ECONOMICS

What's the damage from climate change?

Improved damage models put social cost of carbon estimates on a firmer footing

By **William A. Pizer**

Questions of environmental regulation typically involve trade-offs between economic activity and environmental protection. A tally of these trade-offs, put into common monetary terms—that is, a cost-benefit analysis (CBA)—has been required for significant regulations (e.g., those having an annual effect on the economy of $100 million or more) by the U.S. government for more than four decades (*1–3*). Ethical debate over the role of CBA is at least as old as the requirement itself (*4*), but the practical reality is that it pervades government policy-making. If estimates of environmental impacts and valuation are absent or questionable, the case for environmental protection is weakened. This is why the estimates of climate change damages reported by Hsiang *et al.* on page 1362 of this issue (*5*) are particularly important.

Between 2009 and 2016, the U.S. government established an interagency working group to produce improved estimates of the cost associated with carbon dioxide emissions (*6–8*). It made use of the only three models, based on peer-reviewed research, that put together the four key components necessary to value the benefits of reducing climate change: projections of population, economic activity, and emissions; climate models to predict how small perturbations to baseline emissions affect the climate; damage models that translate climate change into impacts measured against the baseline economic activity and population; and a discounting model to translate the future damages associated with current incremental emissions into an appropriate damage value today (see the figure). The damage component is arguably the most challenging: Information must be combined from numerous studies, covering multiple climate change impacts, spanning a range of disciplines, and often requiring considerable work to make them fit together.

In combination, these four components can be used to compute the social cost of carbon dioxide (SC-CO_2)—that is, the dollar value associated with damage from 1 ton of additional emissions. The SC-CO_2 equivalently represents the benefits (avoided damages) from reducing emissions by 1 ton. It can thus be used to value the benefits of proposed regulatory actions, such as power plant regulations or fuel economy standards for vehicles, and weigh them against their costs.

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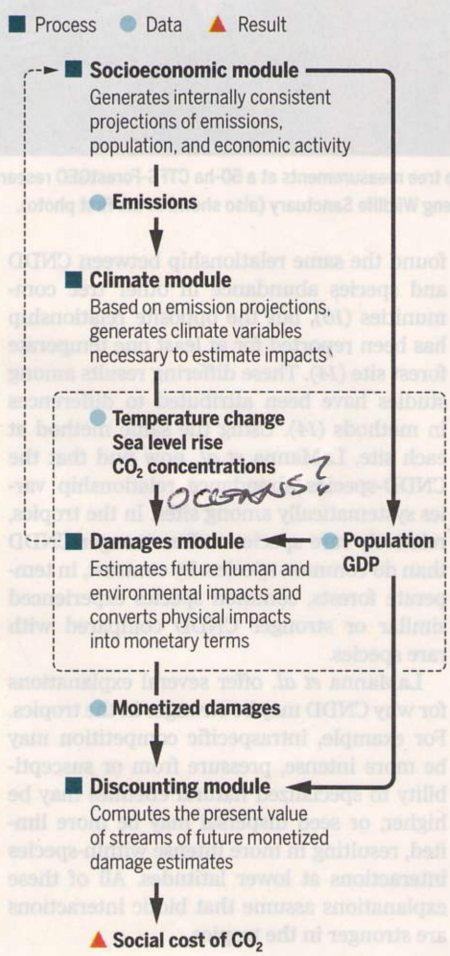
When a U.S. National Academy of Sciences panel reviewed the government estimates in 2017, it made recommendations on all four components (*9*). For the damage component, the panel recommended inclusion of updated damage functions based on more recent studies. It also called for quicker integration of future climate damage estimates once they are peer-reviewed. Hsiang *et al.* now report updated damage estimates based on recent evidence, as well as a novel architecture for integrating future work. The study offers a notable improvement in damage models for the United States and, hopefully soon, the world.

Computing the benefits of reduced climate change

Four modeling components are necessary to estimate the benefits from reduced climate change, summarized by the social cost of CO_2. This figure illustrates those components and their linkages.



GRAPHIC: ADAPTED FROM (9) BY V. ALTOUNIAN/*SCIENCE*

The estimates show that 3°C of warming would lead to a loss of ~2% of U.S. gross domestic product (GDP); 6°C of warming would lead to a ~6% loss. These estimates, for the United States only, are similar to global damage estimates from two models included in the earlier U.S. government estimates; the third model showed somewhat lower global damages (*10*). It remains to be seen whether the pattern stays the same when Hsiang *et al.* extend their work to the rest of the world. But regardless of where their global damage estimates come out, the true achievement is the enhanced credibility for future benefit estimates built on this work.

Equally tantalizing is the promise of the model architecture that Hsiang *et al.* have developed. This architecture allows the addition of further sectors and studies, alongside the noted expansion to cover the global economy. Damage estimates are driven by temporally and geographically detailed climate projections across a range of possible future outcomes. Such detail matches that required by recent studies tied to similarly detailed historical data (*11*), while standardization facilitates the rapid inclusion of future studies. In this way, Hsiang *et al.*'s architecture speaks directly to recommendations 2.2 and 2.4 from the National Academy of Sciences that modeling "should be consistent with the state of scientific knowledge as reflected in the body of current, peer-reviewed literature" and that there be "a regularized process for updating SC-CO_2 estimates" (*8*).

These results are not without caveats. Hsiang *et al.* appropriately focus much attention on quantifying uncertainty in the estimates. Yet key parameters are fixed, including the value associated with mortality consequences (which drives one-half to two-thirds of the estimated damages). Other, subjective choices abound in an exercise of this kind and deserve further discourse and debate. For example, Hsiang *et al.* describe seven criteria for including and excluding recent studies. Are these the right ones? Ethical or policy choices may also be subjective. For instance, should damage estimates include societal preferences for risk aversion and inequality, particularly if applied to government CBA? Hsiang *et al.* explore this question in side cases.

Although these improved damage estimates are critical for improved CBA, the other three components used to compute the SC-CO_2 also need upgrades (*9*). Hsiang *et al.*'s estimates are based on the U.S. economy in 2012. Assuming the structure of the U.S. economy is relatively stable, one can make necessary extrapolations to 2100. Such an assumption is untenable for the world as a whole, however. Global damage estimates will require projections of population growth and economic activity. CBA also requires estimating the incremental impact of a small amount of additional emissions. This requires realistic baseline emission forecasts and a climate model that captures impulse response, not just long-term climate sensitivity.

This is a big but worthy agenda. As recent actions by the current U.S. administration highlight, the pendulum for environmental protection can swing back and forth. Yet conservative governments, including the current one, have maintained an emphasis on CBA (*12*, *13*). Improved analysis of the costs and benefits of climate change mitigation can thus be a cornerstone for a durable policy architecture. ■

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