Price Setting with Customer Retention Concerns

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Customer retention concerns

- Departure from purely static demand
- Distinguish between two margins of demand
  - Intensive: $P \uparrow \Rightarrow Q \downarrow$
  - Extensive: “chunks” of demand (i.e. customers) are gained or lost
- If there are frictions it is hard to regain lost customers
What we do (and aim to do)

1) Novel evidence on shopping behavior from supermarket scanner data
   - freq. of shopping, freq. of customers exiting, dist. of basket price changes
   - measure elasticity of customer exit to own basket price

2) GE model of price setting with customer retention concerns
   - features
     - customers incur random search cost to leave producer of homogenous good
     - persistent idiosyncratic productivity shocks make producers heterogenous

3) Bring together data and model to estimate some key parameter
Why do we care?

Framework allows to make three main contributions

- optimal price setting policy
- quantify cost pass-through/real price rigidity
- quantify relevance for economy response to aggregate TFP shocks
Data description

1) Scanner data on grocery purchases at a large supermarket chain
   - two years of data (2004-2006)
   - information on timing, quantities, and prices of purchased goods (UPC’s)

2) Store data
   - weekly revenue and quantities for each UPC
   - >200 stores (representative of all price areas) in 10 states

3) Census data to match demographic characteristics at block group level.
## Descriptive statistics: shopping behavior

### Longitudinal variation

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>25th pctl</th>
<th>75th pctl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure per trip (USD)</td>
<td>56</td>
<td>66</td>
<td>12</td>
<td>78</td>
</tr>
<tr>
<td>Days elapsed between trips</td>
<td>4.2</td>
<td>7.5</td>
<td>1</td>
<td>5</td>
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</tbody>
</table>

### Cross-sectional variation

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>25th pctl</th>
<th>75th pctl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure per trip (USD)</td>
<td>69</td>
<td>40</td>
<td>40</td>
<td>87</td>
</tr>
<tr>
<td>Days elapsed between trips</td>
<td>7.7</td>
<td>11.6</td>
<td>3.4</td>
<td>8.6</td>
</tr>
<tr>
<td>Number of trips (Avg across hhid’s)</td>
<td>150</td>
<td>128</td>
<td>66</td>
<td>200</td>
</tr>
</tbody>
</table>
Construction of key variables

1) Price of a customer’s basket
   - match household to own complete value price series
     - can be done for a subset of households
   - weighted average of prices of goods in the agent’s basket
     - basket is set of UPCs purchased by agent over the two years
     - the weight of each UPC is its share of total expenditure for this agent

2) Exit from customer base
   - an agent is no longer in the customer base when it does not visit the chain for \( n=4 \) consecutive weeks
   - we attribute the exit to the week of the last visit
Identifying times of customer leaving

Exiting = Missing at least 4 consecutive weeks

Date of exit: last date of shopping

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>25th pctile</th>
<th>75th pctile</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Longitudinal variation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration as customer (weeks)</td>
<td>39</td>
<td>38</td>
<td>7</td>
<td>78</td>
</tr>
<tr>
<td><strong>Cross-sectional variation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration as customer (weeks)</td>
<td>61</td>
<td>38</td>
<td>21</td>
<td>99</td>
</tr>
</tbody>
</table>
Probability of exiting the customer base
Descriptive statistics: prices

Table: Descriptive statistics on basket price changes

<table>
<thead>
<tr>
<th></th>
<th>Shoppers Basket</th>
<th>Stores Basket</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std.dev.</td>
</tr>
<tr>
<td># of UPC in the basket</td>
<td>290</td>
<td>172</td>
</tr>
<tr>
<td>$\Delta p$</td>
<td>-0.01%</td>
<td>4.3%</td>
</tr>
<tr>
<td>$</td>
<td>\Delta p</td>
<td>$</td>
</tr>
<tr>
<td>$%</td>
<td>\Delta p</td>
<td>&gt; 1%</td>
</tr>
<tr>
<td>$%</td>
<td>\Delta p</td>
<td>&gt; 5%</td>
</tr>
<tr>
<td>$%</td>
<td>\Delta p</td>
<td>&gt; 10%</td>
</tr>
</tbody>
</table>
The effect of prices on probability of leaving

**Dep. variable:** Indicator for leaving the chain in that week
(mean=0.042; st.dev.=0.20)

\[
\text{Exit}_{ht} = b_0 + b_1 dp_{ht} + X_h' b_2 + X_t' b_3 + \varepsilon_{ht}
\]

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(dp^h)</td>
<td>0.031**</td>
<td>0.023**</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>(dp^{store})</td>
<td></td>
<td>-0.013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.022)</td>
</tr>
<tr>
<td>Observations</td>
<td>103,507</td>
<td>91,555</td>
</tr>
<tr>
<td>Dem. controls</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Time f.e.</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Summing up

- Persistence in the customer-retailer relationship
  
  and

- Sensitivity to prices of break in the customer-retailer relationship

Suggest frictions in customer’s search for a new retailer.

Next: What are the implications for price setting and pass-through?
Setup

3 types of agents:
- measure one of firms producing good 1 (price $p$) - object of interest
- competitive rep. firm producing good 2 (price $q$)
- rep. household: a worker and measure $\Gamma > 1$ of shoppers

Timing:
1. At beginning of $t$, each shopper matched to a producer $j$ of good 1.
2. idiosyncratic productivity shocks realize
3. each producer set price
4. each shopper draws own search cost $\psi \sim G(\cdot), \psi \in [0, +\infty)$
   - if incur cost $\psi$, *randomly* assigned to a new producer
   - otherwise, stays with current producer
5. consumption occurs
6. the match is exogenously disrupted w.p. $\tau$
Production technology

Production of good 1: linear in labor, $y_{1,j} = z_j l_{1,j}$.

Productivity $z$: K values $z_1 < z_2 < \cdots < z_k < \cdots < z_K$,

$$\Pr[z_j' = s | z_j = k] = \mu_{ks}.$$

Production of good 2: linear in labor, $y_2 = l_2$. 
The household’s problem

Preferences:

\[ E_0 \left[ \sum_{t=0}^{\infty} \beta^t \left( \int u(c_i(t)) di - \frac{L(t)^{1+\phi}}{1 + \phi} - \int \chi_i(t) \psi_i(t) \, di \right) \right] \]

where

\[ u(c_i(t)) = \frac{c_i(t)^{1-\gamma}}{1 - \gamma} \]

\[ c_i(t) = (\omega^{1-\theta} c_{1,i}(t)^{\theta} + (1 - \omega)^{1-\theta} c_{2,i}(t)^{\theta})^{1/\theta}, \quad \theta < 1, \quad \omega \in (0, 1) \]

Assumptions:

- no inventories/full perishability
- no within-household insurance/non-verifiability of shopping
Household’s intra-temporal decisions

Consumption decision:

\[ u_0(p_i, I) = \max_{c_{1,i}, c_{2,i}} \frac{\left( \omega^{1-\theta} c_{1,i}^\theta + (1-\omega)^{1-\theta} c_{2,i}^\theta \right)^{(1-\gamma)/\theta}}{1 - \gamma} \]

subject to

\[ p_i c_{1,i} + q c_{2,i} = I , \]

Labor decision:

\[
\max_{L(t)} E_t \left[ \sum_{\tau = t}^{\infty} \beta^{\tau-t} \left( \int u_0(p_i(t), l(t))di - \frac{L(t)^{1+\phi}}{1 + \phi} \right) \right] \\
\text{subject to} \\
\Gamma l(t) = W(t) L(t) + \int_0^1 \pi_j(t) dj
\]
Shopper’s search decision

Conjecture equilibrium Markovian structure for prices:

\[ P \equiv \{ p_1, p_2, \ldots, p_k, \ldots, p_K \} \]

Value of staying \( (\bar{V}(p, k, P^j)) \) is

\[ u_0(p) + \beta \left[ \tau \hat{V} + (1 - \tau) \sum_{k'}^{K} \mu_{kk'} \int \max \left\{ \bar{V}(p_{k'}, k', P^j), \hat{V} - \psi \right\} g(\psi) d\psi \right], \]

Outside option: \( \hat{V} \)
Exogenous probability of leaving: \( \tau \)
Optimal search policy

$p_k$: price below which no-one leaves, i.e.

$$\bar{V}(p_k, k; \mathbf{P}) = \bar{V}.$$ 

$\bar{\psi}(p_k)$: threshold rule s.t. shopper leaves if $\psi \leq \bar{\psi}(p, p_k)$, i.e.

$$\bar{\psi}(p, p_k) = \begin{cases} 0 & \text{if } p \leq p_k, \\ u_0(p_k) - u_0(p) & \text{otherwise,} \end{cases}$$

$\bar{\psi}(p, p_k)$ is strictly increasing in $p$ and strictly decreasing in $p_k$, for all $p \geq p_k$. 

\[\text{Paciello, Pozzi, Trachter (EIEF)}\]
Firm’s problem: customer base

\( m_j \) ≡ customer base of producer \( j \) at the beginning of the period.
\( m_j^+ \) ≡ customer base of producer \( j \) after stay/leave decisions are made.
\( \delta \) ≡ arrival rate of new shoppers, proportional to \( m_j \).

Producer \( j \)’s shoppers dynamics:

\[
\begin{align*}
    m_j^+ &= m_j (1 + \delta) - m_j \ G \left( \psi(p, \bar{p}_k^j) \right) = m_j \left[ \delta + 1 - G \left( \psi(p, \bar{p}_k^j) \right) \right], \\
    m'_j &= m_j^+ (1 - \tau) = m_j \left[ \delta + 1 - G \left( \psi(p, \bar{p}_k^j) \right) \right] (1 - \tau).
\end{align*}
\] (1) (2)

Producer \( j \)’s period profits:

\[
\pi(p, z_k) = c_1(p) \left( p - \frac{W}{z_k} \right)
\]

\( \hat{p}_k \equiv \text{argmax}_p \pi(p, z_k) \)
Firm’s problem: Construction of value function

Value function of firm $j$ with productivity $k$

$$\tilde{F}(z_k, m_j) = \max_p m_j^+ \pi(p, z_k) + \hat{\beta} \sum_s \mu_{ks} \tilde{F}(z_s, m'_j) \quad \text{for each } k,$$

s.t. eq. for customer base dynamics and static profits

Contraction Mapping theorem implies that $\tilde{F}(z_k, m_j) = m_j \tilde{F}(z_k, 1) = m_j F(z_k)$

where

$$F(p, k) = (\delta + 1 - G(\bar{\psi}(p, \bar{p}_k))) \left( \pi(p, z_k) + (1 - \tau) \hat{\beta} \sum_{k' = 1}^K \mu_{kk'} F(p_{k'}, k') \right)$$

$$p_k^* \equiv \argmax_p F(p, k)$$
Firm’s problem: caveats

1. $F(z_k)$ may not be a contraction $\Rightarrow$ Include probability of firm death
2. The problem of the firm is not globally concave in $p$ $\Rightarrow$ FOC can be used only because we prove the following

**Proposition:** The value function for a firm with productivity $z_k$, i.e. $F(z_k)$, is single-peaked, attaining its maximum at $p = p^*_k$ solving the first order condition of the problem.
Moreover, let $\hat{p}_k$ denote the price that maximizes static profits for a firm with current productivity $z_k$, i.e. $\partial \pi(\hat{p}_k, z_k) / \partial p = 0$. If $\bar{p}_k \geq \hat{p}_k$, then $p^*_k = \hat{p}_k$. If $\bar{p}_k < \hat{p}_k$, then $p^*_k \in (\bar{p}_k, \hat{p}_k)$. 
Case 1: $\hat{p}_k \leq \bar{p}_k$

$\hat{p}_k > \bar{p}_k \Rightarrow p^*_k \in (\bar{p}_k, \hat{p}_k)$ OR $\hat{p}_k \leq \bar{p}_k \Rightarrow p^*_k = \hat{p}_k$.

If $\hat{p}_k > \bar{p}_k$, "k" has two effects on $p^*_k$:
- Standard cost channel: $k \uparrow \Rightarrow z_k \uparrow \Rightarrow p^*_k \downarrow$
- Novel search channel: $k \uparrow \Rightarrow \bar{p}_k \uparrow \downarrow \Rightarrow p^*_k \uparrow \downarrow$

Persistent productivity + search costs give non-monotonicity of $p^*_k$. 

Paciello, Pozzi, Trachter (EIEF)
Equilibrium

All producers choose same pricing policy $P^* = \{p_k^*\}_{k \leq K}$

$f(m, k)$: invariant distribution of $(m, k)$ solves

$$f(m, y) = \sum_{k=1}^{K} \mu_{ky} f \left( \frac{m}{\delta + 1 - G (\psi(p_k^*, \bar{p_k})) (1 - \tau)}, k \right),$$

$$\Gamma = \sum_{k=1}^{K} \int_{0}^{\infty} m f(m, k) \, dm$$

$$\delta = \sum_{k=1}^{K} \frac{M(k) G (\psi(p_k^*, \bar{p_k}))}{\Gamma} + \frac{\tau}{1 - \tau}$$

$$M(k) \equiv \int_{0}^{\infty} m f(m, k) \, dm$$

Shopper outside option:

$$\hat{V} = \sum_{k=1}^{K} \mu_k^* \tilde{V}(p_k^*, k, P^*)$$
Statistics of interest

(Observable) Avg. elasticity of probability of exit to price changes:

\[ b \equiv \sum_{k=1}^{K} \frac{M(k)}{\Gamma} \lim_{\epsilon \to 0} \frac{G(\psi(p_k^* e^\epsilon, \bar{p}_k)) - G(\psi(p_k^*, \bar{p}_k))}{\epsilon} , \]

(Observable?) Avg. change in probability of exit conditional on \( |\Delta p| > 0 \):

\[ \kappa \equiv \sum_{k=1}^{K} \frac{M(k)}{\Gamma} \sum_{k' | p_{k'}^* > p_k^*} \mu_{k' | p_{k'}^* > p_k^*} \left[ G(\psi(p_{k'}^*, \bar{p}_{k'})) - G(\psi(p_k^*, \bar{p}_k)) \right] , \]

(Model Output) Pass-through:

\[ \xi \equiv \sum_{k} \sum_{k' \neq k} \mu_{k k'} \frac{\log(p_{k'}^*) - \log(p_k^*)}{1 - \mu_{k k}} \frac{\log(z_{k'}) - \log(z_k)}{\log(z_{k'}) - \log(z_k)} . \]
## Parameter choices

<table>
<thead>
<tr>
<th>Parameter/function</th>
<th>Value</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td></td>
<td>Data</td>
</tr>
<tr>
<td><strong>Calibrated parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discount factor, $\beta$</td>
<td>0.999</td>
<td>Standard</td>
</tr>
<tr>
<td>Inter. elast. of subst., $\gamma$</td>
<td>1</td>
<td>Standard</td>
</tr>
<tr>
<td>Disutility of labor, $\phi$</td>
<td>1</td>
<td>Frisch elasticity = 1</td>
</tr>
<tr>
<td>Elast. of subst. good 1 and 2, $\theta$</td>
<td>5/6</td>
<td>Avg. markup in 10%-20% range</td>
</tr>
<tr>
<td><strong>Estimated parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity process, $\ln z_t = \rho \ln z_{t-1} + \sigma \epsilon_t$</td>
<td></td>
<td>OLS using cost data on a panel of stores</td>
</tr>
<tr>
<td>Persistence parameter, $\rho$</td>
<td>0.84</td>
<td></td>
</tr>
<tr>
<td>Standard deviation parameter, $\sigma$</td>
<td>0.035</td>
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<tr>
<td>Distribution of search cost, $g(\psi)$</td>
<td></td>
<td>Simulated method of moments</td>
</tr>
<tr>
<td>Shape parameter, $\lambda_1$</td>
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<td>Target $b$</td>
</tr>
<tr>
<td>Scale parameter, $\lambda_2$</td>
<td>??</td>
<td>Target $\kappa$</td>
</tr>
<tr>
<td>Expenditure share, $\omega$</td>
<td>0.55</td>
<td>Target grocery share of disp. income (0.38)</td>
</tr>
</tbody>
</table>
Results

Avg. elasticity of customer base \((b)\)  

Avg. pass-through \((\xi)\)
Non-monotonicity in prices

Optimal Price vs Productivity

Probability of leaving vs Productivity
Extensions

1. Returning customers

2. Loyal customers
What’s next

Response to aggregate productivity shock

Comparison to linear model.
Construction of key variables

1) Price of a customer’s basket

- match household to own complete value price series
  - can be done for a subset of households

- weighted average of prices of goods in the agent’s basket
  - basket is set of UPCs purchased by agent over the two years
  - the weight of each UPC is its share of total expenditure for this agent

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- we attribute the exit to the week of the last visit