Variety Pass-Through: an Examination of the Ready-to-Eat Cereal Market

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24th May 2011
Retail-Wholesale Pass-Through

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Variety Pass-Through
VARIETY PASS-THROUGH
OVERVIEW

- Research Problem
- Objectives and Contribution
- Econometric Model
- Data Sources and Limitations
- Estimation
- Results and Discussion
- Conclusions
Objective

Estimate retail pass-through accounting for endogenous retail assortment decisions
Theory of Pass-Through

- Pass-through rates depend on:
  - Local costs conditions
  - Market competitiveness
  - Price rigidity
  - Demand curvature

- Pass-through is generally less than 100%, except:
  - Demand curvature: $E > 1$, Delipalla and Keen (1992); Anderson, de Palma and Kreider (2001)
Empirical Models of Pass-Through

- Recent literature
  - Trade: Goldberg and Hellerstein (2007); Hellerstein (2007); Nakamura and Zerom (2010)
  - IO: Kim and Cotterill (2008)

- Model attributes:
  - Single-product sellers
  - Commodity prices

- Retail prices are set by retailers that sell many products and face wholesale prices
Theory of Variety and Pass-Through

- Retailers can do many things to raise profit if wholesale prices rise:
  - Increase retail prices
  - Reduce quality / package size / cost
  - Reduce breadth of assortment

- Effects:
  - Smaller assortment softens price competition
  - Retail prices rise further
  - Pass-through can be more than 100% (Hamilton, 2009)
CONTRIBUTION

- Endogenize product-line choices
  - Previously: Product assortment decisions considered exogenous
  - Our Model: Assortment and pricing are jointly determined
- Empirical estimate of variety- and price-pass-through
  - Previously: Pass-through for price only
  - Previously: Retail pass-through generally < 100%
  - Our Model: Variety changes associated with pass-through > 100%
Retail Data

- Cereal category: 19 top brands
- Scanner data: sales dollars, units, imputed promotion
- 33 months (June 2007 - March 2010) for L.A. market
- Six retailers with different assortment / pricing strategies
- Data is IRI Infoscan
- Why cereal?
  - Frequently purchased by large number of households
  - Supply dominated by two firms (Kelloggs and General Mills)
  - Produced from commodity with wide variation in price
  - Frequent changes in assortments / broad assortments
Wholesale Data

- Promodata - PriceTrak service
- Covers non-self distributing retailers
- Assume wholesale prices are market price
  - Nakamura and Zerom (2010)
  - Robinson / Patman Act
- Weekly price series
  - Flags price increases
  - Flags manufacturer promotions
- Comprehensive data at brand / UPC level
Econometric Model

Overview

- Structural Model Retail / Manufacturer Equilibrium
  - Demand Equation: random-parameter nested Logit
  - Consumers choose stores, and then brands of cereal
  - "Supply" Model: retailer pricing and variety
  - Equilibrium Concept: Bertrand-Nash in price and variety

- Estimated with SML (demand) and GMM (supply)
  - Instrumented with input prices, brand indicators on demand side
  - Instrumented with demographics, brand indicators on supply side
Random Utility Model

Consumer $i$ Chooses Alternative with Highest Utility

$$u_{hijt} = \delta_{hij} + \alpha_{hpijt} + f(N_{it}) + \sum_{k=1}^{K} \beta_k x_{jkt} + \xi_{jt} + \tau_{hijt} + (1 - \sigma)\varepsilon_{hijt},$$

where:

- $x_{jk}$ = elements of the marketing mix such as promotion, couponing or features
- $\delta_{hij}$ = product-and-store specific preference parameter
- $N_i$ = measure of variety (SKU count) per store
- $p_{ij}$ = vector of prices
- $\xi_j$ = effects unobserved by researcher
- $\sigma$ = heterogeneity or nesting parameter
- $\tau_{hijt} + (1 - \sigma)\varepsilon_{hijt} = \text{iid extreme value error term}$
Demand for Variety

- Utility rises in variety
  - Ideal point likely in range of variety offered by supermarkets
  - Concept supported by McAlister and Pessemier (1982); Kim, Allenby and Rossi (2002)

- Assume quadratic function for $f(N_{it})$

  $$f(N_{it}) = \gamma_1 N_{it} + 1/2 \gamma_2 N_{it}^2,$$

- Expect $\gamma_1 > 0$ and $\gamma_2 < 0$
**Unobserved Consumer Heterogeneity**

- Estimate random parameter GEV, \( z_{mh} \) are HH attributes.
- Marginal utility of income, brand preference, variety preference random:

\[
\alpha_h = \alpha_0 + \sum_{m=1}^{M} \alpha_m z_{mh} + \sigma_\alpha \nu_h, \quad \nu_h \sim N(0, 1),
\]

\[
\delta_{hij} = \delta_{0ij} + \sum_{m=1}^{M} \delta_m z_{mh} + \sigma_\delta \mu_h, \quad \mu_h \sim N(0, 1),
\]

\[
\gamma_{1h} = \gamma_{10} + \sum_{m=1}^{M} \gamma_{1m} z_{mh} + \sigma_1 \kappa_h, \quad \kappa_h \sim N(0, 1),
\]
Retailer Game

- We model three-stage game on the supply-side:
  1. Retailers choose assortments conditional on rival prices and observed wholesale prices
  2. Retailers compete in prices
  3. Consumers choose among stores (6) and brands
- Model the game backward, beginning with consumer demand
**Retailer Game**

- **Profit equation for retailer** $i$:
  \[
  \pi_i = M \sum_{j \in J} s_{ij} (p_{ij} - c_{ij} - w_{ij}) - g(N_i),
  \]

- **Marginal retailing cost**:
  \[
  c_{ij}(v_r) = \sum_{i \in I} \sum_{j \in J} \eta_{ij0} + \sum_{l \in L} \eta_{wl} v_{rl} + \epsilon_{ijr},
  \]

- **Cost of variety**:
  \[
  g(N_i) = \lambda_0 + \lambda_1 N_i.
  \]
ECONOMETRIC MODEL

EQUILIBRIUM PRICES

- Equilibrium concept is Bertrand / Nash
- First-order conditions with respect to price:

\[
\frac{\partial \pi_i}{\partial p_{ij}} = Ms_{ij} + M \sum_{k \in J} (p_{ik} - c_{ik} - w_k) \frac{\partial s_{ik}}{\partial p_{ij}} = 0, \; \forall i \in I, \; j \in J,
\]

- Written in matrix notation:

\[
p = c + w - (\Omega S_p)^{-1}s,
\]

- \(\Omega = "ownership\ matrix","\)
- \(S_p = \text{matrix of share-derivatives in price}\)
EQUILIBRIUM ASSORTMENT

- Equilibrium concept is again Bertrand-Nash in $N_i$
- Solution captures externalities on own and rival prices:

$$\frac{\partial \pi_i}{\partial N_i} = 0 = M \sum_{j \in J} s_{ij} \frac{\partial p_{ij}}{\partial N_i} + M \sum_{j \in J} (p_{ij} - c_{ij} - w_j) \frac{\partial s_{ij}}{\partial N_i} + M \sum_{l \in I} \sum_{k \in J} (p_{lk} - c_{lk} - w_k) \left( \frac{\partial s_{lk}}{\partial p_{lk}} \frac{\partial p_{lk}}{\partial N_i} - \frac{\partial g_i}{\partial N_i} \right).$$
EQUILIBRIUM ASSORTMENT

- Solve for $N_i$ and write in matrix notation:

$$N = (1/\lambda_1)(Ms'P_N + M(p - c - w)'S_N + M(p - c - w)'S_pP_N),$$

- $P_N = \text{matrix of price-derivatives in variety}$
- $S_N = \text{matrix of share-derivatives in variety}$
- $M = \text{size of the total market.}$
Finding Equilibrium Pass-Through Rates

- Two options:
  1. Simulate price and variety solutions (Kim and Cotterill 2008)
  2. Totally differentiate FOC with respect to wholesale prices

- Total differential of retail FOC in prices:

\[
\left( \sum_{k \in J} \frac{\partial s_{ik}}{\partial p_{ik}} + \sum_{l \in J} \sum_{k \in J} (p_{il} - c_{il} - w_l) \frac{\partial^2 s_{il}}{\partial p_{ij} \partial p_{ik}} + \sum_{l \in J} \frac{\partial s_{il}}{\partial p_{ij}} \right) \frac{\partial p_{il}}{\partial w_j} + \\
\left( \sum_{k \in J} \frac{\partial s_{ik}}{\partial N_i} + \sum_{l \in J} \sum_{k \in J} (p_{il} - c_{il} - w_l) \frac{\partial^2 s_{il}}{\partial p_{ij} \partial N_i} + \sum_{l \in J} \frac{\partial s_{il}}{\partial N_i} \right) \frac{\partial N_i}{\partial w_j} = \frac{\partial s_{ik}}{\partial p_{ij}},
\]

- Where:
  - $\partial p_{il}/\partial w_j$ is the retail pass-through rate and,
  - $\partial N_i/\partial w_j$ is the "variety" pass-through rate.
**Estimating Equations**

- Totally differentiate variety FOC and solve both to find...
- One big ugly mess (see paper), but we can simplify...
- Retail price pass-through:

\[
SP_{ij} = SPP_{ij} \phi + SN_{ij} \theta + \varepsilon_P,
\]

and variety-pass-through:

\[
SN_{ij} = SPN_{ij} \phi + SNN_{ij} \theta + \varepsilon_N,
\]

where:

- \(SPP_{ij}\) = first- and second-order share derivatives in price,
- \(SN_{ij}\) = first-order share derivatives in variety,
- \(SPN_{ij}\) = share derivatives in price and variety,
- \(SNN_{ij}\) = first- and second order share derivatives in variety,
Estimation Method

- Estimate demand using control function (Petrin and Train 2010)
  - Simulated maximum likelihood
  - Residuals from IV regression for prices used as explanatory variables
  - Demand IVs: brand indicators, input prices, lagged shares

- Estimate supply with GMM
  - Compare to NLSUR to evaluate need for endogeneity
  - Supply IVs: brand indicators, market demos, lagged margins
Four Sets of Results

- Specification tests
- Structural demand parameters
- Elasticities of demand
- Supply estimates / pass-through rates
### Specification Tests

Table 1: Specification Tests: RP–GEV Model

<table>
<thead>
<tr>
<th>Test</th>
<th>Estimate</th>
<th>Test Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. GEV vs Simple Logit</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>- GEV Scale Parameter</td>
<td>0.768*</td>
<td>216.473</td>
</tr>
<tr>
<td>2. Random Parameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- LR Test</td>
<td></td>
<td>1,077.322</td>
</tr>
<tr>
<td>- Price Response</td>
<td>0.964*</td>
<td>39.047</td>
</tr>
<tr>
<td>- Brand Preference</td>
<td>0.412*</td>
<td>32.245</td>
</tr>
<tr>
<td>- Variety Response</td>
<td>0.050*</td>
<td>16.527</td>
</tr>
<tr>
<td>3. Control Function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>µ</td>
<td>0.608*</td>
<td>2.593</td>
</tr>
<tr>
<td>η</td>
<td>-0.001*</td>
<td>-2.793</td>
</tr>
</tbody>
</table>
## Structural Demand Estimates

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>t ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-11.671*</td>
<td>-42.433</td>
</tr>
<tr>
<td>Cheerios</td>
<td>0.131*</td>
<td>3.776</td>
</tr>
<tr>
<td>Cinn. Toast Crunch</td>
<td>0.223*</td>
<td>5.989</td>
</tr>
<tr>
<td>Lucky Charms</td>
<td>0.100*</td>
<td>2.408</td>
</tr>
<tr>
<td>Corn Flakes</td>
<td>0.154*</td>
<td>3.208</td>
</tr>
<tr>
<td>Frosted Flakes</td>
<td>0.234</td>
<td>5.119</td>
</tr>
<tr>
<td>Raisin Bran</td>
<td>0.195*</td>
<td>4.989</td>
</tr>
<tr>
<td>Special K</td>
<td>0.390*</td>
<td>8.660</td>
</tr>
<tr>
<td>Fr. Mini Wheats</td>
<td>0.235*</td>
<td>4.955</td>
</tr>
<tr>
<td>Price</td>
<td>-2.800*</td>
<td>-11.100</td>
</tr>
<tr>
<td>Variety</td>
<td>25.918*</td>
<td>17.022</td>
</tr>
<tr>
<td>Variety$^2$</td>
<td>-30.259*</td>
<td>-13.964</td>
</tr>
</tbody>
</table>
**Results**

**Structural Demand Estimates**

- Product-specific preference parameters plausible
- Price parameter significant, plausible elasticities (see below)
- Variety effect quadratic
  - Optimal assortment = 428 SKUs
  - Observed = 329 SKUs
  - Retailers not fully exploiting assortment effect
- Age and Income
  - Reduce price elasticity
  - Reduce optimal assortment
Demand Elasticities

Table 3. Selected Elements of Elasticity Matrix

<table>
<thead>
<tr>
<th>Product</th>
<th>-2.984</th>
<th>0.127</th>
<th>0.075</th>
<th>0.099</th>
<th>0.143</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheerios</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cinn. Toast Crunch</td>
<td>0.127</td>
<td>-2.165</td>
<td>0.121</td>
<td>0.145</td>
<td>0.189</td>
</tr>
<tr>
<td>Lucky Charms</td>
<td>0.075</td>
<td>0.121</td>
<td>-3.076</td>
<td>0.093</td>
<td>0.137</td>
</tr>
<tr>
<td>Corn Flakes</td>
<td>0.099</td>
<td>0.145</td>
<td>0.093</td>
<td>-2.196</td>
<td>0.161</td>
</tr>
<tr>
<td>Frosted Flakes</td>
<td>0.143</td>
<td>0.189</td>
<td>0.137</td>
<td>0.161</td>
<td>-1.641</td>
</tr>
</tbody>
</table>

Note how similar products have higher cross-elasticities.
# Pass-Through Model Estimates

Table 4. Pass-Through Model Estimates: NLSUR and GMM

<table>
<thead>
<tr>
<th>Variable</th>
<th>NLSUR Estimate</th>
<th>t-ratio</th>
<th>GMM Estimate</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.737</td>
<td>60.316</td>
<td>0.849</td>
<td>3.834</td>
</tr>
<tr>
<td>Retailing Wage</td>
<td>-0.458</td>
<td>-30.243</td>
<td>-0.594</td>
<td>-2.458</td>
</tr>
<tr>
<td>Health Care</td>
<td>-0.952</td>
<td>-30.146</td>
<td>-1.946</td>
<td>-4.871</td>
</tr>
<tr>
<td>Utilities</td>
<td>-0.029</td>
<td>-0.541</td>
<td>1.855</td>
<td>1.759</td>
</tr>
<tr>
<td>$\phi$</td>
<td>0.730</td>
<td>664.310</td>
<td>1.010</td>
<td>164.498</td>
</tr>
<tr>
<td>$\delta_2$</td>
<td>-0.016</td>
<td>-51.638</td>
<td>-0.022</td>
<td>-11.799</td>
</tr>
<tr>
<td>LLF</td>
<td>3,567.663</td>
<td></td>
<td>265.368</td>
<td></td>
</tr>
</tbody>
</table>
Pass-Through Estimates

- Variety pass-through rate
  - $\theta = -9.655$
  - Wholesale price negatively related to variety

- Retail price pass-through rate
  - $\phi_{NLSUR} = 0.730$
  - $\phi_{GMM} = 1.01$
  - Pass-through $> 1.0$ when variety endogenous

- Cost of variety is convex function
General Implications of Results

- Hypothesis 1: Wholesale price and variety negatively related
  - Supported by the LA cereal data
- Hypothesis 2: Overshifting is possible when variety endogenous
  - Supported by the LA cereal data
- Multi-product pricing is critical to pass-through estimation
- Pass-through estimates must account for endogenous variety
- Price competition is softened when firms reduce product lines
- Potential for food-price inflation is generally understated
Strategic behavior important to understanding retail prices

Store-level scanner data necessary to understand multi-product pricing

Wholesale price data is important
  - Promodata only measures prices paid by non-self distributing retailers
  - Does not include off-invoice items

ScanTrack and Infoscan do not include Wal-Mart

Homescan does not include competitive prices

iSpendwise option
  - Wiki-data gathering concept
  - Competitive prices and promotions
  - Self-updating data gathering process