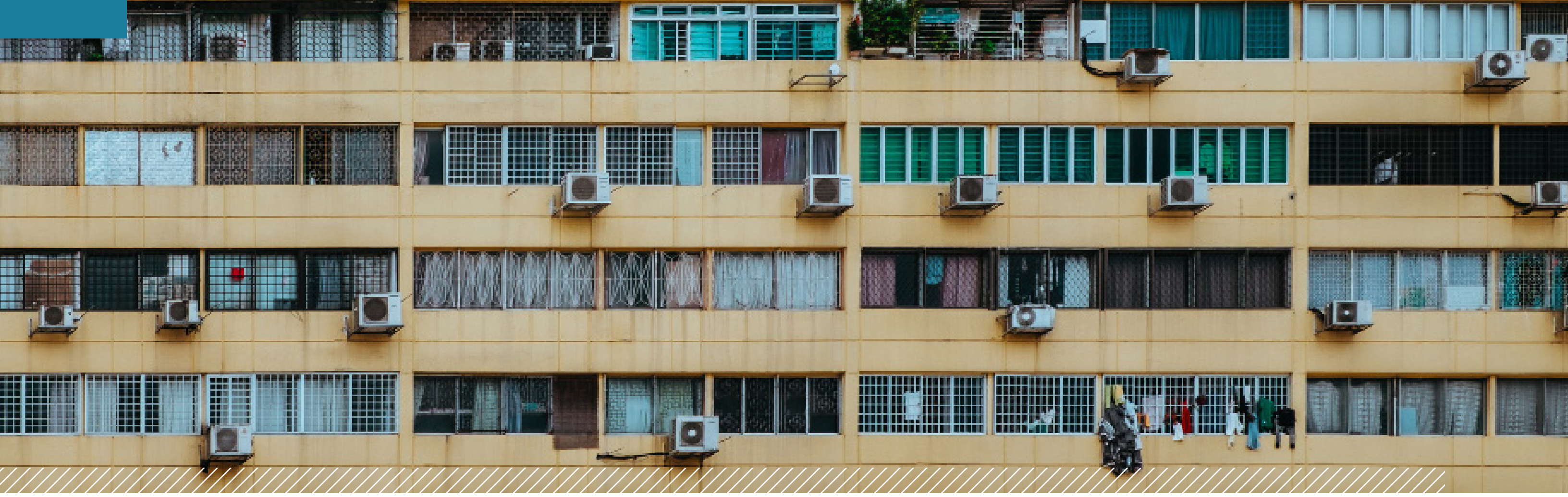


RESEARCH SUMMARY

Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits

by the Climate Impact Lab team

KEY TAKEAWAYS

1. The cost of climate-driven changes in global mortality risk alone are as large as previous estimates of the economy-wide toll of climate change, according to an analysis of mortality data from 56% of the world's population. In the first global, empirical study of mortality risk to capture both the costs and benefits of climate adaptation, researchers at the Climate Impact Lab find the increased global mortality burden from climate change to be 3.7% of global GDP by the end of century if past emissions trends continue.

2. Utilizing a unique, big data approach to generate global information, the Climate Impact Lab finds that a metric ton of CO2 emitted today generates a median mortality risk of roughly $39 in a high emissions scenario. This value represents a "partial" social cost of carbon (SCC) that accounts for the value of lost life, as well as the net costs of adaptation to withstand temperature extremes, but excludes all other climate impacts. As a basis of comparison, a leading model that had not relied on similar data-driven approaches estimated the total mortality impacts of climate change at less than $1.50 per metric ton (Diaz 2014).

3. The analysis is conducted with the most comprehensive data set ever compiled on mortality, historical temperature, income, and climate simulations. For example, it is derived from data covering 399 million deaths all over the world over the last several decades—accounting for different incomes, climates, and varying levels of development — and modeling future population and income growth.

4. This research demonstrates the importance of updating estimates of the SCC used in policymaking to incorporate empirically-derived damage estimates. For comparison, the Obama administration's most recent estimate of the economy-wide cost of climate change was roughly $41 per ton. In 2017, the National Academies of Science recommended ways in which the U.S. government should update this estimate to incorporate the most recent scientific and economic research. The Climate Impact Lab's work shows that updating the mortality cost estimates alone would significantly alter any economy-wide number.

5. Even after accounting for adaptation, an additional 1.5 million people die per year from climate change by 2100 if past emissions trends continue. For comparison, road injuries killed roughly 1.4 million people worldwide in 2016, and diabetes, ranked as the seventh leading cause of death worldwide, killed 1.6 million people in 2016. These projections include net gains in many regions of the world where lives will be saved from fewer cold days.

6. Extreme heat is measurably deadlier for the poorest third of the world, and the decline in cold-related deaths does not offset the harm caused by temperature rise. Higher incomes make societies more resilient to extreme heat, allowing people to make a range of protective investments, including in air conditioning and better building insulation. But for the most vulnerable developing countries, even optimistic economic growth projections do not provide complete protection. The findings show warming caused by an additional ton of CO2 harms 72 percent of the global population, while the rest benefit on net, primarily due to a decrease in cold days.

Introduction

Decades of research have increased our understanding of the impacts of climate change on human health, but our understanding of the benefits and costs of adaptation to climate change has been limited. This new study uses data from across the world to narrow this gulf in understanding, using a data-driven approach to measure human health impacts at global scale, accounting for both benefits and costs of adaptation.

Previous studies on the effect of extreme heat on mortality, one of the most well-documented climate impacts, have shown how air conditioning has played a key role in reducing sensitivity to extreme heat in wealthy, warm parts of the world. For example, the installation of air conditioning in American homes reduced the chances of dying on an extremely hot day by 80 percent over the past half-century, according to one recent study.

Harder to measure are the costs that prevent a rich country like the United States from reducing its mortality risk to zero, or stand in the way of developing nations following a similar trajectory to minimize death rates. Further, a thorough examination of mortality impacts must also include data from colder regions of the world to account for the potential of rising temperatures to reduce the deadly effect of frigid days. Researchers at the Climate Impact Lab find these trade-offs become easier to observe when studying populations that have adopted a wide range of adaptations to their local climates.

Take, for instance, Seattle, Washington, and Houston, Texas. These two cities share similar income levels but have very different climates. On average, each year from 1981 to 2010, Seattle experienced just two days where the temperature exceeded 90° F and zero days above 100° F. Houston experienced, on average, 74 of the 90° F days annually and three days over 100° F.

The difference between mortality rates in Seattle and Houston on days above 90° F shows that Houston has adapted to this hotter climate. Compared to a 90° F day Seattle, a 90° F day in Houston causes one-fortieth or 2.5 percent as many heat-related deaths. We can infer that people living in Seattle, where extreme heat is rare, find the costs required to achieve Houston's resilience to 90-degree days are not worth it.

The researchers aimed to account for increased deaths in parts of the world that are not rich enough to endure extreme heat, declining mortality rates in cold regions, and the economic toll of adaptation in wealthier societies that can adapt. These economic trade-offs range from installing air conditioning or building public cooling centers to curbing time spent outdoors. Capturing the ways households, communities, and planners are reducing vulnerability to life-threatening heat waves requires analyzing troves of real-world, local data collected around the globe.

Research Design

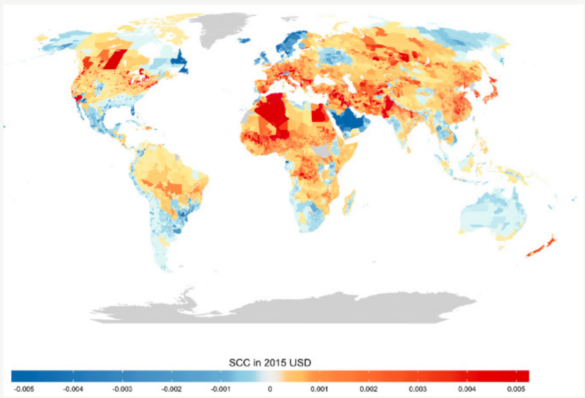
This study provides the first comprehensive economic assessment of the lethal potential of climate change with a method that accounts for both the benefits and costs of adaptation. The researchers' ultimate goal is to estimate the mortality consequences of climate change, both deaths caused by extreme heat and the costs society will pay to keep people out of harm's way, in terms of dollars per ton of carbon dioxide (CO_2) emitted.

The Obama Administration's initial central estimate for this metric, known as the "social cost of carbon," included mortality and all other sectors of the economy and was valued at roughly $41 per ton of CO_2 emitted in 2015, under a 3 percent discount rate. This estimate has served as the foundation for analysis of both domestic and international climate policies. Indeed, it was the basis for more than 80 U.S. regulations and was adopted by Canada, Mexico, and other governments around the world as their official social cost of carbon.

This research aims to strengthen the empirical foundation of "partial" estimate for the social cost of carbon, one that focuses on estimates of climate-change induced mortality. It is "partial" precisely because it only measures the mortality impacts and misses the myriad other ways that climate change will impact well being. Doing so provides an approach that can be applied to other aspects of the global economy to provide a full and clear picture of how, why, and where the costs of climate change are likely to emerge in the future.

To study these risks, the Climate Impact Lab compiled the largest sub-national vital statistics database in the world. It details 399 million deaths from all causes in 41 countries around the world — accounting for 56 percent of the global population — with age-specific mortality rates that reveal each population's distinct level of vulnerability. Analyzing this data revealed a U-shape curve that represents how both extreme cold and extreme heat increase death rates, particularly for the elderly.

Figure 1 · Partial Social Cost of Carbon for Mortality, Central Estimate



The researchers used this curve to construct what is called a "damage function" — linking changes in the global climate to economic costs — that shows the total value of lives lost and the costs for adapting to a warming climate. To bring this relationship into focus for the rest of the world, the researchers rely on local historical climate observations and socioeconomic data.

Their model divides the world into 24,378 regions – each with roughly equivalent populations and uniform temperature conditions within their boundaries. The researchers calculate mortality impacts within each region. These high-resolution estimates generate local information on how sensitive each population is likely to be as temperatures rise, building a robust empirical foundation that is more globally representative than earlier models of the damages of climate change (Figure 1).

Next, they combined this analysis with three projections for future income and population growth, two trajectories of future greenhouse gas emissions, and simulations from 33 climate models to project how the sensitivity of mortality rates to temperature relationship could evolve through the end of the century. Their computer simulation calculates mortality impacts for each region and scenario for every day from the present through 2100 — generating 10 billion estimated mortality impacts. This big data approach to climate impacts marks a huge step forward from previous estimates of the costs of climate change, which assume that society's response remains constant over time, ignoring any adaptations that populations are likely to undertake.

By modeling these pathways, the team was able to estimate how rising income levels would allow populations to adapt and increase their resiliency to extreme heat. As populations notice their climate changing, their behaviors and investments begin to reflect expectation of new weather normals — like more heat waves or fewer cold snaps — and further adaptation takes place. The team uncovered estimates of this additional adaptation, while simultaneously tracking the costs of these protective measures. The method they have developed calculates how much people are willing to pay to avoid the mortality risks of climate change, reflecting both the costs and benefits of adaptation.

Findings

1. In dollar terms, this paper's empirically-grounded estimates of mortality risks substantially exceed mortality risks in the models that underlie previous U.S. government estimates of the social cost of carbon. Only one of the three integrated assessment models supporting the figure — roughly $41 in per ton of CO2 emitted in 2015 — allows calculation of a partial cost assigned to mortality risk. The Climate Framework for Uncertainty, Negotiation and Distribution (FUND) values three comparable health impacts of climate change — diarrhea, vector borne diseases, and cardiovascular/respiratory impacts — without data-driven evidence of how these outcomes are actually impacted by changing climates. The FUND estimate for these three impacts is less than $1.50 per ton, while the Climate Impact Lab values mortality risks at roughly $39, reflecting the importance of examining historical data from diverse and globally representative populations.

2. The amount people spend to adapt accounts for roughly two-thirds of total damages, with the value of actual lives lost accounting for the remainder. Declining cold-related deaths will benefit some parts of the world, while the impacts of high temperatures will be lowest for some well-adapted regions. For example, Northern Europe, Singapore, the Andes, and Alaska, stand to gain from climate change. Several regions that are relatively wealthy and hot today, such as Australia, Saudi Arabia, and the southeastern United States, are already so heavily adapted to their hot climate that the findings show additional warming will lead to limited additional mortality or adaptation costs.

3. Each of the study's 24,378 regions exhibits a unique relationship between mortality and temperature. To capture these effects in a way that is relevant to policymakers, the value of lost life and the net costs of life-saving adaptations are expressed in death-equivalents. These calculations are done for all regions in the world. By 2100, for example, the researchers project that climate change will cause annual damages equivalent to approximately 3,700 deaths in Mogadishu, Somalia, but generate benefits equivalent to roughly 1,100 lives in Oslo, Norway.

4. Vulnerability to extreme temperatures depends on a location's climate and its level of income, which must be tracked at a local scale. The costs of mortality are distributed unevenly around the world, and extreme heat is measurably deadlier for the poorest populations of the world. These findings were only possible due to the collection and analysis of high-resolution data covering nearly half of the global population, which also account for the positive impacts of reduced cold-related deaths as the world warms.

ABOUT THE CLIMATE IMPACT LAB

The Climate Impact Lab is a collaboration of more than 20 researchers from the University of California, Berkeley, the Energy Policy Institute at the University of Chicago (EPIC), Rhodium Group, and Rutgers University. Together, they are linking state-of-the-art climate modeling, economic statistics, and big data analytics to build the world's most comprehensive body of research quantifying the impacts of climate change around the globe. EPIC provides core financial and administrative support for the Lab.

Learn more at impactlab.org

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