Effect of Uncertainty and Learning on Decisions

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Course so far…

• Projecting climate impacts

• Costs of GHG emissions reductions

• Analysis under certainty

• Descriptions of uncertainty
  – Probability distributions
Outline

• Motivation: Why uncertainty matters
• Effect of learning on decisions
• Application of decision analysis to climate policy
Motivation I
The “Question”

Since climate change is so uncertain, shouldn’t we just wait until we know more?
Why Does Uncertainty Matter?

If $10 million investment is required, would you do it? What about $60m?

μ = $30m
Why Does Uncertainty Matter?

• If no learning is possible and no risk aversion
  – Make decision based on expected value
• If you can learn and revise along the way
  – May want to do more or less at first (hedging)
• If you are risk-averse
  – You care about more than mean outcomes
What is “Risk-Aversion”?

Choose:

A) A gamble with 50% chance of paying $100 and 50% chance of paying $0

or

B) Pay $49 for sure
Risk-Averse Utility Function

Monetary outcome (Billion $)

Utility

Risk-Averse

Risk-Neutral
Why Does Learning Matter?

• *Why* would you do something different today if you can learn tomorrow?

• Answer: if the outcome is irreversible
Arrow-Fisher Irreversibility

• Problem:
  – Two time periods $t=1, 2$
  – Total forest area = 100
  – Cost of cutting forest $C(x)$
  – Benefits of cutting forest $B(x)$ - UNCERTAIN
  – Choose $x_1, x_2$ to Max $(B-C)$.
• What is $x_1$ if you can’t learn?
• What is $x_1$ if you can learn between $t_1$ and $t_2$?
Irreversibilities in Climate Change

• GHG Concentrations
  – Temperature Change
  – Climate Damages

• Capital Stock / Economic Investments
DICE
Model of Climate and Economy

• Simple Model of Economy:
  – Capital and Labor Make GDP
  – GDP split between Savings and Consumption
  – CO$_2$ Emissions from Production

• Simple Climate Model
  – Carbon Cycle – Emissions to Concentrations
  – Radiative Forcing
  – Energy Balance
DICE (Continued)

• Policy Variable:
  – Reduce Emissions by Fraction ($\mu$)
  – Abatement Costs $C = f(\mu)$
  – Damage Costs $D = f(\Delta T)$

• Maximize Discounted Utility (Consumption)

• Two Types of Analysis
  – Cost-Benefit (balance abatement costs with damage costs)
  – Cost-Effectiveness (set absolute constraint)
Focus of this Study: Climate Sensitivity

• One of the critical uncertainties

• Defn:
  – Amount of global mean temperature change from a doubling of CO$_2$ at equilibrium.

• Meaning:
  – Represents net effect of feedbacks in the atmosphere.
Current Uncertainty in Climate Sensitivity
Alternative Analysis Frameworks

• **Cost-Benefit**
  – Use damage function to monetize climate impacts
  – Find economically efficient path of abatement

• **Cost-Effectiveness**
  – Pick some target (e.g., concentration or temperature stabilization)
  – Find least cost way to meet target
Effect of Learning on Efficient Policy

![Graph showing the effect of learning on carbon tax policy over time. The graph compares different scenarios including perfect information, never learning, and complete resolution in 2040, with carbon tax levels denoted by CS values of 8.0, 5.0, 3.0, and 1.5.]
Effect of Learning under Cost-Benefit

![Graph showing the effect of learning under cost-benefit over time]

- **Optimal Tax in 2015**
  - 2020: 17.0
  - 2030: 17.2
  - 2040: 17.4
  - 2050: 17.6
  - 2060: 17.8
  - Never: 18.0

*Graph legend:*
- Time When Learning Occurs
  - 2020, 2030, 2040, 2050, 2060, Never
Hedging Policy Under Uncertainty Cost-Benefit Case

Perfect Information

Never Learn
What Determines the Optimal Hedge?

Answer: The Shape of the Probability Distribution
Decision-Making under Uncertainty

Some Simple Starting Points:
1) What should you do if you KNOW?
2) What should you do if you will NEVER LEARN?
3) What should you do if you don’t know, but WILL LEARN at time T?
4) What should you do if you don’t know and will reduce your uncertainty at time T?
Illustration: Optimal Carbon Tax for Temperature Target of 2°C
Realized Temperature Change for 2 Degree Target
QUESTION: What should we do now if we are uncertain?

• Wait (do nothing until we know more)?

• Implement Highest Tax (worst case)?

• Implement Lowest Tax (best case)?

• Something in the Middle?
  – Where in the middle?
Relative to Best Policy in Each Case…
If We Learn in 2020

Carbon Tax ($/ton)

- Perfect Information
- Learn in 2020
Simulating Learning: Stochastic Programming

![Graph showing carbon tax over time with different CS values]
If We Learn in 2030

Carbon Tax ($/ton)

- Perfect Information
- Learn in 2020
- Learn in 2030
If We Learn in 2040

- Perfect Information
- Learn in 2020
- Learn in 2030
- Learn in 2040

Graph showing carbon tax ($/ton) over time from 2000 to 2100.
If We Never Learn

Carbon Tax ($/ton)

- Perfect Information
- Learn in 2020
- Learn in 2030
- Learn in 2040
- Never Learn
Summary – Effect of Learning Later with $2^\circ$ target

![Graph showing the effect of learning later with a $2^\circ$ target. The graph plots the optimal tax in 2015 against the time when learning occurs, ranging from 2020 to never. The graph shows a significant increase in optimal tax when learning occurs before 2030, with a plateau from 2030 onwards.](image-url)
Effect of Learning for Several Temperature Targets
Decision under uncertainty with partial learning

- Near-term hedging under uncertainty
- Revised policy after reducing uncertainty
- Perfect Information after 2100
Effect of Partial Learning on Optimal Hedging

- Target = 2°C
  Learning in 2020, Perfect Info by 2030
- Target = 2°C
  Learning in 2020, Perfect Info by 2040
- Target = 2.5°C
  Learning in 2020, Perfect Info by 2060
Summary

• Wait to Learn?
  – No, start now, adjust later.
  – How much depends on your expectations.

• If I can learn
  – Do a little less now
  – Depends on when you will learn
  – Depends on your goal (stabilization vs balancing costs and benefits)