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The Economics of Climate Change: A First Fed Conference

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To better understand the implications of climate change for the financial sector and the broader economy, the Federal Reserve Bank of San Francisco recently hosted a conference on the economics of climate change to gather and debate the latest analyses from universities and policy institutions, nationally and abroad. It was the first Fed-sponsored conference devoted to investigating the economic and financial consequences and risks arising from climate change and potential policy responses.

The scientific community around the world has reached a broad consensus on the ongoing climate change caused by human activities. As the Intergovernmental Panel on Climate Change (2014), stated, "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and the sea level has risen" (p. 40). Scientists also attribute more frequent and extreme storms, floods, droughts, and heat waves to these adverse developments (U.S. Global Change Research Program 2018, hereafter USGCRP).

This climate change will have sweeping effects on our economy and financial system (Network for Greening the Financial System 2018, hereafter NGFS; USGCRP 2018). Climate-related shifts in the physical environment can slow economic growth, increase volatility, and depreciate the value of business and household assets and property. Avoiding further climate change will involve a substantial transformation of the economy. Consequently, climate change appears increasingly relevant to central bankers and financial supervisors for achieving their macroeconomic, inflation, and financial stability mandates (NGFS 2018, Rudebusch 2019).

As a topic for research in economics, climate change touches many fields of study, including finance, macroeconomics, and environmental, international, development, and labor economics. Partly as a result, climate change research has been slow to gain traction in the mainstream of the economics profession (Diaz-Rainey, Robertson, and Wilson 2017, Oswald and Stern 2019). To foster greater interaction and interest among researchers and policymakers on this important topic, the Federal Reserve Bank of San Francisco recently hosted a conference on "The Economics of Climate Change." This was the first Fed-sponsored conference on this issue. Along with discussions and presentations, the conference also featured speeches by three monetary policymakers: Mary Daly, President of the San Francisco Fed; Lael Brainard, Governor of Federal Reserve Board; and Frank Elderson, Member of the Governing Board of the Dutch Central Bank and Chairman of the NGFS. All three of these policymakers stressed the significance of understanding climate-related trends and risks as an input to policy.

This *Economic Letter* summarizes the main themes of the conference. The speeches and research presented are available on the conference website, https://www.frbsf.org/economic-research/events/2019/november/economics-of-climate-change/.

The macroeconomic implications of a warmer world

Climate change has long-term macroeconomic implications for worker productivity and the composition and profitability of business investment. To study the links among climate change, climate adaptation, and climate policy, researchers have constructed large-scale models of the connections between the global climate and global economy. These integrated assessment models are often very complex, in some cases involving hundreds of variables and equations. Using one such model, Solomon Hsiang (U.C. Berkeley) presented research on how warmer temperatures make exposed workers less productive. This is particularly important for outdoor workers, as in agriculture and construction. Over time, the higher temperatures may result in significant losses for the overall economy and notable shifts in the occupations workers choose.

Conny Olvosson (Sveriges Riksbank) constructed another integrated assessment model to investigate how a world with multiple energy sources and alternative policies to tax carbon would affect carbon dioxide emissions and economic growth. His findings emphasize the importance of taxing coal—which produces large amounts of carbon pollution—even over other fossil fuel energy sources, such as oil. His research demonstrated that subsidizing green energy without taxing coal or other fossil fuels is unlikely to reduce emissions, because energy subsidies tend to increase overall energy use. What makes these results especially valuable is that they quantify the economic gains and losses from each policy and thus could serve as a tangible guide for policymakers.

There are wide differences in how climate change affects various areas of the world. Moreover, regional disparities in resources, policies, and technology only exacerbate these differences. Still, changes in one region of the world can have consequences elsewhere, including people migrating to avoid adverse climate developments and extreme natural events disrupting international trade. Accounting for such regional differences and spillovers, while a complicated task, is nevertheless crucial for assessing the long-run economic impact of climate on growth. Work presented by Hashem Pesaran (USC) suggested that the permanent losses in welfare can be substantial across the board, even in the United States, which is usually seen as being better positioned to adapt to climate change. Moreover, global climate change mitigation efforts so far have had little effect on moderating these permanent losses.

Nicholas Muller (Carnegie Mellon University) argued that the costs of carbon pollution and the associated losses to productivity have a variety of macroeconomic implications. He recommended taking a broader view of aggregate output by considering pollution as a reduction in welfare. As such, a permanent decline in the economy's capacity to grow due to climate change will diminish the returns from economic activity in the future and lower the interest rate that borrowers will accept. Under this perspective, unabated pollution would be expected to put further downward pressure on interest rates.

Climate risks are financial risks

When pricing an asset, investors demand compensation for risk, and climate change is an emerging risk that may be especially relevant for equity prices. Some businesses are more exposed to climate risk than others, and investors will require a higher premium for investing in such firms. Using standard asset pricing

arguments, Dana Kiku (University of Illinois at Urbana-Champaign) showed that equity prices are sensitive to long-run temperature uncertainty and that such climate risk carries a risk premium. Using estimates of these premiums, Kiku calculated the implied cost that investors place on future carbon emissions. Those implicit prices of carbon are notably higher than current prices in markets for carbon emission permits.

Extracting carbon emission prices from financial markets relies on investors being able to appropriately assess climate risks. But what if they are not? What would happen if investors misunderstood the risks that carbon emissions pose to the climate and in turn to the economy? Some possible future climate scenarios include catastrophic consequences—in other words, worst-case outcomes. Even if these scenarios have only a small chance of coming true, the extreme losses they entail might affect an asset's price significantly. Research presented by Ryan Riordan (University of Oregon) suggests that investors have not yet fully priced the carbon risk in such extreme scenarios.

As economies adapt to climate change and gradually switch from carbon-based, so-called brown, energy to greener energy alternatives, the value of assets associated with brown technologies will decline and, in the extreme, assets may become "stranded." Because carbon extraction industries—such as coal mining, oil drilling, and fracking—are capital intensive, they tend to require substantial external funding. However, loans to these industries depend on collateral whose value can evaporate quickly. In turn, if lenders' capital buffers are insufficient for the risk involved, the loan losses can generate systemic financial instability. These developments are exacerbated by the response of energy companies, as Michael Barnett (Arizona State University) discussed. For example, oil extraction companies may ramp up production and curtail exploration in the short run. This could cause oil prices to drop and oil firm valuations to fall further relative to green energy producers.

The policy implications of climate change

Economic policies can have unintended consequences. Such appears to be the case with current trade policies in many countries, which may have increased carbon emissions. Tariffs imposed worldwide to protect certain industries from competition abroad implicitly subsidize carbon emissions. The reason is that tariffs are lower for high-emitting industries than for low-emitting industries, as Joseph Shapiro (U.C. Berkeley) explained. This research emphasizes the importance of considering climate change consequences when negotiating new trade agreements. Balancing trade policy to improve incentives for low-emitting industries could result in sizable reductions of carbon emissions.

Although the United States does not currently have a federal carbon tax nor a cap-and-trade system, there is a chance such policies could be adopted in the future to help reduce carbon emissions. Could expectations about imposing a future carbon tax be sufficient to change the behavior of businesses and hasten a shift in energy usage toward greener alternatives? Or would it be more effective to actually impose a carbon tax? Stephie Fried (Arizona State University) showed that there are fewer distortions to the economy and more carbon reductions when policymakers actually institute a carbon tax than when they simply threaten to impose one or rely on the public's expectation that one will be imposed sometime in the future.

Trade policy and carbon pricing clearly fall outside a central bank's mandate. But climate change has important consequences for monetary policy and financial stability, as Sandra Batten (Bank of England) argued. For example, natural disasters are disturbances to the productive capacity of the economy that

operate similarly to an oil price spike. They both tend to raise inflation in the short run. This presents a challenge for monetary policy. Raising interest rates to control inflation also may damp economic activity at a time of distress. The transition to greener energy and other forms of climate mitigation are also likely to aggravate the stranded assets problem and may add to financial stability risk.

Conclusion

The ramifications of climate change extend to numerous areas of economic life, yet many are not well understood. As the research described in this *Letter* demonstrates, the economic consequences of climate change are likely to be substantial and will require responses from a wide range of policy institutions. Future conferences on climate change will improve our understanding of these issues and provide the foundation for the best possible policy responses.

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Conference papers

Conference papers, speeches, and videos of sessions are available on our website: https://www.frbsf.org/economic-research/events/2019/november/economics-of-climate-change/

"Why Climate Change Matters to Us," speech by Mary C. Daly

"Labor Supply in a Warmer World: The Impact of Climate Change on the Global Workforce," presented by Solomon Hsiang

"Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis," presented by M. Hashem Pesaran

"Integrated Assessment in a Multi-region World with Multiple Energy Sources and Endogenous Technical Change," presented by Conny Olovsson

"On the Implications of Pollution for the Measurement of Output, Volatility, and the Natural Interest Rate," presented by Nicholas Z. Muller

"Climate Change Risk," presented by Dana Kiku

"Carbon Risk," presented by Ryan Riordan

"A Run on Oil: Climate Policy, Stranded Assets, and Asset Prices," presented by Michael Barnett

"The Environmental Bias of Trade Policy," presented by Joseph S. Shapiro

"The Systemic Risk of Climate Policy," presented by Stephie Fried

"Climate Change: Macroeconomic Impact and Implications for Monetary Policy," presented by Sandra Batten

"Why Climate Change Matters for Monetary Policy and Financial Stability," speech by Lael Brainard

"Discussing Financial Risks during Wildfire," speech by Frank Elderson

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