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Commentary

Our Knowledge of the World is Often Not Simple: Policymakers Should Not Duck that Fact, But Should Deal with It

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Although I share some of Bolger and Rowe's reservations about the use of "seed questions" as a means of assessing the quality of judgments provided by experts and developing weights with which to combine their subjective judgments, I do not accept their argument that "for policy making a single representation of the uncertain quantity, and related probability, is commonly needed."

A single representation is certainly commonly *desired* by decisionmakers whose life is simplified if they can find Senator Muskie's hypothetical "one-handed scientist." But, the world is frequently not that simple, and policymakers need to acknowledge that fact and deal with it, not hide behind some mathematical procedure that masks important disagreements.

Bolger and Rowe did add a footnote to their assertion, noting that combining may be inappropriate when it "leads to an average that does not properly represent the views of any experts, or when judgments form input to a very non-linear model." Those qualifications deserve elaboration.

On "an average that does not properly represent the views of any experts," consider Fig. 1, which shows a result from an expert elicitation my colleagues and I conducted just under a decade ago.[1] We asked a set of ocean science experts to provide probabilistic judgments about the possibility that, as the planet warms due to climate change, the Atlantic Meridional Overturning Circulation (AMOC, sometimes termed the "ocean conveyer belt") will shut down, as data from sediment cores demonstrates it has in the past. Fig. 1 displays the mean probability that each expert assigned for the event that collapse would be initiated if different amounts of warming have resulted by the end of the century. For some vertical cuts in this figure we also elicited full probability distributions. If one combined those distributions, one would see a broad distribution ranging from a very low probability of collapse to quite a high probability of collapse. What one would *not* see is that (at least when we ran this study) the community of experts was split—one group believing that with expected amounts of warming there was quite a high probability that collapse would be initiated, and

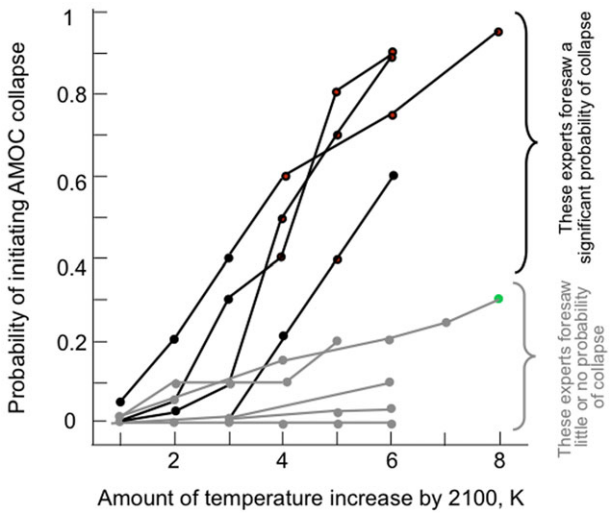

Fig. 1. Example of a situation in which the expert community was divided, with some thinking that the probability of initiating a collapse of the AMOC with plausible amounts for global warming was substantial (upper curves) and some thinking that it was quite low (lower curves). Combining such a group of experts could mask the fundamental disagreement within the community. Figure modified from Zickfeld *et al.*[1]

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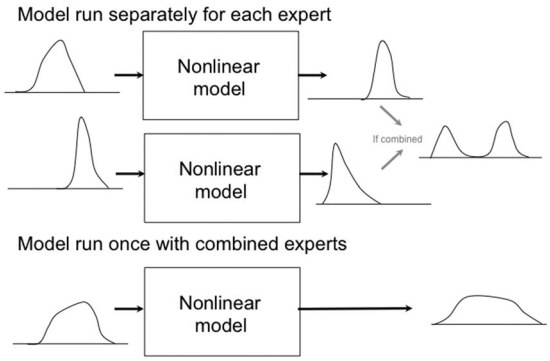

Fig. 2. Hypothetical illustration of the very different results one might obtain if expert probabilistic judgments are used separately as input to a nonlinear model (above) or combined before inputting them to such a model (below).

a second group believing there was very little likelihood of collapse.

In a situation of this sort, it is my belief that a decisionmaker should know that there is such a diversity of views. It is important to remember that science is not a democratic process of "majority rules." One expert who is an outliner may end up being correct, and all his or her colleagues may be wrong. That outlier's views should not get masked by combining multiple experts. A decisionmaker needs to listen to the underlying arguments for why there is range of opinions. Sometimes it may be prudent to seek a decision that, although a bit less efficient, is "robust" across that range, as opposed to seeking an "optimal" course of action.

As to "when judgments form input to a very nonlinear model," consider Fig. 2. In this hypothetical case, there are two experts who have provided assessments that are to be used as inputs to a nonlinear model. In the upper diagram, the model is run twice, once with the inputs from each expert.[2] In the lower case, the distributions are combined and used as a single representation of the value of the uncertain coefficient. Because of the nonlinearity of the model, the resulting output distributions can be quite different.

As I have recently elaborated elsewhere,[3] when matters of complex and substantively detailed science are at issue, rather than synthesizing a "one-handed" expert through the use of some weighting procedure, it is my view that decisionmakers are often far better served by examining the diversity of that opinion, considering carefully the implications of the range and the reasoning on which the various views are based.

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