

Evaluation of Public Policies and Social Programs

Session 12: Uncertainty, Sensitivity Analysis & Option Value

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Today

1. Put uncertainty into practice: one-way analysis, scenarios, Monte Carlo
2. How assumptions change recommendations (and what each tool misses)
3. Option value and irreversibility
4. Workshop and communicating uncertainty
5. Paper presentation (closes today's session)

Learning Objectives

By the end of today's session, you will be able to:

- Implement one-way sensitivity analysis, coherent scenarios, and a basic Monte Carlo simulation
- Explain how each method can change a recommendation, and state its main strengths and limitations
- Read and build a tornado chart, and use break-even analysis to find where a recommendation flips
- Understand option value: why the ability to wait for information has value when a decision is irreversible
- Present uncertainty transparently, as ranges rather than false-precision point estimates

Handling Uncertainty

Three kinds of uncertainty

- **Parameter uncertainty:** you trust the model, but a specific number (the elasticity, the discount rate, the take-up rate) is estimated with a confidence interval, not known exactly
- **Model uncertainty:** you're not sure the model's functional form or channel is even right (does displacement operate the way you assumed?)
- **Scenario uncertainty:** the future itself could unfold in a small number of qualitatively different ways (a policy change, a demand shock) that aren't well described by a probability distribution at all

Most of what you've done all semester — point estimates plugged into a formula — silently assumes all three problems away.

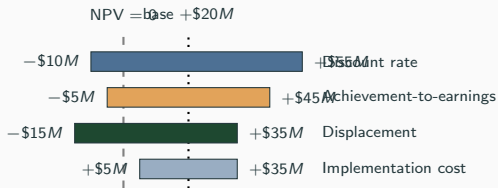
Start with one-way sensitivity analysis

- Start with a base-case spreadsheet that calculates NPV from clearly named inputs.
- Change one input at a time across a defensible low/base/high range; hold the others at baseline. Record the NPV for each endpoint.
- Sort variables by how much their ranges move NPV and plot the results as a tornado chart. If NPV crosses zero, find the break-even value and compare it with plausible values from evidence.
- **Example:** if the base NPV is +\$20M, changing only the discount rate might move it from -\$10M to +\$55M. That parameter can flip the recommendation.

What one-way analysis can and cannot say

It shows which assumptions matter most *one at a time*; it does not say how likely any outcome is, or what happens when assumptions move together.

Reading the tornado: does the recommendation flip?



Illustrative NPV ranges from changing each input alone. Ranges crossing zero (dashed line) can flip the recommendation; a range entirely above zero is robust to that input within the tested bounds. Bar width is impact, *not probability*.

Scenario analysis: move assumptions together

- Use scenarios when uncertain inputs are linked or the future can unfold in distinct ways; write a short story for each bundle before assigning numbers.
- For each scenario, set a coherent combination of inputs, then recalculate the same outcome (e.g., NPV). Do not call the scenarios probabilities unless you have a basis for doing so.

Key practice

Vary linked assumptions together only when you can explain why they move together. Include a base case and at least one adverse but plausible case.

Scenario example: what if several things go wrong?

Scenario	Example assumptions for the school project	Illustrative NPV
Downside	Slower achievement-to-earnings gains; higher displacement; cost overrun	−\$45M
Base case	Central estimates; planned implementation	+\$20M
Upside	Stronger earnings gains; lower displacement; on-budget delivery	+\$95M

NPVs are illustrative, not estimates for Astoreca. Scenario values describe outcomes, not probabilities.

How scenarios change what we recommend

- Downside negative / base positive / upside positive: a fragile recommendation; identify what evidence or design changes could reduce downside exposure.
- All scenarios positive: robust across the narratives tested, but not proof that the project is worthwhile in every plausible world.
- All scenarios negative: reconsider the design or the case for proceeding; do not hide behind the base case.
- Scenarios reveal which combinations matter, but results depend on which stories and ranges the analyst chose; three scenarios do not describe every possible future.

Practice

Explain why the downside assumptions can occur together. If there is no plausible story for the bundle, it may not be a useful scenario.

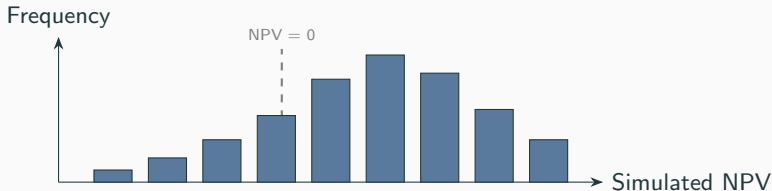
Monte Carlo: how to implement it

1. Start with the same spreadsheet formula for NPV and list uncertain inputs.
2. Assign each input a defensible distribution or empirical sample (e.g., confidence interval, bootstrap draws, or elicited triangular range); document sources and bounds.
3. Draw one value for each input, calculate NPV, and repeat many times. Preserve dependence where inputs move together; do not assume independence by default.
4. Summarize the simulated NPVs: median and percentiles, share with $\text{NPV} > 0$, and the assumptions driving the tails.

Remember

Simulation cannot repair weak evidence or a misspecified model.

Monte Carlo: interpret the output distribution



- This hypothetical distribution straddles zero: simulated NPV can be positive or negative.
- Report the share above zero and meaningful percentiles; discuss expected value and downside risk.
- $P(NPV > 0)$ is conditional on the model and input distributions; it is not the probability the project “works” in every sense.

What Monte Carlo adds — and what it cannot fix

Useful when

- Many uncertain inputs jointly affect the result
- Evidence supports meaningful distributions
- Decision-makers need probabilities or percentile ranges

Use cautiously

- Outputs inherit the assumed model and input distributions
- Wrong independence assumptions distort the tails
- Precise-looking probabilities can conceal weak evidence
- It does not quantify model uncertainty automatically

More simulation draws reduce simulation noise; they do not make the assumptions more credible.

Choose the tool for the question

	One-way sensitivity	Scenarios	Monte Carlo	These tools
Question	Which single input matters most?	What if a coherent future unfolds?	How is the outcome distributed under stated uncertainty?	
Strength	Transparent; easy to explain	Captures linked assumptions and narratives	Combines many uncertain inputs; estimates probabilities	
Limitation	Misses interactions	Selected scenarios are not probabilities	Depends on distributions, model, and dependence	
Use when	Early diagnosis / break-even	Structural or policy uncertainty	Adequate data and a probability question	

complement one another; none can substitute for a credible model or transparent judgment.

Option Value and Irreversibility

Opening a school is a large, lumpy, largely irreversible investment.

If you could wait one year and observe a pilot cohort's results before committing fully, would that option be worth something — even before you know what the pilot will show?

Worked example: the value of waiting

Setup

A new approach has uncertain payoff: \$80M (probability 0.5) or $-\$20\text{M}$ (probability 0.5).

- **Commit now, blind:** you must commit before learning which state occurs
- **Wait one year:** a pilot perfectly reveals the state; you then choose whether to proceed

Solution

$$E[\text{commit now}] = 0.5 \times 80 + 0.5 \times (-20) = \$30\text{M}$$

$$E[\text{wait, then decide}] = 0.5 \times 80 + 0.5 \times \underbrace{0}_{\text{walk away}} = \$40\text{M}$$

$$\text{Option value} = 40 - 30 = \$10\text{M}$$

The \$10M is created purely by preserving the ability to walk away from the bad state
— not by the pilot changing the underlying odds.

The general lesson

- Irreversibility + uncertainty + the ability to acquire information over time $\Rightarrow$ waiting has positive value, even when $NPV(\text{commit now}) > 0$
- The right decision rule is not “invest if $NPV > 0$ ” but “invest now only if NPV exceeds the value of waiting” — a higher hurdle
- For Astoreca: could a phased rollout (a pilot classroom or grade cohort before full build-out) reveal information cheaply, before the largest and least reversible costs are sunk?

Workshop: Sensitivity Analysis for Your Project

Workshop: uncertainty map for your project

1. Choose your headline outcome (e.g., NPV) and identify its three most uncertain inputs.
2. For one input, record evidence-based low/base/high values and predict whether its range crosses the decision threshold.
3. Write one coherent downside scenario: which assumptions move together, and why?
4. Name one input you could represent probabilistically, what data would inform its distribution, and what a Monte Carlo result would help you decide.

20 minutes in teams. Report one recommendation-sensitive uncertainty and one piece of evidence that would reduce it.

Communicating Uncertainty

Ranges, not point estimates

- “Our best estimate is an NPV of \$50M, robustly positive under all plausible parameter combinations except an extreme discount-rate assumption” is more informative than reporting only “NPV = \$50M”
- A single point estimate invites a reader to find the one assumption they disagree with and dismiss the whole analysis; a well-constructed range invites them to argue about *where in the range* the truth lies — a much better conversation
- Your project’s final report and presentations should state ranges explicitly, and name the one or two parameters the recommendation is most sensitive to

What We Learned Today

- One-way analysis diagnoses influential inputs; scenarios test coherent futures; Monte Carlo summarizes outcomes conditional on explicit distributions
- Parameter, model, and scenario uncertainty are distinct; none of these methods automatically solves all three
- A tornado chart tells you where to spend scrutiny; break-even analysis tells you exactly where the recommendation flips
- Option value is real and quantifiable: irreversibility plus the ability to wait for information raises the bar for committing now
- Present ranges, not false precision — and name what the recommendation is most sensitive to

- Problem Set 3 (self-study checkpoint: by Session 14)

Paper Presentation (75–90 min)

Emilia Welkner & R. Lagomarsino

Deming, D.J. (2011), “Better Schools, Less Crime?” *QJE*, 126(4)