing the transition risks substantially.

There is a rich program of research and translation required to help SSA central banks deliver on their mandates in the climate-change-affected environments they operate. We have suggested that this spans several key areas, including (*a*) improvement and standardization of financial information and their consistent application in the development of scenarios, (*b*) a corresponding coordinated approach to climate-risk stress testing and to the development of green taxonomies, and (*c*) the further understanding of the transmission mechanism of monetary policy in response to increased acute and chronic climate-related risks and volatility.

In summary, we find that, without action, the risks posed by climate change outweigh the opportunities. To fulfil their mandates, SSA's central banks are obliged to react; however, the paucity of peer-reviewed evidence hinders the development and execution of appropriate responses. Preparedness is crucial if actions by SSA central banks are to play their part in shifting the balance toward managing risks and grasping opportunities.

DISCLOSURE STATEMENT

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