

Introduction to Decision Theory: Econ 260
Spring, 2016

1/7. Instructor Details:

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2/7. Website: courseweb.library.upenn.edu (Canvas Course site)

3/7. Overview: This course will provide an introduction to Decision Theory. The goal of the course is to make the student think rigorously about decision-making in contexts of objective and subjective uncertainty.

The heart of the class is delving deeply into the axiomatic tradition of Decision Theory in Economics, and covering the classic theorems of De Finetti, Von Neumann & Morgenstern, and Savage and reevaluating them in light of recent research in behavioral economics and Neuro-economics. Time permitting; we will study other extensions (dynamic models and variants of other static models) as well, with the discussion anchored by comparison and reference to these classic models.

There is **no required text** for the class, as there is no suitable one for undergraduates that covers the material we plan to do. We will reply on lecture notes and references (see below).

4/7. Policies of the Economics Department, including course pre-requisites and academic integrity Issues may be found at:

<http://economics.sas.upenn.edu/undergraduate-program/course-information/guidelines/policies>

5/7. Grades: There will be two non-cumulative in-class midterms (20% each) during the course and one cumulative final (40%). **The midterms will be on Feb 11** (will be graded and returned by Feb 18) **and April 5th. The final is on May 6th.**

If exams are missed, documentable reasons of the validity of such actions must be provided within a reasonable period of time and **the instructor will have the choice of pro-rating your grade over the missed exam** rather than deliver a make-up.

The remainder of the grade (20%) will be based on class participation. My teaching style is very interactive, and I like to ask a lot of questions, convey difficult concepts by way of lots of examples, and do a lot of problems in class, so this last part (class

participation) is very important. You get points from asking good questions and providing correct answers.

Homework will not be formally collected but I may set some challenging problems to think about and then call upon students to answer these questions in class, and factor the nature of the responses into the class participation scores.

6/7. Structure of Class (Note – we will likely not be able to cover all of these topics, but sections III,V and VII will be covered in detail and will be the heart of the class).

I. Introduction: the nature of choice, reasoning, measurement and decisions. (1 class)

Choice: The nature of making a decision: Free-will of consciousness or determinism stemming from evolutionary or social factors? Philosophical discussions and evidence from surveys of human attitudes. We discuss the assumptions about consequentialism, assumptions about being able to envision the entire set of choices, the role of time-consistency of preferences (being able to imagine *a priori* what the choices will bring), evidence from neurobiology of problems arising from having too much choice.

Reasoning: Deductive versus inductive reasoning, why we will use the former, simple rules of logic that we assume human beings will follow. A puzzle by Raymond Smullyan.

Measurement: Moving from qualitative to quantitative descriptions. Assumptions behind measurability, limitations of language, limitation of mathematical forms in expressing language, the results of measuring something often depend non-trivially on the units of measurement- how long is the coastline of Britain?

Decisions: The 5 steps to making a decision according to John Dewey and Herbert Simon. The notion of optimality. Newcombe's paradox. Decision trees without uncertainty.

Decision trees with uncertainty. Decision trees with many layers of uncertainty.

Theories: Descriptive, positive, prescriptive and normative theories. As mentioned earlier, we will look primarily at the classic models of decision making that come from Economics and that dominate in practical applications everywhere, but we will also look at models from Neurobiology, Psychology, Evolutionary Biology and Computer Science. A quick look ahead and some puzzles.

References:

The article by Bell, Raiffa, Tversky.

The article by Herbert Simon.

Gilboa. 2010. Chapter 1.

Gilboa. 2009. Chapters 2 and 7.

II. Choice without risk (1-2 classes)

What are preferences over consequences? What kind of assumptions do we need to make about preferences in order to lay down a good theory and why?

The completeness axiom and discussion. Is it believable? When is it reasonable? If we measure the length of sets in the unit interval, will we be always able to rank sets according to their length? (The answer is no – an example of inherent incompleteness of the ‘length order.’)

The Reflexive axiom – Is it obvious? Why is it necessary?

The Transitive axioms – should it always hold? The Sorites Paradox and its application by Armstrong to utility theory, failures of transitivity in multi-criterion decision making.

The existence of a utility function if the completeness, reflexive and transitive axioms hold.

The nature of complete versus partial orders. The proof of existence with and without best and worst elements in choice set.

Other kinds of preferences. For example, maxi-min preferences and when they might be justified in decision theory (complementary goods) and in ‘social choice’ problems (the philosophical underpinnings in Rawl’s Theory of Justice). A look at lexicographic preferences.

Can we derive a theory of utility simply by observing behavior? What conditions should that behavior obey?: The theory of Revealed Preference. What are cardinal utilities and what are ordinal utilities.? Does anything change if we use an ‘affine transformation’ of the utility function?

References:

Varian: Chapters 3, 5 and 7.

Kreps: Chapters 2 and 3.

The article by Armstrong.

III. Uncertainty and Probability (1 class)

Informal descriptions of probability. Why we need quantitative measures.

Two different occurrences of probabilities: objective and subjective probabilities.

Interpretations of objective (classical) and subjective probabilities. Justifications of subjective probability—The strong law of large numbers and using that to illustrate Dutch Book arguments for the establishment of internal probabilities. A brief look ahead to the Savage axioms, which also derive probabilities from axioms (and are thus theoretical justifications of ‘internal probabilities’).

Another interpretation of subjective probability as degree of belief in truthfulness of a statement.

Do we always assign a consistent probability to situations of uncertainty? Ellsberg’s Paradox. How does *ambiguity* defer from uncertainty?

Kolmogorov’s axiomatization of probability. Finite versus countable additivity.

Other measures of uncertainty: upper and lower probabilities, qualitative probabilities.

References:

Gilboa, 2009: Chapters 4 and 5.

Varian: Chapter 12.

Resnik: *pp.* 47- 80, especially *pp.* 61-75.

IV. Conditional Probability (1 class)

How should we update beliefs upon receiving information? (Re)visiting Bayes' rule. Bayesian versus non-Bayesian (frequentist analysis): the example of the stranger on an island, the example of the cookie jars, and the example of the island problem if the observed child has a particular characteristic the probability distribution of which is known.

Does conditional probability preserve intuition?: Simpson's paradox. Definition of independent events – 2 related definitions. Looking at the notion of irrelevance versus independence. Can there be two events that are both disjoint and independent according to either definition of independence?

Other rules of updating and inference: Jeffrey's rule, Dempster-Shafer rule, upper and lower probabilities, qualitative probabilities. Comparing such measures of updating with Bayes' rule.

References:

Freedman, Pisani and Purves: *pp.* 226-233

Pearl: *pp.* 62-68 (Jeffrey's Rule) and *pp.* 415-424 (Dempster-Shafer Rule)

V. The Von-Neumann (VNM) Axioms and expected utility theory (EUT) (2 classes)

Constructing decision trees with given (objective) probabilities. Assumptions behind the simplifications of decision trees (multiplying probabilities across paths, coalescing limbs with common outcomes).

Why we need a theory of expected utility instead of expected value– the St. Petersburg paradox.

Discussion of the axioms – the axioms that impose a complete order, the Substitution Axiom and the Archimedean Axiom – are they believable? Class experiments inspired by Kahneman and Tversky where we see if student preferences obey these axioms.

What do the axioms 'buy us'; going through the proof of the VNM representation theorem. Using the Marschak-Machina triangle to denote probabilistic indifference curves and see what EUT looks like in 3 prize gambles and what violations of it would imply visually. Do humans always behave in a way that is consistent with VNM axioms: the Allais paradox? The experiments of Kahneman and Tversky again.

References:

Kreps. Chapter 5.

Gilboa. 2009. Chapter 8.

Kahneman and Tversky. *pp.* 1-16

VI. Topics in the application of expected utility (1 class)

Preferences over money and risk aversion. Looking at the Arrow-Pratt measure of risk aversion. Increasing, decreasing and constant risk-aversion and functions that display such characteristics.

Looking at three measures of riskiness of distributions: standard deviation, stochastic dominance and entropy —and comparison in an economic example.

Applications of risk-aversion: the demand for insurance, inter-temporal consumption smoothing, optimal portfolio selection. Looking at trading amongst individuals with different approaches to risk (different degrees of risk-aversion or different valuation of outcomes).

Learning about Matthew Rabin's criticism of risk-aversion measures. The defense by Watt and the response by Thaler and Rabin.

References:

Varian: Chapter 12 and parts of 13.

Hirshleifer and Riley: *pp.* 105-113.

The exchange between Watt and Rabin & Thaler.

VII. Decision Theory with subjective probabilities (2 classes)

Detailed discussion of the concept of 'acts' and 'states of the world'. Discussion of the 7 Savage axioms, especially the Sure Thing Principle. A (very) brief sketch of proof of theorem. Discussion of what decision-theory with Savage axioms means – The two envelope problem (to be compared with the Monty Hall problem to be done later).

Newcombe's problem revisited. The second ace puzzle, the two card puzzle. The Aumann-Anscombe theory: what happens if people are allowed to have roulette wheels?

The fact that more information is always better in Decision Theory (in Game Theory, more information for *any subset of* players can lead to worse outcomes for *all* players. We will provide an example in games of incomplete information).

References:

Gilboa, 2009: Chapters 10,11 and 12.

Kreps: Chapter 8 and 9.

VIII. Behavioral Decision Theory (2 classes)

Looking at observed deviations from Expected Utility Theory (EUT). Recalling the critiques of Kahneman and Tversky again. The notions of mental accounting, frames, hyperbolic discounting and moral preferences.

While the critiques of Kahneman and Tversky are widely known and there are many piecemeal violations of EUT, the most complete alternative theory from the behavioral literature is that of Prospect Theory. Prospect Theory derives particularly from observed attitudes towards loss (recall the discussion of risk-aversion in Rabin's criticism of EU). We will look at the shape of the value function under Prospect Theory and compare its behavior with Conventional Utility Theory. We will also do an extended example involving 'probabilistic insurance' to compare the predictions of Expected Utility Theory (with risk aversion), Human Behavior and Prospect Theory.

References:

The chapter by Camerer and Loewenstein, and parts of chapters 1,2,3,8 and 15 from the same book.

The article by Laibson and List.

Gilboa, 2009: Chapter 12.

Part I: "Prospect Theory and Extensions," in the book (edited) by Kahneman and Tversky.

IX. Neuroeconomics (1 class)

We will visit a number of recent discoveries, including the understanding of the processing of information in the primate brain. For example, we will look at whether capuchin monkeys act according to Expected Utility Theory predictions in very simple problems? Do they display the same biases as humans? The role of visual saccades in the brain is of increasing importance and we will familiarize ourselves with basic issues. The role of rewards and valuation in neural circuits. The neurotransmitter dopamine has been much studied. We will look at whether the production of dopamine is based on rewards or beliefs about rewards?

Other topics will include neuroeconomic evidence for risk-aversion, Neuroeconomic evidence for Prospect Theory and learning in the human brain. The role of emotions and valuation will be discussed as well as what the brain displays about social preferences – such as empathy and fairness. What's in it (neuroeconomics) for the economic theorists who prefer to investigate economic behavior using the axiomatic method? – Perspectives of two prominent theorists: Douglas Bernheim and Itzhak Gilboa.

References:

The chapter by Vernon Smith in Neuroeconomics.

The article by Caplan and Dean.

The book chapter by Glimcher.

X. Decision Theory with multiple decision makers (2 classes)

The Bayesian view of all possible actions of players as part of the states of the world. Dominant Strategies and the Sure Thing Principle. How far can we get while using the Sure Thing Principle iteratively to make predictions in games? Nash equilibrium versus Rationalizability. How do predictions change if we change the information in a game – for example, by moving to a sequential structure from a simultaneous structure?

What if we use the concept of roulette wheels (as in the Anscombe-Aumann method we looked at earlier) to enlarge the set of strategies and call them ‘mixed strategies’? The deletion of strategies dominated by mixed strategies.

Incomplete information and moves by ‘Nature.’ Is more information always better in a strategic context? (We look at the equilibria before and after the addition of information.)

The Monty-Hall game analyzed as equilibrium in a game of incomplete information and compared with the guessing the gender of children in island game.

The notion of states of the world in situations involving more than one player: partitions to represent information about external states of the world.

References:

Dixit, Skeat and Reiley: Parts of Chapters 3,4,7 and 8.

7/7. References:

Armstrong, Wallace E., 1939, “The Determinateness of the Utility Function”, *Economic Journal*, 49: 453–467.

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Caplin, Andrew and Dean, Mark. 2007. “Dopamine and Reward Prediction Error: An Axiomatic Approach to Neuroeconomics.” *Social Science Research Network*.

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Hirshleifer, Jack and Riley, John. 1992. *The Analytics of Uncertainty and Information*. Cambridge Surveys of Economic Literature, Cambridge University Press.

Daniel Kahneman and Amos Tversky edited: *Choices, Values and Frames*," Cambridge University Press, 2000.

Kreps, David. 1988. Notes on the Theory of Choice. Undergraduate Classics in Economics: Westview Press.

Laibson, David and List John A.. 2015. "Principles of (Behavioral) Economics." *American Economic Review Papers and Proceedings* pp:385-390.

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Smith, Vernon. 2008. "Introduction: Experimental Economics and Neuroeconomics" *Neuroeconomics: Decision Making and the Brain*. Ed. By P. Glimcher, C. Camerer, E. Fehr, R Poldrack. Burlington Academic Press.

Varian, Hal. 2014. *Intermediate Microeconomics: A Modern Approach*. W.W. Norton: 9th edition.

Watt, Richard. 2002. "Defending Expected Utility Theory." Comments. *Journal of Economic Perspectives*. Vol. 16, No. 2. Spring: pp. 227-228