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The Economic benefits of weather forecasting

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As the remarkable series of record-breaking temperatures, storms, and wildfires around the world this summer highlights, the consequences of climate change are here. It is no longer (only) a future threat. Adaptation to these consequences is a policy imperative for governments around the world. This is not to say that mitigation does not remain important, but responding to climate change no longer means only taking actions to mitigate future warming.

However, while the policy priorities to achieve mitigation are clear – engage in actions that reduce greenhouse gas emissions – the policy priorities for adaptation are less clear. How can governments most effectively take action to help their citizens adapt to the consequences of climate change?

Answering that question was the goal of a recent workshop at Stanford University. The workshop featured great work examining a range of adaptation options, from migration to insurance. But I was struck by the potential power of one, seemingly mundane, adaptation option: improving weather forecasts.

It is well-known that climate change will increase the frequency and intensity of damaging weather events. Whether these are acute storms like cyclones or blizzards or more diffuse weather events like heat waves or heavy precipitation events, climate change will make them more frequent in much of the world - including places that may not have historically experienced them - and often more severe. There is now a deep literature in economics that shows the negative consequences of these extreme weather events for a variety of economic outcomes. Indeed, in many cases extreme weather is the mechanism that links the diffuse presence of more carbon in the atmosphere to specific economic outcomes.

A more recent, and growing, body of literature in economics highlights that it is not only the extreme nature of extreme weather events but their *unexpectedness* that drives many of the worst negative outcomes. Historically, the importance of the surprising nature of these events has been hard to separately identify: an extreme event is, by definition, rare and so is often unexpected in addition to being large in magnitude. But Shrader, Bakkensen, and Lemoine take advantage of data on forecasts to show that, at least in the context of extreme heat, it is the unexpected events that drive much of the mortality effects that we detect.

Why does this happen? Presumably because when warned about extreme events ahead of time individuals can engage in a variety of behavioral (or other) adjustments that reduce either their exposure or vulnerability to the extreme event. Shrader's paper examining the impact of forecasts of ENSO events (El Ni˜no/Southern Oscillation) indicates that, when provided with forecasts about the ENSO cycle in advance, fishers adjust allocations of effort in ways that reduce the negative impacts of the ENSO cycle.

In recent years residents of high-income countries have grown accustomed to relatively accurate short-term forecasts of extreme weather events. By some measures, weather forecasts are more than 5 times as accurate as they were 40 years ago. Given this substantial improvement in accuracy, are there still gains to be had? That question was addressed indirectly by Anand's study at the Stanford workshop. The answer is a resounding yes. Having longer lead times on forecasts of severe winter weather reduces traffic accidents by 0.5% per hour of lead time. Existing lead times result in savings of nearly $150 million in 11 U.S. states. That savings, in roughly a fifth of the country, represents 3% of the annual budget of the entire meteorological arm of the U.S. Federal government.

And it is not just winter storms. Molina and Rudik find that additional improvements in forecasting of hurricanes in the U.S., which have already improved by 3x in the last four decades, are estimated to be an order of magnitude larger than the current budget of the hurricane forecast system. Improvements in forecasting since 2009 alone have reduced damages by 5%.

These estimated benefits of improvements in weather forecasting largely come from the United States, at least in part because the U.S. already has some of the most accurate weather forecasts in the world. That there remain large benefits for marginal improvements of forecasting in this setting suggest that the benefits in the majority of the world that does not have highly accurate forecasts may be even larger. Estimating benefits in a context outside of the United States is the goal of on-going work that was also presented at the Stanford workshop. Using data on mobile money providers in Ghana the authors show market participants suffer severe reductions in business as a consequence of extreme weather. However, those

impacts are reduced by 50% if the extreme weather is anticipated. I hope that we see more of this kind of work in the future.

Enabling adaptation to climate change will obviously require more than simply improving weather forecasting. One obvious reason why these improvements alone will be insufficient is that they do not address the problem of getting information into the hands of those who need it. One discussant at this year's AAEA observed that researchers in Washington, DC may know more about the weather forecast facing farmers in Kenya than those farmers. Improvements in forecasting alone is clearly not sufficient, interventions improving access to more accurate forecasts are also necessary.

But there is growing evidence that investing in improvements in weather forecasting is a highly cost-effective means of reducing damages from extreme weather. The tight relationship between climate change and extreme weather implies that these investments are thus also likely to be an important form of climate adaptation.

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