The Beauty of Uncertainty

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Relevance

- Uncertainty is pervasive. Yet, its pervasiveness became especially stark in the past few years
- Partly because of some recent "catastrophic" events:
    1. Economic uncertainty: financial crisis
    2. Technological uncertainty: Fukushima
- Partly because of a growing awareness about:
    1. Environmental uncertainty: climate change
    2. Demographic uncertainty: longevity/mortality risk
    3. Risk management: operational risks (Basileas)

Relevance

- Uncertainty affects decision making
  1. directly by making contingent the payoffs of a course of action: harvest/weather
  2. indirectly by generating private information

Relevance

- The latter point is key in strategic interactions, where uncertainty and private information are essentially two sides of the same coin:
    1. uncertainty generates private information when different agents have access to different information about the uncertain phenomenon
    2. private information per se may generate uncertainty when agents are aware of it and think about it (moral hazard/adverse selection issues)

Beauty

- In the real world, uncertainty is thus a main source of competitive edges (and so of business opportunities)
- In the theoretical world, it makes the study of agents' decisions and strategic interactions a beautiful and intellectually sophisticated exercise (altogether different from the study of physical particles' actions and interactions)

The problem

- Uncertainty and information are thus twin notions
- Uncertainty is indeed a form of partial/limited knowledge about the possible realizations of a phenomenon (toss a die: what face will come up?)
- The first order of business is to frame properly the problem
- First key breakthrough: probabilities
- You can assign numbers to alternatives that quantify their relative likelihoods (and manipulate them according to some rules; probability calculus)

Probability: emergence and consolidation

- 16th-17th centuries: probability and its calculus emerged with the works of Cardano, Huygens, Pascal et al
- 18th-19th centuries: consolidation phase with the works of the Bernoullis, Gauss, Laplace et al
- Laplace canon (1812), based on equally likely cases/alternatives: the probability of an event equals the number of "favorable" cases over their total number

Twentieth century: the Bayesian leap

- Originally, the "equally likely" notion was essentially viewed as an objective/physical feature (faces of a die, sides of a fair coin, etc.)
- de Finetti and Ramsey in the 1920s freed probability of physics and rendered "equally likely" a subjective evaluation
- By elaborating on this subjective perspective of Laplace canon, they were able to attach probabilities to any event; such probabilities (often called subjective) quantify degrees of belief
- The events "tomorrow it will rain" or "left wing parties will increase their votes in the next elections" will obtain with some (subjective) probability that quantifies the decision maker's degrees of belief
- In this way, all uncertainty can be probabilized: Bayesianism

Types of uncertainty

- All uncertainty relevant for decision making is ultimately subjective
- But, in applications (especially when involving empirical data) it is convenient to distinguish between aleatory/objective uncertainty and epistemic/subjective uncertainty

Types of uncertainty

What is at work is not only objective, but also subjective uncertainty [...] Subjective uncertainty is about the "unknown unknowns". When, as today, the unknown unknowns dominate, and the economic environment is so complex as to appear nearly incomprehensible, the result is extreme prudence, if not outright paralysis, on the part of investors, consumers and firms. And this behaviour, in turn, feeds the crisis.

Olivier Blanchard, The Economist, 2009

Types of uncertainty: aleatory

- A "common law" approach to aleatory and epistemic uncertainty: I do not know how to define them precisely, but I recognize them (e.g., the US Supreme Court attitude on pornography)
- Examples of aleatory uncertainty are coin/dice tossing, measurement errors
- It is concerned with variability in data (e.g., economic time series), because of their inherent randomness or measurement errors
- In applications, it characterizes data generating processes (DGP), i.e., probability models for data

Types of uncertainty: aleatory

- Aleatory uncertainty is irreducible: take either an urn with 50 white and 50 black balls or a fair coin, the probability of each alternative is 1/2
- There is nothing to learn, and information is captured by conditioning
- Here probability is a measure of randomness/variability

Types of uncertainty: epistemic

- Epistemic uncertainty is concerned with the truth of propositions, e.g., "tomorrow it will rain" or "left wing parties will increase their votes in the next elections" or "the parameter that characterizes the DGP has value x" or "the composition of the urn is 50 white and 50 black balls"
- It is reducible: take an urn with only black and white balls, in unknown (and so uncertain) proportion; repeated drawing allows to learn about such uncertainty and reduce it
- Via Bayes' rule, learning reduces epistemic uncertainty
- Here probability is a measure of degree of belief

Ambiguity/Robustness: the problem

- Aleatory and epistemic uncertainties need to be treated differently
- The standard expected utility model does not
- In the past twenty years, a strand of economic literature focused on this issue, called ambiguity/Knightian uncertainty/robustness, by studying its theoretical and empirical aspects
- Seminal contributions of Itzhak Gilboa and David Schmeidler, and Lars Peter Hansen and Thomas Sargent

Ambiguity/Robustness: a first solution

- A first distinction: decision makers easily quantify aleatory uncertainty with a probability, less so epistemic uncertainty
- In an urn with 50 black and 50 white balls, the probability of drawing either color is 1/2
- In an urn with black and white balls, in unknown proportion, by symmetry (of ignorance) we again assign a 1/2 probability to either color
- Though in both urns we end up with a 1/2 probabilities, their status is clearly different

Ambiguity/Robustness: a first solution

- Need to relax the requirement that a single number quantifies beliefs: the multiple (prior) probabilities model
- Decision makers may not have enough information to quantify their beliefs through a single probability, but need a set of them
- Expected utility is computed with respect to each probability and decision makers act according to the minimum among such expected utilities

Ambiguity/Robustness: a second solution

- A second distinction: decision makers do not have attitudes toward uncertainty per se, but rather toward aleatory uncertainty and toward epistemic uncertainty
- Such attitudes may differ: typically decision makers are more averse to epistemic than to aleatory uncertainty
- This distinction in attitudes is captured by a recent more general model, which enriches standard expected utility by allowing such distinction
- In this way "aleatory" and "epistemic" risk aversions are disentangled and their separate roles can be studied (via comparative statics exercises)

Ambiguity/Robustness: final remarks

- Under these (and other) approaches, a more cautious rational behavior toward uncertainty emerges
- Better understanding of exchange mechanics (a dark side of uncertainty: no-trade or small-trade results because of cumulative effects of aleatory/objective and epistemic/subjective uncertainty; see recent financial crisis)
- Better calibration and quantitative exercises (applications in Finance, Macroeconomics, and Environmental Economics / Science)
- Better modelling of decision/policy making (applications in Risk Management; for example, the otherwise elusive precautionary principle easily fits within this framework)
- Rare combination in the social sciences of sophisticated formal reasoning and empirical relevance