National Institute of Environmental Health Sciences

Decision-Making Under Scientific and Moral Uncertainty

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What is a decision? Investing $10,000

	Growing economy	Stable economy	Shrinking economy
Stocks	$20,000	$10,000	$5,000
Bonds	$8,000	$9,000	$12,000
Mutual funds	$14,000	$11,000	$7,500

Decision consists of:

- Options
- Outcomes
- States of the world that give rise to outcomes

I am assuming that outcomes are causally independent of independent of options. This is known as causal decision theory. Epistemic decision theory does not make this assumption.

Treating stage II prostate cancer, 65-year-old man

	Cancer is aggressive	Cancer is non-aggressive
Surveillance	1 year	15 years
Radiation therapy	4 years	14 years
Hormone therapy	7 years	14 years
Prostatectomy	14 years	14 years

Values are life expectancy, not considering quality of life of financial costs

Two Types of Uncertainty

- **Epistemological or scientific**: uncertainty with respect to knowledge or belief, due to incomplete or inconclusive evidence. Note: scientific knowledge is never absolutely certain; only mathematical or logical knowledge can be absolutely certain.
- **Axiological or moral/social/political**: uncertainty with respect to decisions or actions, due to lack of justification, clarity, or agreement about values.
- Certainty has to do with the degree or level of evidence or justification; it is not a feeling.
- Very often we face both types of uncertainty when making decisions.

Investing example

- **Knowledge**: Do I know whether the economy will grow, shrink, or be stable? Do I know how these different investments will perform under different conditions? What evidence do I/my financial advisor have for my beliefs?
- **Values**: How much do I care about gaining money? Not losing money? What other values affect my decision?
  - Risk aversion: preferring choices where there is less risk; “a bird in the hand is worth 2 in the bush”
  - Loss aversion: preferring choices where there is less risk of loss

Prostate Treatment Example

- **Knowledge**: Do I know if my tumor is aggressive or non-aggressive? Do I know how the tumor will respond to different treatments? Do I know how the treatments will affect me? What evidence do I/my doctor have for these beliefs?
- **Values**: What other values, other than life expectancy affect my decision? What about quality of life?

Probability vs. Uncertainty

- Probabilities are different from uncertainty.
- Probabilities may be known or estimated with a degree of certainty.
  - Weather forecast says there is a 50% chance of rain; uncertain probability
  - 1/6 chance of rolling a fair die and getting a 6: certain probability
- Probabilities can be based on mathematical relationships, observed frequencies, systems analysis/modeling, or educated guesses (subjective).

Decision-making under Risk: Expected Utility Theory

- Choose the option that maximizes overall expected utility, which is a sum of the expected utilities for different options.
- Expected utility = (utility) (probability)
- Utility is based on one's preferences or values.
- Utilities must meet conditions of mathematical and logical consistency, such as ordering and transitivity.
- EUT is an evidence-based approach to decision-making used in science, medicine, business, and government, examples: e.g. cost benefit analysis, environmental risk assessment, evidence-based medicine

Investing $10,000

	Growing economy	Stable economy	Shrinking economy	Total expected utility
Stocks	20,000 x 0.5 = 10,000	10,000 x 0.25 = 2,500	5,000 x 0.25 = 1,250	13,750
Bonds	8,000 x 0.5 = 4,000	9,000 x .025 2,250	12,000 x 0.25 = 4,000	10,250
Mutual funds	14,000 x 0.5 = 7,000	11,000 x 0.25 = 2,750	7,500 x 0.25 = 1,875	11,625

Stocks have the highest expected utility ($13,750) when we assume there is 50% chance the economy will grow, a 25% chance it will remain stable, and a 25% chance it will shrink.

Treating stage II prostate cancer, 67-year-old man

	Cancer is aggressive	Cancer is non-aggressive	Total Expected utility
Surveillance	1 year x 0. 15 = 0.15	15 years x .85 = 12.75	12.9 years
Radiation therapy	4 years x 0.15 = 0.60	14 years x 0.85 = 11.9	12.50 years
Hormone therapy	7 years x 0.15 = 1.05	14 years x 0.85 11.9	12.95 years
Prostatectomy	14 years x 0.15 = 2.1	14 years x 0.85 = 11.9	14 years

Assuming a 15% chance the tumor is aggressive, prostatectomy has the highest expected utility (14 years)

Complications

- This are very simple, idealized examples.
  - In the real world, there may be many different options including combinations of options.
  - There may be many different possible outcomes, including some that may not be realistic but must be ruled out for the purposes of decision-making.
  - Probabilities may be uncertain.
  - Not accounting for attitudes toward risk and loss.
  - Values may be uncertain because we don't know what should take priority or our values are incommensurable (i.e. not reducible to a common metric). Can you put a price on life? Quality of life?

What should we do when we face scientific uncertainty?

- Suppose that we are not confident in our probability estimates, due to incomplete or inconclusive evidence.
- One could use continue to use EUT and work with subjective probabilities, but this is fraught with peril, due to initial biases that may not be eliminated by updating probabilities in light of new evidence (Bayesian updating).

Decision-Making under Ignorance

	Growing economy	Stable economy	Shrinking economy
Stocks	$20,000	$10,000	$5,000
Bonds	$8,000	$9,000	$12,000
Mutual funds	$14,000	$11,000	$7,500

Decision rules from formal decision theory

Maximin: choose the option with highest worst worst outcome (bonds, $-2,000)
Maximax: choose the option with the highest best outcome (stocks, +$10,000)
Minimax regret: choose the option with the lowest regret (mutual funds $6,000): regret is the difference option and the best option, for a group of outcomes
Principle of indifference: assume all outcomes are equally probable; choose the option with the best average outcome (stocks, $11,667)

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Maximin: prostatectomy (14 years is the worst outcome you can get)
Maximax: surveillance (15 years is the best outcome you can get)
Minimax regret (prostatectomy, maximum regret: 1 year)
Indifference: prostatectomy: best average outcome is 14 years

Problems with rules from decision theory

- Highly simplistic, idealized.
- Assumes a small range of options and but in the real world, there may be many different possible outcomes, including some that are not realistic [e.g. sky is falling or unbelievable luck] that could radically change the application of the rules.
- Assumes an assignment and ranking of utilities, but in the real world there may be value uncertainty (e.g. moral disagreement/ pluralism), especially for social policy decisions.
- Difficult to know which rule to use in a given situation, some are risk-averse, others, risk-taking.

Alternative approach?

We made need to make decisions when dealing with significant scientific or moral uncertainty.

The Precautionary Principle

- Developed in the 1970s by Swedish and German legal theorists for an alternative to evidence-based methods for making public health and environmental decisions.
- Recommends taking effective action to deal with serious risks even when scientific evidence is uncertain; evidence-based methods might recommend doing nothing until you have more evidence.
- Appears in international treaties
- Used in Europe, not so much in the US.
- Controversial: many view it as excessively risk-averse and opposed to science, technology, and economic development.

PP (my version)

- **Precautionary Principle**: In the absence of the degree of scientific evidence required to establish accurate and precise probabilities for outcomes related to a decision, take reasonable precautionary measures to avoid, minimize, or mitigate plausible and serious harms.

Note: the PP can be applied to individual or group decisions or decisions for others [e.g. trusteeship, guardianship].

PP

- **Plausibility** is a degree or level of evidence which is less than confirmation; something is plausible if it is at least consistent with established scientific facts and theories.
- **Reasonableness** is all things considered, moral assessment; not the same as means/ends rationality.
- Basic precautionary strategies include risk avoidance (e.g. bans, moratoria), risk minimization, and risk mitigation, or some combination.

Criteria for Reasonableness

Criterion	Definition
Proportionality	Reasonable measures balance risks and benefits proportionally
Fairness	Reasonable measures balance benefits and risks fairly; fairness includes distributive and procedural fairness
Epistemic responsibility	Reasonable measures are based on the best available evidence, knowledge, and expertise
Consistency	Reasonable measures are based on a consistent rationale

Note: these criteria could be used in qualitative risk/benefit decision-making even if one does not explicitly use the PP.

Benefits and Risks

- The PP involves assessment of risk and benefits, but the assessment is qualitative, not quantitative, because you are not working with known quantitative measurements of probabilities or utilities (i.e. values).
- It is a confluence of ideas from decision theory and moral theory.
- Some versions of the PP are much more risk-averse than mine are emphasize avoiding risks rather than balancing risks and benefits.

Applying the PP

- To apply the PP to particular case, one must assess the harm (is it plausible, serious?), identify precautionary measures, and apply the criteria for reasonableness to them.
- Criteria may conflict in some situations, and you may need to prioritize.
- It might be the case that two or more choices are equally reasonable.

Example: PFAS testing

A 50-year-old male patient is concerned that he may be exposed to PFAS (per- and poly-fluoroalkyl substances) from their drinking water. He lives outside of town and drinks well water. Firefighters used PFAS chemicals to put out a fire about a 2 miles from his home three months ago. He has read that PFAS exposure can increase the risks of high cholesterol and kidney, prostate, breast, liver and ovarian cancer. He is concerned about cancer and high cholesterol. He has family history of both although his cholesterol is good (200 md/dl with LDL 80 mg/dl from a test done last week). He is about 10 pounds overweight but it otherwise healthy.

PFAS Testing

PFAS testing is an option. Private, certified laboratories offer PFAS blood testing for about $600, not including processing fees. Uncertified labs will do the testing for about $100. The patient's insurance does not cover PFAS blood testing. The patient cannot afford to pay for certified testing out-of-pocket but can afford uncertified testing. However, it is not clear what could be done with the information from the test, since almost everyone has some PFAS in their blood, there is no established safe or normal level of PFAS in blood, no treatment for reducing PFAS levels in the blood, it may not be possible to determine the route of exposure. However, PFAS blood levels will decrease over time if the exposure stops.

Questions

- What would be a reasonable precautionary measure to take in this case? Should the patient's blood be tested? Should the insurance company cover the cost of testing?
- Suppose the patient's total cholesterol and/or LDL had increased significantly in the last year without any obvious cause. Would that strengthen the argument for PFSA blood testing?

PP Questions

- Are the possible harms serious? Yes; cancer and high cholesterol
- Are they plausible? Yes, consistent with established scientific facts and theories.
- What are some precautions to deal with the possible harms?
  - Do nothing; watch and wait.
  - Get blood tested for PFAS from a certified lab; if the results are positive, try to identify the route of exposure (e.g. test drinking water), take steps to reduce exposure, such as drinking bottled water.
  - Get blood tested from an uncertified lab.

Would getting a patient's blood tested for PFAS levels balance benefits and risk proportionally?

Benefits

- Taking action to identify and reduce PFAS exposure if levels are high
- Preventing cancer or other adverse health effects from PFAS exposure
- Peace of mind if blood is okay
- Knowledge of PFAS levels is good in any case
- Filing a lawsuit if levels are high and the source is identified and has deep pockets and harm can be proven

Risks

- Needless worry and expense from a false positive result; false assurance from a false negative
- Worry and expense even if the test is positive and there's not much one can do
- Costs of testing, remediation, which may not be covered by insurance
- If water tests positive, having to disclose this when selling the house

Uncertainties related to risks and benefits

- How accurate and reliable are the tests? False positive and false negative rates?
- Is there an established “safe” or “normal” level of PFAS in blood?
- What are the risks of PFAS exposure? What is the evidence for risks?
- How easy is it to identify routes of PFAS exposure? Eliminate them?
- Does health insurance cover blood testing?
- Does homeowner’s insurance cover water testing and remediation?

Other Considerations

- **Fairness:** not so much of an issue here unless other people are involved. Fairness would be an issue if other people, such as family or guests, are involved or implicated by the decision.
- **Epistemic responsibility:** Is the decision based on the best available evidence? Does the evidence continue to evolve? Should decisions change in response to new evidence?
- **Consistency**: What other risks is the individual taking? Would it be inconsistent to be worried about PFAS exposure but not exposure to other chemicals? Note: individuals are often very inconsistent when it comes to risk exposure, but governments should not be.

Group Decision-Making

- Should PFAS blood testing be legal? Does it provide a benefit that outweighs the risk? Should it be used for diagnosis? [FDA regulatory issues]
- Should health insurance cover PFAS blood testing? Governments? What are the social costs and benefits of testing? How are these distributed?
- Should homeowner's insurance cover PFSA water testing and remediation?

Group Decision-Making

- Notice that things get much more complicated when we move to group decision-making, since we must deal with questions about social benefits and risks, fairness, moral pluralism/disagreement, limited resources, politics, etc.
- It could be reasonable to allow individuals to pursue testing at their own expense but not require others to pay for it, if this policy is adopted by a procedurally fair, democratic process, is consistent with similar policies, and is based on the best available evidence.
- Policies could change as new evidence becomes available or people change their value priorities.

Considerations for using the PP

	High Moral Uncertainty	Low Moral Uncertainty
High Scientific Uncertainty	Use the PP or moral theories	Use the PP or rules for decision-making under ignorance
Low Scientific Uncertainty	Use the PP	Use expected utility theory or its offshoots, such as cost/benefit analysis, risk assessment/management, evidence-based medicine

The PP complements other approaches to decision-making; which approach we decide to use is itself an important decision that depends on various contextual factors, such as knowledge, values, and social/political dynamics. **It might be reasonable to use the PP when scientific and moral uncertainty are high then switch to EUT as uncertainties diminish.**

Discussion

The presentation is based on my book, *Precautionary Reasoning in Environmental and Public Health Policy* (Springer 2021).