Using Scanner Data To Answer Food Policy Questions

Conference

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

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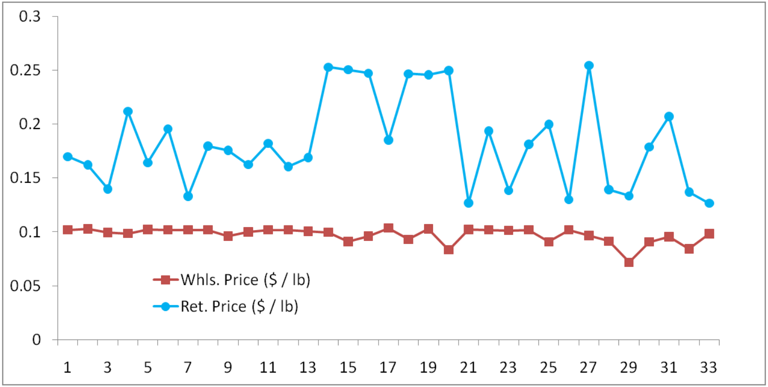
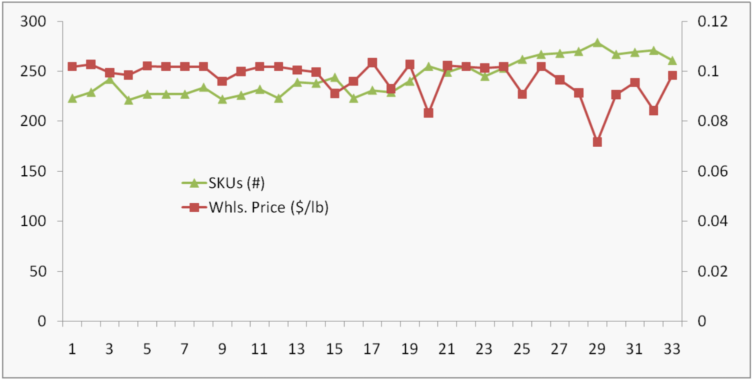
Retail-Wholesale Pass-Through



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:
  - Oligopoly: Bulow and Pfleiderer (1983); Seade (1987)
  - Multi-product sellers: Hamilton (2009)
  - 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)
  - Marketing: Dube and Gupta (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

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

where:

- $\mathbf{x}_{jk}$ = elements of the marketing mix such as promotion, couponing or features
- $\boldsymbol{\delta}_{hij}$= product-and-store specific preference parameter
- N_i = measure of variety (SKU count) per store
- p_{ij} = vector of prices
- ξ_j = effects unobserved by researcher
- σ = heterogeneity or nesting parameter
- $\tau_{hijt} + (1-\sigma)\varepsilon_{hijt}$ = iid extreme value error term

Demand for Variety

- Utility rises in variety
  - Not uncontroversial assumption: Schwartz (2002); Diehl and Poynor (2010); Kuksov and Villas-Boas (2010)
  - 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:

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

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

$$\gamma_{1h} = \gamma_{10} + \sum_{m=1}^{M} \gamma_{1m} z_{mh} + \sigma_{1\gamma} \kappa_h,\ \kappa_h \sim N(0,1),$$

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:

$$c_{ij}(\mathbf{v}_r) = \sum_{i \in I} \sum_{j \in J} \eta_{ij0} + \sum_{l \in L} \eta_{wl} v_{rl} + \epsilon_{ijr},$$

- Cost of variety:

$$g(N_i) = \lambda_0 + \lambda_1 N_i.$$

Equilibrium Prices

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

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

- Written in matrix notation:

$$\mathbf{p} = \mathbf{c} + \mathbf{w} - (\boldsymbol{\Omega} \mathbf{S}_p)^{-1} \mathbf{s},$$

  - Ω = "ownership matrix,"
  - $\mathbf{S}_p$ = 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:

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

Equilibrium Assortment

- Solve for N_i and write in matrix notation:

$$\mathbf{N} = (1/\lambda_1)(\mathbf{M}\mathbf{s}'\mathbf{P}_N + \mathbf{M}(\mathbf{p} - \mathbf{c} - \mathbf{w})'\mathbf{S}_N + \mathbf{M}(\mathbf{p} - \mathbf{c} - \mathbf{w})'\mathbf{S}_p\mathbf{P}_N),$$

  - $\mathbf{P}_N$ = matrix of price-derivatives in variety
  - $\mathbf{S}_N$ = matrix of share-derivatives in variety
  - $\mathbf{M}$ = 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

Overview

- 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

Test	Estimate	Test Statistic
1. GEV vs Simple Logit	*	
- GEV Scale Parameter	0.768*	216.473
2. Random Parameter		
- LR Test		1,077.322
- Price Response	0.964*	39.047
- Brand Preference	0.412*	32.245
- Variety Response	0.050*	16.527
3. Control Function		
μ	0.608*	2.593
η	-0.001*	-2.793

Structural Demand Estimates

Table 2: RP-GEV Demand: U.S. Cereal

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

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 exploting assortment effect
- Age and Income
  - Reduce price elasticity
  - Reduce optimal assortment

Demand Elasticities

Table 3. Selected Elements of Elasticity Matrix

Cheerios	-2.984	0.127	0.075	0.099	0.143
Cinn. Toast Crunch	0.127	-2.165	0.121	0.145	0.189
Lucky Charms	0.075	0.121	-3.076	0.093	0.137
Corn Flakes	0.099	0.145	0.093	-2.196	0.161
Frosted Flakes	0.143	0.189	0.137	0.161	-1.641

- Note how similar products have higher cross-elasticities

Pass-Through Model Estimates

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

	NLSUR		GMM	
Variable	Estimate	t-ratio	Estimate	t-ratio
Constant	0.737	60.316	0.849	3.834
Retailing Wage	-0.458	-30.243	-0.594	-2.458
Health Care	-0.952	-30.146	-1.946	-4.871
Utilities	-0.029	-0.541	1.855	1.759
ϕ	0.730	664.310	1.010	164.498
θ	-8.125	-160.216	-9.655	-53.922
δ_2	-0.016	-51.638	-0.022	-11.799
LLF	3,567.663		265.368	

Pass-Through Estimates

- Variety pass-through rate
  - θ = -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

Conclusions

- 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