The Implications of Uncertainty and Ignorance for Solar Geoengineering

Richard J. Zeckhauser
Harvard Kennedy School

Gernot Wagner
Harvard University Center for the Environment

Key Points

- Both unchecked climate change and any potential deployment of solar geoengineering (SG) are governed by processes that are currently unknowable; i.e., either is afflicted with *ignorance*.
- Risk, uncertainty, and ignorance are often greeted with the precautionary principle: "do not proceed." Such inertia helps politicians and bureaucrats avoid blame. However, the future of the planet is too important a consequence to leave to knee-jerk caution and strategic blame avoidance. Rational decision requires the equal weighting of errors of commission and omission.
- Significant temperature increase, at least to the 2°C level, is almost certainly in our planet's future. This makes research on SG a prudent priority, with experimentation to follow, barring red-light findings.
- On an expected-value basis, greater SG uncertainties make SG itself more attractive. That is because the uncertainties of unchecked climate change and SG are highly correlated. The uncertainties of climate change are likely far more consequential.

What's known about climate change provides a lower bound on its cost.[1] What's unknown makes it possibly much costlier. And then there are climatic unknowables, consequences that we can't even conjecture. These unknowns and unknowables, which we label UUs, make the expected costs of climate change greater than calculations employing known factors would indicate. It is hard to imagine pleasant surprises about climate effects.

It is against this backdrop of UU-afflicted climatic consequences that solar geoengineering (SG) must be evaluated.

1 The official U.S. social cost of carbon dioxide (SC-CO_2) under the Obama Administration was around \$40/ton (U.S. Government Interagency Working Group on Social Cost of Carbon 2010, 2015). Climate sensitivity tail uncertainty points to that quantification as a lower bound (Wagner and Weitzman 2015; Weitzman 2009, 2011). The latest attempts at estimating the SC-CO_2, for example, point to values possibly ten times higher than the \$40 figure, with large uncertainty ranges (Ricke *et al.*, 2018).

Risk, uncertainty, and ignorance

Risk arises when the probabilities of all possible states of the world are known, as say securing a "7" with the roll of two dice. Uncertainty arises when the states of the world are known, but not their probabilities – for example, the chance that a particular politician will win re-election. Virtually nothing about climate change merely involves risk, but it is a hot bed of uncertainties.[2]

When considering a cloudy future, and notably a climate future, there is a third, critical concept: ignorance. Given ignorance, even the identities of important states of the world are not known.[3] Neither 9/11 nor the Arab Spring was seriously contemplated. Although some climate outcomes, like climate sensitivity, can be neatly captured by assumed probability distributions, hence are merely uncertain, other important climate-related outcomes reside in the realm of ignorance.[4] Consider for example how societies will respond to massive in-migrations.

SG, if implemented, would also usher in ignorance. A case in point here is a recent *Nature* cover article analyzing the effects of volcanic eruptions, chiefly Mt. Pinatubo, on crop yields.[5] Its main conclusion: Volcanic eruptions had no statistically significant effect on global crop yields, as the temperature effects from reduced heat stress on plants were counterbalanced by an "insolation effect" due to more scattered sunlight. The study's headline-grabbing conclusion then extrapolates this finding to SG. Without going into the science itself, the mere date of the study demonstrates that SG brings with it UUs: Mt. Pinatubo erupted in 1991. Most of its effects were felt in 1992. Yet the *Nature* study was not published until a quarter century later, in 2018. And it, too, is far from perfect, having likely missed important aspects of SG, such as the CO_2 fertilization effect. Many of nature's deeply buried secrets have yet to be uncovered.

How then should we think about policy decisions in the climate change context, where uncertainty and ignorance prevail, and where human life is threatened? Some critics urge a departure from the prescriptions of rational decision theory and its guiding principle that expected utility be maximized. Such departures – the precautionary principle would be a salient example – usually place a much greater emphasis on avoiding actions that might introduce unexpected undesired consequences,[6] as would the use of SG. We observe that when the stakes are enormous, as they are when the Earth is on track for 2°C warming or much worse, it is too expensive to take refuge in the blame-avoidance methods of the precautionary principle and its non-rational cousins.

Errors of commission versus omission

Decision-making around SG – both about research but especially around deployment – shows that individuals, including many scholars in the area, often treat errors of commission as being

2 Knight (1921) offers the seminal introduction to the topic, distinguishing between risk and uncertainty.

3 See Zeckhauser (2006), which expands on Knightian risk and uncertainty to include "ignorance."

4 See, e.g., Kopp *et al.* (2016) for a recent assessment.

5 See Proctor *et al.* (2018).

6 See Heal and Millner (2014) for a survey of alternative decision criteria in the context of climate policy.

significantly more serious than errors of omission. Psychologically such an imbalance is understandable.[7] However, from the perspective of a rational decision theory, or as best assuring the future of the planet, the two should indeed be weighted equally.

Consider the decision of whether to enroll in a high-risk medical trial. Faced with a bad case of cancer, the standard treatment is high-dose chemotherapy. Now consider as an alternative treatment an experimental bone-marrow transplant. The additional treatment mortality of the trial, of say 4 percentage points, is surely an important aspect of the decision – but so should be the gain in long-run survival probability. If that estimated gain is greater than 4 percentage points, say 10 or even "only" 6 percentage points, a decision maker with the rational goal of maximizing the likelihood of survival should opt for the experimental treatment.[8]

All too often, however, psychology intervenes, including that of doctors. Errors of commission get weighted more heavily; expected lives are sacrificed. The Hippocratic Oath bans the intention of harm, not its possibility. Its common misinterpretation of "first do no harm" enshrines the bias of overweighing errors of commission.

To be sure, errors of commission incur greater blame or self-blame than those of omission when something bad happens, a major source of their greater weight. But blame is surely small potatoes relative to survival, whether of a patient or of the Earth. Hence, we assert once again, *italics* and all: *Where climate change and solar geoengineering are concerned, errors of commission and omission should be weighted equally*.

That also implies that the dangers of SG – and they are real – should be weighed objectively and dispassionately on an equal basis against the dangers of an unmitigated climate path for planet Earth.[9]

The precautionary principle, however tempting to invoke, makes little sense in this context. It would be akin to suffering chronic kidney disease, and being on the path to renal failure, yet refusing a new treatment that has had short-run success, because it could have long-term serious side effects that tests to date have been unable to discover. Failure to assiduously research geoengineering and, positing no red-light findings, to experiment with it would be to allow rising temperatures to go unchecked, despite great uncertainties about their destinations and dangers. That is hardly a path of caution.

7 Wagner and Weitzman (2015) explore it in the context of SG. Wagner and Zeckhauser (2012) survey biases in climate policy decision-making more broadly.

8 We are simplifying by positing that survival and non-survival are the two possible outcomes. See Schneider and Lane (2005) for decision-making in medicine.

9 While the SG deployment decision itself might influence decisions around cutting CO_2 emissions in the first place, a concept often (falsely) called "moral hazard," we will not discuss this phenomenon further. See brief by Merk and Wagner in this volume.

A model of optimal learning

We are developing a simple model to illustrate potential decision-making about the use of SG in the context of UUs. SG's key characteristics can perhaps best be described as *fast*, *cheap*, and *imperfect*: SG is *fast* in the sense that its effects are felt within months of deployment, within one model period; it is *cheap* in that its direct costs are low, orders of magnitude below both the costs of unmitigated climate damages and also of cutting CO_2 dramatically in the first place; and is clearly *imperfect*. It neither destroys nor removes CO_2, and it could possibly produce large damages. Other key model assumptions include incomplete learning, and that feedback, albeit swift, is also imperfect.

The objective in our model is to pick the level of learning – through the use of experimental (partial) deployment of SG – as a complement to scientific study, to determine to what extent, if any, SG should be deployed. The optimal level would minimize the sum total of expected damages from both climate change and SG. The goal of the exercise is to straighten one's thinking about optimal testing in a highly simplified context where there is a period of testing and a period of implementation. In the testing period, one learns imperfectly about both the unfolding consequences of climate change, and both the positive and adverse effects of SG.

While the model itself is too technical to describe here, one conclusion is already evident: the greater are the uncertainties about SG damages, the more appealing, on an expected value basis, is SG. One reason for this perhaps counterintuitive result is simply the strongly positive correlation between SG uncertainty on the one hand and climate change uncertainty on the other. We would also hasten to add our speculation that, in the end, climate change uncertainty is likely to be dramatically more consequential.

References

Heal, G. and A. Millner. 2014. "Uncertainty and decision making in climate change economics." *Review of Environmental Economics and Policy* 8: 120-137. https://doi.org/10.1093/reep/ret023.

Knight, F.H. 1921. *Risk, Uncertainty and Profit*. Hart Schaffner Marx.

Kopp, R.E., R. Shwom, G. Wagner, and J. Yuan. 2016. "Tipping elements and climate-economic shocks: Pathways toward integrated assessment." *Earth's Future* 4: 346-372. https://doi.org/10.1002/2016EF000362.

Proctor, J., S. Hsiang, J. Burney, M. Burke, and W. Schlenker. 2018. "Estimating global agricultural effects of geoengineering using volcanic eruptions." *Nature* 560: 480-483. https://doi.org/10.1038/s41586-018-0417-3.

Ricke, K., L. Drouet, K. Caldeira, and M. Tavoni. 2018. "Country-level social cost of carbon." *Nature Climate Change* 8: 895-900. https://doi.org/10.1038/s41558-018-0282-y.

Schneider, S.H. and J. Lane. 2005. *The Patient from Hell: How I Worked with My Doctors to Get the Best of Modern Medicine and How You Can Too*. Da Capo Lifelong Books.

U.S. Government Interagency Working Group on Social Cost of Carbon. 2010. *Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*. February. https://www.epa.gov/sites/production/files/2016-12/documents/scc_tsd_2010.pdf.

U.S. Government Interagency Working Group on Social Cost of Carbon. 2015. *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. July. (Revision to May 2013 version.) https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf.

Wagner, G. and M. Weitzman. 2015. *Climate Shock: The Economic Consequences of a Hotter Planet*. Princeton University Press.

Wagner, G. and R.J. Zeckhauser. 2012. "Climate policy: hard problem, soft thinking." *Climatic Change* 110: 507-521. http://doi.org/10.1007/s10584-011-0067-z.

Weitzman, M.L. 2011. "Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change." *Review of Environmental Economics and Policy* 5: 275-292. https://doi.org/10.1093/reep/rer006.

Weitzman, M.L. 2009. "On Modeling and Interpreting the Economics of Catastrophic Climate Change." *Review of Economics and Statistics* 91: 1-19. https://doi.org/10.1162/rest.91.1.1

Zeckhauser, R.J. 2006. "Investing in the Unknown and Unknowable." Behavioral Finance and Investment Management. https://sites.hks.harvard.edu/fs/rzeckhau/InvestinginUnknownandUnknowable.pdf.