Are consumers really strategic?

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Joint work with Elliot Bendoly (Ohio State)
Motivation

• 35% of inventory is being sold at discount (Ghemawat and Nueno 2006)
• Consumers are hunting for bargains
• Purchase timing recommender systems
• Innovative pricing schemes: clearance seasons, progressive markdowns, reservations, auctions
Motivation (cont’d) and Research questions

RM literature with strategic consumer behavior
i. Contingent vs. pre-announced pricing
ii. Myopic vs. strategic behavior
iii. Role of information in evaluating intertemporal and risky options
iv. Imbalance between theoretical work and empirical evidence

Choosing between buy-now vs. buy-later people have to evaluate riskiness of the latter option:

1. Are consumers strategic (forward looking)?
   - How do they evaluate risk (overly optimistic, pessimistic)?
   - How heterogeneous are they?
   - Do they incorporate available information fully?

2. What is an equilibrium, empirically?
   - Bayesian Nash
   - Heuristics
Literature review

- Economics/Behavioral studies
  - Context really matters!

- Revenue management
  - Empirics and Experiments: Li et al. (2014), Mak et al. (2014), Mantin et al (2014)

- Role of information (salience, cognitive limits, bounded rationality)
  - Steckel et al. (2004), Klingberg (2009), Su (2008), Kremer, Moritz, Siemsen (2011)
Choose “Buy Later” to purchase items automatically when they drop to that price, providing they do not sell out first.

Example provided by Elmaghraby et al. (2009)
Normative model

- $v$ – valuation
- $p_h$ – buy now price
- $p_l$ – buy later price
- $\pi$ – probability of getting an item (successful reservation). Computed in equilibrium.
- $W$ – risk attitude (notice no time discounting)

Buy now if: $$(v - p_h) \geq (v - p_l) \pi_{subj},$$ (1)

$$\pi_{subj} = \pi^w$$

Challenge: $W$ is unobservable
- Two step estimation/classification procedure
Design of experiment

• Treatments: $p_h, p_l, v, t, \pi$ shown
  – 270 possible combinations, randomized counterbalancing
  – Can identify the strategic wait if the rational response is to reserve:
    • Risk neutral response: 70/30 towards Reserve

• Treatment: $\pi$ is shown in 50% cases

• Subjects play against ‘environment’ consumers.
  – Forward looking, play equilibrium strategy
    • Equilibrium is proven to exist (O and Vulcano, 2010)
You've just arrived at a retailer's site. You've found an item that you'd like to purchase. However, this is an item that the retailer will not be ordering more of in the future. To help make room for new offerings, the retailer has set up a Special Sale period of 10 days to liquidate its stock on this item.

You happened to have arrived on Day 3 of this 10 day window.

You estimate that the item's value to you in dollars is $6.18

At this point, the item you are interested in can be bought one of two ways:

**Buy Now** at a price $6.00  
(Agree to pay this price now, and you are guaranteed to receive it. Payment and delivery will take place at the end of the Special Sales period)

**Reserve Now** at a price $5.40  
(If there are any left at the end of the Special Sales period, you'll pay this price and it will be sent to you at that point)

Note that there is no guarantee that any of these items will be available for purchase at this price, but Reserving Now will put you in line for this opportunity. Remaining items will be sold at this price at the end of the period to those at the front of this line.

**Given this uncertainty, you have a 82.9% chance of successfully getting this item this way**

Please indicate your choice of the two above options by clicking on the green button for the option you prefer.
Experiment: demographics and payoff

- 155 participants
  - 53% undergraduate seniors
  - 47% MBAs
  - 54% female
- Each subject was presented with 30 randomly selected scenarios
- Actual responses split 50/50
- Individual effort, no communication, no time limit
- Payoff based on the cumulative performance
  - Randomized payoff scheme for “Reserve” decisions
  - Guaranteed minimum $5, average $17, maximum ≈$35
Identification of strategic behavior

1. Forward-looking
   a) Correctly estimate risk
   b) Overly pessimistic ($\ln w > 1$)
   c) Overly optimistic ($\ln w < -1$)

2. Counter rational
3. Statistically random
4. Unclassified

Classification is performed by binomial tests

Challenge: Need to estimate unobservable risk attitude
Estimating risk attitude from observed choice


2. NPMLE
   - Each decision provides a bound on \( w \)
   - E.g., a reserve decision corresponds to:
     \[
     w(i) \leq \frac{\ln(v(i) - p_{h(i)}) - \ln(v(i) - p_{l(i)})}{\ln(\pi(i))} = U(i)
     \]

   - Algorithm (Huang and Wellner, 1997):
     1. Define \( \delta(i) = 1(w \leq U(i)) \)
     2. Sort \( U(i) \) in non decreasing order and re-label \( \delta(i) \) accordingly.
     3. Form the function \( (i, \sum_{j=1}^{i} \delta(j)), i = 1..n \)
     4. Build a maximum convex minorant \( G^* \) of the function in step 2.
     5. The NPMLE estimate is a left derivative of \( G^* \) at \( i = 1..n \)
Heterogeneity in risk attitudes

1. Information availability affects heterogeneity of risk attitudes

2. Absence of risk information encourages bargain-seeking behavior (delayed purchases)
Are consumers strategic?

<table>
<thead>
<tr>
<th>Category</th>
<th>Pooled</th>
<th>Limited Information</th>
<th>Full Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Forward-looking</td>
<td>115</td>
<td>62</td>
<td>115</td>
</tr>
<tr>
<td>(1a) Correctly estimate risk</td>
<td>38 (33%)</td>
<td>12 (19%)</td>
<td>42 (37%)</td>
</tr>
<tr>
<td>(1b) Pessimistic</td>
<td>66 (57%)</td>
<td>37 (60%)</td>
<td>72 (63%)</td>
</tr>
<tr>
<td>(1c) Optimistic</td>
<td>11 (10%)</td>
<td>13 (21%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>(4) Opposite of (1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(5) Random</td>
<td>3</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>(6) Unclassified</td>
<td>37</td>
<td>86</td>
<td>37</td>
</tr>
<tr>
<td>% forward-looking</td>
<td>74%</td>
<td>40%</td>
<td>74%</td>
</tr>
<tr>
<td>% forward-looking among classified</td>
<td>97%</td>
<td>90%</td>
<td>97%</td>
</tr>
</tbody>
</table>

1. 74% are forward-looking
2. Among classified subjects 97% are forward-looking
3. Distribution of tendencies in the ‘Unclassified’ category mimics the classified population

Consumers are strategic but heterogeneous in their risk attitudes
### Informational impact

<table>
<thead>
<tr>
<th></th>
<th>(1) Forward-looking</th>
<th>(2) Opposite of (1)</th>
<th>(3) Random</th>
<th>(4) Unclassified</th>
<th>Total</th>
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<tr>
<td>Limited information setting</td>
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<td>(1) Forward-looking</td>
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<td>5</td>
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<td>(2) Opposite of (1)</td>
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<td>0</td>
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<tr>
<td>(3) Random</td>
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<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>(4) Unclassified</td>
<td>14</td>
<td>0</td>
<td>2</td>
<td>21</td>
<td>37</td>
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<tr>
<td>Total</td>
<td>62</td>
<td>0</td>
<td>7</td>
<td>86</td>
<td>155</td>
</tr>
</tbody>
</table>

1. Notice transitions out of ‘Unclassified’
2. 76% of forward looking consumers retain the classification even when \( \pi \) is shown.
3. Random behavior is more prevalent if \( \pi \) is not given
Experiment: Summary

• Fraction of forward looking consumers increases from 40% to 74% when \( \pi \) is given
  – 76% remain forward looking when \( \pi \) is given

• Random behavior decreases when \( \pi \) is given

• Subclasses of forward looking
  – Correctly estimate risk: almost doubles (19% to 37%)
  – Pessimistic: remains approximately the same (60% to 63%)
  – Optimistic (bargain seeking): decreases dramatically (21% to 1%)

• Providing information facilitates risk-neutral forward looking behavior
• Limiting information facilitates risk-taking and random behavior
Individual decisions and parameters of experiment

\[ Y_{ij} = \text{Probit}(\beta_1 \ln(v_{(i)} - p_{h(i)}) - \beta_2 \ln(v_{(i)} - p_{l(i)}) - \beta_3 \ln(\pi_{(i)}) + u_{(j)} + \varepsilon_{(ij)}) \]

\[ Y_{ij} = 1, \text{ if 'BuyNow'} \]

- Probit model:
  - random effects (individual discount factors)
  - interaction terms (\(\pi\) shown or not)
  - Differential time effects
  - Price scale effects
  - Asymptotic and bootstrapped S.E.
<table>
<thead>
<tr>
<th></th>
<th>Base Model</th>
<th></th>
<th>Differential Time effect model</th>
<th></th>
<th>Differential time and scale effect model</th>
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<tbody>
<tr>
<td></td>
<td>b</td>
<td>Boot-strap S.E.</td>
<td>Marg. Effect</td>
<td>Inter. Effect</td>
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</tr>
<tr>
<td>ln(v-p_h)</td>
<td>0.098**</td>
<td>0.025</td>
<td>0.039</td>
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<tr>
<td>ln(v-p_h) x</td>
<td>0.130**</td>
<td>0.027</td>
<td>0.052</td>
<td>0.051**</td>
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<tr>
<td>π_shown</td>
<td>-0.230**</td>
<td>0.031</td>
<td>-0.091</td>
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<tr>
<td>ln(v-p_i)</td>
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<td>0.030</td>
<td>-0.075</td>
<td>-0.079**</td>
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<tr>
<td>ln(π)</td>
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<td>0.024</td>
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<tr>
<td>π_shown</td>
<td>-0.470**</td>
<td>0.050</td>
<td>-0.187</td>
<td>-0.171**</td>
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<td>T</td>
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<td>Scalefactor1 x</td>
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<td>Scalefactor2 x</td>
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<td>π_shown</td>
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<td>0.579**</td>
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<td>0.07</td>
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<td>Ln L</td>
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<tr>
<td>Prob &gt; c²</td>
<td>0.000</td>
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<tr>
<td>ρ</td>
<td>0.232</td>
<td></td>
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<tr>
<td>Prob(ρ=0)</td>
<td>0.000</td>
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<tr>
<td>% Correctly Classified</td>
<td>65.3</td>
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</tbody>
</table>

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Alternative heuristics for strategic consumers

• Explain observed decisions
• If $\pi$ is given it is clearly important
  – Including $\pi$ increases the % of correctly classified (predicted) decisions from 72% to 85%

• If $\pi$ is not given, can strategic behavior be explained by a simple heuristic?
  – Yes
  – Including the arrival time increases % of correctly classified from 74% to 86%
  – Including $\pi$ increases % of correctly classified only to 81%
Conclusions

• Consumers are **strategic but heterogeneous**
  – Important to control for individual risk aversion
    • Approach similar to ours can be applied in the purchase context in general
  – Implications for RM models
    • Strategic/myopic mixed case is not enough
    • Incorporate the heterogeneity explicitly?

• Information enables strategic behavior

• Subjects respond to the information differently:
  – Those pessimistic about the risk are less sensitive to \( \pi \)

• Providing availability information (\( \pi \)) facilitates strategic behavior and limits bargain-seeking behavior
  – Positive revenue lift

• If \( \pi \) is not available, simple heuristics explain the behavior even better than the complete model