COMMENT BY

MAR REGUANT This paper makes significant contributions to updating the social cost of carbon (SCC) calculations, which estimate the marginal damages from climate change and are vital to climate policy (Nordhaus 1982). As explained by the authors, the SCC is often used to inform the design of important legislation, and it has influenced over sixty federal regulatory analyses (Aldy and others 2021).

The authors' goal is to present a framework with several steps to improve current estimations of the SCC. The proposed methodology corrects for the intertemporal changes in the utility of income due to income effects by introducing a stochastic discount factor. The authors also propose eliciting experts' beliefs on uncertain processes, such as emissions, growth, and population trends.

The work by Rennert and colleagues is part of a larger agenda conducted by the Resources for the Future's (RFF) Social Cost of Carbon Initiative and collaborators to improve and expand the tools to inform the metrics surrounding the SCC. This agenda follows the recommendations from a 2017 committee report by the National Academies of Sciences, Engineering, and Medicine (NASEM 2017).[1] This initiative plans to expand further the treatment of uncertainty surrounding economic damages, another recommendation not yet addressed in this contribution which suffers from several limitations.[2]

In this comment, I focus first on the mechanics behind the correction when using a stochastic discount factor. I then discuss the challenges in eliciting beliefs about future outcomes for scenarios that have never happened, a difficulty shared when estimating the SCC with micro data. I also point out the benefits of complementing the SCC calculation with more detailed sectoral analyses. Finally, I conclude by discussing the importance of understanding what the estimates of SCC imply for our abatement strategies, highlighting the necessity of assessing that the recommended SCC is consistent, under reasonable assumptions, with the emissions trajectory that informs it.

1. See, for example, Newell, Pizer, and Prest (2021), which lays out the methodological aspects of the stochastic discount factor in more detail.

2. The treatment of economic damages is at the moment based on Nordhaus (2017), who estimates that by 3 degrees Celsius, the GDP impact will be 2.1 percent. Using the revised DICE model (DICE-2016R), these damages imply an SCC of $31 per ton of CO_2 in 2010 US dollars. These are quite optimistic scenarios, and expanding the set of damages in the presence of uncertainty seems of first order, for example, as in Barnett, Brock, and Hansen (2021).

CORRECTING FOR THE DECLINING MARGINAL UTILITY OF INCOME A key finding of the authors is that considering the declining marginal utility of income, in an intertemporal sense, leads to a lower SCC estimate.[3] Table 1 in the article shows that accounting for stochastic growth discounting (declining marginal utility of income in future events) reduces the SCC by a factor of two to four. The authors find that outliers drive part of the magnitude of the correction. However, muting the role of outliers, the SCC still goes from $96 to $61 when introducing this correction. In sum, considering the declining marginal utility of income leads to less emphasis on climate mitigation efforts.

It is essential to understand the factors driving this finding, which leads to a downward correction of the SCC. This finding clashed with my initial economic intuition, as I had expected the SCC to become more prominent after considering the declining marginal utility of income. My instinct was based on two premises. From a cross-sectional point of view, marginal damages from climate change tend to be largest for poor agents (countries or households), and these agents also have the largest marginal utility of income. From an intertemporal point of view, I expected bad news from climate (severe marginal damages) to correlate with poor growth outcomes, leading to low income and high marginal utility of income as well.

The fact that the SCC is larger for better outcomes is in part driven by the model's assumptions. As explained by the authors, the role of the correction can critically depend on the "climate beta," a parameter summarizing the relationship between damages and aggregate consumption: "The magnitude of this bias [of the SCC that ignores the stochastic discount factor] depends on the climate beta and on the nature of the uncertainty in socioeconomic and emissions trajectories."

The methodology takes a climate beta of essentially one in the short run, partly driven by damages being proportional to GDP (Dietz, Gollier, and Kessler 2018). In good states, marginal damages are *larger* and potentially much larger, given that growth is exponential. However, states with severe damages are also the richest, so they are less important from a relative point of view with Ramsey-like discounting. Therefore, there is a substantial downward correction of the SCC for those states in which the uncorrected SCC is highest.

An additional aspect contributing to a significant downward correction of the SCC is that expert beliefs about growth have a relatively symmetric bell shape centered around a roughly 2 percent growth rate. Because damages

3. Contemporaneous differences in the marginal utility of income are not considered in the paper.

are exponential in growth via the previous assumption, marginal damages in high growth states are more heavily corrected downward when compared to low growth states. Still, these are similarly likely, leading to an overall downward correction of the central estimates of the SCC.

It would be helpful to consider departures more explicitly from the baseline assumptions in the model, for example, by assessing the magnitude of the bias correction for a range of climate betas.

ON THE DIFFICULTIES OF FORECASTING Expert beliefs determine trajectories about population, emissions paths, and growth in the proposed calibration of the SCC. However, this is a challenging object to forecast, even by experts, because it is a process that we have never observed.

In truth, forecasting the socioeconomic impacts of climate change is difficult for any methodological approach taken, be it expert elicitation, data estimation, or mathematical modeling.[4] Climate change is an extrapolation of a process that we have never witnessed. The socioeconomic processes behind population growth, emissions, and economic outcomes are extremely difficult to inform in uncharted territory. As soon as we move away from physical processes that follow well-understood laws of physics, nonlinearities in the impacts of climate change are hard to foresee.

The highly uncertain nature of growth, emissions, population, and climate damages affects the precision of the distribution of the SCC. Even without incorporating uncertainty about economic damages, figure 11 shows that there is a wide distribution of implied marginal damages for any given approach or set of assumptions. Therefore, the calculation should be interpreted as an improvement to a "scenario" approach to calibrating the SCC but of a highly uncertain nature.

Whereas this might be the best possible strategy, I believe there is room for improvement in future work. In particular, the modeling of interactions between these three processes is limited, given that the three processes are elicited from different experts. The paper allows for some considerations on the correlations between the distributions, but it is not very clear in the current contribution to what extent they play a significant role. Additionally, it would be interesting to include elicitation of climate betas in future iterations.

The elicitation of independent experts for these categories can lead at times to seemingly inconsistent beliefs. For example, when describing the correlation between growth and emissions, "many [growth] experts expected

4. Pindyck (2013) discusses some of the pitfalls of mathematical assumptions in the calculation of the SCC. Auffhammer (2018) discusses some of the challenges and progress on the empirical data–driven front.

that technology breakthroughs in clean energy would dramatically lower global emissions. Implicit in this narrative is a negative correlation between economic growth and carbon dioxide emissions."

However, when looking at emissions elicitation, the beliefs by emissions experts, as implied by figure 7, seem to associate higher emissions to higher growth, at least in the medium run (2050). Some further discussion on how to deal with these relationships could be a potentially fruitful area of improvement.

BRIDGING THE GAP BETWEEN SHADOW VALUES As countries announce pledges to reduce their emissions by 2030 and to achieve net zero by 2050, there has been a focus on how to reduce emissions most effectively for a given goal. This alternative approach calculates the price of carbon that would be consistent with a specific reduction in emissions by solving for the optimal portfolio of climate policies with a given target. The target is taken as given, and therefore this approach is not explicit about what the damages from climate change are. Examples of such an optimization approach are the models solving for how to reach net zero in the United States or the policy framing of the Fit for 55 goals in the European Union.[5]

There has been a recent discussion on the merits and pitfalls of using either approach (Stern and Stiglitz 2021; Aldy and others 2021). While the SCC approach has been preferred in the US context, the target approach is much more common in Europe. This is in part due to the higher agreement on the politically established emissions reduction goals across a broad range of the political spectrum. Europe, indeed, has had a cap-and-trade mechanism with explicit cross-sectoral goals since 2005 and has explicit reduction goals by 2030 and 2050 that are being built into legislation.

While it seems natural to stick to the SCC for US regulatory purposes, I believe there could be some fruitful interactions between these two methods. Like the traditional quantities versus prices trade-off, the two approaches suffer from limitations in the presence of uncertainty about the costs and benefits of fighting climate change (Weitzman 1974). Since the target approach focuses on efficient cost abatement, it tends to have a much more detailed accounting of uncertainties on the technological front, something missing in the highly aggregated integrated assessment models (e.g., Dynamic Integrated Climate Change [DICE], Climate Framework for

5. See, for example, Princeton University Andlinger Center for Energy and the Environment, "The Net-Zero America Project," https://acee.princeton.edu/rapidswitch/projects/net-zero-america-project/; or European Council, "Fit for 55," https://www.consilium.europa.eu/en/policies/green-deal/eu-plan-for-a-green-transition/.

Uncertainty, Negotiation and Distribution [FUND], Policy Analysis of the Greenhouse Effect [PAGE]). In the approach proposed by the authors, and given the focus of SCC calculations on damages, such uncertainty is only indirectly present in the trajectories forecasted during expert elicitation.[6]

More accurately describing the expected transformation at a given SCC would add credibility to the forecasted emissions trajectories. Using detailed modeling of technology, even if only for specific sectors in which technology is well understood, such as the electricity sector, could help bound the expected impacts of using the SCC as a tool for cost-benefit analysis. Considering the implications for abatement of a given SCC is particularly important for the proposed methodology, which takes the SCC as an output rather than an equilibrium object, as I discuss next.

A CRITICAL FEEDBACK LOOP In contrast with other attempts at quantifying the SCC, the proposed methodology does not use an integrated assessment model to derive an equilibrium value for the SCC. Instead, the SCC is estimated as the marginal damage of climate change evaluated at the forecasted level of emissions.

This simplicity in the framework can be achieved thanks to directly incorporating expert elicitation for equilibrium trajectories of growth, emissions, and population. However, it comes at the risk of being an out-of-equilibrium object that is potentially inconsistent with the estimated SCC.[7]

The importance of the output from this research, an updated SCC to be used in US policy, makes this concern even more crucial. The SCC is a vital number for US policymaking. As explained in the article, "as political leaders and stakeholders debate both the broad outlines and the fine details of policies to reduce carbon dioxide emissions, the SCC lies in the background as a remarkably important calculation, used by the US federal government for more than a decade for developing vehicle fuel economy standards and power plant emissions rules."

Precisely for this reason, it is important to ensure that the predicted SCC is consistent with the fundamentals that inform it. Estimating damages from climate change cannot be independent from accurately understanding the abatement cost function. Indeed, the equilibrium feedback loop of the calculation can be even more critical if the obtained SCC has a direct impact on climate policy, and thus the emissions trajectory.

6. Experts are considering beliefs on technological progress and breakthroughs when forecasting growth and emissions, but these are not quantitatively modeled.

7. In line with this concern, Diaz and Moore (2017) emphasize the value of using more detailed integrated assessment models that model more closely the functioning of resources and sectors but that ensure that the calculations of the SCC are in equilibrium.

To make this point more concrete, it is useful to take the illustrative estimate of \$61 SCC in the article. While this is an SCC larger than previously estimated by the US federal government, it is unclear that it can be consistent with the substantial and fast decarbonization efforts that one would need to see to achieve emissions reductions consistent with those expected by the experts. In the electricity sector, one of the most easily decarbonized, it is unclear that such a threshold for cost-benefit analysis would lead to massive transformation and almost net zero generation that many governments have announced.

One response to this criticism is that almost net zero targets in the electricity sector is not a desirable goal, as implied by the estimated SCC. However, because the estimate is not an equilibrium object under the proposed methodology—the heart of this criticism—it is unclear how emissions at this SCC can decrease as projected by the experts. Thus, coupling the estimated SCC with information about expected actions that pass the cost-benefit analysis at such value, even if limited to a subset of policies, would be tremendously useful.

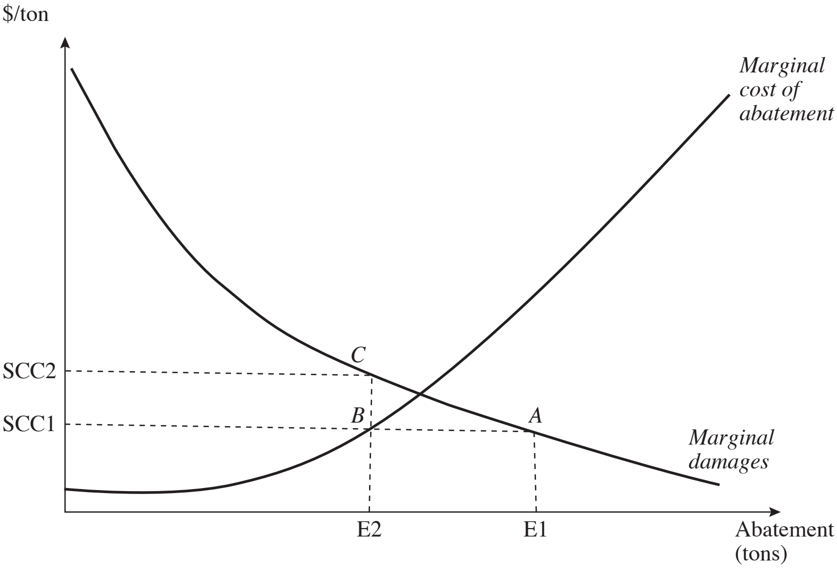
Figure 1 clarifies this point. The increasing cost curve represents the marginal cost curve of abatement. The downward damage curve represents the marginal damages of climate change, which are highest when no abatement occurs and the temperature rises the most.[8] In a simplified environment without uncertainty, the goal should be to equalize the costs of abatement to the avoided damages.

In the proposed methodology, experts are the ones who determine where in the damage function we are crossing. The researcher elicits the emissions reductions from experts and then estimates the SCC at that point. Suppose that experts do not necessarily have equilibrium beliefs about emissions reductions and are optimistic, concluding that abatement efforts will be at point E1. This would imply an SCC of SCC1 (point A). If these beliefs are out of equilibrium, however, abatement efforts might be much lower at a threshold of SCC1, and emissions reductions might only be E2 (point B). However, at E2, marginal damages should have been estimated to be larger and equal to SCC2 (point C).

Any guidance on whether the emissions reductions implied by E1 are plausible under an SCC equal to SCC1 would add validity to the approach. One possibility would be to take a battery of more complex integrated

8. Note that the illustration gives the illusion that this might be a static formulation, but it should be interpreted as a summary of complex relationships with dynamic abatement and damage curves, including stochastic discounting and so forth.

Figure 1. Potential Pitfalls with an Out-of-Equilibrium SCC



Source: Author's illustration.

assessment models and run them under the assumption that the benchmark for cost-benefit analysis is SCC1. Because complex integrated assessment models can be sensitive to their technological modeling, the researcher could get a sense of the sectoral and technological assumptions consistent with such an equilibrium outcome.

I believe this is an important missing link. In the example above, I highlight the case where experts might be optimistic about emissions declines because this is the riskiest scenario. Underestimating the need for climate action could lead to substantially more serious marginal damages. Thus, having a more explicit bridge between experts' beliefs and bottom-up approaches that more systematically model expected policies and their impacts on emissions reductions could prove useful to make the recommendations more robust.

CONCLUSIONS The SCC is a critical measure to inform climate policy. The authors present an expanded approach to include stochastic discounting and expert elicitation in the estimation of the SCC. A few limitations are yet present in these calculations. First, it would be important to consider expanded damage functions that are more robust to those based on the DICE model, something the authors are already exploring. Second, it would be useful to consider complementing the top-down modeling of the SCC with bottom-up approaches of sectoral abatement efforts that give robustness to the estimated SCC.

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