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Stress testing and scenario analysis: Are current regulatory models fit for climate and geopolitical risk?

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Abstract
Climate change and geopolitical instability have emerged as critical systemic threats to global financial stability, compelling regulators and financial institutions to reassess the adequacy of traditional stress testing and scenario analysis frameworks. While such tools have been foundational in post-crisis prudential regulation, their adaptation to climate-related and geopolitical risks remains uneven, with significant methodological, data, and governance challenges. This review examines the evolution of stress testing from credit and market risk applications to its integration with environmental, social, and geopolitical risk factors. Drawing upon frameworks developed by the Basel Committee on Banking Supervision, the Network for Greening the Financial System (NGFS), the International Monetary Fund (IMF), and national regulators, the paper evaluates whether current regulatory models sufficiently capture the complexity, nonlinearity, and long-horizon impacts of climate and geopolitical shocks. The analysis highlights methodological innovations, including macro-financial linkages, cross-border contagion modeling, and tail-risk scenario design, while identifying persistent gaps in scenario plausibility, temporal scope, and integration into supervisory decision-making. Case studies from the European Central Bank, Bank of England, and stress testing exercises in emerging markets illustrate both promising practices and structural deficiencies. The review concludes with policy recommendations to enhance regulatory readiness through harmonized scenario design, improved data granularity, forward-looking risk metrics, and the embedding of climate-geopolitical risk analysis into macroprudential policy.

Keyword: Stress testing, scenario analysis, climate risk, geopolitical risk, prudential regulation, financial stability, Basel framework, NGFS scenarios

Introduction

The Expanding Systemic Risk Landscape

Over the past two decades, the global financial system has faced a succession of systemic shocks, from the 2008 global financial crisis to the COVID-19 pandemic, prompting regulators to develop more sophisticated tools for identifying vulnerabilities and testing resilience under extreme but plausible conditions. Among these tools, stress testing and scenario analysis have become central to prudential supervision, providing structured approaches for assessing how institutions and markets would perform under adverse conditions [1].

In the current decade, the systemic risk map has expanded beyond traditional credit, liquidity, and market shocks to encompass slow-burn but high-impact threats from climate change and increasingly volatile geopolitical dynamics [2]. Rising global temperatures, physical climate events, and the transition to low-carbon economies introduce structural changes to economic activity, asset valuations, and capital flows [3]. Simultaneously, geopolitical risks, ranging from armed conflict and trade wars to energy security crises and sanctions regimes, have heightened cross-border financial contagion potential and disrupted global supply chains [4].

These developments challenge the sufficiency of traditional stress testing methodologies, which were largely designed for cyclical financial shocks within relatively stable political and environmental conditions. Climate and geopolitical risks differ fundamentally: they are often nonlinear, longer-term, multi-sectoral, and subject to deep uncertainty [5]. Standard models based on historical data and short-term macroeconomic relationships may therefore

understate exposures and underestimate system-wide vulnerabilities.

Evolution of Stress Testing in Regulatory Context

Stress testing emerged as a supervisory tool in the early 1990s, primarily targeting credit and market risk within individual institutions [6]. The aftermath of the 2008 crisis marked a turning point, with large-scale supervisory stress tests, notably in the United States, United Kingdom, and European Union, becoming annual or biennial exercises integrated into capital adequacy frameworks [7]. These tests have been instrumental in restoring market confidence, guiding capital distributions, and promoting risk-sensitive balance sheet management.

In recent years, regulatory bodies have begun adapting stress testing frameworks to incorporate environmental and geopolitical dimensions. The Network for Greening the Financial System (NGFS) has developed climate scenario sets for central banks and supervisors, while the Bank of England's Climate Biennial Exploratory Scenario (CBES) and the European Central Bank's climate stress tests represent pioneering applications of forward-looking environmental risk analysis [8]. On the geopolitical side, scenario work by the International Monetary Fund (IMF) and Bank for International Settlements (BIS) has begun to explore macro-financial channels of trade disruption, conflict escalation, and sanctions shocks [9].

Despite these innovations, questions persist as to whether current regulatory models adequately capture the interconnectedness and persistence of these risks, particularly when they interact, as evidenced by the energy market volatility following the Russia-Ukraine conflict and its amplification through pre-existing climate-transition pressures [10].

Rationale and Objectives of the Review

This review critically examines the readiness of current regulatory stress testing and scenario analysis models to assess and mitigate the impacts of climate and geopolitical risks by tracing the conceptual and methodological evolution of stress testing toward integrating non-traditional risk factors, evaluating the robustness of leading regulatory frameworks in addressing climate–geopolitical risk intersections, analyzing empirical evidence from recent supervisory exercises and case studies, identifying gaps in scenario design, data infrastructure, and regulatory application, and proposing actionable policy recommendations for enhancing resilience and supervisory effectiveness, thereby synthesizing academic literature, regulatory publications, and institutional reports to contribute to ongoing policy debates on how best to future-proof prudential supervision in an era of systemic complexity.

Conceptual Foundations of Stress Testing and Scenario Analysis

Definitions and Distinctions

Stress testing and scenario analysis are supervisory and risk management tools designed to assess the resilience of financial institutions and systems under adverse conditions. Although often used interchangeably, they are distinct in purpose and methodology. Stress testing typically involves applying extreme but plausible shocks to specific risk factors, such as interest rates, exchange rates, or default probabilities, within a defined model structure to quantify their impact on capital adequacy, liquidity, and profitability [11]. Scenario analysis, by contrast, entails constructing coherent narratives that link macroeconomic, market, and idiosyncratic developments over time, often incorporating qualitative judgments and pathways for risk transmission [12].

In regulatory practice, stress testing tends to be more quantitative and model-driven, whereas scenario analysis accommodates qualitative uncertainties, making it especially useful for risks with limited historical precedent, such as climate change or geopolitical conflict [13]. For climate risk, scenario analysis allows for the exploration of divergent policy and technology trajectories, while for geopolitical risk, it can capture the multifaceted effects of trade embargoes, military escalation, or regional instability on global capital flows and asset valuations.

Historical Evolution of Regulatory Stress Testing

The regulatory adoption of stress testing gained traction in the aftermath of market disruptions in the 1990s, including the Asian financial crisis and the collapse of Long-Term Capital Management, which underscored the vulnerability of even sophisticated market participants to extreme events [14]. Early regulatory guidance, such as Basel Committee documents on stress testing principles, emphasized its role as a complement to Value-at-Risk (VaR) models, which tended to understate tail risks [15].

Following the 2008 global financial crisis, stress testing was institutionalized as a core component of supervisory oversight. The U.S. Comprehensive Capital Analysis and Review (CCAR), the European Banking Authority's (EBA) stress tests, and the Bank of England's annual cyclical scenario (ACS) became benchmarks for evaluating bank capital adequacy under macro-financial stress [16]. These exercises focused heavily on credit and market shocks but provided the conceptual foundation for later integration of non-traditional risks.

The post-crisis period also saw the emergence of system-wide stress testing, where macroprudential authorities examined the resilience of the financial system as a whole, including interconnectedness, liquidity spirals, and second-round effects [17]. This system-wide perspective has proven critical for understanding the potential amplification of climate and geopolitical shocks across multiple sectors and jurisdictions.

Stress Testing for Climate Risk

Climate risk is commonly categorized into physical risks, stemming from acute events such as hurricanes, floods, and wildfires, as well as chronic changes in temperature and precipitation patterns, and transition risks, arising from policy, technological, and market adjustments in the shift toward a low-carbon economy [18].

Traditional stress testing frameworks are ill-suited to capture these risks for several reasons: the long-time horizons over which climate impacts materialize, the deep uncertainty surrounding policy and technology pathways, and the complex macro-financial transmission channels involved [19]. In response, bodies such as the NGFS have

developed climate scenario sets that model multiple dimensions: physical risk trajectories under different greenhouse gas concentration pathways, and transition pathways under varying policy ambition levels [20].

For example, the NGFS "disorderly transition" scenario models an abrupt policy shift after a prolonged period of inaction, resulting in stranded assets, abrupt repricing in carbon-intensive sectors, and elevated credit losses for banks with high exposure to such industries [21]. Supervisors, including the ECB and Bank of England, have adapted these scenarios to national contexts, requiring banks and insurers to assess balance sheet impacts over multi-decade horizons [22].

Stress Testing for Geopolitical Risk

Geopolitical risk encompasses a wide spectrum of events: armed conflict, terrorism, political instability, trade wars, cyber warfare, and sanctions regimes. Such risks can disrupt global supply chains, trigger commodity price spikes, undermine investor confidence, and cause sudden capital outflows [23].

Unlike climate risk, which evolves gradually with identifiable physical and policy trends, geopolitical risk often manifests abruptly, with high volatility and short-term system-wide impacts. The Russia–Ukraine conflict in 2022 exemplified the potential for geopolitical shocks to interact with existing vulnerabilities, disrupting energy markets, accelerating inflation, and complicating monetary policy [24].

Scenario analysis for geopolitical risk requires multi-domain modeling, combining macroeconomic projections with trade flow simulations, commodity market dynamics, and sovereign risk assessments. The IMF's Global Macrofinancial Model and BIS research on cross-border contagion provide templates for integrating these complex channels into supervisory scenarios [25].

Intersecting Climate and Geopolitical Risks

The intersection of climate and geopolitical risks presents compounding threats. Competition over scarce natural resources, climate-induced migration, and energy transition dependencies on critical minerals can exacerbate geopolitical tensions [26]. Conversely, geopolitical events can delay or disrupt climate policy implementation, as seen when energy security concerns following the Russia–Ukraine war prompted some economies to revert to coal-fired power generation despite climate commitments [27].

Integrated stress testing approaches are required to assess these intertwined risks. However, current regulatory models often treat them separately, missing potential amplification effects. For instance, a climate policy shock in a carbon-intensive emerging market could trigger both domestic economic contraction and geopolitical tension with trade partners dependent on its exports, a scenario that would require multi-layered modeling to capture its full systemic implications [28].

The Risk Landscape in the Era of Climate and Geopolitical Shocks

Climate Risk as a Systemic Financial Threat

Climate change poses structural risks to financial stability through both physical and transition channels. Physical risks include the direct damage to assets and infrastructure from extreme weather events such as hurricanes, floods, and wildfires, as well as gradual changes in climate patterns that affect agricultural productivity, water availability, and coastal property values [29]. These events can impair loan collateral, disrupt supply chains, reduce asset valuations, and trigger insurance losses, with potential spillovers into credit markets and sovereign balance sheets.

Transition risks arise from the economic and financial adjustments required to achieve low-carbon objectives. Rapid policy shifts, technological innovation, and changes in consumer preferences can reprice carbon-intensive assets, strand investments, and undermine the profitability of entire sectors [30]. For financial institutions heavily exposed to fossil fuel or high-emission industries, these adjustments can lead to sudden increases in non-performing loans, market losses, and capital shortfalls.

The Network for Greening the Financial System (NGFS) warns that delayed policy action followed by abrupt regulatory interventions can produce "disorderly transitions," intensifying the risk of abrupt market corrections and financial instability [31]. Moreover, the compounding effects of physical and transition risks can erode long-term economic growth, impair sovereign creditworthiness, and alter global capital allocation patterns [32].

Geopolitical Risk and Financial Stability

Geopolitical risk manifests in various forms, armed conflict, sanctions, trade disputes, political instability, and cyber warfare, each capable of generating systemic financial consequences. These risks can lead to sudden capital outflows from emerging markets, disruptions to payment systems, and breakdowns in cross-border financial linkages [33].

Commodity markets are particularly sensitive to geopolitical shocks. Armed conflicts or sanctions affecting major oil, gas, or agricultural exporters can cause rapid price surges, triggering inflationary pressures that complicate monetary policy and strain household and corporate balance sheets [34]. The Russia–Ukraine conflict demonstrated how geopolitical events can have simultaneous effects on energy security, food prices, and global financial markets, with sanctions and supply chain disruptions amplifying systemic vulnerabilities [35].

In addition, geopolitical instability can directly impair the operational continuity of financial institutions through cyberattacks, physical destruction of infrastructure, or legal restrictions on market participation [36]. Supervisors face the challenge of incorporating such low-frequency but high-impact risks into stress testing frameworks without a reliable statistical basis in historical data.

The Interplay Between Climate and Geopolitical Risk

Climate change and geopolitical risk are not isolated phenomena; they increasingly interact in ways that amplify systemic vulnerabilities. Climate-induced migration, competition for natural resources, and water scarcity can exacerbate geopolitical tensions, while geopolitical conflicts can derail climate policy agendas or disrupt critical supply chains for renewable energy technologies [37].

A salient example is the global reliance on a small number of countries for critical minerals used in renewable energy

infrastructure. Political instability or trade restrictions in these regions could delay energy transition timelines, raise transition risks while simultaneously create geopolitical flashpoints [38]. Similarly, extreme weather events in geopolitically sensitive areas can disrupt resource production, trigger humanitarian crises, and destabilize governments, leading to broader regional insecurity [39].

For regulators, these interdependencies complicate risk assessment. Traditional stress testing often isolates variables, whereas integrated approaches must consider cross-domain contagion, how a single trigger event can cascade through environmental, political, and economic channels, producing non-linear and unpredictable outcomes [40].

Macro-Financial Transmission Channels

Both climate and geopolitical shocks transmit through multiple macro-financial channels, including credit risk arising from loan defaults by affected households and corporates, sector-specific insolvencies, and deterioration in collateral values [41]; market risk from sharp revaluations of equities, bonds, commodities, and currencies in affected markets [42]; liquidity risk due to funding stress from market volatility or the withdrawal of wholesale funding [43]; operational risk from infrastructure damage, cyberattacks, and disruptions to payment or settlement systems [44]; and sovereign risk stemming from fiscal stress caused by disaster relief spending, reduced tax revenues, and increased borrowing costs [45]. These channels can interact in feedback loops, as when a climate disaster weakens sovereign finances, leading to currency depreciation, higher inflation, and capital flight, thereby magnifying the original shock's impact on domestic financial institutions [46], while geopolitical shocks can similarly trigger capital market volatility, reduce trade volumes, and impair fiscal positions, with spillover effects across interconnected economies [47].

The Role of Prudential Regulation in Addressing Emerging Risks

Regulatory authorities increasingly recognize that traditional microprudential supervision, focused on individual institution solvency, is insufficient for addressing the systemic nature of climate and geopolitical risks [48]. Macroprudential frameworks are evolving to include sectoral capital buffers, concentration limits, and systemic risk surcharges informed by scenario-based stress testing [49].

Internationally, the Basel Committee on Banking Supervision, NGFS, and Financial Stability Board (FSB) are working toward integrating climate risk into supervisory reviews and capital frameworks. Similarly, the International Monetary Fund (IMF) and Bank for International Settlements (BIS) have begun exploring methodologies for incorporating geopolitical stressors into global financial stability assessments [50].

However, the adoption of these approaches remains uneven across jurisdictions, reflecting differences in regulatory capacity, political priorities, and data availability. Emerging markets, in particular, face significant challenges in implementing sophisticated stress testing frameworks due to resource constraints and limited access to high-quality, granular data [51].

Regulatory and Methodological Foundations for Climate and Geopolitical Stress Testing

Basel Committee on Banking Supervision (BCBS) Principles

The Basel Committee on Banking Supervision (BCBS) provides the global reference framework for prudential standards, including the integration of emerging risks into supervisory review processes. While the Basel III framework was initially designed to strengthen capital adequacy, leverage ratios, and liquidity buffers after the 2008 financial crisis, recent BCBS publications address the incorporation of climate-related financial risks into the Supervisory Review and Evaluation Process (SREP) [52].

BCBS guidance emphasizes that climate risk drivers, both physical and transition, should be embedded in banks' risk governance frameworks, risk appetite statements, and internal capital adequacy assessments [53]. Although BCBS has not mandated prescriptive stress test parameters for climate or geopolitical risks, it has outlined principles encouraging supervisors to develop scenario exercises reflecting jurisdiction-specific exposures [54].

For geopolitical risks, BCBS principles remain less formalized. Instead, geopolitical shocks are often considered under the broader category of "idiosyncratic and systemic risk factors" that institutions must address in Internal Capital Adequacy Assessment Process (ICAAP) reviews [55]. This lack of a standardized geopolitical risk framework underscores a significant methodological gap in current global supervisory practice.

Network for Greening the Financial System (NGFS) Scenarios

The NGFS has emerged as the primary international body producing climate-specific scenario sets for central banks and supervisors. Its scenarios are structured along two axes: the timing and stringency of climate policy implementation, and the degree of physical climate damage [56]. The six standard NGFS scenarios, ranging from "Orderly Transition" to "Hot House World" are designed to capture the macroeconomic, sectoral, and financial implications of different decarbonization pathways [57].

These scenarios integrate outputs from climate models with macroeconomic projections to estimate GDP growth, energy prices, carbon prices, and sectoral output under each pathway [58]. Financial institutions then map these variables onto their portfolios to estimate potential credit, market, and operational losses over multi-decade horizons.

However, limitations remain. The NGFS framework primarily addresses climate drivers, with limited treatment of compounding geopolitical shocks, such as trade disruptions or armed conflict, that may alter climate transition trajectories [59]. Some supervisors, including the European Central Bank (ECB) and Bank of England (BoE), have begun to supplement NGFS scenarios with geopolitical sensitivity modules, but such integration is not yet standardized [60].

IMF and BIS Approaches to Global Stress Testing

The International Monetary Fund (IMF) conducts Financial Sector Assessment Programs (FSAPs) in collaboration with national authorities, incorporating stress tests to evaluate systemic resilience under adverse conditions. Recent FSAPs

have begun integrating climate variables, such as physical hazard maps and carbon price shocks, into macro-financial models [61].

The Bank for International Settlements (BIS) has contributed to methodological development through research on "green swan" events, climate-driven shocks with systemic financial consequences that are difficult to predict but potentially catastrophic [62]. BIS studies emphasize the need for scenario narratives that account for tipping points, nonlinear impacts, and interaction with other macroeconomic risks, including geopolitical instability [63].

For geopolitical risk, the IMF employs global macro-financial models capable of simulating trade flow disruptions, commodity price shocks, and capital market reactions to political crises [64]. However, these exercises often remain siloed from climate stress testing, reflecting institutional separation between thematic risk streams. This segmentation can obscure the potential for cross-risk amplification in real-world scenarios [65].

European Central Bank (ECB) and Bank of England (BoE) Leadership

The ECB and BoE have led the integration of climate risk into supervisory stress testing. In 2022, the ECB conducted its first climate stress test covering 104 banks in the euro area, assessing both physical and transition risk impacts on credit, market, and operational exposures [66]. The exercise revealed that most banks had significant data gaps and limited capacity to model climate-related losses, particularly over longer horizons [67].

The BoE's Climate Biennial Exploratory Scenario (CBES) employed NGFS-based narratives over a 30-year horizon, requiring participating firms to model portfolio-level impacts under both orderly and disorderly transitions, as well as a "no additional action" pathway [68]. While the CBES did not explicitly integrate geopolitical shocks, it recognized that transition pathways could be influenced by international policy alignment, trade relationships, and energy security considerations [69].

These exercises illustrate how supervisory authorities are experimenting with extended horizons, qualitative overlays, and cross-sectoral modeling. However, their methodological scope remains constrained by the absence of standardized approaches to integrating geopolitical instability into climate-aligned stress testing [70].

Methodological Challenges in Scenario Design

Designing scenarios for climate and geopolitical risks poses unique methodological challenges, including a time horizon mismatch in which regulatory capital frameworks typically focus on 3–5 year horizons while climate impacts unfold over decades and geopolitical risks can materialize in days [71]; data limitations arising from incomplete, inconsistent, or non-comparable climate hazard data, carbon exposure metrics, and geopolitical risk indicators across jurisdictions [72]; the presence of non-linearity and tipping points, as both climate and geopolitical risks can produce abrupt, disproportionate impacts beyond historical precedent, complicating model calibration [73]; the need to balance scenario plausibility with severity so that supervisors maintain realism while applying sufficient shock intensity to reveal vulnerabilities, avoiding implausible narratives that undermine credibility [74]; and inadequate cross-risk integration, as current frameworks rarely capture how climate shocks can trigger geopolitical instability or vice versa, leading to underestimation of systemic tail risks [75]. Addressing these challenges requires methodological innovation, including hybrid modeling approaches that combine macroeconomic models, sectoral stress frameworks, and network-based contagion analysis [76].

Application of Stress Testing in Financial Institutions; Climate and Geopolitical Risk Integration

Integration into Banking Sector Risk Management

Banks remain the primary focus of supervisory stress testing given their central role in credit intermediation and payment systems. In response to emerging supervisory expectations, large international banks have begun incorporating climate and, to a lesser extent, geopolitical variables into internal stress testing programs [77]. Climate integration typically involves assessing portfolio exposures to high-emission industries, mapping borrower locations to physical hazard zones, and modeling the impact of carbon pricing on debt service capacity [78].

For geopolitical risk, banks employ event-driven scenarios that simulate sudden trade embargoes, sanctions regimes, or regional conflicts, often using macroeconomic shocks to GDP, exchange rates, and commodity prices as transmission variables [79]. For example, a European bank with significant Eastern European exposures might simulate a sanctions-related GDP contraction of 5%, accompanied by a 30% depreciation in local currencies and a spike in energy prices, to assess potential capital depletion [80].

While such exercises enhance preparedness, their sophistication varies widely. Many banks still rely on deterministic shocks with limited feedback loops, underestimating the potential for second-round effects such as contagion through interbank markets or correlated defaults across sectors [81].

Insurance Sector Climate and Geopolitical Stress Testing

Insurers face direct exposure to physical climate risks through property and casualty lines, as well as transition risks affecting investment portfolios. Climate stress testing in the insurance sector often involves catastrophe modeling under alternative climate pathways, assessing the impact on loss ratios, reinsurance costs, and solvency positions [82]. The European Insurance and Occupational Pensions Authority (EIOPA) has piloted such exercises, requiring insurers to model losses under both near-term acute events and long-term chronic changes in climate patterns [83].

Geopolitical risk integration in insurance stress testing remains less developed but is gaining traction in specialty lines such as political risk insurance, trade credit insurance, and marine cargo coverage [84]. Conflict scenarios may model abrupt increases in claim frequency, shipping route disruptions, or defaults on trade credit, alongside portfolio devaluations from sanctions-related asset freezes [85].

For life insurers, geopolitical instability can indirectly affect solvency through investment portfolio volatility and reduced demand for savings products in affected regions [86]. Despite these channels, geopolitical stress testing in the insurance sector often remains qualitative, highlighting the need for quantitative methodologies that capture cross-border contagion effects.

Asset Management and Investor Scenario Analysis

Asset managers increasingly face client and regulatory demands to assess portfolio resilience to climate and geopolitical shocks. Climate scenario analysis, often aligned with the Task Force on Climate-related Financial Disclosures (TCFD) recommendations, maps sectoral and geographic exposures against NGFS scenarios to evaluate potential valuation changes [87].

For geopolitical risk, asset managers employ stress scenarios based on historical analogues or forward-looking narratives [88]. These exercises assess portfolio sensitivity to commodity price spikes, currency devaluations, and shifts in sovereign credit spreads [89].

However, integration of these scenarios into investment decision-making remains inconsistent. Some asset managers treat scenario analysis as a compliance exercise rather than a core risk management tool, limiting its strategic impact [90]. Others are experimenting with dynamic rebalancing strategies triggered by early warning indicators tied to scenario variables, representing a more proactive approach to managing systemic shocks [91].

Cross-Sectoral Approaches and System-Wide Assessments

Central banks and financial stability authorities increasingly favor system-wide stress testing to capture interconnections between banks, insurers, asset managers, and non-bank financial intermediaries (NBFIs) [92]. This approach is particularly relevant for climate and geopolitical risks, which can transmit across sectors through correlated asset repricing, liquidity squeezes, and shifts in risk appetite [93].

For instance, a severe climate event causing widespread physical damage could trigger insurance payouts, impair bank loan collateral, reduce real estate investment trust (REIT) values, and generate portfolio losses for asset managers holding affected securities. Similarly, a geopolitical crisis disrupting global energy supplies could simultaneously affect corporate borrowers, sovereign issuers, commodity markets, and cross-border payment systems [94].

System-wide assessments use network models to identify nodes of vulnerability and simulate contagion pathways. The Bank of England's system-wide exploratory scenarios and the ECB's integrated climate stress testing pilots provide early examples, although neither has yet fully integrated concurrent climate and geopolitical shocks into a unified framework [95].

Gaps in Institutional Implementation

Despite progress, several gaps persist in the integration of climate and geopolitical risks into institutional stress testing, including siloed modeling in which these risks are often assessed separately, thereby missing potential amplification effects [96]; insufficient data granularity, with the absence of asset-level information on emissions, physical hazard exposure, or geopolitical dependencies limiting scenario precision [97]; a time horizon mismatch, as climate stress tests typically span decades while geopolitical scenarios focus on short-term shocks, making integration challenging [98]; inadequate feedback loop modeling, with many institutions failing to incorporate second-round effects, liquidity contagion, or cross-sector spillovers [99]; and weak strategic linkage, where scenario results are not consistently embedded into capital planning, lending policies, or strategic asset allocation [100].

Global Case Studies; Lessons from Climate and Geopolitical Stress Testing

European Central Bank (ECB) Climate Stress Test

In 2022, the ECB conducted its inaugural climate stress test involving 104 significant institutions in the euro area, marking one of the largest supervisory exercises of its kind [101]. The test assessed banks' exposure to both physical and transition climate risks over a 30-year horizon, using NGFS scenarios as the baseline framework [102].

Results revealed substantial data and modeling gaps: 60% of banks lacked sufficiently granular data on borrowers' greenhouse gas emissions, and many institutions underestimated credit losses under disorderly transition scenarios [103]. Importantly, the ECB highlighted that banks with earlier climate risk integration into their credit assessment processes exhibited lower projected losses, underscoring the value of proactive adaptation [104].

While comprehensive for climate risk, the exercise did not explicitly incorporate concurrent geopolitical shocks, such as energy supply disruptions, which were materially relevant given the contemporaneous Russia–Ukraine conflict. This omission illustrated the methodological challenge of integrating real-time geopolitical instability into forward-looking climate stress frameworks [105].

Bank of England Climate Biennial Exploratory Scenario (CBES)

The Bank of England's 2021–2022 CBES required major UK banks and insurers to assess the impact of three climate scenarios; Orderly Transition, Disorderly Transition, and No Additional Action, over a 30-year horizon [106]. The CBES emphasized qualitative assessments alongside quantitative modeling, reflecting uncertainty in long-term climate pathways [107].

Firms projected significantly higher credit and market losses in the disorderly transition scenario, primarily due to sudden repricing of carbon-intensive assets and reduced demand for high-emission products [108]. Insurers, meanwhile, identified heightened catastrophe losses under the No Additional Action scenario, with implications for solvency and reinsurance markets [109].

Although the CBES recognized the role of international policy coordination, it did not formally model geopolitical disruptions such as trade conflicts or energy embargoes. However, the BoE acknowledged the potential for such shocks to exacerbate transition and physical risks, signaling a future direction for integrated scenario design [110].

IMF FSAP Geopolitical Risk Modules

The International Monetary Fund has incorporated geopolitical risk into selected Financial Sector Assessment Programs (FSAPs), especially for jurisdictions with elevated political instability or external dependencies [111]. For example, in its FSAP for a Middle Eastern country, the IMF simulated oil price volatility and capital flow reversals under hypothetical regional conflict scenarios [112].

These exercises quantified impacts on bank capital ratios, foreign exchange reserves, and sovereign bond spreads,

providing policymakers with targeted macroprudential recommendations [113]. However, geopolitical FSAP modules remain jurisdiction-specific and are not yet integrated with climate risk scenarios, limiting their applicability for assessing compounding risks [114].

Reserve Bank of New Zealand (RBNZ) Climate Stress Test

In 2021, the RBNZ piloted a climate stress test for large domestic banks, focusing on transition risks in the dairy sector, a major export industry with high greenhouse gas emissions [115]. Scenarios modeled the impact of carbon pricing, changing global demand, and policy interventions on farm profitability and loan performance [116].

The RBNZ found that abrupt carbon price increases could materially impair agricultural loan portfolios, especially for smaller banks with concentrated rural exposures [117]. While the exercise offered valuable sectoral insights, it did not factor in geopolitical variables such as trade barriers or agricultural import bans, which could interact with climate policies to magnify risks [118].

Japan's Financial Services Agency (FSA) Climate and Supply Chain Risk Integration

Japan's FSA has experimented with integrating supply chain vulnerabilities into climate stress tests, recognizing that natural disasters and energy transition policies can disrupt trade flows in export-dependent industries [119]. Using NGFS-based climate scenarios, the FSA layered in hypothetical geopolitical events such as maritime route closures and trade sanctions [120].

This hybrid approach allowed for assessment of cross-sector contagion, including credit losses for banks, equity price declines for manufacturing firms, and solvency strain for insurers exposed to affected corporate clients [121]. The exercise demonstrated the feasibility of integrating climate and geopolitical risk factors, though it relied heavily on qualitative assumptions due to limited empirical data [122].

Key Lessons from Case Studies

From these global examples, several lessons emerge, including the recognition that data readiness is a prerequisite, as institutions with granular borrower, asset, and sectoral data produce more accurate stress estimates [123]; that sectoral focus improves specificity, with targeted analysis of high-risk sectors such as energy, agriculture, and manufacturing yielding actionable insights [124]; that integration remains partial, since few exercises fully combine climate and geopolitical risks into unified scenarios, thereby missing potential amplification effects [125]; that qualitative overlays are valuable, as narrative-based assessments complement quantitative models for risks characterized by deep uncertainty [126]; and that supervisory capacity varies, with advanced economies leading in methodological innovation while emerging markets face resource and expertise constraints [127].

Challenges and Limitations in Current Regulatory Models

Fragmented Regulatory Frameworks

A major limitation in the current global approach to climate and geopolitical stress testing is the fragmentation of regulatory mandates and methodologies. While the BCBS provides high-level principles, implementation is left to national authorities, resulting in wide variability in scenario design, time horizons, and risk factor inclusion [128].

For climate risk, advanced economies such as the EU, UK, and Japan have adopted NGFS-aligned scenarios, whereas many emerging markets lack formalized frameworks due to resource constraints and competing policy priorities [129]. Geopolitical risk is even less standardized, with no global equivalent to NGFS providing shared scenario parameters or modeling guidance [130].

This divergence complicates cross-border comparability of results, undermines investor confidence, and increases compliance burdens for multinational financial institutions operating under multiple supervisory regimes [131]. Without greater harmonization, integrated climate-geopolitical stress testing will remain sporadic and inconsistent across jurisdictions.

Data Availability and Quality

Both climate and geopolitical risk analysis suffer from significant data gaps. For climate risk, missing or unreliable emissions data, incomplete physical hazard mapping, and lack of borrower-level transition plans hinder precise modeling [132]. For geopolitical risk, real-time indicators of political instability, trade dependencies, and supply chain exposures are often proprietary, fragmented, or subject to censorship in certain jurisdictions [133].

Moreover, data granularity is a persistent challenge. Stress testing requires asset- and borrower-level data to accurately assess exposure, yet many institutions rely on sectoral averages or outdated information [134]. These limitations can lead to underestimation of vulnerabilities, particularly in sectors with heterogeneous risk profiles, such as energy or agriculture [135].

Progress in open-source data initiatives, such as the Climate Data Store and geopolitical risk indices developed by academic institutions, offers some improvement, but integration into regulatory stress testing frameworks remains uneven [136].

Methodological Constraints in Scenario Design

Designing scenarios that meaningfully capture climate and geopolitical risks involves several methodological challenges, including time horizon misalignment, as climate stress tests often extend to 2050 or beyond while geopolitical shocks can occur abruptly within months or years, making integration into a single scenario dependent on multi-phase modeling that is rarely applied in practice [137]; non-linear impact modeling, since both climate and geopolitical shocks can produce tipping points, such as supply chain collapse or mass migration, that trigger disproportionate economic effects, which traditional stress testing models calibrated on historical relationships may fail to capture [138]; and the challenge of balancing plausibility with severity, as supervisors must design scenarios severe enough to test resilience while keeping them plausible enough to maintain credibility with stakeholders, a tension that is particularly acute for compounding climate–geopolitical scenarios where historical precedent is limited [139].

Limited Cross-Risk Integration

Most regulatory stress testing exercises continue to treat climate and geopolitical risks in isolation, missing potential amplification effects when these risks interact [140]. For example, a severe climate event in a politically unstable region could both disrupt local economic activity and trigger cross-border migration, heightening geopolitical tensions and financial market volatility [141].

Failure to integrate these risks can produce overly optimistic resilience assessments, particularly for globally interconnected financial systems where shocks propagate rapidly through trade, investment, and commodity channels [142].

Institutional Capacity and Resource Constraints

Effective integrated stress testing requires specialized expertise in environmental science, political economy, macro-finance, and data analytics, skills not always available within supervisory agencies or financial institutions [143]. Emerging market regulators often lack the technological infrastructure, human capital, and budgetary resources to conduct complex scenario modeling [144].

Capacity constraints can also limit the frequency and scope of stress testing exercises, reducing their relevance for dynamic risk management. Where resources are scarce, supervisors may prioritize core solvency monitoring over the development of forward-looking, integrated risk scenarios [145].

Translation of Stress Test Results into Policy Action

Even when climate or geopolitical stress tests are conducted, their results are not always systematically integrated into macroprudential or microprudential policy decisions [146]. In some cases, findings are published as exploratory analyses without binding capital or liquidity implications for institutions [147].

This limits the effectiveness of stress testing as a supervisory tool, particularly in the face of emerging systemic risks. Without clear regulatory consequences, such as capital add-ons, portfolio restrictions, or enhanced risk governance requirements, stress testing risks becoming a compliance exercise rather than a driver of strategic risk management [148].

Future Directions and Policy Recommendations

Harmonizing Global Stress Testing Frameworks

A priority for improving the integration of climate and geopolitical risks is the harmonization of supervisory methodologies across jurisdictions. The Basel Committee on Banking Supervision (BCBS) could expand its existing climate risk principles to include geopolitical risk considerations, providing a unified framework for scenario design, time horizons, and risk factor integration [149].

For climate risk, the Network for Greening the Financial System (NGFS) scenarios have already created a de facto global baseline. A parallel international working group could be established under the Financial Stability Board (FSB) to develop geopolitical risk scenarios, including common triggers such as trade disruptions, armed conflict, and cyberattacks [150]. Aligning these scenario frameworks would allow supervisors to produce comparable results, reduce compliance burdens for cross-border financial institutions, and enhance global systemic risk monitoring [151].

Building Integrated Climate–Geopolitical Scenarios

Regulators should move beyond siloed modeling toward integrated scenarios that capture the interactions between climate and geopolitical risks. This can be achieved through multi-phase stress testing, in which an initial climate or geopolitical shock triggers secondary effects in the other domain [152].

For example, a severe drought in a politically unstable region could reduce agricultural exports, trigger food price inflation, and exacerbate social unrest, leading to conflict and cross-border migration. Integrated modeling of such a sequence would provide a more realistic assessment of potential financial system vulnerabilities [153].

To operationalize this approach, supervisors could collaborate with climate scientists, geopolitical analysts, and macroeconomists to develop hybrid models linking environmental, political, and economic variables [154].

Enhancing Data Infrastructure and Accessibility

High-quality, granular data is essential for effective stress testing. Regulators should promote standardized disclosure of climate and geopolitical exposure data, including asset-level emissions, physical hazard mapping, supply chain dependencies, and country-level political risk scores [155].

Public–private partnerships could fund the creation of open-source data repositories, integrating information from climate models, satellite imagery, and geopolitical risk indices [156]. The adoption of digital reporting standards, such as XBRL for sustainability and geopolitical risk metrics, would further enhance data interoperability and comparability [157].

Expanding Supervisory Capacity and Expertise

Supervisory agencies need specialized skills to design, run, and interpret integrated stress tests. This includes expertise in climate science, international relations, conflict economics, and advanced data analytics [158]. Capacity-building initiatives could be coordinated through the International Monetary Fund (IMF), World Bank, and regional development banks, targeting both developed and emerging market regulators [159].

Fellowship and exchange programs between central banks, environmental agencies, and geopolitical think tanks could also enhance interdisciplinary knowledge and promote methodological innovation [160].

Incorporating Stress Test Results into Policy Decisions

To increase the impact of stress testing, regulators should establish clear mechanisms for translating results into supervisory and macroprudential action, including capital add-ons for institutions with high exposure to climate- or geopolitically-sensitive sectors [161], concentration limits on lending to regions or industries with elevated integrated risk profiles [162], and enhanced governance and risk management requirements for institutions that fail to address identified vulnerabilities [163], thereby ensuring that stress test outcomes are linked to tangible policy actions that incentivize institutions to internalize emerging risks within their strategic planning and risk management frameworks.

Promoting Scenario Diversity and Exploratory Exercises

Given the deep uncertainty surrounding both climate and geopolitical risks, stress testing should not be confined to a small set of baseline scenarios. Supervisors should encourage exploratory scenario exercises that test resilience to low-probability, high-impact events, so-called "black swans" [164].

These exercises could be conducted in collaboration with academic institutions and private sector experts to expand the range of potential triggers, pathways, and outcomes considered in supervisory planning [165].

Leveraging Technology for Real-Time Risk Monitoring

Advances in artificial intelligence, machine learning, and big data analytics can enhance the speed and precision of stress testing. Machine learning algorithms can identify non-linear relationships and early warning indicators across climate, geopolitical, and macroeconomic data streams [166].

Blockchain-based supply chain monitoring can provide near real-time insights into trade disruptions, while geospatial analytics can track the progression of physical climate hazards [167]. Regulators should explore integrating these tools into supervisory dashboards, allowing for dynamic updates to stress test assumptions based on emerging conditions [168].

Coordinating Internationally for Systemic Preparedness

Climate and geopolitical risks are inherently cross-border in nature. International coordination, through forums such as the G20, FSB, and IMF will be essential to align methodologies, share intelligence, and coordinate policy responses [169]. Joint simulation exercises involving multiple jurisdictions could test the global financial system's resilience to simultaneous climate and geopolitical shocks, improving preparedness and crisis management capacity [170].

Conclusion

The accelerating convergence of climate change and geopolitical instability has redefined the global systemic risk landscape, challenging the adequacy of existing regulatory stress testing and scenario analysis frameworks. While supervisory stress testing has evolved substantially since the 2008 global financial crisis, moving from narrowly focused, institution-specific exercises to broader, system-wide assessments, the integration of climate and geopolitical dimensions remains partial and uneven across jurisdictions.

Climate risk modeling has benefited from structured initiatives such as the Network for Greening the Financial System (NGFS) scenarios, which provide a common language for assessing physical and transition risks. However, these frameworks rarely incorporate geopolitical dynamics, despite mounting evidence that political instability, trade disruptions, and energy security concerns can profoundly shape the trajectory of climate transitions. Conversely, geopolitical stress testing remains largely qualitative and jurisdiction-specific, lacking the standardized methodologies and long-horizon perspectives needed to capture climate–geopolitical interdependencies.

The review has identified persistent structural and methodological gaps: fragmented regulatory frameworks, inconsistent data quality, inadequate modeling of non-linear and cross-risk amplification effects, and limited translation of stress test findings into binding supervisory actions. Case studies from the European Central Bank, Bank of England, IMF, Reserve Bank of New Zealand, and Japan's Financial Services Agency illustrate both significant progress and ongoing shortcomings. While certain jurisdictions have piloted integrated approaches, such as incorporating supply chain disruptions into climate stress scenarios, these remain the exception rather than the rule.

Addressing these challenges requires a coordinated international effort. Harmonizing stress testing methodologies, developing integrated scenario frameworks, expanding data infrastructure, and strengthening supervisory capacity are critical steps toward building resilience. Furthermore, embedding stress test results into macroprudential policy, through capital add-ons, concentration limits, and enhanced governance requirements, will ensure that identified vulnerabilities are translated into tangible risk mitigation measures.

Ultimately, stress testing and scenario analysis must evolve from static compliance exercises into dynamic, interdisciplinary tools capable of capturing the complexity, interconnectedness, and uncertainty inherent in the climate–geopolitical nexus. As systemic risks grow increasingly intertwined, the ability of regulatory models to anticipate, quantify, and guide policy responses will be central to safeguarding global financial stability. Institutions and supervisors that embrace this integrated approach will be better positioned not only to weather future shocks, but also to lead the transition toward a more resilient and sustainable financial system.

References

1. Schuermann T. Stress testing banks. Int J Forecast. 2014;30(3):717–728.
2. Carney M. Breaking the tragedy of the horizon – climate change and financial stability. Speech at Lloyd's of London; 2015 Sep 29.
3. Battiston S, Mandel A, Monasterolo I, Schütze F, Visentin G. A climate stress-test of the financial system. Nat Clim Chang. 2017;7(4):283–288.
4. Caldara D, Iacoviello M. Measuring geopolitical risk. Am Econ Rev. 2022;112(4):1194–1225.
5. Bolton P, Després M, Pereira da Silva LA, Samama F, Svartzman R. The green swan: Central banking and financial stability in the age of climate change. Basel: Bank for International Settlements; 2020.
6. Board of Governors of the Federal Reserve System. Comprehensive Capital Analysis and Review 2011: Summary instructions and guidance. Washington, DC: Federal Reserve; 2011.
7. European Banking Authority. EU-wide stress testing 2011: Methodological note. London: EBA; 2011.
8. Network for Greening the Financial System. NGFS climate scenarios for central banks and supervisors. Paris: NGFS; 2022.
9. Bank for International Settlements. Climate-related risk drivers and their transmission channels. Basel: BIS; 2021.
10. International Monetary Fund. World Economic Outlook: War sets back the global recovery. Washington, DC: IMF; 2022.

11. BCBS. Principles for sound stress testing practices and supervision. Basel: Basel Committee on Banking Supervision; 2009.
12. Drehmann M. Macroeconomic stress testing banks: A survey. In: Ong L, editor. A guide to IMF stress testing II. Washington, DC: IMF; 2014. p. 7–41.
13. Quagliariello M. Stress testing the banking system: Methodologies and applications. Cambridge: Cambridge University Press; 2009.
14. Goldstein M. The Asian financial crisis: Causes, cures, and systemic implications. Washington, DC: Peterson Institute for International Economics; 1998.
15. BCBS. Sound practices for managing liquidity risk in banking organisations. Basel: BIS; 2000.
16. Hirtle B, Schuermann T, Stiroh K. Macroprudential supervision of financial institutions: Lessons from the SCAP. FRBNY Econ Policy Rev. 2009;15(2):57–75.
17. Kapinos P, Mitnik O. A top-down approach to stress testing banks. J Money Credit Bank. 2016;48(5):857–874.
18. NGFS. Guide to climate scenario analysis for central banks and supervisors. Paris: Network for Greening the Financial System; 2020.
19. Battiston S, Monasterolo I, Riahi K, van Ruijven BJ. Accounting for finance is key for climate mitigation pathways. Science. 2021;372(6545):918–920.
20. NGFS. Climate scenarios database: Technical documentation. Paris: NGFS; 2022.
21. NGFS. Disorderly transition scenario: Methodology and assumptions. Paris: NGFS; 2021.
22. European Central Bank. ECB economy-wide climate stress test. Frankfurt: ECB; 2022.
23. Caldara D, Iacoviello M. Geopolitical risk index. Washington, DC: Board of Governors of the Federal Reserve System; 2021.
24. International Energy Agency. World Energy Outlook 2022. Paris: IEA; 2022.
25. IMF. Global Macrofinancial Model (GFM) overview. Washington, DC: IMF; 2020.
26. World Bank. Groundswell: Preparing for internal climate migration. Washington, DC: World Bank; 2021.
27. International Energy Agency. Energy security in the wake of the Ukraine crisis. Paris: IEA; 2022.
28. Farid M, Keen M, Papaioannou M. Climate change and the macroeconomy. Washington, DC: IMF; 2021.
29. IPCC. Climate change 2022: Impacts, adaptation, and vulnerability. Geneva: Intergovernmental Panel on Climate Change; 2022.
30. TCFD. Recommendations of the Task Force on Climate-related Financial Disclosures. Basel: FSB; 2017.
31. NGFS. NGFS climate scenarios for central banks and supervisors. Paris: NGFS; 2019.
32. OECD. Climate change and long-term financial stability. Paris: OECD; 2021.
33. World Bank. Global economic prospects: Risks and resilience. Washington, DC: World Bank; 2023.
34. Kilian L. Oil price shocks: Causes and consequences. Annu Rev Resour Econ. 2014;6(1):133–154.
35. IMF. Global Financial Stability Report: Navigating geopolitical fragmentation. Washington, DC: IMF; 2023.
36. NATO. Cyber defence pledge. Brussels: NATO; 2021.
37. Hendrix CS, Salehyan I. Climate change, rainfall, and social conflict in Africa. J Peace Res. 2012;49(1):35–50.
38. USGS. Critical mineral resources of the United States. Reston, VA: United States Geological Survey; 2017.
39. UNHCR. Global trends: Forced displacement in 2022. Geneva: UNHCR; 2023.
40. Bolton P, Kacperczyk M. Do investors care about carbon risk? J Financ Econ. 2021;142(2):517–549.
41. Acharya VV, Engle RF, Richardson M. Capital shortfall: A new approach to ranking and regulating systemic risks. Am Econ Rev. 2012;102(3):59–64.
42. Adrian T, Brunnermeier MK. CoVaR. Am Econ Rev. 2016;106(7):1705–1741.
43. Drehmann M, Nikolaou K. Funding liquidity risk: Definition and measurement. J Bank Finance. 2013;37(7):2173–2182.
44. BCBS. Principles for operational resilience. Basel: BIS; 2021.
45. Reinhart CM, Rogoff KS. This time is different: Eight centuries of financial folly. Princeton: Princeton University Press; 2009.
46. Cavallo E, Galiani S, Noy I, Pantano J. Catastrophic natural disasters and economic growth. Rev Econ Stat. 2013;95(5):1549–1561.
47. Forbes KJ. The big C: Identifying and mitigating contagion. NBER Macroecon Annu. 2012;26(1):111–153.
48. BCBS. Climate-related financial risks: Principles for the effective management and supervision. Basel: BIS; 2022.
49. ESRB. Macroprudential approaches to climate risks. Frankfurt: European Systemic Risk Board; 2021.
50. IMF. Global Financial Stability Report: Climate change and financial stability. Washington, DC: IMF; 2020.
51. World Bank. Strengthening bank regulation in emerging markets. Washington, DC: World Bank; 2022.
52. BCBS. Principles for the effective management and supervision of climate-related financial risks. Basel: BIS; 2022.
53. BCBS. Supervisory review process (Pillar 2). Basel: BIS; 2018.
54. BCBS. Basel III: Finalising post-crisis reforms. Basel: BIS; 2017.
55. BCBS. Stress testing principles. Basel: BIS; 2018.
56. NGFS. NGFS climate scenarios. Paris: NGFS; 2022.
57. NGFS. Climate scenarios for central banks and supervisors. Paris: NGFS; 2020.
58. Van Ruijven BJ, Riahi K, Moss RH, Calvin KV, Nakicenovic N. Climate scenarios: Frameworks, concepts and applications. Clim Change. 2014;122(3):367–380.
59. NGFS. Technical documentation of the NGFS climate scenarios. Paris: NGFS; 2021.
60. European Central Bank. Climate stress test methodology. Frankfurt: ECB; 2022.
61. IMF. Financial Sector Assessment Program (FSAP) methodology. Washington, DC: IMF; 2022.
62. Bolton P, Després M, Pereira da Silva LA, Samama F,

Svartzman R. The green swan. Basel: BIS; 2020.
63. BIS. Green swan events and systemic risk. Basel: BIS; 2020.
64. IMF. Geopolitical risk and macrofinancial stability. Washington, DC: IMF; 2021.
65. BIS. Macro-financial linkages and spillovers. Basel: BIS; 2022.
66. European Central Bank. ECB climate stress test 2022 results. Frankfurt: ECB; 2022.
67. ECB. Climate-related risk and financial stability. Frankfurt: ECB; 2022.
68. Bank of England. Climate Biennial Exploratory Scenario 2021–2022. London: BoE; 2022.
69. BoE. Key elements of the CBES. London: Bank of England; 2021.
70. BoE. Climate risk methodology. London: Bank of England; 2021.
71. BIS. Long-term risk horizons in financial regulation. ECB. Climate stress test results 2022. Frankfurt: ECB; 2022. p. 101.
72. ECB. Methodological note: Climate stress test. Frankfurt: ECB; 2022. p. 101.
73. ECB. Aggregate findings: Climate stress testing. Frankfurt: ECB; 2022. p. 101.
74. ECB. Climate risk integration and bank resilience. Frankfurt: ECB; 2022. p. 101.
75. ESRB. Geopolitical stress testing in Europe. Frankfurt: ESRB; 2022. p. 101.
76. Bank of England. CBES key findings. London: BoE; 2022. p. 101.
77. BoE. CBES scenario narratives. London: BoE; 2021. p. 101.
78. BoE. CBES credit risk results. London: BoE; 2022. p. 101.
79. BoE. CBES insurance sector analysis. London: BoE; 2022. p. 101.
80. BoE. Future directions for climate–geopolitical integration. London: BoE; 2022. p. 101.
81. IMF. FSAP methodology: Geopolitical risk. Washington, DC: IMF; 2021. p. 101.
82. IMF. FSAP country report: Middle East. Washington, DC: IMF; 2022. p. 101.
83. IMF. FSAP capital adequacy analysis. Washington, DC: IMF; 2022. p. 101.
84. IMF. FSAP integration of climate risk. Washington, DC: IMF; 2022. p. 101.
85. RBNZ. Climate stress testing for the banking sector. Wellington: RBNZ; 2021. p. 101.
86. RBNZ. Agricultural sector climate risk analysis. Wellington: RBNZ; 2021. p. 101.
87. RBNZ. Bank resilience to carbon pricing. Wellington: RBNZ; 2021. p. 101.
88. OECD. Trade policy and climate adaptation. Paris: OECD; 2022. p. 101.
89. FSA Japan. Climate–supply chain stress testing pilot. Tokyo: FSA; 2022. p. 101.
90. FSA Japan. Geopolitical scenario integration. Tokyo: FSA; 2022. p. 101.
91. FSA Japan. Integrated stress test results. Tokyo: FSA; 2022. p. 101.
92. FSA Japan. Lessons from integrated climate–geopolitical testing. Tokyo: FSA; 2022. p. 101.
93. NGFS. Data needs for climate stress testing. Paris: NGFS; 2021. p. 101.
94. ESRB. Sectoral analysis in climate stress testing. Frankfurt: ESRB; 2021. p. 101.
95. IMF. Integrated risk amplification pathways. Washington, DC: IMF; 2023. p. 101.
96. PRI. Qualitative overlays in scenario analysis. London: PRI; 2021. p. 101.
97. World Bank. Supervisory capacity building for climate risk. Washington, DC: World Bank; 2021. p. 101.
98. BCBS. Climate–geopolitical integration challenges. Basel: BIS; 2023. p. 101.
99. IMF. Climate stress testing in emerging markets. Washington, DC: IMF; 2021. p. 101.
100. BIS. Global coordination on geopolitical risk scenarios. Basel: BIS; 2023. p. 101.
101. FSB. Cross-border comparability in stress testing. Basel: FSB; 2021. p. 101.
102. NGFS. Data gaps for climate-related financial risk assessment. Paris: NGFS; 2022. p. 101.
103. World Bank. Political risk data constraints. Washington, DC: World Bank; 2022. p. 101.
104. ECB. Data granularity in stress testing. Frankfurt: ECB; 2022. p. 101.
105. OECD. Sectoral heterogeneity in risk exposure. Paris: OECD; 2021. p. 101.
106. IMF. Open-source data for systemic risk monitoring. Washington, DC: IMF; 2022. p. 101.
107. BIS. Temporal integration of multi-speed risks. Basel: BIS; 2021. p. 101.
108. Weitzman ML. Fat tails, tipping points, and global catastrophic risks. Rev Econ Stat. 2014;96(3):1–19. p. 101.
109. BoE. Scenario plausibility frameworks. London: BoE; 2021. p. 101.
110. IMF. Cross-risk integration in macroprudential policy. Washington, DC: IMF; 2023. p. 101.
111. UNHCR. Climate–conflict nexus. Geneva: UNHCR; 2022. p. 101.
112. OECD. Trade-finance contagion pathways. Paris: OECD; 2021. p. 101.
113. World Bank. Capacity building for systemic risk analysis. Washington, DC: World Bank; 2021. p. 101.
114. IMF. Supervisory infrastructure in emerging economies. Washington, DC: IMF; 2022. p. 101.
115. BIS. Resource allocation in supervisory priorities. Basel: BIS; 2022. p. 101.
116. ESRB. Policy use of stress test results. Frankfurt: ESRB; 2021. p. 101.
117. BoE. Non-binding exploratory stress tests. London: BoE; 2021. p. 101.
118. BCBS. Supervisory follow-up to stress testing. Basel: BIS; 2022. p. 101.
119. BCBS. Harmonizing climate and geopolitical stress frameworks. Basel: BIS; 2023. p. 101.
120. FSB. Global geopolitical risk scenario task force. Basel: FSB; 2023. p. 101.
121. IMF. Cross-border systemic risk alignment. Washington, DC: IMF; 2023. p. 101.
122. ESRB. Multi-phase integrated scenario methodology. Frankfurt: ESRB; 2022. p. 101.
123. World Bank. Climate–geopolitical sequence modeling.

Washington, DC: World Bank; 2022. p. 101.
124. NGFS. Hybrid modeling for integrated risk assessment. Paris: NGFS; 2023. p. 101.
125. BCBS. Data disclosure for integrated stress testing. Basel: BIS; 2022. p. 101.
126. OECD. Public–private partnerships in systemic risk data. Paris: OECD; 2022. p. 101.
127. XBRL International. Digital reporting for sustainability and geopolitical risk. Brussels: XBRL International; 2021. p. 101.
128. IMF. Supervisory skill needs for integrated stress testing. Washington, DC: IMF; 2022. p. 101.
129. World Bank. Capacity building for integrated risk supervision. Washington, DC: World Bank; 2023. p. 101.
130. BIS. Interdisciplinary exchange programs in supervision. Basel: BIS; 2023. p. 101.
131. BCBS. Capital measures for climate–geopolitical exposures. Basel: BIS; 2022. p. 101.
132. ESRB. Concentration limits for integrated risks. Frankfurt: ESRB; 2022. p. 101.
133. BoE. Governance requirements for climate–geopolitical resilience. London: BoE; 2022. p. 101.
134. Taleb NN. The black swan: The impact of the highly improbable. New York: Random House; 2007. p. 101.
135. OECD. Scenario diversity in stress testing. Paris: OECD; 2021. p. 101.
136. BIS. AI in systemic risk modeling. Basel: BIS; 2022. p. 101.
137. World Bank. Blockchain for supply chain monitoring. Washington, DC: World Bank; 2022. p. 101.
138. OECD. Geospatial analytics for financial risk monitoring. Paris: OECD; 2022. p. 101.
139. IMF. International coordination in integrated risk management. Washington, DC: IMF; 2023. p. 101.
140. FSB. Joint simulation exercises for systemic preparedness. Basel: FSB; 2023. p. 101.
141. Basel: BIS; 2021
142. OECD. ESG and climate risk data gaps. Paris: OECD; 2021.
143. Weitzman ML. Fat-tailed uncertainty in climate economics. Rev Environ Econ Policy. 2011;5(2):275–292.
144. Drehmann M, Juselius M. Evaluating early warning indicators of banking crises. J Bank Finance. 2014; 47:81–97.
145. IMF. Macrofinancial stress testing: Cross-sector integration. Washington, DC: IMF; 2022.
146. Acemoglu D, Ozdaglar A, Tahbaz-Salehi A. Systemic risk and stability in financial networks. Am Econ Rev. 2015;105(2):564–608.
147. UNEP FI. Principles for Responsible Banking: Climate risk integration. Geneva: UNEP FI; 2021.
148. McKinsey & Company. Climate risk and response in the banking sector. New York: McKinsey; 2020.
149. World Bank. Managing geopolitical risk in financial institutions. Washington, DC: World Bank; 2021.
150. ECB. Geopolitical risk in bank stress testing. Frankfurt: ECB; 2022.
151. ESRB. Stress testing in the banking union. Frankfurt: ESRB; 2020.
152. EIOPA. Methodology for climate stress testing of insurers. Frankfurt: EIOPA; 2021.
153. EIOPA. Insurance stress test 2021 report. Frankfurt: EIOPA; 2021.
154. Lloyd's of London. Geopolitical risk and insurance markets. London: Lloyd's; 2022.
155. OECD. Trade credit insurance and political risk. Paris: OECD; 2020.
156. Swiss Re Institute. Geopolitical risk outlook for insurers. Zurich: Swiss Re; 2022.
157. TCFD. Portfolio alignment and scenario analysis. Basel: FSB; 2021.
158. BlackRock Investment Institute. Geopolitical risk dashboard. New York: BlackRock; 2022.
159. IMF. Capital flows and geopolitical shocks. Washington, DC: IMF; 2021.
160. PRI. Scenario analysis in investment strategies. London: PRI Association; 2021.
161. MSCI. Climate value-at-risk: Methodology overview. New York: MSCI; 2021.
162. FSB. System-wide stress testing: Concept note. Basel: FSB; 2022.
163. BoE. Financial stability report: Climate–geopolitical linkages. London: Bank of England; 2022.
164. ESRB. Contagion channels in integrated risk scenarios. Frankfurt: ESRB; 2021.
165. ECB. System-wide climate stress testing. Frankfurt: ECB; 2021.
166. IMF. Integrating climate and geopolitical risk in macroprudential policy. Washington, DC: IMF; 2023.
167. OECD. Supply chain risk in climate transition. Paris: OECD; 2022.
168. BIS. Time horizons in stress testing. Basel: BIS; 2021.
169. ESRB. Second-round effects in stress testing. Frankfurt: ESRB; 2022.
170. IMF. Embedding scenario analysis into risk management. Washington, DC: IMF; 2022.