Deep Uncertainty

Lecture

Dr. James Doss-Gollin

2024-03-25

Introduction and Definitions

1. Introduction to uncertainty in decision-making
    1. Uncertainty is a fundamental challenge in many decision-making contexts, particularly those involving complex, long-term issues like climate change.
    2. Understanding different types of uncertainty and how they influence decision-making is crucial for developing effective strategies and policies.
2. The spectrum of uncertainty: from "certain" to "deep uncertainty"
    1. Certain: representing decision variables without any uncertainty
        1. Examples:
            - cost-benefit analysis with a single time series of future water demand or future sea level
            - a single deterministic depth-damage function
    2. "Objective" probabilities: uncertainties represented using well-established probabilistic models with widely agreed-upon parameters or methods for estimating the parameters
        1. Examples:
            - distribution of storm surge (with very long records)
            - probabilistic depth-damage curve calibrated on many similar structures
    3. "Subjective" probabilities: uncertainties represented using probabilistic models informed by expert judgement
        1. Not actually different from "objective" probabilities (you always have to make assumptions)
        2. Examples:
            - future price of carbon
            - probability distribution for future sea-level rise
    4. Deep uncertainty: Situations where probabilities cannot be reliably quantified, and even the range of possible outcomes may be unknown.
        1. Examples:
            - The long-term impact of artificial intelligence on society and the economy is deeply uncertain, as it depends on complex and unpredictable technological, social, and political factors
            - many samples of future sea-level rise
        2. No one disputes that research on climate change and climate impacts is subject to deep uncertainties! The question is what to do about it.
3. What tools do different approaches enable?

1. Probabilities are required for many traditional decision-making tools, such as cost-benefit analysis and optimization
    1. These tools rely on quantifying the likelihood of different outcomes and evaluating the expected value of different strategies.
    2. Risk-based and risk-averse approaches can be used (e.g., look at 95th percentile of damages, weight bad outcomes more heavily, etc.)
2. There are many methods for accounting for deep uncertainty
    1. Exploratory modeling: no assumptions of likelihood made
    2. Robustness approaches: involve aggregating some metric across scenarios, which is sensitive to the range of scenarios considered (equivalent to a probability distribution)

Schneider-Lempert Debate:

A very interesting debate, well exemplified by Lempert & Schlesinger (2000) and Schneider (2002):

Context

1. The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for assessing climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO).
    1. The IPCC's role is to provide policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and potential adaptation and mitigation options.
    2. The IPCC does not conduct its own research, but rather reviews and assesses the most recent scientific, technical, and socio-economic information produced worldwide relevant to understanding climate change.
2. Scenarios are used in climate change modeling to explore and understand the potential consequences of different future pathways of greenhouse gas emissions and socio-economic development.
    1. Scenarios are not predictions or forecasts, but rather plausible descriptions of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, economic growth, population growth) and their relationships.
    2. The IPCC's Special Report on Emissions Scenarios (SRES) published in 2000 developed a set of scenarios that have been widely used in climate change research and assessment.
3. There are significant uncertainties in assessing the potential impacts of climate change, arising from uncertainties in each step of the modeling chain:
    1. Emissions scenarios: Future greenhouse gas emissions depend on complex factors such as population growth, economic development, technological change, and climate policies, leading to a wide range of plausible emissions pathways.
    2. Carbon cycle modeling: There are uncertainties in how the carbon cycle will respond to increasing emissions, such as the rate at which the oceans and terrestrial ecosystems will absorb CO_2.
    3. Climate sensitivity: The magnitude of warming in response to a given increase in greenhouse gas concentrations (radiative forcing) is uncertain, with estimates ranging from 1.5°C to 4.5°C for a doubling of CO_2.

    4. Climate impacts: Translating changes in global temperature into impacts on natural and human systems (e.g., sea-level rise, changes in precipitation patterns, ecosystem impacts, agricultural productivity) introduces additional uncertainties.
4. In 2000, James Hansen and colleagues published a paper proposing a low CO2 emissions scenario that was below the lowest emissions levels considered in the IPCC's SRES scenarios.
    1. This scenario was criticized by some, including Donald Wuebbles, as being inconsistent with the bulk of published literature and the IPCC's work, and for having the potential to be misinterpreted.
    2. The controversy surrounding Hansen's paper highlights the debate over how to handle low-probability, high-consequence scenarios in climate change risk assessment, and whether it is appropriate to assign subjective probabilities to different emissions scenarios.
5. Stephen Schneider argues that the IPCC's failure to assign probabilities to emissions scenarios and climate model projections leads to confusion and allows for misinterpretation by those seeking to highlight extreme outcomes.
    1. Schneider suggests that probabilistic assessments should be attempted for different steps in the climate change modeling chain, even if they are highly uncertain, in order to support meaningful risk management and decision-making.

Lempert argument

1. Lempert argues that the traditional framework for assessing climate change policies, which relies on predicting the future and identifying optimal policies, is inadequate given the deep uncertainty surrounding climate change.
    1. This prediction-based approach assumes that we can estimate the likelihood of different future scenarios and use these estimates to identify the best policy option.
    2. However, Lempert contends that such predictions are inherently unreliable, especially when dealing with complex, long-term issues like climate change, where there are many unknowns and the potential for surprises.
2. Optimal policies based on point estimates of the future are brittle and fail to support consensus among stakeholders with divergent expectations.
    1. Different stakeholders often hold very different views about the likelihood of various climate change scenarios, driven by differences in interpretation of scientific evidence and divergent interests.
    2. Attempting to base policies on a single set of subjective probability estimates is unlikely to generate agreement among these competing perspectives.
3. Instead of seeking optimal policies, Lempert proposes that we should focus on identifying robust strategies that perform reasonably well across a wide range of plausible futures.
    1. Robust strategies are those that are insensitive to uncertainty about the future and provide reasonable outcomes no matter which future scenario unfolds.
    2. By focusing on robustness rather than optimality, policymakers can develop strategies that are more likely to garner support from stakeholders with differing expectations and values.
4. Lempert advocates exploratory modeling to help identify robust strategies under deep uncertainty.
    1. This approach uses computer simulations to create large ensembles of plausible future scenarios, based on different assumptions about key uncertainties and policy choices.
    2. Analysts can then systematically explore the performance of different strategies across

this wide range of scenarios, looking for those that perform well under a variety of conditions.

Schneider argument

1. While assigning subjective probabilities to different climate change scenarios is challenging and controversial, it is necessary for meaningful risk management and decision support.
    1. The concept of risk combines the probability of an event with the magnitude of its consequences. Without considering probabilities, decision-makers are left with only a "consequences alone" view of risk, which can lead to misplaced priorities and poor decisions.
    2. Even though subjective probability estimates may be deeply uncertain and subject to disagreement among experts, Schneider believes that attempting to provide such estimates is preferable to leaving decision-makers to make their own assumptions about the likelihood of different outcomes.
2. The IPCC's failure to assign probabilities to its emissions scenarios and climate model projections leads to confusion and allows for misinterpretation by those seeking to highlight extreme outcomes.
    1. By presenting a range of scenarios and model results without any indication of their relative likelihood, the IPCC leaves room for individuals to cherry-pick the results that best support their preferred narrative or agenda.
    2. This lack of guidance on probabilities can lead to a situation where low-probability, high-consequence outcomes are given undue emphasis, distorting the public debate and policy response.
3. Schneider proposes that probabilistic assessments should be attempted for each step in the climate change modeling chain, from emissions scenarios to carbon cycle modeling, climate sensitivity, and impacts.
    1. While acknowledging that these assessments will necessarily be subjective and uncertain, Schneider argues that they can still provide valuable information for decision-making if done transparently and with clear communication of uncertainties.
    2. By integrating expert judgment with available empirical evidence and modeling results, these probabilistic assessments can help to characterize the relative likelihood of different outcomes and identify the most important sources of uncertainty.
4. Schneider illustrates the importance of considering probabilities by showing how different assumptions about the likelihood of IPCC emissions scenarios and climate model sensitivities can lead to very different estimates of the probability of exceeding key temperature thresholds.
    1. Depending on the specific assumptions made, the probability of global temperature increase exceeding a "dangerous" threshold (e.g., 3.5°C) by 2100 can range from less than 25% to nearly 40%.
    2. This wide range highlights the sensitivity of risk assessments to underlying probability assumptions and underscores the need for more explicit and transparent treatment of these assumptions in the IPCC process.

Discussion

Small Group Discussion

1. What are the potential benefits and drawbacks of relying on expert judgment to estimate probabilities under deep uncertainty, as advocated by Schneider?
2. In what ways might Lempert's approach of seeking robust strategies be better suited to decision-making under deep uncertainty? What are the limitations of this approach?
3. Considering the climate change context specifically, which approach do you think is more appropriate and why? Is there value in combining elements of both approaches?

Debrief and Wrap-up

1. Our context is about whether or not it is helpful to assign probabilities to IPCC scenarios. Ultimately this is a debate about the role of the IPCC – is it to consolidate all available information for decision-makers? Or is it an assessment of the things we really know, which requires leaving everything we're not sure about as "what-ifs"?
2. Recap key points from the small group discussions
3. Emphasize that while there is no one-size-fits-all approach to decision-making under deep uncertainty, the Lempert-Schneider debate highlights the importance of:
    1. Recognizing the limitations of traditional optimization-based approaches in the face of deep uncertainty
    2. Considering the role of expert judgment and subjective probability estimates in informing risk management and decision-making
    3. Exploring the use of robust strategies and adaptive decision-making approaches to navigate complex and uncertain decision landscapes

Lempert, R. J., & Schlesinger, M. E. (2000). Robust strategies for abating climate change. *Climatic Change*, *45*(3-4), 387–401. https://doi.org/10.1023/A:1005698407365

Schneider, S. H. (2002). Can we estimate the likelihood of climatic changes at 2100? *Climatic Change*, *52*(4), 441–451. https://doi.org/http://dx.doi.org/10.1023/A:1014276210717