Bounded Rationality I: Consideration Sets

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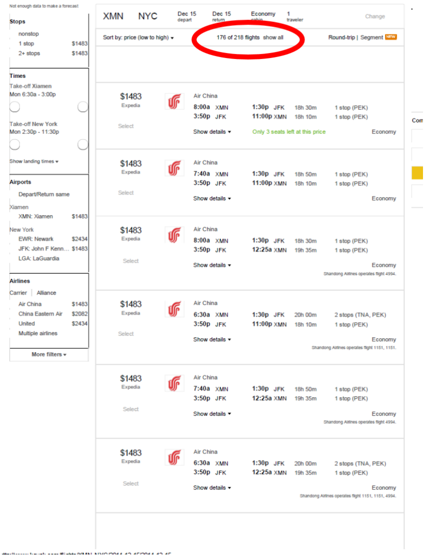
Choice Problem 1



Choice Problem 2

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Candidate Functions

List Candidates | Candidates by Field | Reviewer Assignments | Search Candidates | Search Recommenders | Add Candidate | My Favorite Candidates | Make a Comment | My Comments | All Comments | My Grades | All Grades | Placement Recommendations

List of Candidates by Primary Field (from EconJobMarket.org)

Click on the blue hyperlink to the number of candidates in each field to list all candidates in that field.
Click on the link to the number of assigned reviewers to assign (or modify the assignment) of reviewers for all candidates in the specified field.

#	Field	Assigned Committee Members	# Candidates	# Reviewers
1	Accounting		0	0
2	Any Field		9	0
3	Behavioral Economics		14	0
4	Business Economics		6	0
5	Computational Economics		0	0
6	Decision Sciences		1	0
7	Development		60	0
8	Econometrics		52	0
9	Economic History		9	0
10	Environmental Economics		23	0
11	Experimental Economics		6	0
12	Finance		67	0
13	Health, Education, Welfare Economics		37	0
14	Industrial Organization		45	0
15	Insurance		1	0
16	International Finance		19	0
17	International Trade		35	0
18	Labor		67	0
19	Law and Economics		0	0
20	Macroeconomics		118	0
21	Management, General		1	0
22	Management, Health Care		1	0
23	Management, Information Technology		1	0
24	Marketing		0	0
25	Microeconomics		84	0
26	Operations Research		0	0
27	Organizational Behavior		0	0
28	Other		4	0
29	Political Economy		7	0
30	Public Economics		32	0
31	Real Estate		1	0
32	Theory		25	0
33	Urban, Rural, Regional Economics		6	0
34	No primary field entered	Eggertsson	0	0
35	All Candidates		731	0

Head Hunter

Time left in this session: 40
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Consideration Sets

- Choice Problem 1 and 2 are difficult
  - Lots of available alternatives
  - Understanding each available alternative takes time and effort
- Do people really think hard about each available alternative?
- The marketing literature thinks not
- Since the 1960s have made use of the concept of consideration (or evoked) set
  - A subset of the available options from which the consumer makes their choice
  - Alternatives outside the consideration set are ignored
- Some key references
  - Hauser and Wernerfelt [1990]
  - Roberts and Lattin [1991]

- What was the evidence that convinced marketers that consideration sets played an important role in choice?
  - Intuitive plausibility
  - Verbal reports (e.g. Brown and Wildt 1992)
  - Lurking around supermarkets and seeing what people look at (e.g. Hoyer 1984)
- More recently richer data has been used
  - Eye tracking
  - Internet search data

De los Santos et al [2012]

- Use data from internet search engines on book purchases
- Makes visible what was *searched* not just what was *chosen*
- Dataset: 152,000 users from ComScore
  - Company that records web browsing activity (!)
    - Date
    - Time
    - Duration
    - Purchase description, price and quantity
- Divide the internet into four 'bookshops'
  - Amazon
  - Barnes and Noble
  - Book Clubs
  - All other
- Looks at the search histories of people who bought books in the seven days prior to purchase

De los Santos et al [2012]

TABLE 2—DESCRIPTIVE STATISTICS OF COMSCORE BOOK SAMPLE

	2002		2004	
	Mean	Std. Dev.	Mean	Std. Dev.
Duration of each website visit (in minutes)				
Visits not within 7 days of transaction	8.89	13.03	7.69	12.36
Visits within 7 days, excluding transactions	12.72	15.83	11.02	15.00
Visits within 7 days, including transactions	19.04	18.26	15.74	17.37
Transactions only	28.06	17.69	26.08	17.71
Total duration, excluding transaction visits	32.47	49.80	38.41	78.33
Total duration, including transaction visits	43.88	43.27	47.43	66.11
Number of stores searched	1.27	0.54	1.30	0.56
Number of books per transaction	2.38	2.10	2.20	1.95
Transaction expenditures (books only)	36.67	40.64	32.21	35.68
Number of books purchased	17,956		17,631	
Number of transaction sessions	7,559		8,002	
Number of visits within 7 days	18,350		25,556	
Number of visits not within 7 days	94,011		189,157	

- On average people don't go to all bookshops
- Also do not buy from the lowest priced store in 37% of observations

A (Naive) Model of Choice with Consideration Sets

- So people don't think about all alternatives before making a choice
- What happens if we bake this into our standard model of choice?

A (Naive) Model of Choice with Consideration Sets

- Let
  - $u : X \to \mathbb{R}$ be a utility function
  - $E : \mathcal{X} \to \mathcal{X}$ describe the evoked set
    - $E(A) \subseteq A$ is the set of considered alternatives from choice problem A
- Choice is given by

$$C(A) = \arg \max_{x \in E(A)} u(x)$$

- What are the testable implications of this model?
- Nothing!
- Any data set can be rationalized by assuming utility is constant and setting $E(A) = C(A)$ for all A

A Testable Model of Choice with Consideration Sets

- In order to be able to test the consideration set model we need to do (at least) one of two things
  - Put more *structure* on the way consideration sets are formed
  - Enrich the *data* we use to test the model
- First, let's look at at some approaches that have taken the former route

Masatlioglou et. al. [2012]

- Model choice with consideration sets using standard choice data
- Add an additional assumption to make consideration set model testable

$$E(S/x) = E(S) \text{ if } x \notin E(S)$$

- Removing an item that is not in the consideration set does not affect the consideration set
- This property is satisfied by several intuitively plausible procedures for constructing consideration sets
    - The top N according to some criterion
    - Top on each criterion
    - Most popular category
- But not all
    - Salience?
- Masatlioglou at al. call the resulting model Choice with Limited Attention

Masatlioglou et. al. [2012]

- This assumption also gives the consideration set model empirical bite
  - For simplicity, work in a world of choice functions/no indifference
- Question: What observation 'reveals preference' in this model?
  - Not $x \in C(A)$ $y \in A/C(A)$: Maybe y not in the consideration set
- How do we know that an alternative y is in the consideration set?
  - Obviously if it is chosen
  - But for revealed preference we need to know if it was considered and **not chosen**
  - Say $x \in C(A)$, $y \in A/C(A)$ and $x \notin C(A/y)$
  - As WARP is violated, E must have changed
  - So y must have been in $E(A)$

Masatlioglou et. al. [2012]

$$x \in C(A), y \in A/C(A) \text{ and } x \notin C(A/y)$$

- Same observation implies that x is revealed preferred to y
  - x was chosen, and we know that y was considered
  - We write xPy
- Of course, if we saw xPy and yPz we would want to conclude that x is preferred to z
  - Let P_R be the transitive closure of P
- Turns out that P_R is the only revealed preference information on can extract from the data in the following sense
  - Say C is consistent with the model, but not $xP_R y$
  - Then there exists a representation of the data in which $u(y) > u(x)$

Masatlioglou et. al. [2012]

- A necessary condition for a choice function to have a CLA representation is that P is acyclic
    - Means that there exists a utility function that represents P
- Turns out that this is also a sufficient condition
    - Construct a utility function that agrees with P
    - Construct the 'minimal' consideration sets that are consistent with the model
- This is a trick that we will see again!

- Turns out that the acyclicality of P is equivalent to a weakening of *WARP*

Definition

WARP: For every A there exists an x^* such that, for any B including x^*, if $C(B) \in A$, then $C(B) = x^*$

Definition

WARP with limited attention: For every A there exists an x^* such that, for any B including x^*

$$\text{if } C(B) \in A \text{ and } C(B) \neq C(B \backslash x^*) \text{ then } C(B) = x^*$$

Masatlioglou et. al. [2012]

Lemma

C satisfies WARP with limited inattention if and only if P is acyclic

Theorem

C satisfies WARP with limited attention if and only if it has a CLA representation

Masatlioglou et. al. [2012]

- So, do we like this paper?
- Yes?
  - It derives a model of consideration sets that has testable implications
  - Does so using 'natural' restrictions on the way in which consideration sets work
- But
  - Testable implications may be very weak
  - Note that if there are no violations of WARP we have no revealed preference information
- Similar techniques can be used for different assumptions about the way consideration sets work
  - e.g. Lleras, J. S., Masatlioglu, Y., Nakajima, D., & Ozbay, E. Y. (2017). When more is less: Limited consideration. Journal of Economic Theory, 170, 70-85.

Stochastic Consideration Sets

- One problem with this approach is that it is deterministic
  - Same consideration set and same choice made each time a decision problem is faced
- This
  - May be intuitively implausible
  - Limits applications
- Recent papers have extended the model to *random* consideration sets
- Typically
  - Preferences are fixed
  - Consideration sets are random
- These can be used as an alternative to random utility models

Manzini and Mariotti [2014]

- Let X be a finite set of alternatives
- Model choice with consideration sets using *stochastic* choice data
  - $p(a, A)$: probability of alternative a chosen from set A
- Assume that every alternative has a fixed, strictly positive probability that it will be included in the consideration set
  - Is this a realistic assumption?
- There is a default alternative which is always considered
- As usual, chosen item is the highest utility alternative in the consideration set.

Manzini and Mariotti [2014]

- We say that p has a random consideration set representation if there exist a strict preference order $\succ$ and a probability γ:$X \rightarrow [0, 1]$ such that

$$p(a, A) = \gamma(a) \prod_{b \in A | b \succ a} (1 - \gamma(b))$$

- Probability that a is chosen from A is the probability that
  - a is considered
  - Nothing better than a is considered
- As the probability of any item being considered is independent, has a nice easy form

Manzini and Mariotti [2014]

- Allows preferences to be identified

$$\frac{p(a, A/b)}{p(a, A)} > 1 \Leftrightarrow b \succ a$$

- Provides testable predictions: I-Asymmetry

$$\frac{p(a, A/b)}{p(a, A)} > 1 \Rightarrow \frac{p(b, B/a)}{p(b, B)} = 1$$

- Also I-independence

$$\frac{p(a, A/b)}{p(a, A)} = \frac{p(a, B/b)}{p(a, B)}$$

- These two are necessary and sufficient for a random consideration set representation

Manzini and Mariotti [2014]

- Do we like this paper?
- Yes?
  - Nice clean axiomatization (certainly relative to RUM)
  - Idea that consideration is random seems intuitively plausible
- No?
  - Assumption that probability of consideration is set independent is weird
  - Relaxed in Brady, Richard L., and John Rehbeck. "Menu-dependent stochastic feasibility." Econometrica 84.3 (2016): 1203-1223.

Catteneo et al [2020]

- More recently "A Random Attention Model" takes an even more flexible approach
- Let X be a finite set and $\mathcal{X}$ be the set of all non-empty subsets of X
- An Attention Rule is a function $\mu : \mathcal{X} \times \mathcal{X} \rightarrow [0, 1]$ where $\mu(B|A)$ is the probability of using consideration set B from decision problem A
  - Apply the relevant conditions to μ for this to make sense
- A random consideration set model consists of a μ and a linear order $\succ$ on X such that

$$p(a, A) = \sum_{B \subseteq A} 1(a \text{ is } \succ\text{-maximal in } B)\mu(B|A)$$

- Without further restrictions, this model is vacuous
- Catteneo et al assume Monotonic Attention
    - Adding options cannot make any given consideration set more likely

$$\text{For any } a \in A - B,\ \mu(B|A) \leq \mu(B|A/a)$$

- This is a stochastic vers
- Note that this can allow for violations of monotonicity in choice
    - MM does not

- Revealed preference?
- If $p(a, A) > p(a, A/b)$ then a is revealed preferred to b
- Why?
    - Let $\mathcal{A} \subset \mathcal{X}$ be the subsets of A/b in which a is maximal
    - We know $\mu(\mathcal{A}|A) \leq \mu(\mathcal{A}|A/b)$
    - So if the probability of choosing a is higher in A than is $A \backslash b$ it must be that a is maximal in some other subsets of A
    - These contain b, so a must be preferred to b
- Revealed preference from violations of monotonicity
    - Similar to choice with limited attention
- Data has a representation of this type if and only if revealed preference relation is acyclic

Abaluck and Adams-Prassi [2021]

- There is also a significant literature on this in consumer choice/IO
- Recent example is Abaluck and Adams-Prassi [2021]
  - Also surveys previous literature
- They work with a different data set:
  - Demand functions
- Consideration sets can lead to violations of **Slutsky Symmetry**
  - Absent income effects the following should be equal
    - The impact of a price change in good j on demand for good i
    - The impact of a price change of good i on demand for good j

- Simple example:
  - Two products, 0 and 1
  - x_j price of good j
  - 0 is default - always observed
  - 1 is alternative - whether it is looked at depends on the price of 0
  - $\mu(x_0)$ probability that good 1 will be looked at given x_0

Abaluck and Adams-Prassi [2021]

- $s_i^*(x_0, x_1)$ probability of buying good i given prices **if both are observed**
  - Derived from maximizing a quasilinear utility function
  - Probabilistic due to some random utility component
- $s_i(x_0, x_1)$ probability that good i is chosen:

$$\begin{aligned} s_0(x_0, x_1) &= (1 - \mu(x_0)) + \mu(x_0) s_0^*(x_0, x_1) \\ s_1(x_0, x_1) &= \mu(x_0) s_1^*(x_0, x_1) \end{aligned}$$

- Claim: with quasi-linear utility and no outside option

$$\frac{\partial s_0^*(x_0, x_1)}{\partial x_1} = \frac{\partial s_1^*(x_0, x_1)}{\partial x_0}$$

Abaluck and Adams-Prassi [2021]

- What if consideration is imperfect?

$$\begin{aligned}\frac{\partial s_0(x_0,x_1)}{\partial x_1} &= \mu(x_0)\frac{\partial s_0^*(x_0,x_1)}{\partial x_1}\\ \frac{\partial s_1(x_0,x_1)}{\partial x_0} &= \frac{\partial \mu(x_0)}{\partial x_0}s_1^*(x_0,x_1)+\mu(x_0)\frac{\partial s_1^*(x_0,x_1)}{\partial x_0}\end{aligned}$$

implying

$$\begin{aligned}\frac{\partial s_1(x_0,x_1)}{\partial x_0}-\frac{\partial s_0(x_0,x_1)}{\partial x_1} &= \frac{\partial \mu(x_0)}{\partial x_0}s_1^* = \frac{\partial \ln \mu(x_0)}{\partial x_0}s_1\\ \frac{\partial \ln \mu(x_0)}{\partial x_0} &= \frac{1}{s_1}\left[\frac{\partial s_1(x_0,x_1)}{\partial x_0}-\frac{\partial s_0(x_0,x_1)}{\partial x_1}\right]\end{aligned}$$

- Attention changes with prices if and only if Slutsky symmetry is violated
- Level of attention can be identified by integrating this expression

Other Examples

- For another recent example on literature in this vein see Barseghyan et al [2021]
- Shows that you can get some identification of the distribution of preferences in a RUM with consideration sets
  - If you observe the distribution of choices from a single set
  - Know that individual choices came from a distribution of consideration sets with some minimum size
  - Then you can still set identify some parameters
- For example say that there are 3 possible alternatives, and that $|E| > 2$
  - Probabiity that the worst alternative is chosen is zero
  - So if an alternative x is chose with positive probability, we can rule out parameters which say it is the worst option
- See also Dardanoni et al. [2020]

Introduction

- So far we have talked about strategies for identifying whether people are using consideration sets
- And some of the properties they might have
- But not where they come from, or why
- i.e. we have not discussed procedures that might lead to the generation of consideration sets

Satisficing as Optimal Stopping

- Satisficing model (Simon 1955) was an early model of consideration set formation
- Very simple model:
  - Decision maker faced with a set of alternatives A
  - Searches through this set one by one
  - If they find alternative that is better than some threshold, stop search and choose that alternative
  - If all objects are searched, choose best alternative
- Proved extremely influential in economics, psychology and ecology

Satisficing as Optimal Stopping

- Usually presented as a compelling description of a 'choice procedure'
- Can also be derived as optimal behavior as a simple sequential search model with search costs
- Primitives
  - A set A containing M items from a set X
  - A utility function u: $X \rightarrow \mathbb{R}$
  - A probability distribution f: decision maker's beliefs about the value of each option
  - A per object search cost k

The Stopping Problem

- At any point DM has two options

1. Stop searching, and choose the best alternative so far seen (search with recall)
2. Search another item and pay the cost k

- Familiar problem from labor economics

- Can solve for the optimal strategy by backwards induction
- Choice when there is 1 more object to search and current best alternative has utility $\bar{u}$

1. Stop searching: $\bar{u} - (M - 1)k$
2. Search the final item:

$$\int_{-\infty}^{\bar{u}} \bar{u} f(u) du + \int_{\bar{u}}^{\infty} u f(u) du - Mk$$

- Stop searching if

$$\bar{u} - (M-1)k \leq \int_{-\infty}^{\bar{u}} \bar{u} f(u) du + \int_{\bar{u}}^{\infty} u f(u) du - Mk$$

- Implying

$$k \leq \int_{\bar{u}}^{\infty} (u - \bar{u}) f(u) du$$

- Value of RHS decreasing in $\bar{u}$
- Implies cutoff strategy: search continues if $\bar{u} > u^*$ solving

$$k = \int_{u^*}^{\infty} (u - u^*) f(u) du$$

Optimal Stopping

- Now consider behavior when there are 2 items remaining
- $\bar{u} < u^*$ Search will continue
  - Search optimal if one object remaining
  - Can always operate continuation strategy of stopping after searching only one more option
- $\bar{u} > u^*$ search will stop
  - Not optimal to search one more item only
  - Search will stop next period, as $\bar{u} > u^*$

Optimal Stopping

- Optimal stopping strategy is satisficing!
- Find u^* that solves

$$k = \int_{u^*}^{\infty} (u - u^*) f(u) du$$

- Continue searching until find an object with $u > u^*$, then stop
- Model of underlying constrains allow us to make predictions about how reservation level changes with environment
  - u^* decreasing in k
  - increasing in variance of f (for well behaved distributions)
  - Unaffected by the size of the choice set
- Comes from optimization, not reduced form satisficing model

Optimal Stopping - Extensions and Notes

- Satisficing as Framing
  - Imagine you are provided with some ranking of alternatives
  - You believe that this ranking is correlated (arbitrarily weakly) with your preferences
  - This is the only thing you know ex ante about each alternative. (e.g. Google searches)
  - What should your search order be?
  - Should search in the same order as the ranking
  - If list is long and correlation is low
    - Ex ante difference in quality between the first and last alternative is very low
    - But you will never pick the last alternative!
- See for example Feenberg, Daniel, et al. "It's good to be first: Order bias in reading and citing NBER working papers." Review of Economics and Statistics 99.1 (2017): 32-39.

Optimal Stopping - Extensions and Notes

- Satisficing is a knife edge case
  - If one changes the problem
    - Learning
    - Varying information costs
  - Then reservation level will change over time
  - Testable prediction about the ‘satisficing’ model

Optimal Stopping - Extensions and Notes

- Solubility
    - The fact that we can solve this search problem depends on its simple structure
    - Things can get hairy very quickly
        - Explore/exploit
        - Multiple attributes
    - There are some mathematical tools that can help
        - Gittens indicies
    - But often have to rely on approximate solutions
        - e.g. Gabaix et al [2006]

Optimal Stopping - Extensions and Notes

- A broader class of models
  - Clearly models of sequential search with a threshold are more general than either
    - Satisficing (fixed threshold)
    - Optimizing models
  - More generally, one could think of the threshold as an 'aspiration' and consider how it adapts based on
    - Environmental factors
    - The history of search
  - See Selten, Reinhard. "Aspiration adaptation theory." Journal of mathematical psychology 42.2-3 (1998): 191-214.

Testing Satisficing: The Problem

- Satisficing models difficult to test using choice data alone
- If search order is fixed, behavior is indistinguishable from preference maximization
  - Define the binary relation $\trianglerighteq$ as $x \trianglerighteq y$ if
    - x, y above satisficing level and x is searched before y
    - x is above the satisficing level and y below it
    - x, y both satisficing level and $u(x) \geq u(y)$
  - Easy to show that $\trianglerighteq$ is a complete preorder, and consumer chooses as if to maximize $\trianglerighteq$
- If search order changes between choice sets, then any behavior can be rationalized
  - Assume that all alternatives are above satisficing level
  - Chosen alternative is then assumed to be the first alternative searched.

Choice Process Data

- Need to either
  - Add more assumptions
  - Enrich the data
- Examples
  - Search order observed from internet data [De los Santos, Hortacsu, and Wildenbeast 2012]
  - Stochastic choice data [Aguiar, Boccardi and Dean 2016]

Choice Process Data

- We will start by considering one possible data enrichment: ‘choice process’ data
- Records how choice changes with contemplation time
  - $C(A)$: Standard choice data - choice from set A
  - $C_A(t)$: Choice process data - choice made from set A after contemplation time t
- Easy to collect such data in the lab
  - Possible outside the lab using the internet?
- Has been used to
  - Test satisficing model [Caplin, Dean, Martin 2012]
  - Understand play in beauty contest game [Agranov, Caplin and Tergiman 2015]
  - Understand fast and slow processes in generosity [Kessler, Kivimaki and Niederle 2016]
  - In combination with mouselab [Geng 2015]

Notation

- How can we use choice process data to test the satisficing model?
- First, introduce some notation:
  - X : Finite grand choice set
  - $\mathcal{X}$: Non-empty subsets of X
  - $Z \in \{Z_t\}_t^\infty$: Sequences of elements of $\mathcal{X}$
  - $\mathcal{Z}$ set of sequences Z
  - $\mathcal{Z}_A \subset \mathcal{Z}$: set of sequences s.t. $Z_t \subset A \in \mathcal{X}$

Definition

A Choice Process Data Set (X, C) comprises of:

- finite set X
- choice function $C : \mathcal{X} \rightarrow \mathcal{Z}$

such that $C(A) \in \mathcal{Z}_A \; \forall \; A \in \mathcal{X}$

- $C_A(t)$: choice made from set A after contemplation time t

Characterizing the Satisficing Model

- Two main assumptions of the satisficing model of consideration set formation

1. Search is **alternative-based**
    - DM searches through items in choice set sequentially
    - Completely understands each item before moving on to the next
2. Stopping is due to a **fixed reservation rule**
    - Subjects have a fixed reservation utility level
    - Stop searching if and only if find an item with utility above that level

- First think about testing (1), then add (2)

Alternative-Based Search (ABS)

- DM has a fixed utility function
- Searches sequentially through the available options,
- Always chooses the best alternative of those searched
- May not search the entire choice set

Alternative-Based Search

- DM is equipped with a utility function

$$u : X \rightarrow \mathbb{R}$$

- and a search correspondence

$$S : \mathcal{X} \rightarrow \mathcal{Z}$$

  with $S_A(t) \subseteq S_A(t+s)$

- Such that the DM always chooses best option of those searched

$$C_A(t) = \arg \max_{x \in S_A(t)} u(x)$$

Revealed Preference and ABS

- As we have seen with previous models, key to testing is identifying what revealed preference means in this setting
- What type of behavior reveals preference in the ABS model?
- Finally choosing x over y does *not* imply (strict) revealed preference
  - DM may not know that y was available
- Replacing y with x *does* imply (strict) revealed preference
  - DM must know that y is available, as previously chose it
  - Now chooses x, so must prefer x over y
- Choosing x and y at the same time reveals indifference
- Use $\succ^{ABS}$ to indicate ABS strict revealed preference
- Use $\sim^{ABS}$to indicate revealed indifference

- Choice process data will have an ABS representation if and only if $\succ^{ABS}$ and $\sim^{ABS}$ can be represented by a utility function u

$$
\begin{aligned}
x &\succ^{ABS} y \Rightarrow u(x) > u(y) \\
x &\sim^{ABS} y \Rightarrow u(x) = u(y)
\end{aligned}
$$

- Necessary and sufficient conditions for utility representation GARP
  - Let $\succeq^{ABS} = \succ^{ABS} \cup \sim^{ABS}$
  - $xT(\succeq^{ABS})y$ implies not $y \succ^{ABS} x$

Theorem

Choice process data admits an ABS representation if and only if $\succ^{ABS}$ *and* $\sim^{ABS}$ *satisfy GARP*

Proof.

(Sketch of Sufficiency)

1. *Generate* U *that represents* $\succeq^{ABS}$
2. *Set* $S_A(t) = \cup_{s=1}^{t} C_A(s)$

□

Satisficing

- Choice process data admits an **satisficing representation** if we can find
  - An ABS representation (u, S)
  - A reservation level ρ
- Such that search stops if and only if an above reservation object is found
  - If the highest utility object in $S_A(t)$ is above ρ, search stops
  - If it is below ρ, then search continues
- Implies complete search of sets comprising only of below-reservation objects

Revealed Preference and Satisficing

- Final choice can now contain revealed preference information
  - If final choice is **below-reservation** utility
- How do we know if an object is below reservation?
- If they are **non-terminal**: Search continues after that object has been chosen

Directly and Indirectly Non-Terminal Sets

- Directly Non-Terminal: $x \in X^N$ if
  - $x \in C_A(t)$
  - $C_A(t) \neq C_A(t+s)$
- Indirectly Non Terminal: $x \in X^I$ if
  - for some $y \in X^N$
  - $x, y \in A$ and $y \in \lim_{t \to \infty} C_A(t)$
- Let $X^{IN} = X^I \cup X^N$

Add New Revealed Preference Information

- If
  - one of x,$y \in A$ is in X^{IN}
  - x is finally chosen from some set A when y is not,
- then, $x \succ^S y$
  - If x is is in X^{IN}, then A must have been fully searched, and so x must be preferred to y
  - If y is in X^{IN}, then either x is below reservation level, in which case the set is fully searched, or x is above reservation utility
- Let $\succ = \succ^S \cup \succ^{ABS}$

Theorem 2

Theorem

Choice process data admits an satisficing representation if and only if $\succ$ *and* $\sim^{ABS}$ *satisfy GARP*

Experiments and Bounded Rationality

- The experimental lab is often a good place to test models of bounded rationality
- Pros
  - Easy to identify choice mistakes
  - Can collect precisely the type of data you need
  - Can control the parameters of the problem
- Cons
  - Lack of external validity?
- A good approach (and good dissertation!) is to combine
  - Theory
  - Lab experiments
  - Field experiments/non experimental data

Experimental Design

- Experimental design has two aims
  - Identify choice 'mistakes'
  - Test satisficing model as an explanation for these mistakes
- Two design challenges
  - Find a set of choice objects for which 'choice quality' is obvious but subjects do not always choose best option
  - Find a way of eliciting 'choice process data'
- We first test for 'mistakes' in a standard choice task...
- ... then add choice process data in same environment
- Make life easier for ourselves by making preferences directly observable

Choice Objects

- Subjects choose between 'sums'

  four plus eight minus four

- Value of option is the value of the sum
- 'Full information' ranking obvious, but uncovering value takes effort
- 6 treatments
  - 2 x complexity (3 and 7 operations)
  - 3 x choice set size (10, 20 and 40 options)
- No time limit

Size 20, Complexity 7

- ( ) zero
- ( ) seven minus four minus two minus four minus two plus eleven minus four
- ( ) six plus five minus eight plus two minus nine plus one plus four
- ( ) seven minus two minus four plus three plus four minus three minus three
- ( ) seven plus five minus two minus two minus three plus zero minus two
- ( ) six plus seven plus six minus two minus six minus eight plus four
- ( ) six plus two plus five minus four minus two minus seven plus three
- ( ) six minus four minus one minus one plus five plus three minus six
- (•) two plus six plus seven minus two minus four minus two plus zero
- ( ) two minus three minus five plus nine minus one plus five minus three
- ( ) three plus zero plus two plus zero plus one minus three minus one
- ( ) four plus three plus zero minus two plus three plus four minus ten
- ( ) seven plus two plus seven minus seven plus three minus two minus two
- ( ) three plus three minus two plus zero plus zero minus four plus five
- ( ) two minus two plus zero plus nine minus two minus one minus one
- ( ) three plus four minus three plus three minus four plus three minus four
- ( ) three plus five plus seven plus five minus two minus seven minus ten
- ( ) three plus six minus eight plus one plus two minus two plus zero
- ( ) three plus five plus zero plus four plus three minus four minus two
- ( ) eight minus one plus one minus four minus four minus five plus six
- ( ) four minus five plus four minus one minus four plus zero plus four

Finished

Results

Failure rates (%) (22 subjects, 657 choices)

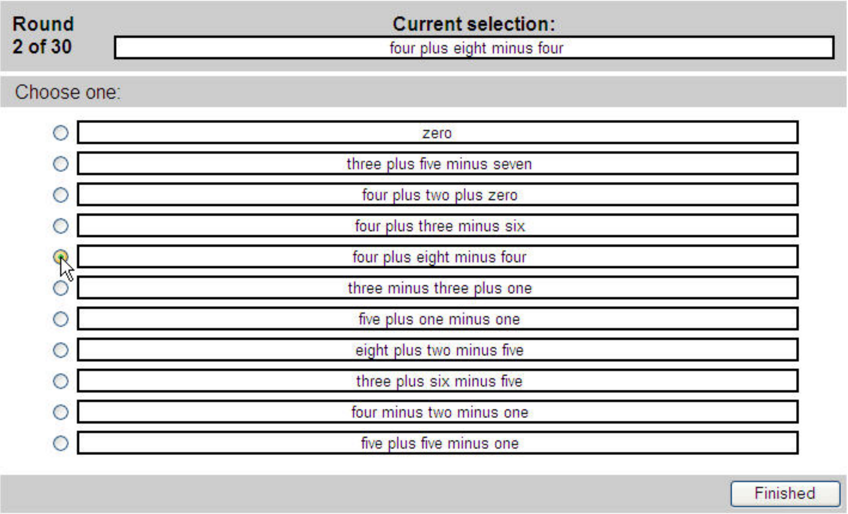
Failure rate		
	Complexity	
Set size	3	7
10	7%	24%
20	22%	56%
40	29%	65%

Average Loss ($)		
	Complexity	
Set size	3	7
10	0.41	1.69
20	1.10	4.00
40	2.30	7.12

Eliciting Choice Process Data

1. Allow subjects to select any alternative at any time
   - Can change selection as often as they like
2. Choice will be recorded at a random time between 0 and 120 seconds unknown to subject
   - Incentivizes subjects to always keep selected current best alternative
   - Treat the sequence of selections as choice process data
3. Round can end in two ways
   - After 120 seconds has elapsed
   - When subject presses the ‘finish’ button
   - We discard any rounds in which subjects do not press ‘finish’

Stage 1: Selection



Stage 2: Choice Recorded

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Choice Recorded

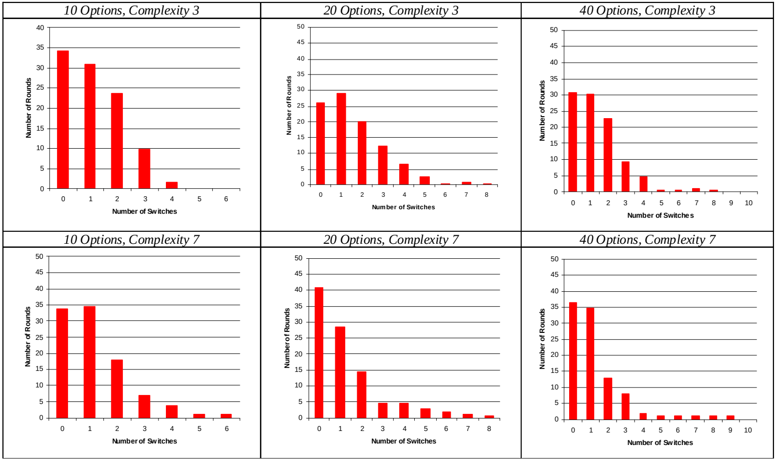
In this round, your choice was recorded after **9** seconds. At that time, you had selected:

four plus four minus six

Next

Do We Get Richer Data from Choice Process Methodology?

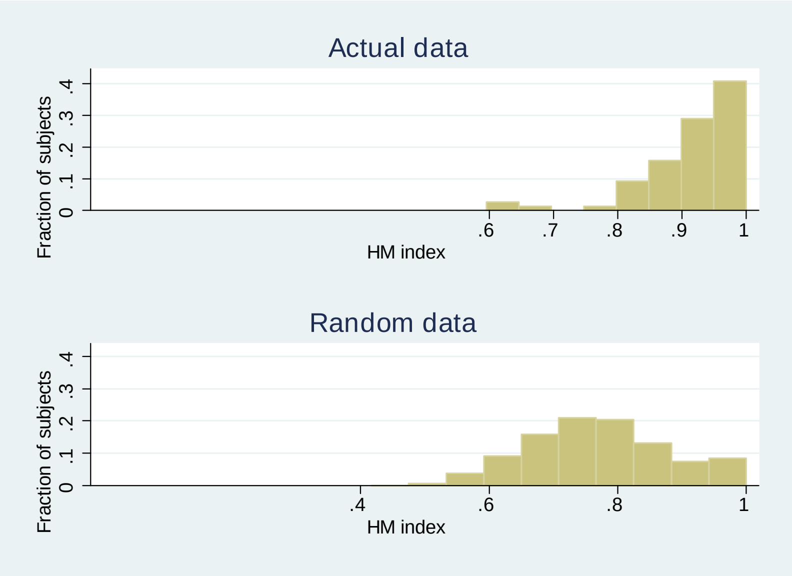
978 Rounds, 76 Subjects



Testing ABS

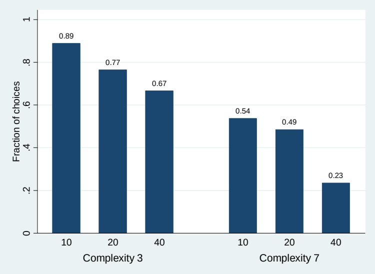
- Choice process data has ABS representation if $\succ^{ABS}$ is *consistent*
- Assume that more money is preferred to less
- Implies subjects must always switch to higher-valued objects **(Condition 1)**
- Calculate Houtman-Maks index for Condition 1
  - Largest subset of choice data that is consistent with condition

Houtman-Maks Measure for ABS

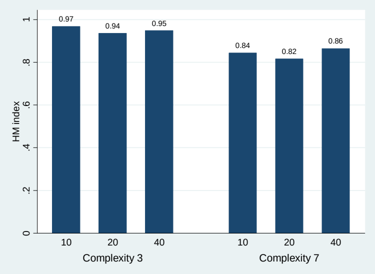


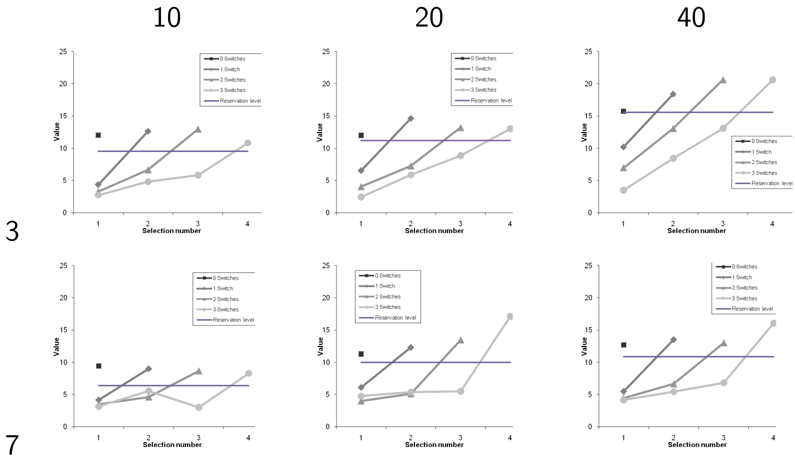
Traditional vs ABS Revealed Preference

Traditional



ABS




10
20
40
3
7
Value
Selection number
0 Switches
1 Switch
2 Switches
3 Switches
Reservation level
0
5
10
15
20
25
1
2
3
4

Estimating Reservation Levels

- Choice process data allows observation of subjects
  - Stopping search
  - Continuing to search
- Allows us to estimate reservation levels
- Assume that reservation level is calculated with some noise at each switch
- Can estimate reservation levels for each treatment using maximum likelihood

Estimated Reservation Levels

Set size	**Complexity** 3		7	
10	9.54	(0.20)	6.36	(0.13)
20	11.18	(0.12)	9.95	(0.10)
40	15.54	(0.11)	10.84	(0.10)

Estimating Reservation Levels

- Increase with ‘Cost of Search’
  - In line with model predictions
- Increase with size of choice set
  - In violation of model predictions
- See Brown, Flinn and Schotter [2011] for further insights

But....

- De los Santos et al. [2012] come to a different conclusion using their data
- If search is visible, Satisficing makes one strong prediction
- Should choose last object searched (unless search is complete)
- But this is not what they find
- Data more consistent with a model in which the consideration set is decided upon ahead of time
- For a more complete review see reading
    - Honka, Elisabeth, Ali Hortaçsu, and Matthijs Wildenbeest. "Empirical search and consideration sets." Handbook of the Economics of Marketing. Vol. 1. North-Holland, 2019. 193-257.

Summary

- There is good evidence that people do not look at all the available alternatives when making a choice
  - Lab experiments
  - Internet search
  - Verbal reports
  - Direct observation of search
- Pure consideration set models cannot be tested on choice data alone
- Need either more data or more assumptions
- A variety of both approaches have been applied in the literature
  - Choice process
  - Internet search
  - Stochastic choice
- As yet, no real consensus on what is the correct model of consideration set formation
  - Though we do have some hints.