Product Labeling for Inattentive Consumers

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Columbia University - Cognition & Decision Lab Meeting

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Motivation

- Labeling as “coarse information” (category) about the product
- *Reduced fat milk* label: fat content $\leq 2\%$
- Nutrition facts: Indicates the precise amount

- Why using labels?
- No effect on a fully attentive or fully inattentive consumer
- Possible effect only on partially attentive consumers
  - Information collection is costly
  - Decreasing returns of information collection
- Discrete choice model with cognitively bounded consumers

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Perception problem vs Choice problem

Literature review

- **Behavioral and cognitive economics**
  - Categorization and optimal coding: Parducci (1965), Arthur (1994), Gennaioli and Shleifer (2010), Manzini and Mariotti (2012), Robson and Whitehead (2017)
  - Perceptual bias: Krueger and Cement (1994), Stewart, Brown, and Chater (2002), Koszegi and Szeidl (2012)
  - Rational inattention: Sims (2003), Gabaix (2014)
- **Discrete choice models**
  - Empirical literature: Kiesel (2007), De los Santos et al. (2012), Allcott et al. (2017), Moraga-Gonzales et al. (2017)
  - Bounded rational consumers: Mehta et al. (2003), Abaluck (2011), Pires (2015), Clerides and Courty (2015), Pires (2015)
  - Rational inattention to discrete choices: Matejka and McKay (2015), Fosgerau et al. (2017), Cheremukhin et al. (2015), Matejka (2016), Aguiar and Riabov (2017), Fosgerau et al. (2018)
  - Information design, regulation: Diamond (1989), Mullainathan et al. (2008), Piccione and Spiegler (2012), Hui et al. (2017)

Research proposal

1. **How do quality labels affect consumer behavior?**
   - Jointly estimate preference and information cost
   - This is my challenge for the 2YP
2. **How do quality labels affect producers?**
   - Price adjustment under stable product set
   - Quality adjustment
   - Reduced form analysis only
3. **Counterfactual: Alternative labeling schemes**
   - This is a classic information design problem
   - In this model more (coarse) information is not necessarily better

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Intuition of the model

- A consumer faces a two-stage choice problem: collect information, then choose a product
- At the begin (no information) the product space is blurry: all the products (e.g. refrigerators) look identical
- No information: binary decision buy/no buy, no choice
- By collecting information the consumer can reduce coarseness
- Infinite information leads to perfect refinement
- Information is costly, it takes time to refine the space
- Intuition: reduce the variance of the T1EV logit error
- A label delivers immediate, free, yet coarse information

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Intuition of the model

- Three categories of agents: consumers (C), retailer (R), and an information designer (ID)

- The information designer decides the minimum requirement for a label that is displayed on all the high-quality products
- Product quality and label are exogenous for the retailer (monopolist producer) who only sets prices
- The consumers faces a two-stages discrete choice problem: select information level, then choose a product

What is a good industry for this model?

1. European Union Energy Label
   - 2010 reform: change in the regulation
   - 25 product categories: heterogeneous requirement
2. US Energy Star Label
   - 2011 reform: certification is more demanding
   - product heterogeneity as above
3. US FDA food labeling regulation
   - 2011 Nutrition Keys front-of-pack labeling
   - Additional to previously adopted standard labels

1. European Union Energy Label

- EU Directive 1992/75/EC established the energy consumption labeling scheme A-G to indicate energy efficiency classes
- Replaced by Directive 2010/30/EU that introduces A+, A++, and A+++ in the attempt to keep up with advances in energy efficiency
- 2010 regulation (applied since 31 July 2011) introduces new high-quality levels (A+) and modifies the threshold for the different classes
- 25 categories, including fridges, dishwashers, air conditioners

EU Energy Label: Identification strategy

- Geographical/temporal heterogeneity in prices and choice sets
- IV price of energy: exogenous wrt product characteristic
- Consumers differ in preference over observable characteristics (e.g. brand, power, size,...), coarse characteristics (e.g. energy consumption), and price elasticity

- Quasi-natural experiment: 2010 regulation change
- Transition phase: from announcement to implementation
- Post-change phase: after 1 August 2011

- Stated preference survey data: Heinzle and Wustenhagen 2012

2. US Energy Star Label

- Energy guide appliance label of qualifying products, aka Energy Star
- Voluntary program launched by US Environmental Protection Agency (EPA)
- 75 product categories, it indicates cost-saving energy efficient products
- Specifications differ across item categories: average refrigerators need 20% savings over the minimum standard, dishwashers need at least 41%
- Established in 1992, reformed in 2010 because of a scandal (before it was for the most part a self-certification program, vulnerable to fraud and abuse)
- Since 2011, product are tested in an EPA-recognized laboratory (recognized certification)

3. FDA food labeling regulation

- 1990: Nutrition Labeling and Education Act (NLEA) implemented in 1994. It requires all packaged foods to bear nutrition labeling and all health claims, labels, and serving size to be standardized.
- 2011: The Grocery Manufacturers Association announces Nutrition Keys (now Facts Up Front), a voluntary front-of-pack labeling system, just months before the FDA is to issue its guidance to industry on the matter.
- Coarse labels such as “low calorie” are now less informative as they are combined with other accessible information

Food data: Nielsen HH panel and USDA Nutrient DB

1) Nielsen Consumer Panel Data: longitudinal home scanner data, 40,000 United States households, 2004-2016.

- Demographic and geographic variables (household)
- Purchases: date, the UPC code (for each product purchased), quantity, price.
- Products and product characteristics: all 10 Nielsen food and nonfood departments; UPC code and description, brand, multi-pack, and size, product group, and product module. Some products contain additional characteristics (e.g. flavor).

2) USDA Nutrient Database for Standard Reference

- Database for branded food products
- Energy, protein, lipid, fiber, sugars, and minerals (per 100 g)

Model: Framework

- Products are vertically differentiated and fully represented by the pair of quality and price (x_j, p_j)
- Three categories of agents
  - Information designer
    - Selects the requirement x^* for the high-quality label
    - Agnostic about the objective (agentic/paternalistic?)
  - Producers
    - Set of J distinct products that differ in quality $0 \leq x_j \leq 1$
    - Visible high-quality label if $x_j \geq x^*$
    - Maximize joint profits by choosing prices $\{p_j\}_{j=1}^J$
  - Consumers
    - Each consumer can buy a single unit, or not buy
    - Distribution $f(\beta)$ of consumers with pref. over quality $\beta \geq 0$
    - Constant price elasticity $\alpha = 1$ and information cost $\lambda \geq 0$
    - Maximize expected utility by choosing info. ρ and product x_j

Model: Two-stages choice problem

1) Choose optimal precision level ρ

$$\max_{\rho \geq 0} EU(\rho) := EU^*_\beta(\rho) - \lambda \cdot \rho$$

2) Given ρ, select a random product from the best partition cell

$$EU^*_\beta(\rho) := \max_{c \in [1, \ldots, 2^\rho] \cup \varnothing} \mathbb{E}\left[\beta \cdot q(x_j) - p_j | x_j \in \Pi^c_\rho\right]$$

Consumer's individual choice is summarized by the pair $\left(\rho, \Pi^c_\rho\right)$, that is associated with a pdf over products.

Model: Information acquisition

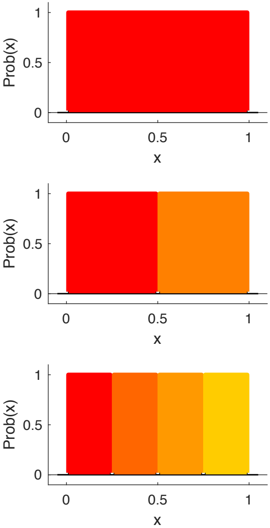

Figure 1: Probability of selecting a product x conditional on partition cell and collected information (top to bottom). Sharp partition (left), fuzzy partition (center), and fuzzy partition with quality label x^* (right).

Model: Information acquisition

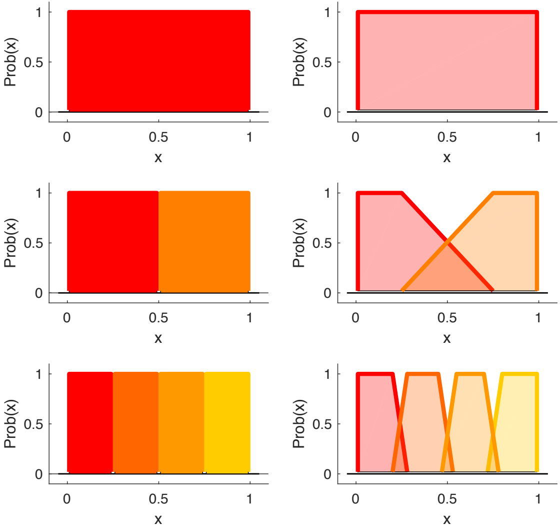

Figure 2: Probability of selecting a product x conditional on partition cell and collected information (top to bottom). Sharp partition (left), fuzzy partition (center), and fuzzy partition with quality label x^* (right).

Model: Information acquisition

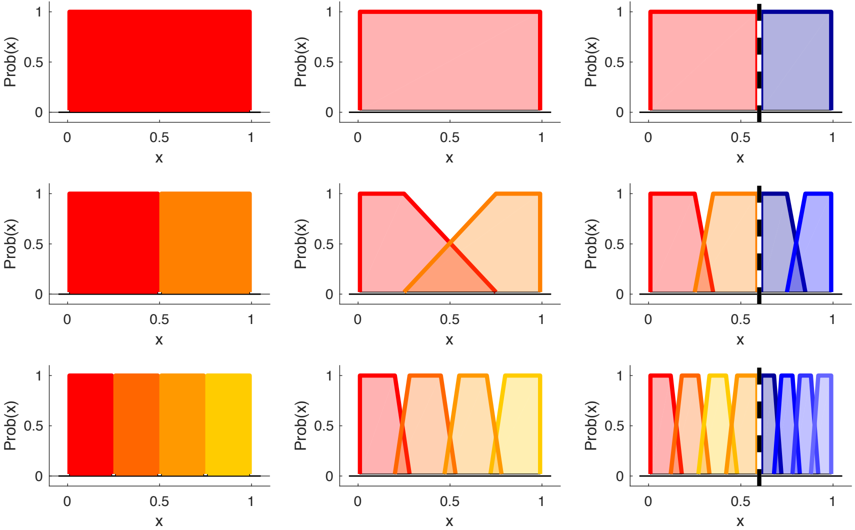

Figure 3: Probability of selecting a product x conditional on partition cell and collected information (top to bottom). Sharp partition (left), fuzzy partition (center), and fuzzy partition with quality label x^* (right).

Model: Product space partition

Given a precision level ρ, the interval $[0, 1]$ is divided into 2^ρ disjoint intervals Π of equal length (sharp partition).
When $\rho \to \infty$ the buyer perfectly distinguishes the products.

Choice probability in the degenerate case (sharp partition)

$$pdf(x_j|\Pi_\rho^c) = \begin{cases} 0 & x \leq \frac{c-1}{2^\rho}, x_j \geq \frac{c}{2^\rho} \\ 2^\rho & \frac{c-1}{2^\rho} \leq x_j \leq \frac{c}{2^\rho} \end{cases}$$

Choice probability for generic trapezoidal pdf (fuzzy partition)

$$pdf(x_j|\Pi_\rho^c; a_\rho^c, b_\rho^c, d_\rho^c, e_\rho^c) = \begin{cases} 0 & x \leq a_\rho^c, x_j \geq d_\rho^c \\ \frac{2(x_j - a_\rho^c)}{(b_\rho^c - a_\rho^c)(e_\rho^c + d_\rho^c - b_\rho^c - a_\rho^c)} & a_\rho^c \leq x_j \leq b_\rho^c \\ \frac{2}{e_\rho^c + d_\rho^c - b_\rho^c - a_\rho^c} & b_\rho^c \leq x_j \leq d_\rho^c \\ \frac{2(d_\rho^c - x_j)}{(e_\rho^c - d_\rho^c)(e_\rho^c + d_\rho^c - b_\rho^c - a_\rho^c)} & d_\rho^c \leq x_j \leq e_\rho^c \end{cases}$$

Model: Consumer

Utility of consumer β from product j after collecting ρ information

$$U_\beta(\rho, x_j, p_j) = \beta \cdot q(x_j) - \alpha \cdot p_j - \lambda \cdot \rho$$

Consumers differ in preference intensity β over product quality x, and have homogeneous information cost $\lambda \geq 0$. A consumer needs to pay the cost $\lambda \cdot \rho$ in order to achieve the precision level $\rho \geq 0$.

The consumer selects a precision level ρ, that corresponds to a partition cell Π_ρ^c of the product space. Then, she selects the cell with the highest expected value and purchases randomly within the cell.

Outside option $(\rho, \varnothing)$, with $U_\beta(\rho, \varnothing) = -\lambda \cdot \rho$.

Example: Solution of the consumer's problem

- Assume functional form $q_j := q(x_j) = log(x_j + 1)$
- Assume free entry, product price linear in quality $p_j = p(x_j) = x_j$, and distribution $x \sim U[0, 1]$
- Under perfect information, consumer β selects $x_j = \beta - 1$
- So every $\beta \geq 1$ purchases a product. Assume $\beta \sim U[1, 2]$
- Under full coarseness ($\lambda = \infty$), consumers buy a product if $\beta \geq \frac{\mathbb{E}[p]}{\mathbb{E}[q]} = \frac{0.5}{2ln(2)-1} \approx 1.3$
- If $q(\cdot)$ is monotonic, the fraction of consumers who do not buy any product is decreasing in the information cost λ

Simulation: Introduction of a label

If there is no price or quality adjustment, the introduction of a label is weakly improving for all the consumers.

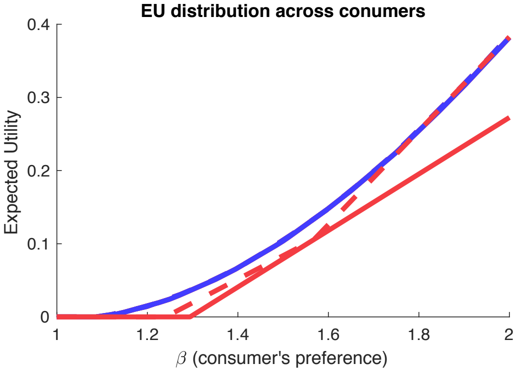

Figure 4: Solution of the model without label (full line) and with label $x^* = 0.8$ (dotted line). Expected utility as a function of β for high ($\lambda > 1$, red) and low information cost ($\lambda = 0.001$, blue).

Simulation: Information cost

Higher information cost leads to a lower share of buyers, and an higher share of high-quality buyers.

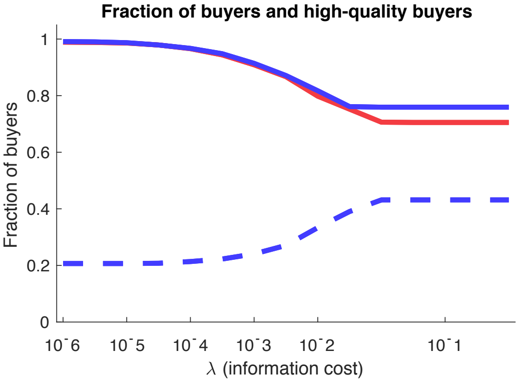

Figure 5: Simulation of the model without label (red) and with label $x^* = 0.8$ (blue line). Fraction of buyers (full line) and high-quality buyers (dotted line).

Simulation: Purchase distribution

The information cost affects the distribution of the purchases.
The introduction of a label also plays a role.

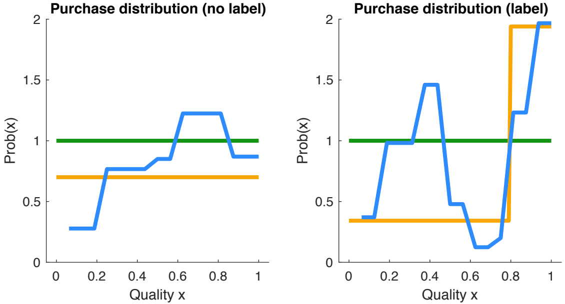

Figure 6: Purchase distribution under coarse (orange), partial (blue), and full info (green). No label (left) and $x^* = 0.8$ label (right), $\lambda = 10, 0.01, 0$.

Simulation: Minimum label requirement

The label requirement affects both the fraction of buyers and high-quality products buyers

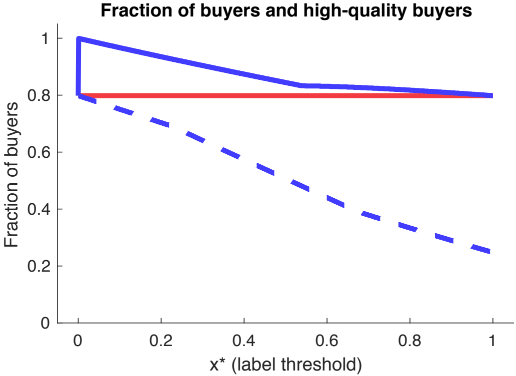

Figure 7: Simulation of the model without label (red) and with label $0 \leq x^* \leq 1$. Fraction of buyers (full line) and high-quality buyers (dotted line) as a function of the minimum label requirement.

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Extra slides

Information theory: Simplicity vs Likelihood

- Shannon information theory relies on the exact knowledge of the likelihood of different events
- Generalized entropy relaxes the functional form of the cost but it still relies on information about the event distribution in order to create the signal structure
- Structural Information Theory (psychology) and Algorithmic Information Theory (computer science) relax this assumption
- Simplicity principle (e.g. data visualization): minimize the information load in a flexible environment
- The code allows a perceptual interpretation that is “fairly veridical” in many possible worlds, instead of “highly veridical” in only one world