Fifteen years of theory?[1]
Decision Theory:
New domains - new models

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June 8 2011

[1] Endless thanks to Bart Lipman for years of explanations; no fault of his that I still make mistakes... Thanks also to Rani Spiegler and Ady Pauzner for insightful discussions.

15 years of theory?

Econometric Society Volumes 2000–2010

- 9 Mechanism design / contracts (one on communication and 1/2 on robustness)
- 4 Behavioral
- 4 IO (Bounded rationality, price discrimination, internet, organizations)
- 2 Decision theory
- 1 each: Communication, global games, networks, matching, organizations, hierarchies of beliefs, testing experts, repeated games

All, aside perhaps from networks and testing experts, continue seminal issues from years ago, albeit with important developments.

Decision Theory

- A historically inaccurate history: Some old and some new models
  - Theme: A main step in DT is finding the **domain of choice that identifies** the model and the concept of interest
  - Why is identification of interest?
- Future?
  - Applications
  - New domains to identify new models

Decision Theory

- The study of *behavior* that is not consistent with existing models
- Inspired by "data": introspection (Allais, Ellsberg), experiments, "market" data
- Different possible reactions to such data.

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- Reactions to such data begin by proposing a model "consistent" with the data, and then:
  - test/"fit" it, or
  - apply it (game, specific decision problem, etc.), or
  - study it, in the context of "general" choice = DT

Decision Theory

- That is, find the **right domain** in order to:
  - **identify** the model
  - develop **comparatives** (e.g., Arrow-Pratt risk aversion)
  - characterize model with elementary behavioral properties–**axioms**
  - see how to (experimentally) **elicit** preferences
  - explore **properties** (e.g., how to update beliefs)
  - study **relationships** to other models

A remark on the hypocrisy of DT

- “As if” perspective: representation doesn’t mean anything; just a tractable functional form

A remark on the hypocrisy of DT

- "As if" perspective: representation doesn't mean anything; just a tractable functional form
- But the interpretation of the representation is important and critical in appeal of functional form

Theme

- A critical aspect in studying new model of behavior in DT:

  The **domain** on which revealed preferences [= choice behavior] **identifies** the model.

Models–"history"

Risk aversion

- What if Arrow – Pratt had taken a different approach?

Models–“history”

Risk aversion

- What if Arrow – Pratt had taken a different approach?
  - Risk aversion is feeling butterflies / jitters

    Behavior / measurement: Sweaty palms, taking Valium,...

    But what decisions do we study?

Risk aversion

EU: vNM and Arrow-Pratt:

- Study (revealed) preferences over lotteries over outcome space B, i.e.,

$$\succeq \text{ over } \beta \in \Delta(B)$$

  - *Representation*: $U(\beta) = \int u(b)\, d\beta(b)$.
  - *Independence axiom:* facilitates testing, connections.
  - *Elicitation:* What mixture between b^* and b_* is indifferent to b.
  - *Uniqueness*
  - *Comparatives:* Arrow-Pratt measure and SOSD – not variance.

Risk aversion

Alternative domains

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- Could also mean discomfort in taking risky decisions:
  - Behavior: avoid or delay risky decisions.
  - Enhance choice domain: allow for non-decision or time to decision.
  - Example of possible future work by expanding the domain of choice

Unknown probabilities

Savage and Anscombe-Aumann

- *Enrich the domain*: Acts

$$\succeq \text{ over } f \in (\Delta(B))^S$$

  - *Representation*:

$$\int U(f(s))\, d\mu(s)$$

  - *Elicitation:* What constant lottery with utility β is indifferent to 1 in state s_1, 0 elsewhere

$$p_1 u(1) + (1 - p_1) u(0) = \beta$$

  - *Uniqueness* of probabilities gives them meaning. (Interpretation)
  - *Separation* of beliefs and utility. (Interpretation)
  - Lotteries complicate the domain but identify representation (calibrate)

Preference for flexibility

Kreps 1979

- $\{\text{beef, fish}\} \succ \{\text{beef}\} \succ \{\text{fish}\}$ indicates two states, one where each is preferred.

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Turns out to be a very useful domain!

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Turns out to be a very useful domain!

- *Representation*:

$$V(x) = \int_S \max_{b \in x} u(b, s)\, d\mu(s)$$

(Overwhelming) Temptation

Strotz

- $\{\text{fish}\} \succ \{\text{beef, fish}\} \sim \{\text{beef}\}$ indicates concern that will choose the "wrong" item:

$$
\begin{aligned}
V(x) &= \max_{\beta \in \arg\max_{\beta' \in x} v(\beta')} u(\beta) \\
\text{``} &= \text{''}\ u\left(\arg\max_{\beta' \in x} v(\beta')\right)
\end{aligned}
$$

(Overwhelming) Temptation

Strotz

- Implies a direct match between desire for commitment and preference reversals:

  v chooses something different than u iff would want to commit to the choice made by u

  Inconsistent with experiments and introspection; Kocherlakota ex.; ignores cost to resisting temptation

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- Welfare: what utility function to use? Pareto?
- Problems in multi-period version (Peleg-Yaari (game), Harris-Laibson (discontinuities, non-monotonicities)

Temptation–costly self control

Gul-Pesendorfer (2001)

- GP Representation:

$$V(x) = \max_{\beta \in x} \left(u(\beta) - c(\beta, x) \right)$$

$$c(\beta, x) = \max_{\gamma \in x} \left(v(\gamma) - v(\beta) \right)$$

$$V(x) = \max_{\beta \in x} \left(u(\beta) + v(\beta) \right) - \max_{\beta \in x} v(\beta)$$

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$$V(x) = \lim_{k \to \infty} \left[\max_{\beta \in x} \left(u(\beta) + kv(\beta) \right) - \max_{\beta \in x} \left(kv(\beta) \right) \right]$$

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  - **Axiom**: Add set betweenness: $x \succeq y \Rightarrow x \succeq x \cup y \succeq y$

Costly self control

- GP Costly self control model
  - Generalizes the Strotz model
  - Relaxes the implication that commitment implies a preference reversal: may desire commitment to avoid cost of resisting temptation even if succumbing to temptation not observed
  - GP argue that it resolves welfare problem: only one preference
  - Does not have the pathologies of multi-period Strotz/$\beta - \delta$

Uncertain temptations

Violations of GP and Strotz model (DLR (2009))

- $$\{b\} \succ \{b, c\}, \{b, p\} \succ \{b, c, p\}.$$

  broccoli, candy, potato chips
- Two snacks may be worse because unsure what temptation will strike
  - Violates SB: $\{b, c, p\}$ is strictly worse than $\{b, c\}$ and $\{b, p\}$

Uncertain temptations

Violations of GP and Strotz model (DLR (2009))

- $$\{b, y\} \succ \{y\} \text{ and } \{b, i, y\} \succ \{b, i\}.$$

  broccoli, frozen yogurt, ice cream
- Rather have a chance of sticking to her diet rather than committing herself to violating it so $\{b, y\} \succ \{y\}$.
  But if the temptation of the ice cream is unavoidable, it's better to also have the frozen yogurt around.
  - Violates a more subtle combination of set betweenness and independence.

Uncertain temptations
DLR (2009, 2010), Stovall (2010)

- Model consistent with above behavior:

$$V(x) = \int_S \left(\max_{\beta \in x} \left[u(\beta) + v_s(\beta) \right] - \max_{\beta \in x} v_s(\beta) \right) \mathrm{d}\mu(s)$$

- **Axiom**: Weak set betweenness: If $\forall \alpha \in x, \beta \in y \; \alpha \succeq \beta$ then $x \succeq x \cup y \succeq y$

Random Strotz

DLR (2010)

- Similarly generalize Strotz model to allow for uncertainty

$$V(x) = \int u\left(\arg\max_{\beta' \in x} v_s(\beta')\right) d\mu(s)$$

Costly resisting = Randomly succumbing to temptation

DLR (2010)

- Given any costly self control preference the choice/preferences over menus coincide with those of a random Strotz model
- Given u and v there exists μ s.t.

$$\max\left[u(\beta)+v(\beta)\right]-\max v(\beta)=\int u\left(\arg\max_{\beta'\in x} v_s(\beta')\right)d\mu(s)$$

  - Extends immediately to random costly temptation model
  - Converse holds for smooth random Strotz models

Costly resisting = randomly succumbing

Implications of equivalence

- *Implications*
  - Same commitment behavior with self-control costs as with uncertain overwhelming temptation.
  - *Choice from menu* matters Must expand domain to pin down.
  - New comparatives.
  - New dynamic models for overwhelming temptation

Temptation with choice **of and from** menus

Noor

- Domain:

$$\succeq_1 \text{ over } 2^{\Delta(B)} \textbf{ and } \succeq_2 \text{ over } \Delta(B)$$

$$\succeq_1: \quad V_{GP}(x) = \max_{\beta \in x} (u(\beta) + v(\beta)) - \max_{\beta \in x} v(\beta)$$

$$\succeq_2: \quad u(\beta) + v(\beta)$$

-
  - Sophistication: tie together both periods' decisions:

$$x \cup \{p\} \succ_1 x \Rightarrow p \succ_2 q, \forall q \in x$$

Naivete

Kopylov and Noor (2009), Kopylov (2009)

- Same domain:

$$\succeq_1 \text{ over } 2^{\Delta(B)} \textbf{ and } \succeq_2 \text{ over } \Delta(B)$$

$$\begin{aligned} \succeq_1: V(x) = \quad & (1-p)\left(\max_{\beta\in x}\left(u(\beta)+v(\beta)\right) - \max_{\beta\in x} v(\beta)\right) \\ & + p\max_{\beta\in x} u(\beta) \\ \succeq_2: \quad & u(\beta)+v(\beta) \end{aligned}$$

- 1^{st} period: prob p that will not be tempted and choose according to u, o/w $u+v$.
- 2^{nd} period: choose according to $u+v$; 1^{st} period is wrong!

Naivete

Kopylov and Noor (2009), Kopylov (2009)

Weak Sophistication: tie together both periods' decisions:

$$x \cup \{p\} \succ_1 x \Rightarrow \begin{array}{c} p \succ_2 q,\ \forall q \in x \text{ or} \\ \{p\} \succ_1 \{q\},\ \forall q \in x \end{array}$$

Interpretation: the decision maker is **not** aware of $\succeq_2$.

Shame

Dillinberger and Sadowski (2010), Saito (2011)

- Individuals may choose allocations between themselves and others differently depending on whether their choice is public or not

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- Two stages: private choice of menu, then public choice from menu:

$\succeq$ over subsets of $(\Delta(B))^I$, where I is set of individuals, 1 is self

$$\text{E.g., } \{(2,2)\} \succ \{(2,2),(0,5)\}$$

Shame
Saito (2011)

$$V(\mathbf{x}) = \max_{\beta \in \mathbf{x}} \left(\sum_i a_i u_i(\beta_i) - b \left(\max_{\gamma \in \mathbf{x}} [a_1 u_1(\gamma_1) - u_1(\beta_1)] \right) - b \left(\max_{\delta \in \mathbf{x}} \sum_{j \neq 1} a_i \left[u_j(\delta_j) - u_j\left(\beta_j\right) \right] \right) \right)$$

Utilitarian – regret cost – shame cost

Anticipation / anxiety

Behavioral model: Utility from beliefs

- Model (dis)utility from disappointment/anxiety or anticipation

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  - Enjoy hope/anticipation: $u(p, G) = 2p$, $u(p, B) = p$
    $Eu(p) = p2p + (1-p)p = p + p^2$

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  - Dislike disappointment: $\hat{u}(p, G) = 2$, $\hat{u}(p, B) = -p$
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    $E\hat{u}(p) = 2p - p(1-p) = p + p^2$
- No choice data can identify these.

- C-L: Identify by observing game with someone who "knows" true preferences and decides what information to give.
  - Specific application, not general behavior
  - Additional untestable / unobservable assumptions, esp. existence of omniscient person – what behavior would she observe that gives her this information?
  - Possible reply: observe not behavior, but feelings...

Anticipation / anxiety

DT model: Commitment

- Model (dis)utility from disappointment/anxiety or anticipation
- Epstein: $\succeq$ over **menu choice and temporal lotteries**, specifically $2^{\Delta(B)} \cup \Delta\left(\Delta\left(B\right)\right)$.
  - p – risky lottery that resolves in 2 periods
  - $\hat{p}$ – same risky lottery that resolves in 1 period
  - q – safe lottery
  - As in KP may have: $p \succ q \succ \hat{p}$ (longer anticipation)

Anticipation / anxiety

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- Thus $\{p, q\} \sim \{q\}$.

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- Thus $\{p, q\} \sim \{q\}$.
- Commitment benefit: $\{p\} \succ \{p, q\} \sim \{q\}$.
    - KP do not allow benefit of commitment.

Anticipation / anxiety

DT model: Commitment

- Benefits of finding identifying domain:
    - Representation pinned down.
    - Characterization of "more anxious"

Choosing beliefs

Behavioral model: Brunnermeier-Parker

- True beliefs q. Take decision a and choose beliefs p s.t.

$$
\begin{aligned}
a^*(p) &= \arg\max_a \sum_i u(a, s_i)\, p_i \\
p^* &= \arg\max_p \alpha \sum_i u(a^*(p), s_i)\, p_i \\
&\quad + (1-\alpha) \sum_i u(a^*(p), s_i)\, q_i
\end{aligned}
$$

where α is degree of enjoyment of optimistic beliefs (anticipation effect).

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- BP application: For high enough α choice between safe act c and risky act r is always r since will choose to believe in good state and get high anticipatory payoff

Choosing beliefs

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- BP application: For high enough α choice between safe act c and risky act r is always r since will choose to believe in good state and get high anticipatory payoff
- Assume $q(s_i) = 1/2$, $\alpha = 1/2$

	s_1	s_2
c	0	0
r	-2	1

Choose r and $p(s_1) = 1$ since $(1/2) + (1/2)(-1/2) > 0$.

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  - If consistent then is there anything new here? Yes–to the extent that interpretation matters.
  - But in any case seems important to know if all that is new is interpretation or behavior as well.

Choosing beliefs
Behavioral model: Brunnermeier-Parker

- DT approach: Spiegler

	s_1	s_2
c	0	0
r	-2	1
r'	-3	2

  - Choose r over r' iff $p(s_1)$ large enough ($\geq 1/2$) whereupon c is chosen over r
  - Violates IIA

Choosing beliefs

Behavioral model: Brunnermeier-Parker

- Another DT approach:
  - Expand domain to induced preferences over $q \in \Delta(S)$

$$V_{BP}(q) = \max_{p,a} \alpha \sum_i u(a^*(p), s_i)\, p_i + (1-\alpha) \sum_i u(a^*(p), s_i)\, q_i \quad (1)$$

$$V_{KP}(q) = \sum_i v(a^*(q), s_i)\, q_i \quad (2)$$

  - Are the preferences over $\Delta(S)$ generated by (2) when we vary v different from those generated by $(1)$when we vary u and α?

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Cold feet

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- Yields subjective "beliefs" over states, and decision maker suffers the temptation to use wrong beliefs later. They will get "cold feet". Knowing this decision maker commits ahead of time.

$$
\begin{aligned}
V(\xi) &= \max_{f \in \xi} \left(p \cdot u(f) + k \min_{q \in Q} (q \cdot u(f)) \right) \\
&\quad - \max_{f \in \xi} k \left(\min_{q \in Q} (q \cdot u(f)) \right) \\
, p &\in Q
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- At what point does domain become so complicated as to be unhelpful?

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- Choice over time
  - Caplin and Dean (2010)

Conclusion and the future

- DT studies novel phenomenon by finding identifying behavioral properties on rich enough choice domains
- Focus is often on axioms–today emphasis on domains
  - One major direction: Choice of menus
  - Saw need of choice from menus as well
- Models for:
  - unforeseen contingencies
  - temptation
  - anxiety
  - shame
  - choice of beliefs
  - ...contemplation costs, regret, richer dynamics

Conclusion and the future

- Other domains: Lists, time, delay,...
  - Will these be useful – lead to interesting models and comparatives – for models on which we focus?
  - Perhaps: these may be useful ways to study in/attention, other implications of risk/ambiguity,...

Conclusion and the future

- Moving further away from "choice": eye movement or mouse lab to determine search behavior and correlate with cognitive models, biological features, brain scans
  - Challenge here is whether domain will be of use: we typically don't want to predict eye movement but we do want to predict how people invest in information collection.
  - Policy makers (correctly) know that how we present information matters: small or large verbal or visual warnings on cigarette boxes and how returns of mutual funds should be presented so models along these lines have potential.