

Frameworks for Decision Making

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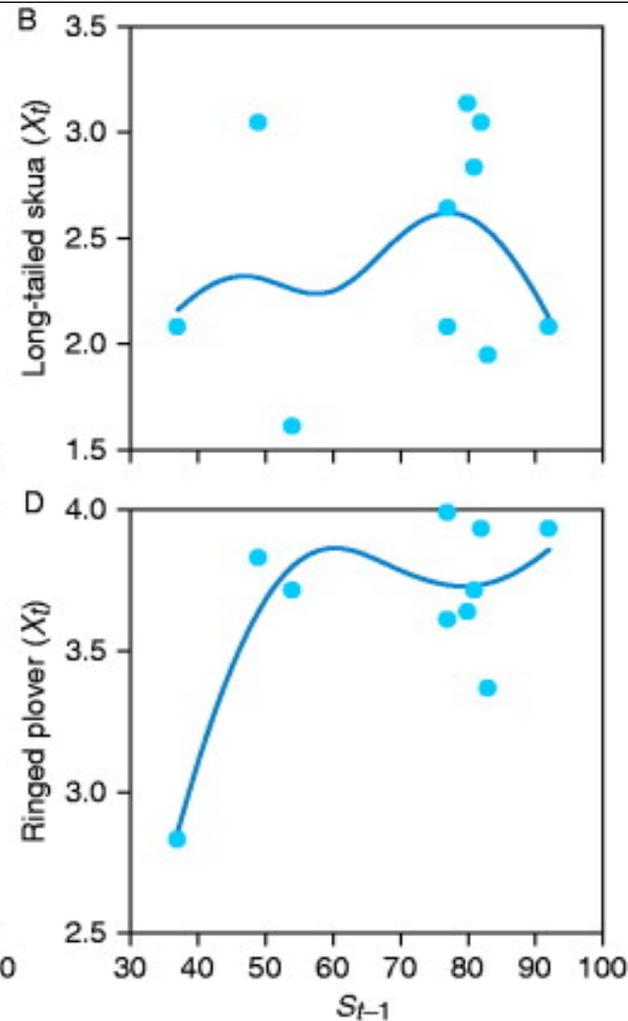
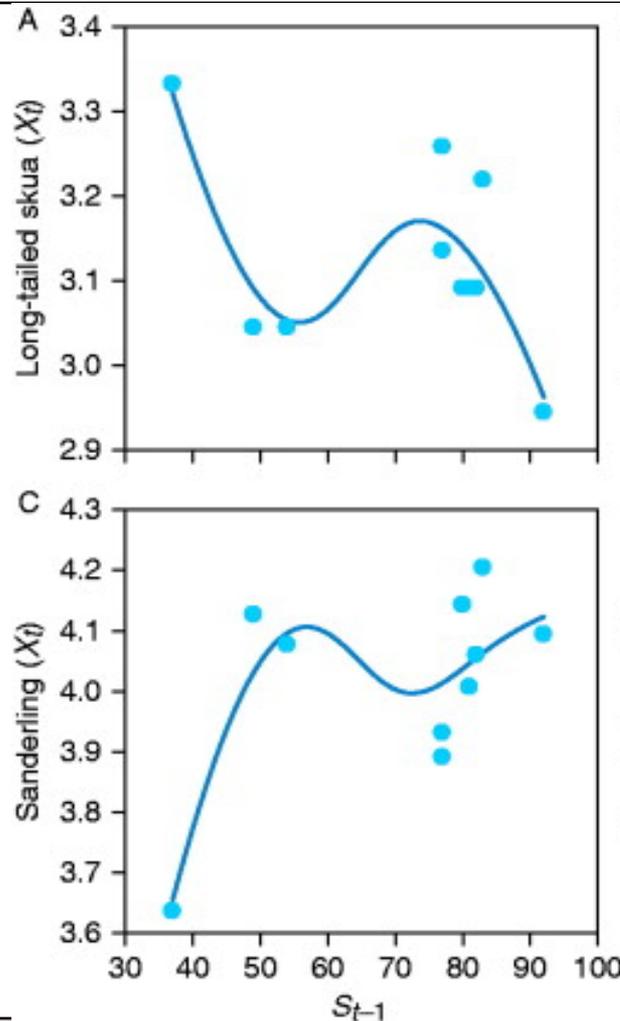
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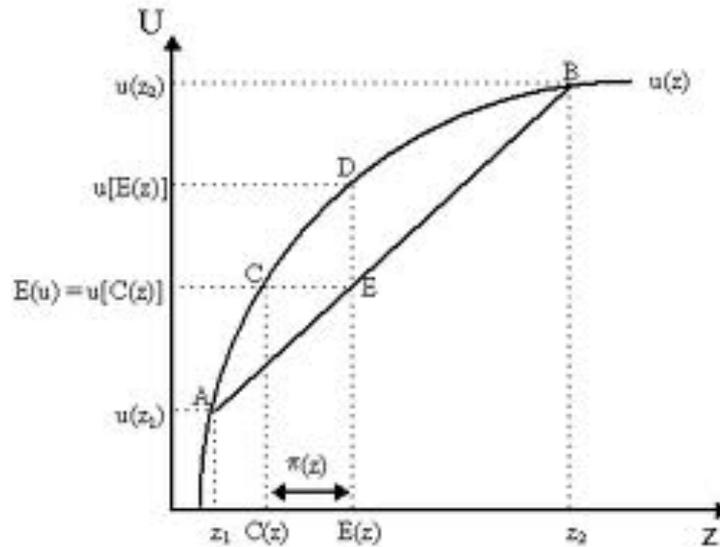
Why incorporate uncertainty?

- The Flaw of Averages:
 - A function of the expected value is not equal to the expected value of the function, unless the function is linear.

$$E[f(x)] \neq f(E[x])$$



Risk Aversion

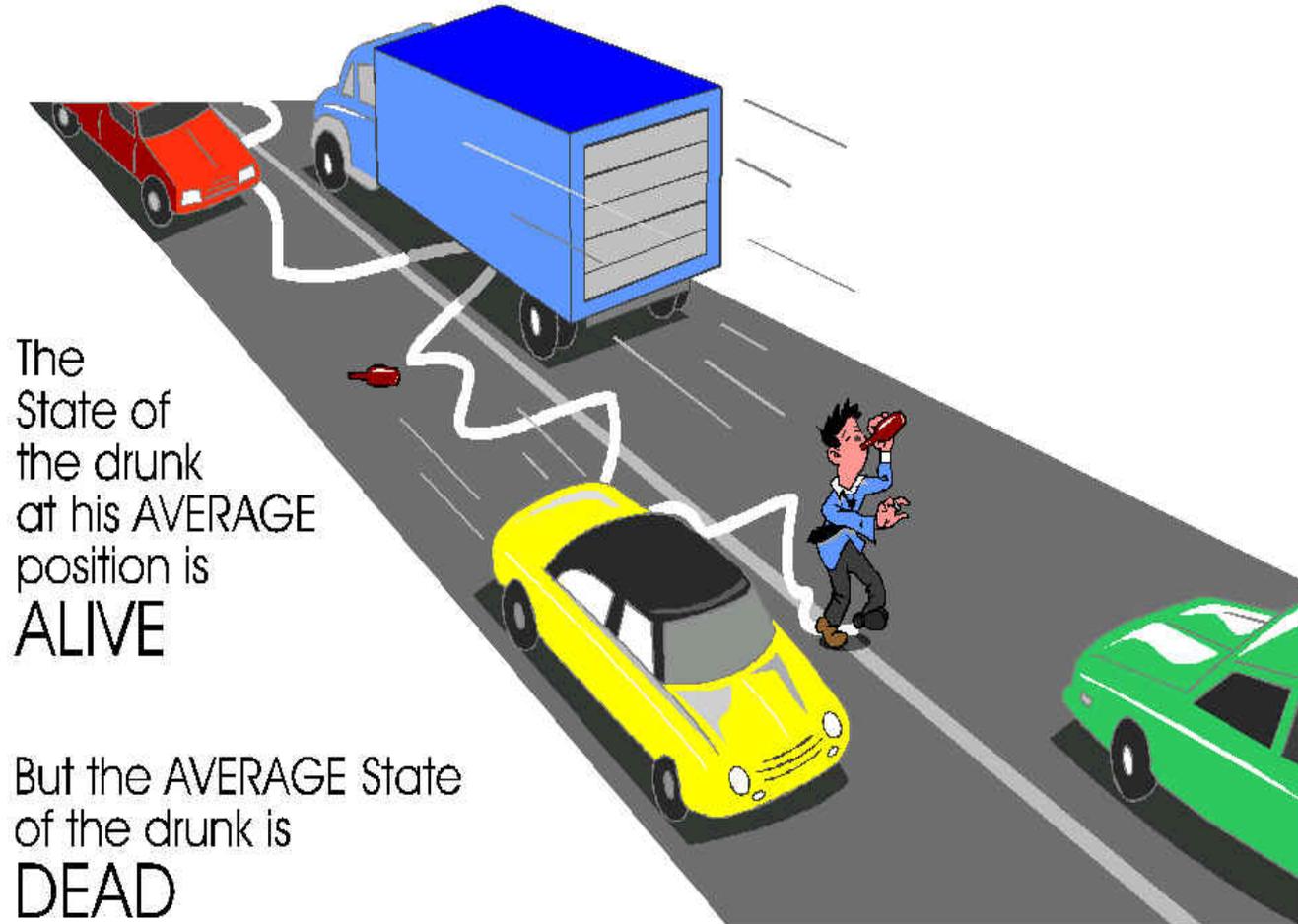


Options



A sobering example of the Flaw of Averages

(taken from Sam Savage's *Insight.xla*)



What do we want to address with uncertainty analysis?

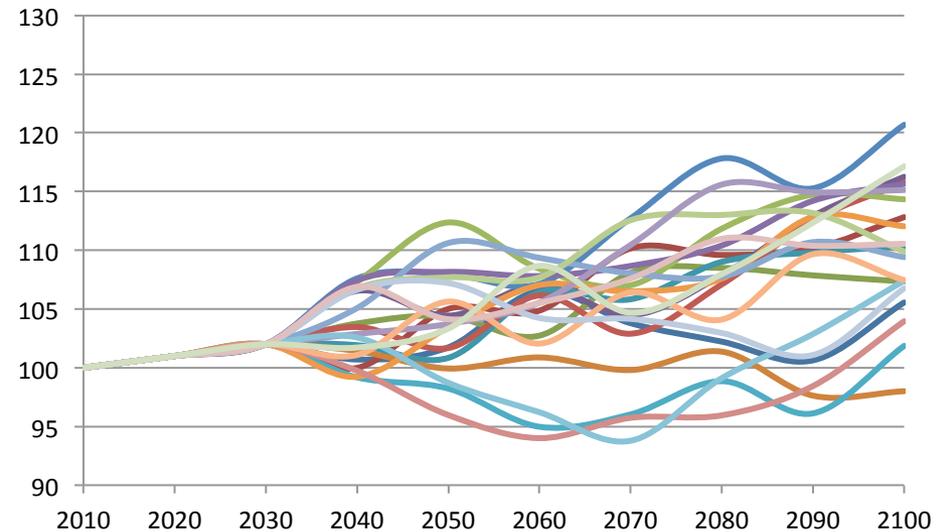
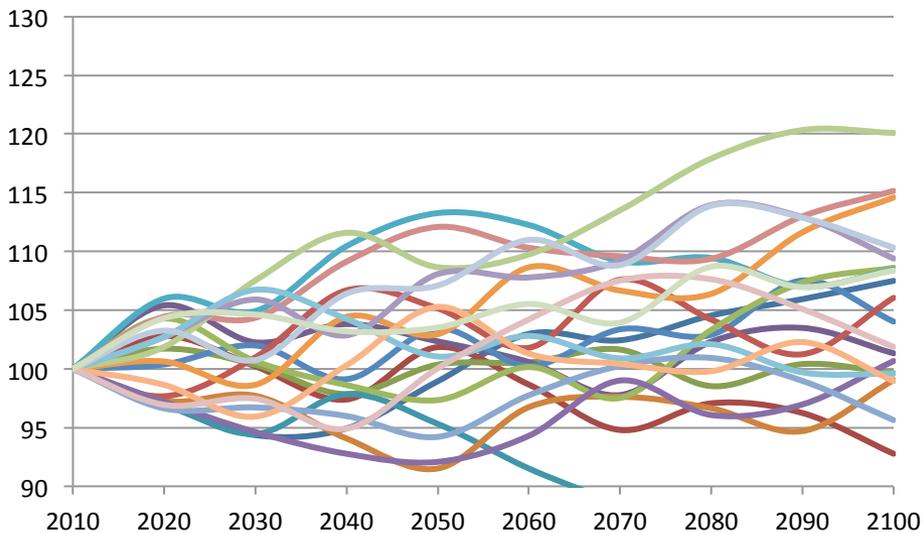
- Don't want to be surprised by bad outcomes (or miss a chance at good outcomes)
- Want to be aware of "options"
- Want to make the best decision in a highly non-linear system (non-convex?)

Some conceptual frameworks

- Sensitivity Analysis
 - How does outcome X change if parameter Y changes?
- Uncertainty Analysis
 - What is the probability distribution of outcome X (for decision D)
 - Which uncertain parameters most influence the uncertainty in X
- Single-Stage Decision Under Uncertainty
 - What decision D is best when we are uncertain
- Sequential Decision Under Uncertainty
 - What decision D_1 is best now if
 - We are uncertain about some parameters, and
 - We will get new information later, and
 - We can make another decision(s) D_2

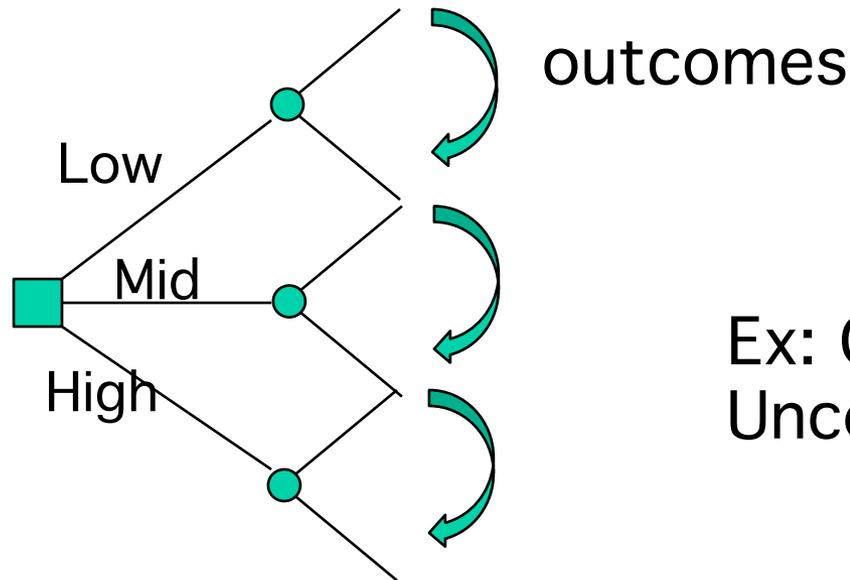
Some conceptual frameworks

- Monte Carlo (sensitivity/uncertainty analysis)
- Simple: All parameters are known from time 0.
- Complicated: Some parameters are learned later
 - How to constrain the early decisions to reflect this?



Some conceptual frameworks

- Single-Stage Decision (No Learning or Recourse)

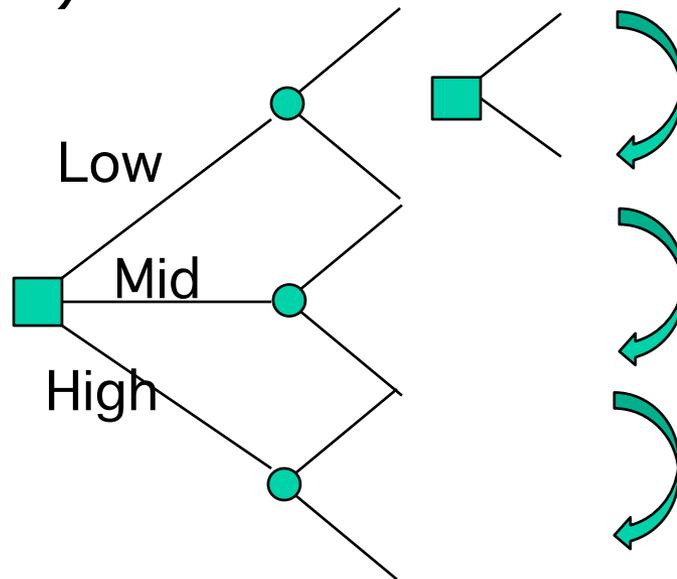


Ex: Optimal R&D under Uncertainty (without learning)

- Sensitivity Analysis
 - Ex: How does optimal R&D change for 450ppm vs. 550ppm?

Some conceptual frameworks

- Single-Stage Decision (No Learning or Recourse *in R&D*)



outcomes

$$\max_R E_{(R)} \left[\max_x f(x, \bar{\alpha}) \right]$$

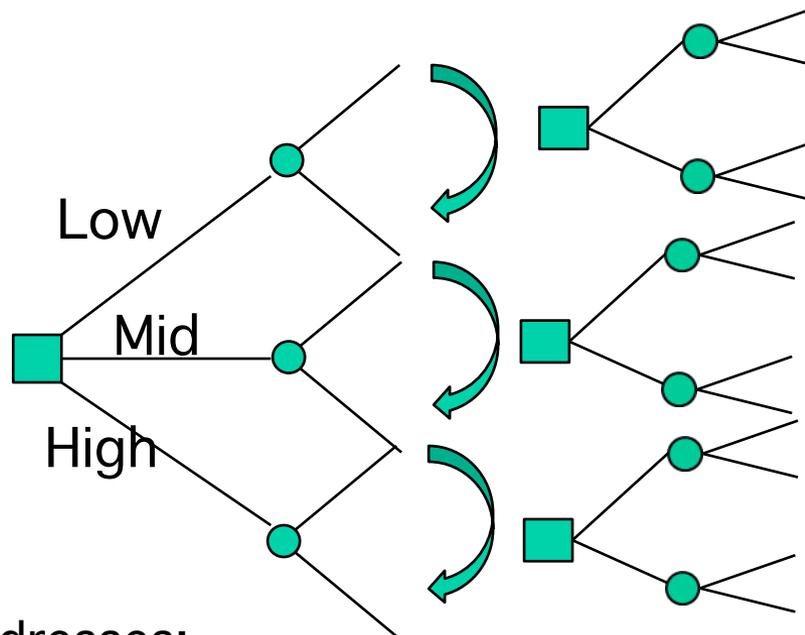
Ex: Optimal R&D under
Uncertainty (without learning)

- Sensitivity Analysis

- Ex: How does optimal R&D change for 450ppm vs. 550ppm?

Some conceptual frameworks

- Two-Stage Decision (with Learning)



Ex: How does R&D portfolio change over time?

Addresses:

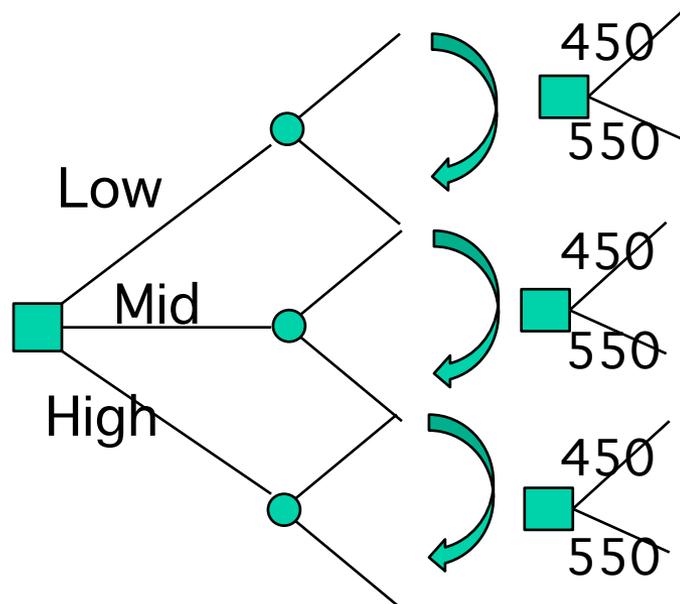
What is a flexible investment strategy?

What is the right R&D balance between different techs (sure bet vs. high risk)?

Are there robust roles for each tech at different times?

Some conceptual frameworks

- Two-Stage Decision (with Learning)



Ex #2: What is optimal R&D portfolio when we can choose the stabilization path downstream?

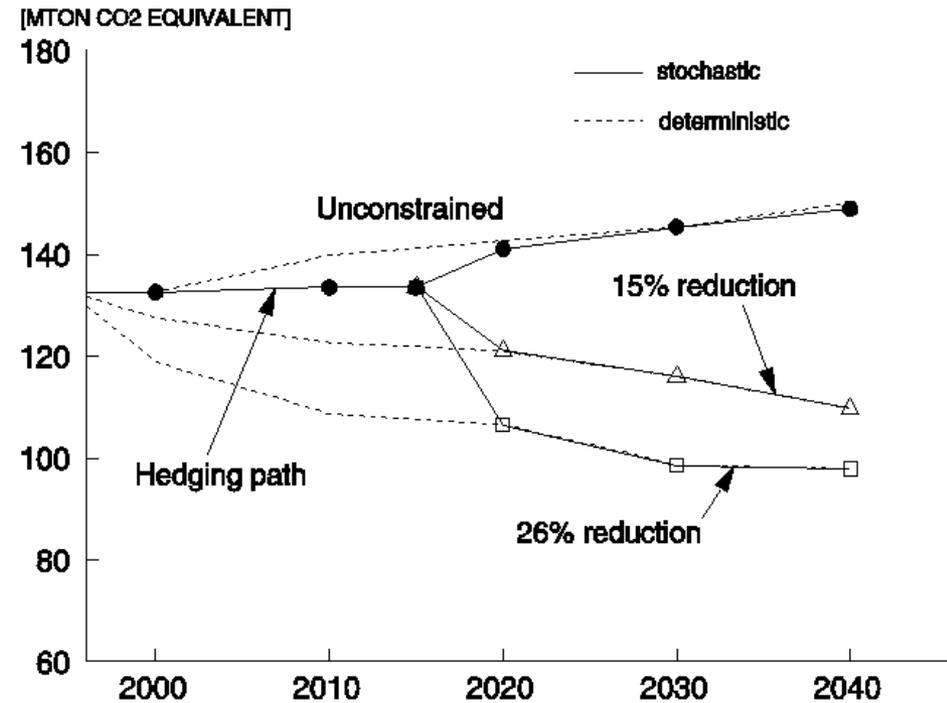
Addresses:

What is the right balance between R&D and Adoption when target depends on tech change?

Does R&D provide flexibility/option value for this decision?

Some conceptual frameworks

- Full stochastic programming within IAMs
 - Optimizing abatement, investment, R&D simultaneously under uncertainty with learning.



Issues

- Utility/Objective Function
 - For a “decision” need a scalar measure to maximize/minimize
 - What are the attributes and tradeoff weights
- Mapping from Model Results to a Decision Framing
 - Results: technology adoption decisions under different R&D outcomes to achieve a given emissions path (e.g., 450, 550)
 - Want to simulate R&D decisions that lead to those outcomes, include the cost of the R&D
 - Need a “post-processing” procedure to solve the decision problem

Questions

- What would we like to do with the probability distributions that we have?
- Are there some important sequential decision problems we'd like to address?
 - What kinds of model runs will make this possible?

TEaM Project: Outputs

1. Probability distributions over technology metrics
 - CCS, nuclear, solar PV, biofuels, bioelectricity
2. Probability distributions over IAM outcomes
 - Emissions, temperatures, costs, welfare...
3. Insights gained from implementing these distributions in decision frameworks