

Revealed Preference and Neuroscience

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Introduction

- Basic question: what are the possible roles for neuroscientific evidence in decision theory?
 - Currently under debate: Gul and Pesendorfer (GP) [2005], NYU conference, and subsequent book
- GP propose a “revealed preference” (RP) approach with neuroscientific evidence only motivation for standard choice theoretic models
 - Is this the limit or can neuroscientific evidence become more fully integrated?
- Converse question equally interesting: can the RP approach provide guidance on theoretical underpinnings for the neuroscience of choice?

Introduction

- First portion of my talk deals with history of decision theory
- Introduces and illustrates principle of RP
 - Emphasizes harmonic nature of decision theory based on RP
 - Explains underlying “as if” principle

Introduction

- Second portion of my talk deals with the proposal to elevate RP to centrality in economics and psychology
 - One motivation is that non RP based economic models are disconnected from new “psychological” data (surveys & neurological)
 - The second motivation is the surprising psychological flexibility of RP
 - Yet the implied prohibition against including neuroscientific data in models is incoherent

Introduction

- Third portion opens discussion of how neuroscientific and other “psychological” data fits with classical decision theory
 - What do decision theoretic principles have to contribute to models of psychological data?
 - This is the subject of several current research projects, including a neuroscientific project on dopamine with Paul Glimcher, Mark Dean, Eric DeWitt, and Robb Rutledge

Introduction

- This is a crucial time for methodological debate
 - Given current model limitations and changes in data availability, methods in economics will be revolutionized over coming decades
 - Degree of unity within social science and between neuroscience and social science depends on methodological awareness
 - Only measurement technologies that are internalized into the main body of social science will ultimately be allowed into the evidentiary base that drives our common theories forward
- Methodology will drive content

I. Modern Decision Theory

- Marginalism and Utility
 - The labor theory of value said prices not related to utility “diamond-water paradox”
 - Paradox disappears if one looks at the margin.
 - DMU explains low prices of commodities in high supply.
 - The hunt was on for U, and to confirm DMU
 - What are the “basic sources” of utility?

I. Modern Decision Theory

- The ordinal revolution killed the search for utility
 - Pareto recognized that logic of choice depends only on ordering, not on the scale.
- Consider a choice set Z with three prizes

$$Z = \{z_1, z_2, z_3\}$$

- A binary relations B is a subset of the product space Z^2 . We say that (z_1, z_2) is “in B ” if and only if z_1 is “preferred or indifferent” to z_2 .
- Natural coherence properties are:
 - Completeness : B contains every pair in some order
 - Transitivity: if (z_1, z_2) and (z_2, z_3) are in B so is (z_1, z_3)

I. Modern Decision Theory

- A utility function is a real-valued function on Z that respects preferred or indifferent
- Basic Theorem: Choices among a finite list of objects can be seen as being based on maximizing a utility function iff these choices respect a **complete** and **transitive** binary relation on them defining “better” and “worse”
 - Choices are unchanged by order respecting transformations of the utility function
 - Stop the hunt for “true” utility
- As we will see, the objects in the choice set matter hugely to the implied psychology

I. Modern Decision Theory

- Revealed preference reverses standard logic
 - Ordinalist starting point asks what coherent inner comparisons will produce in the way of choices
 - Samuelson proposed the converse question: what is the class of “as if” theories that can be supported by a particular pattern of observed choices?
 - Most basic theorem characterizes choices from all subsets of a finite list of objects that can result from maximizing a CT order, or equivalently utility maximization

I. Modern Decision Theory

- With three prizes $Z = \{z_1, z_2, z_3\}$, the choice correspondence is $C(\{z_1, z_2, z_3\})$, $C(\{z_1, z_2\})$, $C(\{z_1, z_3\})$, and $C(\{z_2, z_3\})$ that are assumed non-empty
- Define a binary relation B on Z to include (z_i, z_j) if and only if z_i is in $C(\{z_i, z_j\})$
 - Interpretation is that z_i is revealed preferred or indifferent to z_j :
 - $z_i RP z_j$ for short
- What conditions on $C()$ ensure completeness and transitivity of the RP binary relation and allow utility maximization to characterize choices?

I. Modern Decision Theory

- The answer is WARP
 - “If x is ever chosen from a set A when y is available, then x is chosen from any set from which y is chosen provided x is available”
 - A simple proof in our three prize case: if z_1 is in $C(\{z_1, z_2\})$ and z_2 is in $C(\{z_2, z_3\})$, then WARP says that **if** z_2 is in $C(\{z_1, z_2, z_3\})$, so is z_1 , while if z_2 is not, neither is z_3 leaving z_1 in for sure. Given that z_1 is in $C(\{z_1, z_2, z_3\})$, WARP applies again and it is also in $C(\{z_1, z_3\})$, as required

I. Modern Decision Theory

- Technically a small change but philosophically huge
- Connects an in principle observable choice to a functional method of selecting what is chosen
 - Do not ask if the computation is actually undertaken
- Take instead the “as if” approach.
 - If the predicted behavior is rarely violated, then choice data per se cannot force the rejection of the theory
- Argues against “intuitive” decision procedures in favor of those that connect tightly with choice, the only observable counterpart
 - To date!

I. Modern Decision Theory

- Decision theory based on RP now far richer
- General RP structure: Choices among objects of type $*$ have appealing property $**$ if and only if they are determined by calculations of the form $***$ (typically maximization of a class of functions)
 - Standard case had $*$ as prizes, $**$ as WARP, and $***$ as utility maximization
 - Richer cases change the domain $*$, the property $**$ (generally including WARP), and the nature of $***$

I. Modern Decision Theory

- EU theory of this form:
- Objects in $*$ are lotteries over prize space
- Essential axiom in $**$ is the substitution axiom:
substitution of indifferent lotteries preserves order
 - With two prizes implies only that lottery offering higher probability of better pure prize is preferred
 - Rewrite higher probability lottery as middle lottery mixed with better rather than worse pure prize
- Conclusion in $***$ is that one can now find utility functions defined on the pure prize space such that choices **among all lotteries** can be computed by maximizing expected utility

I. Modern Decision Theory

- Economists love this and the theory of risk aversion to which it connects
 - Risk aversion defined when prizes are monetary amounts
 - Corresponds to the shape of the EU function
 - Explains real world phenomena such as insurance and asset prices to life with insurance

I. Modern Decision Theory

- EU theory does not reinstate the nineteenth century search for “real” utility
- In the two prize example with non-indifferent prizes, any strictly increasing function of the probability of the better prize represents the underlying preferences accurately
- The theorem asserts only that among all of these representations, those that allow all decisions to be made based on expected value of utility are the linear ones

II. Methodology in Econ. & Psych.

- EU known from the outset to be false in some circumstances
 - Allais and Ellsberg paradoxes
- Decision theoretic approach is to produce the violation that occurs and analyze how one needs to adjust axioms in a plausible/minimal manner to allow for new observation
- Kreps and Porteus produced a beautiful example

II. Methodology in Econ. & Psych.

- Information in EU purely instrumental
- Yet many reject genetic test resolving the 50% chance of having Huntington's disease
- KP model can capture this.
 - Uncertain world, choice among signals determining p , belief that no Huntington's (outcome 1) will eventuate
- KP axioms equivalent to existence of $K(p)$, $K : [0, 1] \rightarrow \mathbb{R}$ such that signal s is preferred or indifferent to signal t if and only if $E_s(K) \geq E_t(K)$.
 - Concave iff preference for late resolution of uncertainty

II. Methodology in Econ. & Psych.

- The bottom line is that modern decision theory says:
 - Don't look for utility
 - Don't care about process, just outcome
 - Use the "As If" philosophy
 - Tie theory and observation together in as neat a package as possible
 - Psychology is as psychology does!

II. Methodology in Econ. & Psych.

- For many in economics and psychology by contrast, plausibility of process matters
- Pioneering ideas come from both disciplines
 - Simon [1955] satisficing as “plausible” process
 - Strotz [1956]: Restricting future choices and self control
 - Kahneman and Tversky [1977]: Heuristics and Biases for explanatory purposes
 - Kahneman and Tversky [1979]: Prospect theory for mixed motives
 - Loewenstein [1987]: Delay and anticipatory feelings

II. Methodology in Econ. & Psych.

- An open question concerns what exactly are the observable counterparts of these theories
- No uniformity of approach
- Possible gap between theory and observation exemplified by time inconsistency:
 - Strategic and informational models constructed based on presumed inner logic, not tied directly to observables

II. Methodology in Econ. & Psych.

- Tempting to explore these new theories using not only data on behavior, but also new psychological data
 - Payne, Bettman and Johnson [1988] use Mouselab to understand heuristics
 - McClure, Laibson, Loewenstein, and Cohen [2005] use brain scans to study self control
 - Kahneman and Krueger [2006] uses surveys to measure happiness
 - Ameriks, Caplin, and Leahy [2003] use surveys to measure planning

II. Methodology in Econ. & Psych.

- In practice testing extra-theoretical
 - Few of the models of choice tested by PBJ are rich enough to predict mouse clicks
 - Self control based models of choice do not include a cortical or limbic BOLD signal function
 - There is no model of the meaning of responses to ambiguous survey questions sufficient to guide empirical interpretation

II. Methodology in Econ. & Psych.

- G & P argue “structuralism” important to prevent unified field turning into prior-based fiefdoms
 - While it is rational for an economist well-versed in the literature to have a prior such that they interpret specific brain activation as evidence in favor of self control theory, the majority would not so update given the lack of modeling
 - The risk is of the field splintering based on non-overlapping priors, with little hope of convergence.
 - G & P propose reviving RP: phrase psychological theories in terms of choice alone

II. Methodology in Econ. & Psych.

- Flexibility of RP theory in nature of domain and nature of choices
 - Focus on domain a virtue
 - EU theory already illustrates psychological possibilities of this principle, as does KP
- Savage
 - “Act” domain and subjective probabilities
- The domain of choice sets allows rich psych.
 - Kreps for flexibility
 - G & P for temptation and self control
- Makes other behavioral theories look at best inelegant, at worst dangerous

II. Methodology in Econ. & Psych.

- But standard RP has its limits
- Illustrate in relation to Kreps and Porteus
 - Domain of temporal lotteries: non-instrumental information preferences
- Alternative is PEU of CL based on Loewenstein
- Posits relevant “mental states” such as anxiety that are responsible for informational choices

II. Methodology in Econ. & Psych.

- In the case of Huntington's the PEU formulation posits a psychologically-motivated EU function calibrating the aversive pre-outcome beliefs, p .
- Treat pure prizes, Z , as pairs of beliefs and outcomes.
- Preferences over lotteries on Z defined by PEU function $u^{\text{ANX}} : Z \rightarrow \mathbb{R}$.
- Overall EU of belief p defined by $K^{\text{ANX}} : [0, 1] \rightarrow \mathbb{R}$
$$K^{\text{ANX}}(p) = p u^{\text{ANX}}(p, 1) + (1 - p) u^{\text{ANX}}(p, 2)$$
 - As in KP, information rejected if and only if concave

II. Methodology in Econ. & Psych.

- PEU includes production function relating aversive prior states to the environment
 - Allows one to model e.g. “fear appeals”
 - Paints KP as reduced form of structural PEU
- In principle psychological evidence allows PEU to be tested
 - Psychological comparative statics and fear appeals
- Does PEU provide a legitimate theoretical motivation for neurological measurements?

II. Methodology in Econ. & Psych.

- To implement PEU fit psychological production function to get around “Lucas Critique”
 - Normative value of modeling states: surprise party can give rise to identical signal choice as anxiety, yet better to suppress rather than pass on good news
- Practical problems
 - What are the relevant states?
 - How can they be measured?
 - What produces them?
- Tough work, but who could argue against?

II. Methodology in Econ. & Psych.

- G & P could (must?) since PEU lies on the wrong side of the RP line
- KP domain comprises all possible information choices: exhausts private choice possibilities
 - PEU domain contains fantasies, e.g. a guarantee that a currently uncertain future will turn out well
- The larger domain accounts for ambiguity of interpretation and the welfare question

II. Methodology in Econ. & Psych.

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II. Methodology in Econ. & Psych.

- Absurd to argue against progress in measuring mental states
- Classical RP too limited a methodology
- Yet unstructured alternatives will lead to fragmentation
 - Methodology matters and matters now!
- The key to progress is to explore the grounds in RP theory for limiting data that is allowed to “choice” data

III. Next Steps

- What limits the objects and the selection rules that can be conceptualized as choices in a revealed preference theory?
 - Standard RP relies on a folk understanding
 - I reject this entirely. The alternative I believe in, “Minimalism”, is defined by a universal perspective: any output of human activity measured in any setting can be so modeled.
 - Apply RP-like reasoning to limit style of modeling, not data to be modeled
- Make the case for verbal responses and physical outputs, including neurological

III. Next Steps

- Verbal responses:
 - Ericsson and Simon proposed protocol analysis as a method of gathering decision process data in the context of the debates on behaviorism in psychology
 - "We see verbal behavior as one type of recordable behavior, which should be observed and analyzed like any other behavior.." (Ericsson and Simon , p. 7).
 - Their approach does not assume the literal truth of the recorded statements
 - "The report 'X' need not be used to infer that X is true" (Ericsson and Simon [], p. 9).

III. Next Steps

- In economic context, questions on hypothetical future choices represent a clear case in point
- My current applied research focuses on answers to questions about future contingent choices for separating bequest and precautionary motives
 - With Ameriks, Laufer, van Nieuwerburgh
- It can readily be shown that observed data inadequate to answer key hypothetical question of interest to policy makers
- In principle, survey questions far more revealing of key parameters driving strategy

III. Next Steps

- Inclusion of these as evidence appears consistent with origins of RP theory, as Aumann ([1998], p. 935) highlights:
 - "The essence of the axiomatic approach is that it ... relates the given, "real" situation to a whole lot of other situations, all of them hypothetical. This happens ... even in Savage's development of probabilities themselves."
- Savage requires far more stressful thought experiments
 - "It is quite usual in this theory to contemplate acts that are not actually available..... I can contemplate the possibility that the lady dies medically and yet is restored in good health to her husband." Savage [1971], quoted in Aumann [1998], p. 935

III. Next Steps

- Milton Friedman objected even to the use of answers to questions concerning choices that would surely come to pass (what incentives at play in response?)
 - Assuming orthogonality as limiting as assuming truth
- Where does RP fit?
- I propose that survey responses should ultimately be modeled in a manner suitable for RP based analysis of why these responses were chosen
 - On my theoretical research agenda

III. Next Steps

- More broadly, the economic conception of choice is a weak link in defining RP
 - Rely on “I know it when I do it”
 - Consciousness is therefore a key, but it is not understood. Experiments in social psychology show:
 - many apparently conscious choices are made automatically,
 - ex post explanations for choices may be demonstrably false.
- No clear line separates human activities into mechanistic and chosen
 - The goal of decision theory is after all to model choice itself mechanically

III. Next Steps

- Reinhard Selten made similar observations in a paper prepared for the Dahlem Conference May 1999
 - "Much of human behavior is automatized in the sense that it is not connected to any conscious deliberation. In the process of walking one does not decide after each step which leg to move next and by how much.One might want to distinguish between bounded rationality and automatized routine. However, it is difficult to do this. Conscious attention is not a good criterion. Even thinking is based on automatized routine. We may decide what to think about but not what to think. "

III. Next Steps

- Three collaborative examples of RP like research with richer data
 - Hypothetical future choices: already mentioned
 - Time taken making a standard choice:
 - With Mark Dean
 - Dopaminergic firing rates:
 - With Paul Glimcher, Mark Dean, Eric DeWitt and Robb Rutledge

III. Next Steps

- Theory
 - Dopaminergic version of WARP
 - revealed positive surprise
 - What is the nature of the dopaminergic ordering
 - How does it relate to choice based ordering?
 - Does the difference between them open up a new approach to the impact of preferences on beliefs
 - Needs superb measurement

III. Next Steps

- Driving questions as yet incompletely answered
 - How best to incorporate neuroscientific and other psychological data into social science?
 - How to develop models that relate to this new data?
 - What theoretical base for neuroscience?