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# Building Climate Scenario Analysis on the Foundations of Economic Research

Remarks by

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I want to thank all of you for joining our research conference and the organizing committee for inviting me to share some thoughts on climate scenario analysis.[1]

Economic analysis suggests that climate change could have profound consequences for the level, trend growth, and variability of economic activity over time and across regions and sectors. Some of these effects could occur gradually, while others could occur relatively quickly in the presence of "tipping points." Policy, technology, and behavioral responses could similarly have material financial consequences. Against this backdrop, the Federal Reserve is carefully considering the potential implications of climate-related risks for financial institutions and the financial system, with scenario analysis emerging as a potential key analytical tool for that purpose.

Climate change is projected to have profound effects on the economy and the financial system, and it is already inflicting damage. The Sixth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) notes that "if global warming increases, some compound extreme events with low likelihood in [the] past and current climate will become more frequent, and there will be a higher likelihood that events with increased intensities, durations and/or spatial extents unprecedented in the observational record will occur."[2]

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[1] I am grateful to Luca Guerrieri and Cindy Vojtech as well as Kevin Stiroh of the Federal Reserve Board for their assistance in preparing this text. These views are my own and do not necessarily reflect those of the Federal Reserve Board or the Federal Open Market Committee.

[2] See Intergovernmental Panel on Climate Change (2021; in press), "Summary for Policymakers," in V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, eds., *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, United Kingdom: Cambridge University Press), p. SPM-35, paragraph C.3.3, https://www.ipcc.ch/report/ar6/wg1/#SPM. The report also notes that "global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered" (p. SPM-17, headline statement B.1).

We can already see the growing costs associated with the increasing frequency and severity of climate-related events. The total cost of U.S. weather and climate disasters over the last 5 full years exceeds $630 billion, which is a record.[3] During this period, massive flooding in the Midwest has caused billions of dollars in damages to farms, homes, and businesses.[4] The California Department of Insurance has documented growing problems with the availability of fire insurance for homeowners, and the state legislature provided new protections for wildfire survivors.[5] Last year was the sixth consecutive year that the United States experienced ten or more billion-dollar weather and climate disasters.[6] And this summer, Hurricane Ida alone is estimated to have caused more than $30 billion in insurance losses.[7]

The pandemic is a stark reminder that extreme events can materialize with little warning and trigger severe financial losses and market disruptions, and the IPCC Sixth Assessment Report is a reminder of the high uncertainty and potential costs associated with climate-related risks. It will be important to systematically assess the resilience of

[3] Damage estimate uses events listed in years 2016 through 2020 in the National Oceanic and Atmospheric Administration's Billion-Dollar Weather and Climate Disasters database, available on the agency's website at https://www.ncdc.noaa.gov/billions/events.
[4] See Donnelle Eller (2021), "Climate Change-Driven 'Midwest Water Hose' Caused Massive 2019 Flooding in Iowa, Elsewhere, UI Researchers Find," *Des Moines Register,* March 2, https://www.desmoinesregister.com/story/money/agriculture/2021/03/02/ui-study-climate-change-midwest-water-hose-dumping-rain-university-iowa/6884486002.
[5] See California Department of Insurance (2018), "Insurance Commissioner Dave Jones Releases Report Addressing Fire Insurance Availability Issues," press release, January 4, http://www.insurance.ca.gov/0400-news/0100-press-releases/2018/release002-18.cfm; and California Department of Insurance (2021), "Wildfire Survivors Now Covered by New Insurance Protections," press release, July 27, http://www.insurance.ca.gov/0400-news/0100-press-releases/2021/release078-2021.cfm.
[6] See the National Oceanic and Atmospheric Administration's Billion-Dollar Weather and Climate Disasters database, in note 3.
[7] See Leslie Scism (2021), "Ida Storm Damage Expected to Cost Insurers at Least $31 Billion," *Wall Street Journal,* September 22.

large financial institutions and the broader financial system to climate-related risk scenarios.

**Climate Scenario Analysis**

As we are learning from the pandemic, risks emanating from outside the economy can have devastating financial consequences. As part of our prudential and financial stability responsibilities, we are developing scenario analysis to model the possible financial risks associated with climate change and assess the resilience of individual financial institutions and the financial system to these risks. The future financial and economic consequences of climate change will depend on the severity of the physical effects and the nature and speed of the transition to a sustainable economy. So it is important to model the transition risks arising from changes in policies, technology, and consumer and investor behavior and the physical risks of damages caused by an increase in the frequency and severity of climate-related events as well as chronic changes, such as rising temperatures and sea levels.

From the IPCC's work, we know that the physical risks related to climate change will grow over time, while the transition risks will depend in part on how abruptly policy, technology, and behavioral changes take place. Since financial markets are forward looking, a change in expectations regarding climate-related risks could lead to a sharp repricing of assets at any time. Acute hazards, such as damaging hurricanes, or climate-related policy changes could quickly alter perceptions of future risk or reveal new information about the value of assets. Sudden asset price changes can lead to financial

instability when they interact with other vulnerabilities, such as high leverage or correlated exposures.[8]

Scenario analysis is a useful tool in assessing the links between climate-related risks and economic outcomes because it requires assessing the implications for financial stability and individual financial institutions in a systematic way. The interactions across institutions and market segments must be traced out, and missing data must be identified, acquired, and analyzed, leading to a clearer picture of the transmission of risks. Scenario analysis should ultimately facilitate estimating the possible effects on individual financial institutions as well as on financial markets more broadly. By systematically modeling the effects of climate-related risks across the financial system, scenario analysis can help inform risk management at the level of individual financial institutions and more broadly.

Given that this conference is about stress testing, it is worth revisiting some lessons from the first generation of bank stress tests.[9] Bank stress tests were developed at the height of the 2007–09 financial crisis to provide a more systematic way to assess the effects of complex and interrelated exposures within the financial system. The first test, known as the Supervisory Capital Assessment Program (SCAP), used simplified models with limited data inputs. Despite substantial uncertainty about the economy's path, the SCAP was broadly viewed as successful. It provided a solid foundation for building out

[8] See the box "The Implications of Climate Change for Financial Stability" in Board of Governors of the Federal Reserve System (2020), *Financial Stability Report* (Washington: Board of Governors, November), pp. 58–59, https://www.federalreserve.gov/publications/files/financial-stability-report-20201109.pdf.

[9] Several of the conference papers apply lessons from stress testing to the analysis of climate-related risks. See Paulo Issler, Richard Stanton, Carles Vergara-Alert, and Nancy Wallace (2021), "Mortgage Markets with Climate-Change Risk: Evidence from Wildfires in California"; Hyeyoon Jung, Robert Engle, and Richard Berner (2021), "Climate Stress Testing"; and Henk Jan Reinders, Dirk Schoenmaker, and Mathijs van Dijk (2021), "A Finance Approach to Climate Stress Testing." These three papers can be downloaded from the conference website, hosted by the Federal Reserve Bank of Boston (https://www.bostonfed.org/news-and-events/events/federal-reserve-stress-testing-research-conference/2021.aspx).

the stress-testing program over the subsequent decade. The stress test infrastructure and granular models and data that are currently available bear little resemblance to that first stress test. In parallel, banks have improved their risk-management operations, and large banks now routinely use their own stress tests to assess and manage their risks.

So what are the lessons for scenario analysis? Starting down the path of climate scenario analysis, even with a rudimentary first attempt, will help with risk identification and suggest useful lessons to inform subsequent improvements in modeling, data, and financial disclosures. Although we should be humble about what the first generation of climate scenario analysis is likely to deliver, the challenges we face should not deter us from building the foundations now.

**Learning from Climate Scenario Analysis in Other Countries**

There is a growing international consensus that climate scenario analysis is a vital tool for assessing the effects of climate-related risks on financial institutions and the financial system. Since 2017, a group of regulators from across the world has been sharing best practices regarding climate-related risk management within the Network of Central Banks and Supervisors for Greening the Financial System (NGFS). The Federal Reserve joined this international collaboration late last year.

Several countries have already made substantial progress on climate scenario analysis. The scenarios produced by the NGFS, with appropriate tailoring to local conditions, have been incorporated in climate change analysis by the European Central Bank (ECB) as well as by financial regulators in Canada, France, and the United Kingdom. For instance, the ECB published results from its analysis of climate-related risks in September 2021, and the Bank of England published scenarios in June 2021 with

results expected in the middle of 2022.[10] The Federal Reserve is actively learning from these early adopters.

**Overcoming Challenges in Implementing Climate Scenario Analysis**

There are challenges to quantifying the effects of climate-related risks on the economy and the financial system. Climate scenario analysis faces the challenge of having to consider plausible but novel combinations of risks that are associated with substantial uncertainty. For traditional financial risk scenarios, modelers can draw on the historical record to help gauge the plausible repercussions for different asset classes as well as the economic consequences at the national level. Even in the case of the COVID-19 pandemic, modelers could draw useful lessons from previous pandemics, such as the 1918 influenza.[11] By contrast, there may not be analogous historical precedents to draw on in the formulation of appropriate climate scenarios and the quantification of their effects on different asset classes, regions, and sectors.

In addition, climate scenario analysis may need to consider interdependencies across the financial system. Banks and other financial institutions often rely on insurance and other hedging strategies to reduce potential losses. With climate risk raising insurance premiums charged to property owners or reducing the availability of insurance in certain geographies and on certain asset classes, it may be important to assess the

[10] For the European Central Bank, see ECB (2021), "Firms and Banks to Benefit from Early Adoption of Green Policies, ECB's Economy-wide Climate Stress Test Shows," press release, September 22, https://www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210922~59ade4710b.en.html; and Luis de Guindos (2021), "Shining a Light on Climate Risks: The ECB's Economy-wide Climate Stress Test," *ECB Blog,* March 18, https://www.ecb.europa.eu/press/blog/date/2021/html/ecb.blog210318~3bbc68ffc5.en.html. For the Bank of England, see Bank of England (2021), *Key Elements of the 2021 Biennial Exploratory Scenario: Financial Risks from Climate Change* (London: BOE, June), https://www.bankofengland.co.uk/stress-testing/2021/key-elements-2021-biennial-exploratory-scenario-financial-risks-climate-change.

[11] See Sergio Correia, Stephan Luck, and Emil Verner (2020), "Pandemics Depress the Economy, Public Health Interventions Do Not: Evidence from the 1918 Flu," working paper, June.

resilience of insurance and other hedging strategies and the associated implications for supervised institutions. Stress could be transmitted through a sudden repricing of insurance contracts or by a withdrawal of coverage, as we are already seeing in the case of wildfires and flooding in certain areas. While reinsurance contracts and agreements among investors can transfer risk across the financial system, some level of risk is likely to remain. Climate-related risks could build up in hidden ways that could result in cascading losses.

**Using Established Economic Foundations for Transition Risks**

The costs and timing of the transition to a low-carbon economy will depend on hard-to-predict policy, technology, and behavioral changes.[12] While an orderly and steady transition to a sustainable economy may have manageable economic consequences, more costly changes would likely accompany an abrupt transition. A disorderly scenario could generate sizable economic consequences that vary substantially across geographies, sectors, and assets. Some of these effects could manifest in the near term if investment sentiment were to change suddenly. That said, the long tradition within economics of estimating the effects of policy changes can be applied to the modeling of transition risks, even disorderly scenarios.[13]

**Mapping the Economic Consequences of Physical Risks**

Whereas existing economic tools can be applied to transition risks, the building blocks for assessing the economic consequences of physical risks in the presence of

[12] See International Energy Agency (2021), *Net Zero by 2050: A Roadmap for the Global Energy Sector* (Paris: IEA, May), https://www.iea.org/reports/net-zero-by-2050.

[13] See Robert Vermeulen, Edo Schets, Melanie Lohuis, Barbara Kölbl, David-Jan Jansen, and Willem Heeringa (2018), "An Energy Transition Risk Stress Test for the Financial System of the Netherlands," Occasional Studies, vol. 16-7 (Amsterdam: De Nederlandsche Bank, October), available at https://www.dnb.nl/en/publications/research-publications/occasional-studies/nr-7-2018-an-energy-transition-risk-stress-test-for-the-financial-system-of-the-netherlands.

substantial uncertainty are still in development. The literature on the economic consequences of physical risk is growing, but there are still some challenges in linking this literature to the formulation of scenarios.[14] For instance, extrapolating from the historical experience of sporadic extreme weather events may turn out to be misleading. Economic activity has tended to rebound quickly after sporadic extreme weather events in recent experience, often supported by significant reconstruction. In contrast, climate change is an ongoing, cumulative process that could significantly increase the prevalence and severity of extreme events as well as contribute to chronic changes. These cumulative and chronic changes could have economic effects that differ substantively from the historic experience, for example, if they contribute to shifts in the location of economic activity or the sectoral composition within a region.

The physical manifestations of climate change could increase the volatility of economic activity and slow economic growth.[15] The cumulative effects associated with climate change could lead to irreversible "tipping points" that introduce new climate shocks and change the relationships between climate-related shocks and economic variables. Tipping points, such as melting ice sheets and loss of permafrost or forests, have the potential to create large disruptions in weather systems, regional water supplies, and the habitability of large land masses. The potential cumulative effects of climate-

[14] For instance, see Melissa Dell, Benjamin F. Jones, and Benjamin A. Olken (2012), "Temperature Shocks and Economic Growth: Evidence from the Last Half Century," *American Economic Journal: Macroeconomics,* vol. 4 (July), pp. 66–95; Solomon Hsiang, Robert Kopp, Amir Jina, James Rising, Michael Delgado, Shashank Mohan, D.J. Rasmussen, Robert Muir-Wood, Paul Wilson, Michael Oppenheimer, Kate Larsen, and Trevor Houser (2017), "Estimating Economic Damage from Climate Change in the United States," *Science,* vol. 356 (June), pp. 1362–69; and Maximilian Auffhammer (2018), "Quantifying Economic Damages from Climate Change," *Journal of Economic Perspectives,* vol. 32 (Fall), pp. 33–52.

[15] See Network of Central Banks and Supervisors for Greening the Financial System (2020), *NGFS Climate Scenarios for Central Banks and Supervisors* (Paris: NGFS, June), https://www.ngfs.net/sites/default/files/medias/documents/820184_ngfs_scenarios_final_version_v6.pdf.

related shocks as well as potential climate-related tipping points for the economy and financial system could reduce the accuracy of forecasts based on historical experience.[16]

**Regional and Sectoral Differentiation in Projections of Revenues and Losses**

The consequences of climate change are likely to be highly differentiated by region and economic sector, which can bring both risks and opportunities for financial institutions. Regional and sectoral differentiation has important implications for scenario analysis.[17] Climate-related risks can be expected to have direct effects not only on the valuation of assets on the balance sheets of financial institutions, but also on revenues and costs. While standard models for projecting the net revenues of financial institutions are typically driven by national-level proxies of aggregate demand, such as growth and unemployment levels, additional sectoral and regional granularity will be necessary for climate scenario analysis. And while standard models for projecting losses on assets account for regional and sectoral characteristics, climate scenario analysis will require capturing the potential intensification of climate-related risks.

**Closing Data Gaps**

These efforts to systematically assess climate-related risks will require substantial work to address current data gaps. Financial institutions are collecting data and developing scenario analysis to understand the potential effect of climate-related risks. Similarly, the Federal Reserve is gathering key data resources, such as acquiring external

[16] See, for instance, Simon Dietz, James Rising, Thomas Stoerk, and Gernot Wagner (2021), "Economic Impacts of Tipping Points in the Climate System," *PNAS,* vol. 118 (August), https://www.pnas.org/content/118/34/e2103081118.

[17] See, for instance, ECB (2021), "Firms and Banks to Benefit from Early Adoption of Green Policies, ECB's Economy-wide Climate Stress Test Shows," press release, September 22, https://www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210922~59ade4710b.en.html.

data and making existing publicly available climate data more useful for modeling and research capabilities.

Current voluntary climate-related disclosures are an important first step in closing data gaps, but they are prone to inconsistent quality and incompleteness. Without harmonization of the definitions and methods underlying these disclosures, it will be challenging to make comparisons across firms and exposures. Consistent, comparable, and, ultimately, mandatory disclosures are likely to be vital to enable market participants to measure, monitor, and manage climate risks on a consistent basis across firms.[18] The Securities and Exchange Commission has responsibility for this critical workstream in the United States.[19]

**Making Progress**

Going forward, it will be important to improve our understanding of climate-related financial risks and vulnerabilities. The Federal Reserve's Supervision Climate Committee is engaging with domestic stakeholders and other supervisors from a prudential perspective. Ultimately, I anticipate it will be helpful to provide supervisory guidance for large banking institutions in their efforts to appropriately measure, monitor, and manage material climate-related risks, following the lead of a number of other countries.

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[18] See, for instance, Network of Central Banks and Supervisors for Greening the Financial System (2021), *Progress Report on Bridging Data Gaps* (Paris: NGFS, May), https://www.ngfs.net/sites/default/files/medias/documents/progress_report_on_bridging_data_gaps.pdf; and the communiqué on the Third G-20 Finance Ministers and Central Bank Governors Meeting, held July 9–10, 2021, https://www.g20.org/wp-content/uploads/2021/07/Communique-Third-G20-FMCBG-meeting-9-10-July-2021.pdf.

[19] See Gary Gensler (2021), "Prepared Remarks before the Principles for Responsible Investment 'Climate and Global Financial Markets' Webinar," Washington, July 28, https://www.sec.gov/news/speech/gensler-pri-2021-07-28.

In addition, the Federal Reserve's Financial Stability Climate Committee is assessing climate-related risks to financial stability from a macroprudential perspective—that is, one that considers the potential for complex interactions across the financial system. Both the prudential and macroprudential work programs will benefit from the development of climate scenario analysis.

**Conclusion**

Together these efforts can help ensure that the financial system is resilient to climate-related risks and well positioned for the transition to a sustainable economy. Our conversations with climate experts, large banking institutions, other financial intermediaries, stakeholders, and regulators underscore the complexity of the connections between the climate and economic and financial systems. To better understand these connections, several foreign regulators have already undertaken climate scenario analysis, affording us the opportunity to learn from their experiences. It will be helpful to move ahead with the first generation of climate scenario analysis to identify risks and potential issues and to inform subsequent refinements to our models and data. We will reach better outcomes if we tackle these challenges through open dialogue and continued engagement of the kind exemplified by today's conference.