POLICY FORUM

CLIMATE POLICY

# Equity weighting increases the social cost of carbon

New government guidelines could transform benefit-cost analysis of US climate policy

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The social cost of carbon (SCC) is an estimate of the monetized damages to society from emitting an incremental tonne of carbon dioxide ($CO_2$). This metric helps inform how society navigates the trade-off between near-term carbon emissions mitigation costs and avoided climate damages. One well-recognized factor in determining the SCC is the choice of discount rate, which reflects how people value future versus current economic benefits and costs. Less well understood are potential impacts of "income weighting" (also known as "distributional" or "equity" weighting), a method that emphasizes the distributional equity implications of regulations, placing greater weight on benefits and costs affecting low-income groups relative to higher-income ones. We show that an approach to distributional weighting proposed in 2023 by the US government increases the SCC by nearly a factor of 8.

In December 2023, the US Environmental Protection Agency (EPA) finalized a new SCC estimate of $190 per tonne of $CO_2$ to be used in federal regulatory impact analysis (*1*). More than three times larger than the previous official US SCC, this increase was driven largely by lowering of the discount rate from 3 to 2%. In November 2023, the Office of Management and Budget (OMB) adopted the same 2% discount rate in its new regulatory impact analysis guidelines (Circular A-4) for all federal agencies. Although the effect of this lower rate on the SCC is well understood, the new OMB guidelines also allow the use of income weighting. Agencies are not required to use income weights, but if they do, they must do so uniformly across all costs and benefits and can present results as a sensitivity to a typical unweighted analysis or make weighted results the primary analysis.

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Although the choice of a lower discount rate has received considerable public attention, we demonstrate that this potentially more controversial updated treatment of distributional concerns in Circular A-4 has even larger implications for the SCC. When summing up benefits and costs across society, the distributional weighting approach from Circular A-4—applying weights greater than one on benefits and costs affecting groups of people who have lower incomes than the typical (e.g., median) American today and weights less than one to those who are wealthier—increases the SCC by nearly a factor of 8 in the Greenhouse Gas Impact Value Estimator (GIVE) model. GIVE is one of the three models used by the EPA and is closely representative of EPA's three-model average estimate of $190 per tonne (*1, 2*). This large change in the SCC, on top of the more than threefold increase arising primarily from the lower discount rate, owes to the fact that most of climate change's global welfare impact will occur outside US borders, where most people have lower incomes than the median American and hence receive greater weight.

## DISTRIBUTIONAL WEIGHTING

Conventional benefit-cost analysis assumes that those who benefit from a policy can compensate those who are made worse off, but this compensation is rare in practice. Climate impacts are commonly monetized on the basis of estimates of individuals' willingness to pay to reduce them, yet such willingness-to-pay measures can be limited by an individual's financial resources, implying that monetized damage estimates will generally be lower for lower-income groups. This limitation strikes some as ethically fraught and inequitable. A second and distinct motivation for distributional weighting cited in Circular A-4 reflects the notion that a dollar to a high-income individual is considered less valuable than the same dollar to a low-income one—a concept referred to as diminishing marginal utility of income. Both concerns can be addressed by using distributional weights in benefit-cost analysis. Although the previous version of Circular A-4, published in 2003, considered distributional consequences to some degree, past federal regulatory impact analyses often offered qualitative assessments at most.



The US government's recent update to Circular A-4 allows federal agencies to put these distributional issues center stage by explicitly adjusting dollar-valued impacts on the basis of the income of the individuals to whom they accrue. Distributional weighting is not new to the economics literature (*3*) and has been used for real-world policy analysis in the past. For example, the United Kingdom allows for the use of distributional weights in benefit-cost analysis, and the German government currently uses distributional weights to estimate its official SCC.

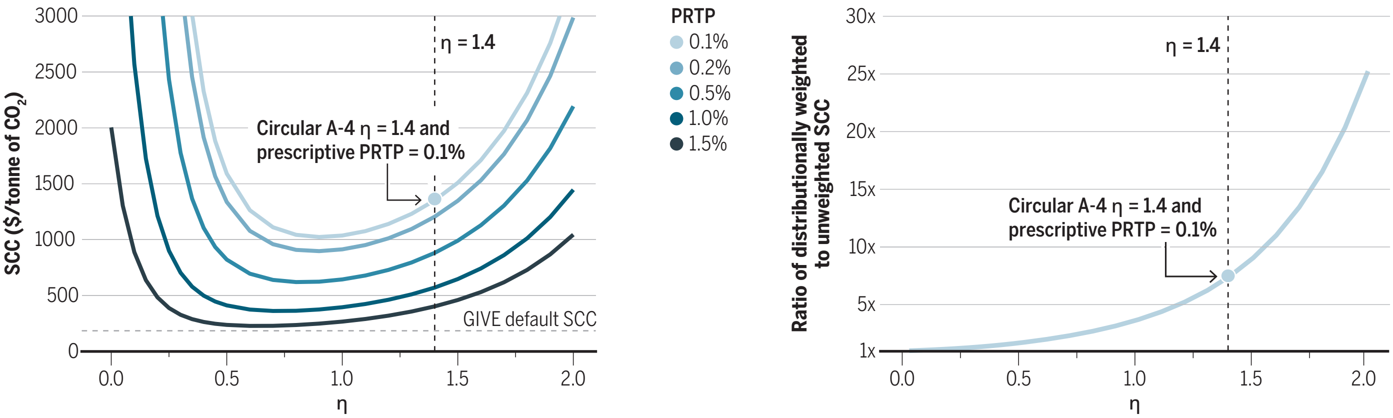
However, distributional weighting has never been used in benefit-cost analysis by the US government. The conceptual approach proposed by the US government is the same that is currently used by the German government, and the relative change that we find from unweighted to weighted SCC estimates is similar to that of previous studies (*4–7*). The US adoption of income weighting is nevertheless especially interesting for at least two reasons: First, the US is using a new generation of underlying integrated assessment models that are much more recent and produce larger unweighted damage estimates, and consequently also much larger weighted damage estimates, than, for example, the application in Germany. Second, the US regulatory process relies much more heavily on benefit-cost analysis than other countries, making the adoption of weighting a much more impactful development.

When applying income weighting, the magnitude of the weight assigned to lower-income groups is determined by a parameter $\eta$ that corresponds to how the marginal value of a dollar declines with income. $\eta$ is most frequently used to represent peoples' preferences about risk as well as the relative value of benefits received at different points in time when they are relatively wealthier. The distributional weighting approach further uses $\eta$ to reflect the relative value of a dollar across groups of people with different incomes. This approach treats income differences between two individuals at any given time in the same way as it treats income differences between individuals at different points in time.

Typical values for $\eta$ range between 1 and 2 (*8*), which represent how much the value of a dollar diminishes as an individual grows wealthier [for a more detailed discussion of appropriate values of $\eta$ for various contexts, see (*9*)]. For example, in the distributional weighting context, an $\eta$ value of 1 implies that an individual with an income of $50,000 values an extra dollar twice as much as an in-

## Isolating the effect of distributional weighting on the social cost of carbon

(Left) The weighted social cost of carbon (SCC) is shown at different values of pure rate of time preference (PRTP) and η, including under the preferred values from Circular A-4 (η = 1.4, PRTP = 0.1%). For comparison, the unweighted central SCC estimate of $185/tonne is shown from the Greenhouse Gas Impact Value Estimator (GIVE) model. The U-shaped relationship reflects how the SCC varies with η, but η represents multiple concerns, not just distributional weighting. (Right) The isolated effect of distributional weighting on the SCC is shown as a function of η, expressed as a ratio to unweighted SCC values. The curve corresponds to a PRTP of 0.1%, but results for other PRTP values are nearly identical (not shown here). The effect under the preferred values from Circular A-4 is highlighted.




dividual with twice that income ($100,000). Thus, dollars accruing to the lower-income individual would receive twice the weight of dollars accruing to the higher-income one [calculated as $(\$50,000/\$100,000)^{-1} = 2$]. More generally, the new approach in Circular A-4 entails assigning distributional weights $w_i$ to a given group of people with median income of $\bar{y}_i$ as follows: $w_i = (\bar{y}_i/y_{med})^{-\eta}$, where $y_{med}$ is the US median income.

As part of the new version of Circular A-4, government analysts reviewed the economic literature on plausible values of η and suggested a "reasonable estimate" of 1.4 derived from a survey of empirical evidence on peoples' observed aversion to risk, time preferences, and more. This value implies that a group of people with half the US median income would receive a weight of approximately 2.6 [$(1/2)^{-1.4} = 2.64$]. This contrasts with the conventional approach in benefit-cost analysis known as Kaldor-Hicks, which treats dollar-valued impacts to all individuals throughout the income distribution equally.

Implicit in the distributional weighting approach is the identification of the population affected by a regulation and the identification of relevant subgroups for whom to calculate distributional weights. To a large degree, Circular A-4 leaves this up to individual agencies to decide. In most cases, a US regulation's primary effects may only be on the US population, and a natural identification of subgroups could be US income quantiles. In those cases, half of the population would receive weights above one, and half would receive weights below one. This implies offsetting effects when evaluating costs and benefits accruing solely within the US population.

### INTERNATIONAL IMPLICATIONS

In contrast to the domestic context, one can also apply weights for impacts accruing to populations outside of the United States. Circular A-4 does not propose specific guidance in such contexts, but the economic theory motivating weighting implies that if one intends to compare resulting estimates to regulatory costs imposed on the US, then it is appropriate to maintain the relative anchor point of US income levels. This is analogous to Germany's implementation of distributional weighting, relative to a German income.

Such an approach, however, produces almost entirely unidirectional effects of distributional weighting. Because greenhouse gas emissions are well mixed in the atmosphere and affect all countries, the SCC reflects the global impacts of each tonne of greenhouse gas emissions. If distributional weights are applied globally using the US median income as the reference, then it is no longer the case that half of the population receives distributional weight above one, and half receives a weight below one. US median income per capita is roughly above the 90th percentile in the global income distribution. This suggests that applying distributional weighting globally will give greater weight to impacts affecting more than 90% of the global population relative to the weights given in conventional benefit-cost analysis, or the weights given to the typical US resident (both being one).

The consequences of this kind of distributional weighting are large and policy relevant. We implement distributional weighting at the country level in the GIVE model (*1*, *2*). Computing country-specific weights in GIVE using US incomes as the reference point, as recommended by Circular A-4, we show how estimates of the distributionally weighted SCC vary with η and the pure rate of time preference (PRTP), which measures the rate at which people discount future economic welfare (see the figure, left panel). Traditionally, these two parameters combine to form the above-mentioned discount rate, which reflects how much society discounts future dollar-denominated climate impacts ($r = \rho + \eta g$, where ρ is the PRTP and $g$ is the rate of global economic growth). In a "normative" (meaning ethics-driven) discounting framework, η reflects the very same notion underlying the distributional weighting approach: that each dollar of benefits accruing to (future) wealthier societies matters less for their welfare than the same dollar of benefits accruing to (current) less wealthy ones. The distributional weighting approach extends this comparison of societies across time to also apply across income groups at each given point in time.

We show a U-shaped relationship between the SCC and η in a distributional weighting framework (see the figure, left panel). This relationship is not new to the climate change economics literature (*3*, *5*, *7*) and owes to the three roles that η plays: (i) risk aversion; (ii) the relative value placed on future societies because they are expected to be relatively wealthier than society today; and (iii) the weight placed on climate impacts experienced by countries that are currently relatively less wealthy than the United States. The first two roles of η apply generally, but the third only comes into play when using distributional weights. As we increase η from zero (implying no risk aversion, discounting of future due to growing wealth, or distributional weighting), the SCC initially falls because less weight is placed on climate impacts to future wealthier societies [η's role

GRAPHIC: M. HERSHER/*SCIENCE*

[ii)]. At higher levels of η, this trend reverses course and begins to rise as concerns about inequitable climate impacts across countries [η's role (iii)] have a stronger effect. Circular A-4's value of η = 1.4, alongside a PRTP value of 0.1%, as used in the Stern Review (*10*) reflecting a normative discounting framework, yields an SCC of more than $1300 per tonne of $CO_2$ (see the figure, left panel) when using distributional weights. This represents a substantial increase over the EPA's recent unweighted $190 per tonne estimate (*1*).

Although the question about the appropriate PRTP parameter is nuanced, the distributionally weighted SCC using the US government's suggested η = 1.4 ranges from $400 [for a high value of PRTP of 1.5% such as that used in (*11*)] to more than $1300 per tonne of $CO_2$ (for PRTP = 0.1%). From a normative discounting perspective, it is commonly argued that the PRTP should be close to zero on the grounds that we should not place lower weight on the well-being of our grandchildren simply because they were born later than we were (*8, 10*). In his seminal 1928 article, Ramsey famously argued that anything else "is ethically indefensible and arises merely from the weakness of the imagination" (*12*). When we use PRTP values on the low end of the range considered, we find SCC estimates on the upper end of the $400 to $1300 range, representing a substantial increase in the SCC.

## ISOLATING THE EFFECT

The U-shaped SCC relationship reflects how the SCC varies with η but η represents multiple concerns: risk, adjustments for the relative wealth of future societies versus today's, and distributional weighting (see the figure, left panel). Hence, this relationship does not isolate the effect of distributional weighting itself. We now isolate the effect of distributional weighting on the SCC, expressed as a ratio of the weighted SCC estimates to the unweighted values computed using the same PRTP and η parameters. The numerator and denominator in these ratios vary only in whether the distributional weights are computed (numerator) or implicitly replaced with a value of $w_i$ = 1 (denominator, corresponding with using a value of η = 0 in the weighting equation, while nonetheless allowing it to vary in its other roles for risk and time preferences), with the latter approach corresponding to the approach in standard GIVE and underlying the EPA's recent $190 per tonne estimate. The results show that the effect of distributional weighting rises nonlinearly with the weighting parameter η and leads to large increases in the SCC (see the figure, right panel). US median income per capita is above the 90th percentile in the global income distribution, meaning that a large fraction of affected countries receive weights that are above one and nonlinearly increasing in the weighting parameter η. For example, using Circular A-4's suggested value of η = 1.4, a country with per capita income about a third of the US level would receive a weight of nearly 5 times [= $(1/3)^{-1.4}$]. This strength and nonlinearity, coupled with the generally regressive impacts of climate change, mean that distributional weighting using a common range of η values (for example, between 1 and 1.5) increases the SCC by a factor of roughly 4 to 10 regardless of the value of PRTP (see the figure, right panel). The specific value of η = 1.4 suggested by the US government would increase the SCC by nearly a factor of 8, roughly consistent with the effect previously found when Germany implemented a distributionally weighted SCC. Using the value of η = 2 used in (*13*) would increase the SCC in GIVE by a factor of more than 25.

## DISCUSSION

These results come with several caveats. We compute distributional weights using US incomes as the reference point as suggested in Circular A-4. One could use a different country for the reference point, like anchoring to German income as Germany does for their SCC estimates. For countries with lower average incomes than the US, this change would imply lower distributional weights and hence smaller SCC values—and could even imply weighted SCC values that are lower than unweighted ones. Although the choice of reference point has a large effect on the particular values for the SCC, the outcome of a benefit-cost analysis is entirely invariant to the reference point choice, as long as all costs and benefits are correctly weighted using the same reference point (*4*). The choice of reference point is analogous to a unit choice.

However, by computing weights at the country level, we only account for distributional concerns across countries, not within them. Accounting for intracountry distributional concerns by weighting at the subnational level would likely increase our SCC estimates (*6*). Further, the impact of distributional weighting will depend on the spatial granularity of the model; GIVE is resolved at the country level, but other models with finer resolution will likely see larger effects owing to the nonlinearity of the weighting function.

Distributional weighting also brings to light questions of standing, which involves identifying whose benefits and costs are considered in the scope of analysis. There is considerable debate over the appropriate standing of non-US residents when the US government evaluates climate policies (*14*). Three potential approaches to standing for such non-US residents include (i) no standing, which effectively implies zero weight; (ii) full standing with unitary weights; or (iii) full standing with nonunitary weights, mostly above one. Past approaches to estimating the SCC typically used the first or second approach. The choice between these two approaches can alter the SCC by an order of magnitude (*1*). Our results show that the choice between the second and the third approaches can be similarly impactful.

It is also still an open question to what extent agencies will adopt income weighting in their regulatory analysis in practice. Although Circular A-4's new discounting guidelines are mandatory, the new income weighting approach is optional, with little to no guidance to agencies on how to exercise that discretion. For some applications, data limitations will presumably prevent agencies from applying income weighting, but in cases like the SCC where income weighting can be used, there is little instruction in Circular A-4 on how agencies should decide whether to adopt this approach or not—Circular A-4 simply permits it.

Caveats aside, the recently finalized updates to the regulatory impact analysis guidelines for US government agencies regarding distributional weighting would increase the SCC by nearly a factor of 8. This effect is much larger than that caused by the recent changes to discounting that have received much more attention. Given its newfound importance, the proper role of distributional weighting warrants careful and judicious dialogue in the scientific and policy communities. ■

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