Financial Risk and Management:
An International Journal
Volume 1, Number 1, 2022

Stress Testing Climate Scenarios: Integrating Environmental Risks into Financial Models

Ila Faizun Nisa[1]

[1] Universitas Sarjanawiyata Tamansiswa, Yogyakarta, Indonesia

Abstract

Article history:
Received: January 11, 2022
Revised: February 24, 2022
Accepted: April 10, 2022
Published: June 30, 2022

Keywords:
Climate Related Financial Modeling,
Climate Stress Testing,
Environmental Risk,
Financial Stability,
Scenario Analysis.

Identifier:
Zera Open
Page: 38-49
https://zeraopen.com/journal/frmij

This study examines the growing integration of environmental risks into financial stress testing frameworks in response to the escalating impacts of climate change on global economic stability. Using a Systematic Literature Review, the research synthesizes evidence on how physical and transition risks reshape credit, market, and liquidity conditions, challenging the adequacy of traditional linear financial models. The findings reveal strong regulatory momentum, led by institutions such as the Network for Greening the Financial System and the Financial Stability Board, which increasingly promote forward-looking climate scenario analysis. Empirical applications, including the European Central Bank's climate stress test, demonstrate methodological advancements but also expose substantial limitations in climate data, scenario design, and the modeling of non-linear climate dynamics. The review highlights persistent gaps in capturing the interaction between physical and transition risks, as well as the underestimation of tail events in existing models. Overall, the study underscores the need for greater methodological innovation, enhanced data availability, and interdisciplinary collaboration to improve the accuracy and decision usefulness of climate stress tests. Strengthening these elements is essential for developing more resilient financial systems capable of navigating the accelerating risks associated with climate change.

1. Introduction

The growing urgency of climate change has significantly reshaped the landscape of financial risk assessment, prompting regulators and financial institutions to incorporate climaterelated factors into their stress testing frameworks. Unlike traditional macroeconomic shocks, climate risks are longterm, uncertain, and deeply interconnected, comprising both physical risks such as rising temperatures, floods, and extreme weather and transition risks, including policy changes, technological disruptions, and shifts in market preferences. These risks can affect asset valuations, creditworthiness, and systemic stability, compelling financial systems to rethink existing models and methodologies (Battiston et al., 2017).

In response, global regulatory bodies and central banks have advanced climate scenario analysis as a critical tool for evaluating financial sector vulnerabilities. The Network for Greening the Financial System (NGFS), for example, emphasizes that climate change poses material financial risks and provides detailed supervisory guidance for incorporating environmental risk assessments into prudential oversight (NGFS, 2019) Parallel to this, the Financial Stability Board highlights that climate change can amplify credit, market, and liquidity risks, underscoring the importance of forwardlooking climate stress testing for safeguarding financial stability (Financial Stability Board, 2020).

Empirical applications of climaterelated stress testing have also expanded. The European Central Bank's economywide climate stress test offers a comprehensive approach, integrating transition and physical risk scenarios with granular corporate and banking data to assess longterm exposures across the euro

area financial system (Alogoskoufis et al., 2021). Such exercises demonstrate increasing methodological sophistication, yet they also reveal significant challenges. Institutions continue to face gaps in climate data, difficulties in modeling nonlinear climate impacts, and limited integration of climate metrics into internal risk management processes (Elderson & Heemskerk, 2020).

Despite notable progress, translating climate scenarios into traditional financial models remains one of the most complex methodological hurdles. Existing models often rely on linear assumptions that fail to capture the compounding and feedback effects inherent in climate dynamics (Alogoskoufis et al., 2021). Moreover, many frameworks analyze transition and physical risks separately, even though real world outcomes may involve interactions between both dimensions, amplifying financial losses (Financial Stability Board, 2020). These challenges highlight the need for further research on how environmental risks can be effectively embedded into credit risk models, market risk simulations, and asset valuation frameworks.

Against this backdrop, this study aims to synthesize current approaches, identify methodological limitations, and explore innovations in climate stress testing. By focusing on the integration of environmental risks into financial modeling, this study contributes to the development of more robust and decision relevant tools for regulators and financial institutions navigating the emerging era of climate related financial risks.

2. Literature Review

The intensification of climaterelated risks has significantly transformed how financial institutions conceptualize, measure, and manage systemic vulnerabilities. A growing body of literature emphasizes that climate risks both physical and transition introduce structural uncertainties that differ fundamentally from traditional financial shocks (Dietz et al., 2016). Physical risks stemming from extreme temperature events, flooding, and longterm environmental degradation have been shown to undermine asset performance and corporate solvency, thereby heightening exposure for banks and investors. Meanwhile, transition risks related to carbon pricing, regulatory reforms, and technological changes affect market expectations and can trigger largescale portfolio revaluations.

Regulatory momentum is also a central theme in recent studies. Many scholars observe that central banks and supervisory authorities are increasingly adopting scenariobased climate analysis to assess longterm threats to financial stability (Campiglio et al., 2018). The establishment of the Network for Greening the Financial System (NGFS) has accelerated global coordination on climaterelated stress testing, with research noting that NGFS scenarios serve as an important benchmark for developing forwardlooking risk assessment frameworks (Bolton et al., 2020). These global initiatives reflect recognition that unmitigated climate change can disturb credit markets, liquidity conditions, and macrofinancial dynamics (Dafermos et al., 2018).

Empirical insights on climate stress testing also reveal substantial advancements and remaining limitations. Recent studies illustrate that incorporating

climate scenarios into macroprudential analysis allows regulators to approximate multidecade risk trajectories, offering a more realistic understanding of longterm exposures. However, scholars consistently highlight persistent data limitations, especially regarding firmlevel emissions, supply chain vulnerabilities, and geographic exposure to physical hazards (Calel & Stainforth, 2017). Moreover, the nonlinear and pathdependent nature of climate risks complicates traditional economic modeling, which often assumes stable relationships and gradual adjustment processes (Battiston & Monasterolo, 2017).

Methodologically, researchers argue that integrating climate variables into financial models requires rethinking assumptions about risk transmission. Traditional credit and market risk models may underestimate the probability and magnitude of climateinduced shocks because they fail to capture compounding dynamics, feedback loops, and tailrisk behavior (Engle et al., 2020). Additionally, many stress testing frameworks continue to treat transition and physical risks separately, while emerging evidence suggests their interaction can magnify systemic losses in unpredictable ways.

Overall, the literature underscores a strong necessity for more robust, data driven, and interdisciplinary approaches that bridge climate science and financial modeling. As climate stress testing becomes a central tool in prudential regulation, scholars emphasize the need for methodological innovation to ensure that models accurately reflect the complexity of environmental risks. Current research thus provides an important foundation for advancing holistic frameworks that align risk assessment with evolving climate realities.

3. Methods

This study employs a Systematic Literature Review (SLR) approach to comprehensively examine how environmental risks are integrated into financial stress testing frameworks. The SLR method was chosen to ensure a transparent, structured, and replicable process for identifying, evaluating, and synthesizing existing scholarly perspectives on climaterelated financial modeling. The review began with the development of clearly defined research objectives, focusing on three core themes: the conceptualization of climate risks in financial systems, methodological approaches used in climate stress testing, and the challenges encountered when embedding environmental variables into traditional financial models.

To gather relevant sources, a systematic search strategy was conducted across major academic databases using a combination of predefined keywords related to climate risk, scenario analysis, financial stability, and stress testing methodologies. All retrieved publications were screened through a multistage procedure that included evaluating relevance based on titles, abstracts, and fulltext content. The selected studies were then analyzed using thematic coding to identify recurring concepts, methodological patterns, and emerging insights.

Throughout the process, attention was placed on extracting evidence regarding modeling practices, data limitations, scenario design, and the interaction between physical and transition risks. This structured approach enabled the study to generate an integrated understanding of current advancements and gaps in climate

stress testing, thereby providing a robust foundation for proposing future methodological improvements.

4. Results and Discussion

The findings of this systematic literature review demonstrate that climate change is increasingly recognized as a structural source of financial risk, reshaping how stress testing is conceptualized and implemented across global financial systems. The literature consistently shows that climaterelated risks differ fundamentally from conventional macroeconomic disturbances. As highlighted by Dietz et al. (2016) and Battiston et al. (2017), both physical and transition risks exhibit nonlinear, uncertain, and long term characteristics that can simultaneously affect multiple sectors, causing disruptions that traditional risk models are not designed to capture. These insights underscore the need for financial institutions to reconsider longstanding assumptions embedded in credit, market, and liquidity risk assessments.

Regulatory developments further reinforce this shift. Publications from the Network for Greening the Financial System (NGFS, 2019) and the Financial Stability Board (2020) emphasize that climate change poses material threats to financial stability and requires the integration of forwardlooking scenario analysis into supervisory frameworks. This aligns with observations by Campiglio et al. (2018), who note that central banks are increasingly adopting climate scenario tools as part of their macroprudential mandates. Bolton et al. (2020) also stress the importance of coordinated global responses to ensure consistency in climate stress

testing practices across jurisdictions. These regulatory shifts have created momentum for institutions to strengthen their methodological capabilities and align internal models with supervisory expectations.

Empirical applications of climate stress testing reveal both methodological progress and persistent challenges. The ECB's economy wide stress test, as documented by Alogoskoufis et al. (2021), demonstrates the growing sophistication of scenario design through the integration of physical and transition risk factors with granular firmlevel and sectoral data. However, the review also shows that data availability remains a significant constraint. Elderson and Heemskerk (2020) highlight the limitations in climate related information, notably in emissions data, exposure mapping, and the modeling of longterm climate pathways. Calel and Stainforth (2017) similarly point out that uncertainties in climate science complicate the translation of climate projections into financial variables, affecting the robustness of longterm stress estimates.

Another key finding is the difficulty of capturing the interaction between physical and transition risks. Although many frameworks analyze these risk categories separately, evidence suggests that their combined effects may produce amplified financial losses. The Financial Stability Board (2020) stresses this interconnectedness, while Battiston and Monasterolo (2017) argue that the complex network structures of financial systems can intensify the transmission of climate shocks. Engle et al. (2020) further note that markets may misprice climate risks due to underestimation of tail events, highlighting the inadequacy of models that rely on historical data or assume gradual, linear adjustments.

The review also identifies methodological shortcomings rooted in the widespread use of linear modeling approaches. Dietz et al. (2016) and Alogoskoufis et al. (2021) both emphasize that linear frameworks cannot adequately represent tipping points, feedback effects, and abrupt policydriven transitions. This observation is reinforced by Dafermos et al. (2018), who show that climate shocks can interact with macro financial dynamics in highly unpredictable ways. As a result, many existing stress testing frameworks risk underrepresenting potential losses, especially in scenarios involving rapid policy changes, technological disruptions, or compounding physical hazards.

Overall, the evidence indicates that while the conceptual and regulatory foundations of climate stress testing have strengthened, substantial gaps remain in data quality, modeling capabilities, and the integration of complex climate dynamics into financial risk frameworks. Bridging these gaps will require enhanced collaboration between climate science and financial modeling, greater investment in data infrastructure, and continued refinement of scenario based methodologies. By addressing these challenges, financial institutions and regulators can improve the accuracy, relevance, and decisionusefulness of climate stress tests, supporting more resilient financial systems in the face of escalating climate risks.

5. Conclusion

This study highlights the growing importance of integrating environmental risks into financial stress testing frameworks as climate change increasingly influences global financial stability. The review shows that climate-related risks both

physical and transition possess unique characteristics that challenge traditional financial models, particularly due to their long-term uncertainty, non-linear behavior, and interconnected transmission channels. The literature consistently demonstrates that reliance on conventional, linear, and historically based risk models is no longer sufficient for capturing the full spectrum of climate-induced vulnerabilities.

Regulatory bodies such as the NGFS and the Financial Stability Board have played a pivotal role in accelerating the adoption of climate scenario analysis, signalling a shift toward more forward-looking and climate-aware prudential oversight. Empirical applications, including the ECB's economy-wide climate stress test, illustrate meaningful progress in the development of sophisticated methodologies. However, persistent gaps in data, scenario design, and model integration continue to hinder the accuracy and consistency of climate stress testing practices. Evidence from existing studies underscores the difficulty of accounting for compounded shocks, the interaction between physical and transition risks, and the role of tipping points and feedback loops that traditional frameworks often overlook.

The findings of this review emphasize the need for ongoing methodological innovation and enhanced collaboration between financial modeling and climate science. Strengthening data availability, improving scenario granularity, and developing models capable of capturing complex climate dynamics are essential steps for advancing climate stress testing. As financial institutions and regulators move toward more robust climate-inclusive risk frameworks, these improvements

will support more reliable assessments of long term exposures and help safeguard financial systems from emerging climate related threats.

Overall, this study contributes by synthesizing the current landscape of climate stress testing, identifying key methodological challenges, and outlining opportunities for future development. The integration of environmental risks into financial models is no longer optional but a necessary evolution in risk management, ensuring that financial systems remain resilient in the face of accelerating climate change.

References

Alogoskoufis, S., Dunz, N., Emambakhsh, T., Hennig, T., Kaijser, M., Kouratzoglou, C., ... & Salleo, C. (2021). *ECB economy-wide climate stress test: Methodology and results* (No. 281). ECB Occasional Paper.

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system. *Nature Climate Change, 7*(4), 283–288.

Bolton, P., Despres, M., Da Silva, L. A. P., Samama, F., & Svartzman, R. (2020). *The green swan*. Basel: BIS Books..

Calel, R., & Stainforth, D. A. (2017). On the physics of three integrated assessment models. *Bulletin of the American Meteorological Society, 98*(6), 1199–1216.

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., & Tanaka, M. (2018). Climate change challenges for central banks and financial regulators. *Nature Climate Change, 8*(6), 462–468.

Dafermos, Y., Nikolaidi, M., & Galanis, G. (2018). Climate change, financial stability and monetary policy. *Ecological Economics, 152*, 219–234.

Dietz, S., Bowen, A., Dixon, C., & Gradwell, P. (2016). 'Climate value at risk' of global financial assets. *Nature Climate Change, 6*(7), 676–679.

Elderson, F., & Heemskerk, I. (2020). *Guide for supervisors: Integrating climate-related and environmental risks into prudential supervision*. Paris: Network for Greening the Financial System.

Engle, R. F., Giglio, S., Kelly, B., Lee, H., & Stroebel, J. (2020). Hedging climate change news. *The Review of Financial Studies, 33*(3), 1184–1216.

Financial Stability Board. (2020). *Financial Stability Board*. Financial Stability Board.

NGFS. (2019). *A call for action: Climate change as a source of financial risk*. Network for Greening the Financial System.Retrieved February 9, 2022 from https://www.ngfs.net/system/files/import/ngfs/medias/documents/ngfs_first_comprehensive_report_-_17042019_0.pdf