Nonlinear Pricing Complexity and Consumer Behavior

(Exploratory) evidence from a uniquely frustrating experiment

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October 29, 2018

Motivation: firm perspective

- Nonlinear pricing mechanisms can increase profits over linear prices. Caveat...
  - Long menus of costs $2^k - 1$ for k goods
  - Assumes perfect knowledge of demand space
  - Assumes consumers do not make mistakes
- Real world examples
  - Cable TV providers (Crawford 2008)
  - Digital media (Shiller & Waldfogel 2011)
  - Tickets to Broadway plays (Leslie 2004)

Motivation: behavioral perspective

- Nonlinear mechanisms can benefit consumers by offering "tailored" choices. Caveat...
  - People make mistakes
  - Assumes no search costs
  - Assumes no stress or cognitive costs
- Real world examples
  - Value perception & bundling (Brough & Chernev 2012)
  - Gym memberships (DellaVigna & Malmendier 2006)
  - Bandwidth & deliberation Costs (Schilbach et al. 2016; Spears 2014))

The known unknown

- Fundamental tension in nonlinear pricing:
  - More options may $\uparrow$ consumer surplus but also $\uparrow$ cognitive costs, $\uparrow$ probability of mistakes, $\uparrow$ firm uncertainty regarding demand
- No closed-form solutions

The known unknown

- Fundamental tension in nonlinear pricing:
  - More options may $\uparrow$ consumer surplus but also $\uparrow$ cognitive costs, $\uparrow$ probability of mistakes, $\uparrow$ firm uncertainty regarding demand
- No closed-form solutions
- How do real people respond to complex nonlinear prices?
  - Reduce performance
  - Increase drop-out
  - Increase response time
  - Welfare
- How do consumer errors affect optimal firm behavior?

Research questions

1. How does price complexity affect consumer choice & welfare?
2. How do price shocks / search difficulty interact with complexity in this context?
3. Do these effects result in changes to optimal firm behavior?

What we do

- Simulate optimal prices (following Chu et al. 2011; Eckalbar 2010)
- Run a lab experiment to measure choice behavior & potential errors
  - how much do participants deviate from optimal?
  - do participants do worse with complex prices?
  - does complexity cause participants to drop out of the market?
- Coming: update price simulation with participant behavior
  - how does participant behavior affect profits?

What we do & what we find

- Simulate optimal prices (following Chu et al. 2011; Eckalbar 2010)
- Run a lab experiment to measure choice behavior & potential errors
  - how much do participants deviate from optimal? Quite a bit!
  - do participants do worse with complex prices? Yep.
  - does complexity cause participants to drop out of the market? Looks like it.
- Coming: update price simulation with participant behavior
  - how does participant behavior affect profits? Don't know yet!

Generalized setup

- Monopolist firm selling N goods
- Consumer valuations: $V_i = [V_{i1}, ..., V_{iN}]$
  - Each valuation drawn from uniform distribution
  - Unit demand for each good
- Consumers maximize surplus: $V_i' D_j - p_j$
  - D_j $K \times 1$ binary vector indicating goods in bundle j
  - p_j price of bundle j

Pricing strategies

- Component Pricing (CP)
  - Set price for each good
  - No bundle discount offered
  - k prices
- Pure Bundling (PB)
  - Set price for bundle
  - No separate sale
  - 1 price
- Mixed Bundling (MB)
  - Set price for each good
  - Set price for each combination
  - $2^k - 1$ prices
- Bundle Sized Pricing (BSP)
  - Set price for a single good
  - Set price for each bundle size
  - k prices

Experimental design

- Random reservation values for 6 goods
    - Constant for each participant throughout experiment
- 6 periods of 6 rounds each
- In each round, randomly draw:
    - Pricing scheme (CP, PB, MB, BSP)
    - Number of goods (2-5)
    - Type of goods (color)
- Prices simulated-optimal
- Interface shows cost and surplus of current selection(s)

Valuations:	
Blue	79
Green	13
Purple	48
Orange	61
Purchase Cost:	**0**

Show Surplus

Purchase Surplus:

Next

You need to select an option before continuing

Color(s)	Price	Selected
Bundle: Blue, Green, Purple, Orange	$137	
Purchase nothing		

Your progress in the experiment:

Game Rules

Valuations:	
Red	77
Blue	27
Purple	45
Orange	11
Maroon	80
Purchase Cost:	**0**

Show Surplus

Purchase Surplus:

Next

You need to select an option before continuing

Bundle: Blue, Purple, Maroon	$186	☐
Bundle: Blue, Orange, Maroon	$161	☐
Bundle: Purple, Orange, Maroon	$151	☐
Bundle: Red, Blue, Purple, Orange	$200	☐
Bundle: Red, Blue, Purple, Maroon	$204	☐
Bundle: Red, Blue, Orange, Maroon	$193	☐
Bundle: Red, Purple, Orange, Maroon	$185	☐
Bundle: Blue, Purple, Orange, Maroon	$196	☐
Bundle: Red, Blue, Purple, Orange, Maroon	$207	☐

Treatments

Price Shock:

- After randomly-selected rounds, extra ‘bonus” round
- **Treatment group:** fix scheme, prices ↑ 40%
- **Control group:** fix scheme, redraw basket

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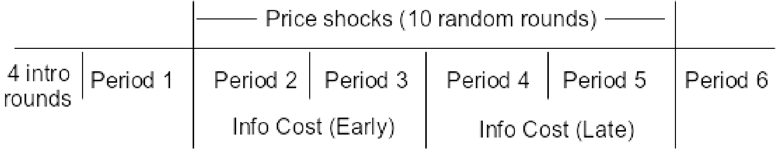
Information Costs:

- Two treatment groups: **early** and **late**
- Small cost to reveal surplus of current selection


Price shocks (10 random rounds)
4 intro rounds
Period 1
Period 2
Period 3
Period 4
Period 5
Period 6
Info Cost (Early)
Info Cost (Late)

Pre-analysis plan

- Several clear primary hypotheses, which we pre-register

Pre-analysis plan

- Several clear primary hypotheses, which we pre-register
- Many low-weight secondary hypotheses
- It can cost more in power to pre-register a hypothesis if either of these are sufficiently small (Anderson & Magruder 2017):
  - the importance of the hypothesis, u_h
  - the prior probability you assign to H_0 being false, p_h

Split sample intuition (A&M, 2017)

- Imagine a main hypothesis, with power 0.8 (in full data set)
- Consider a 2nd hypothesis, same power but p_h is only 0.1
- If we correct for multiple hypothesis testing, then power on both is now 0.71
- So we sacrifice 9% power on main hyp, and gained only 7% power on second

"Hybrid" pre-analysis plan

- Follow "hybrid" split-sample strategy
  - pre-register main hypotheses, test them in full sample
  - use 35% exploratory sample (N=246) to try out secondary
  - update pre-registration with those secondary hypotheses that pass slightly more lenient bar

Outcomes

Primary: Performance

$$Y_{it} = \begin{cases} \frac{\text{surplus achieved}}{\text{max surplus available}} & \text{max surplus} > 0 \\ 1 & \text{max surplus} = \text{surplus achieved} \\ 0 & \text{otherwise} \end{cases}$$

Secondary:

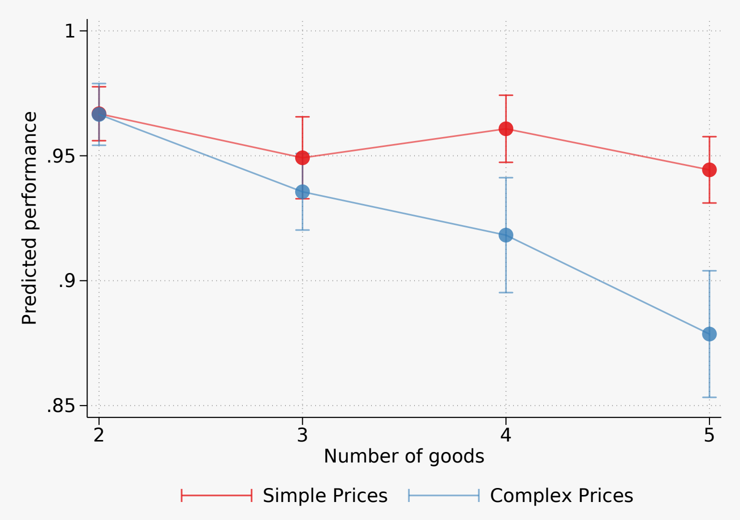
1. *Drop-out:* Purchasing nothing when positive surplus available
2. *Response time:* Number of seconds spent on decision
3. *Emotional response*

Regression specification

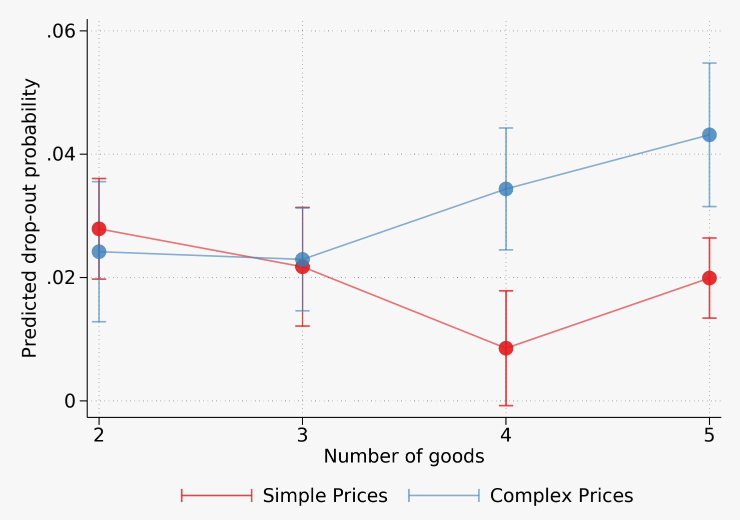
$$Y_{it} = \alpha + \beta_1 B_{it} + \beta_2 N_{it} + \beta_3 (B_{it} \times N_{it}) + \beta_4 G_{it} + \gamma_i + \lambda_t + \epsilon_{it}$$

- B_{it}: complex price dummy
- N_{it}: number of goods
- G_{it}: other round-level game characteristics
- γ_i: participant fixed effects
- λ: round FE

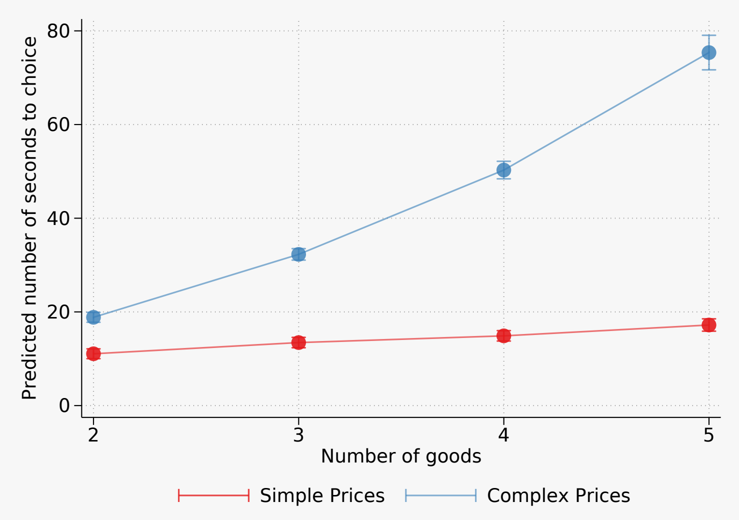
Performance & complexity



Drop-out probability



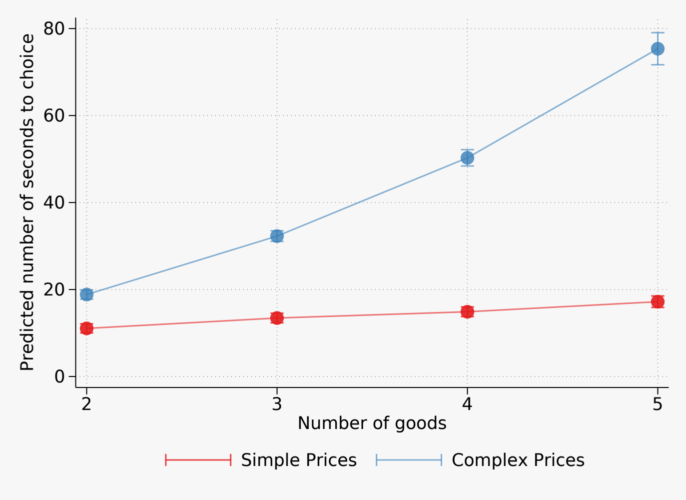
Response time



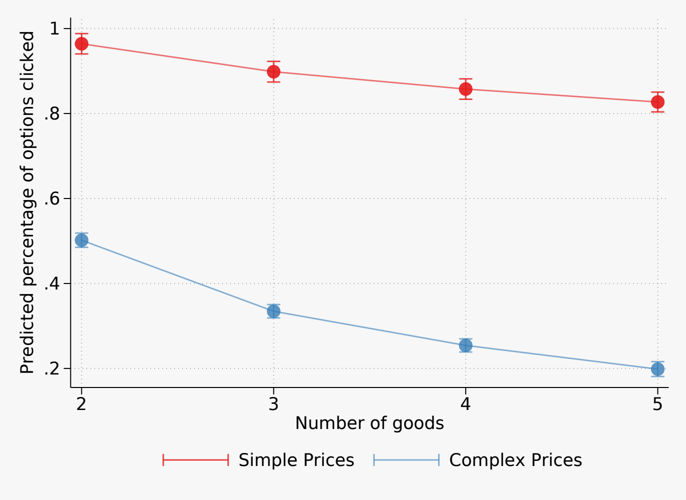
Player behavior and performance

- First: establish that complexity affected behavior
- Then: show that behavior drives performance, instrumenting with:
  1. Pricing scheme
  2. Number of goods
  3. Information cost treatment

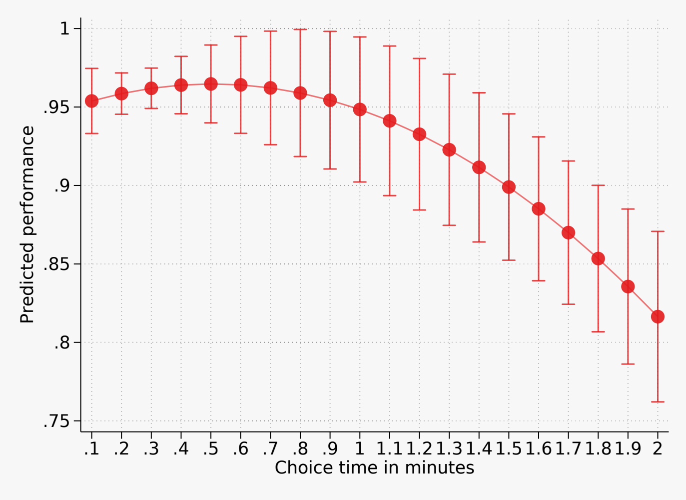
Complexity and response time



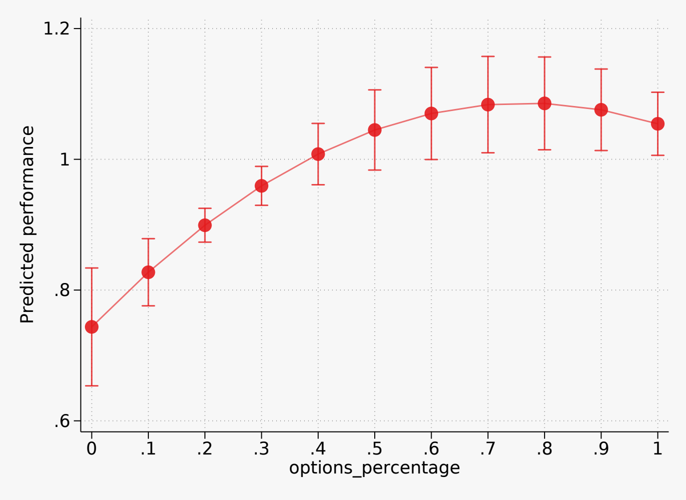
Complexity and search



Response time and performance



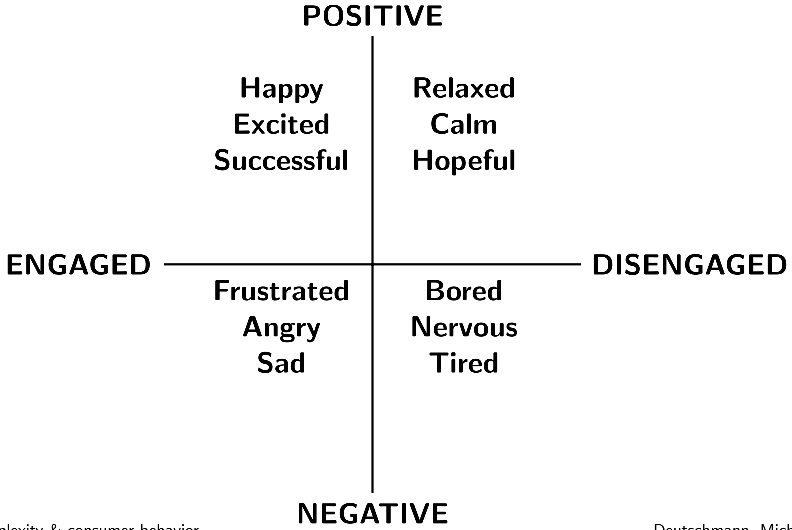
Search and performance

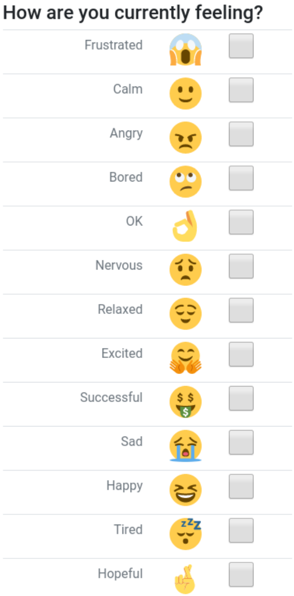


Measuring emotional responses

- We expect treatments to affect emotion
- We measure stress, cognitive load, and emotion using emojis
  - Random order
  - 13 total options, categorized along two axes:
  - **Positive/negative**
  - **Engaged/disengaged**

Emoji diagram

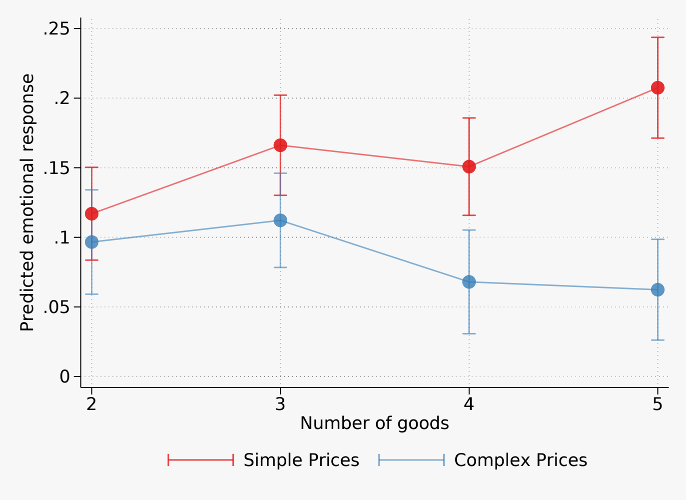




How are you currently feeling?

- Frustrated
- Calm
- Angry
- Bored
- OK
- Nervous
- Relaxed
- Excited
- Successful
- Sad
- Happy
- Tired
- Hopeful

Positive/Negative Emotions



Conclusion

- Exploratory analysis suggests complexity
  - Reduces performance
  - Induces drop-out
  - Increases response time
- Strong emotional responses

Boundedly rational consumers?

Consumers clearly make mistakes but what type of mistakes?

1. Not mistakes, failure to fully account for search costs
   - Consumers are rational; firms just needs to account for this
2. Overconfident or biased mis-weighting of options
   - Leads to systematic distortions in demand that firms can exploit by distorting price
3. Fail to choose the best price due to sub-optimal search, confusion comparing bundles, or excessive inertia
   - Leads to noise in demand that is uncorrelated across consumers and may be hard for firms to fully adjust

More work to do!

- Characterize types of non-optimal behavior
- Re-simulate optimal firm behavior based on revealed demand
  - in particular, do consumer errors change which is the profit-maximizing mechanism?

Click behavior during games

Effect of feedback between periods

Interaction between response time, performance, and drop-out