



A [new study](#) published in the journal *Nature* shows that the global economy will take a harder hit from rising temperatures than previously thought, with incomes falling in most countries by the year 2100 if climate change continues unchecked. Rich countries may experience a brief economic uptick, but growth will drop off sharply after temperatures pass a critical heat threshold.

The study is co-authored by [Marshall Burke](#), a professor of Earth system science at Stanford's School of Earth, Energy and Environmental Sciences; Solomon Hsiang, the Chancellor's Associate Professor of Public Policy at the University of California, Berkeley; and Edward Miguel, UC Berkeley Oxfam Professor in Environmental and Resource Economics.

The team's research provides the clearest picture to date of how climate change will shape the global economy. This has been a critical missing piece for the international climate community leading up to the Paris climate talks. Understanding how much future climate change will cost in terms of global economic losses will help policymakers at the meetings decide how much to invest in emissions reductions today.

Calculating the global economic cost of climate change



## Heat threshold

"The data tell us that there are particular temperatures where we humans are really good at producing stuff," said Burke, who is also Center Fellow at the [Freeman Spogli Institute for International Studies](#) and fellow, by courtesy, at the [Stanford Woods Institute for the Environment](#). "In countries that are normally quite cold - mostly wealthy northern countries - higher temperatures are associated with faster economic growth, but only to a point. After that point, growth declines rapidly."

That point, it turns out, is an annual average temperature of about 55 degrees Fahrenheit.

As average temperatures move past that mark, wealthy countries will start to see a drop-off in economic output. Poorer countries, mostly in the tropics, will suffer even steeper losses because they are already past the temperature threshold. This has the potential to widen the global inequality gap, said Burke.

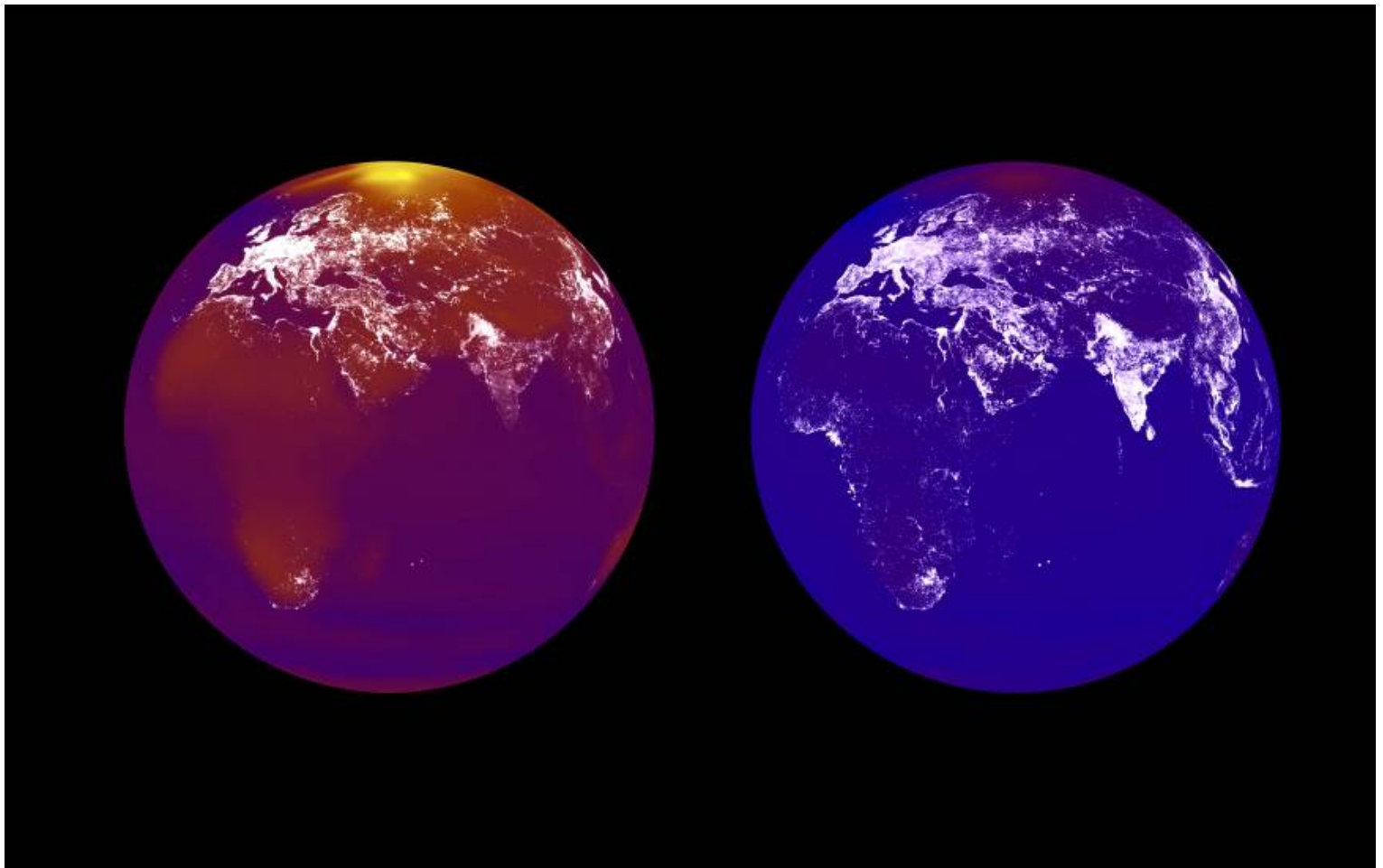
## A new approach

Looking at existing research, the team found a puzzling mismatch between micro-level studies, which show negative impacts of hot temperatures on output in specific sectors such as agriculture, and macro-level studies, which at least in rich countries show limited impacts on economic output.

"Many very careful studies show clearly that high temperatures are bad for things like agriculture and labor productivity, even in rich countries," Burke said. "While these relationships showed up again and again in the micro data – for example when looking at agricultural fields or manufacturing plants – they were not showing up in the existing macro-level studies, and we wanted to understand why."

The researchers suspected the problem was with the analysis, not the data, so they took a new approach.

Analyzing records from 166 countries over a 50-year period from 1960 to 2010, they compared each country's economic output in years of normal temperatures to that of unusually warm or unusually cool years. The data revealed a hill-shaped relationship between economic output and temperature, with output rising until the 55 F threshold and then falling faster and faster at higher temperatures. "Our macro-level results lined up nicely with the micro-level studies," Hsiang said.



**Two possible futures.** Colors are 2100 temperatures under “business as usual” climate change (left) and aggressive climate policy (right). This image shows a simulation of future nightlights, as seen from space, since richer economies tend to glow brighter. A hotter world is a more unequal world, with the north benefitting and tropical economies declining. A cooler world leads to more equitable global growth, offering regions like Africa the chance to “catch up”. Courtesy of Marshall Burke.

## Higher temperatures, lower growth

The team then sought to understand what this historical pattern might mean for the future global economy as temperatures continue to warm.

“Many other researchers have projected economic impacts under future climate change,” Hsiang said. “But we feel our results improve our ability to anticipate how societies in coming decades might respond to warming temperatures.”

Projecting future changes in economic output under climate change was challenging.

“Even without climate change, there are a lot of possible ways in which the future economy might evolve,” Burke said. “We start with a few different baseline scenarios and then we bring in our historical understanding of the relationship between temperature and economic output to better understand how these economic trajectories might change with warming temperatures.”

The researchers’ findings were stark.

In a scenario of unmitigated climate change, the team’s model shows that by 2100 the per-capita incomes of 77 percent of countries in the world would fall relative to current levels. By the team’s main estimate, global incomes could decline 23 percent by 2100, relative to a world without climate change. Other estimates are twice as high. The likelihood of global economic losses larger than 20 percent of current income is at least 40 percent, and much higher in some scenarios.

These estimates are substantially larger than existing models indicate, a difference the research team attributes to their updated and data-driven understanding of how countries have historically responded to temperature increases.

## Rich countries not immune

A common assumption among researchers has been that wealth and technology protect rich countries from the economic impacts of climate change, because they use these resources to adapt to higher temperatures.

"Under this hypothesis, the impacts of future warming should lessen over time as more countries become richer," Burke said. "But we find limited evidence that this is the case."

Burke's team found that, historically, rich countries did not appear to respond any differently to temperature change than poor countries.

“The data definitely don’t provide strong evidence that rich countries are immune from the effects of hot temperatures,” said Hsiang. “Many rich countries just happen to have cooler average temperatures to start with, meaning that future warming will overall be less harmful than in poorer, hotter countries.”

## Paris climate talks

From Nov. 30 to Dec. 11, France will host the 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21/CMP11).

More than 40,000 delegates from national governments, private companies and civil society will meet in Paris to hash out an international agreement aimed at keeping global emissions low enough to prevent warming of more than two degrees Celsius.

On the table are three key issues: climate adaptation, mitigation and financing.

"We don't want to rule out that we could see unprecedented adaptation to hotter temperatures in the future, and we certainly hope we do see it," Burke said. "The historical evidence, though, suggests that this is not something we should count on."

The team says that mitigation, and how to pay for it, should be at the forefront of discussions in Paris.

"Our research is important for COP21 because it suggest that these economic damages could be much larger than current estimates indicate," said Burke. "What that means for policy is that we should be willing to spend a lot more on mitigation than we would otherwise. The benefits of action on mitigation are much greater than we thought, because the costs of inaction are much greater than we thought."

**Note for reporters:** *The research team has created an [interactive map](#) showing country-by-country GDP projections through 2100, as well as a concise explanation of the team's research methodology.*

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