Within-Chain Price Rigidity in US Retail

Stefano DellaVigna, UC Berkeley and NBER
Matthew Gentzkow, Stanford and NBER

Paris-Berkeley Conference
April 7, 2017
How do chains vary prices in response to local demand?

Relevant for:
- IO: Firm behavior
- Macro: Sources of price rigidity
- Behavioral econ: Testing for “behavioral firms”
This Project

- New fact: Many chains charge nearly uniform prices

- Model: Constant-elasticity, monopolistic competition
  - Fits demand data well
  - Direction of prices responses consistent with predictions
  - *Size* of price responses an order of magnitude too small
  - Implied profit losses are sizable

- Explanations?
Literature

- **Pricing in Retail** (Hoch, Kim, Montgomery, and Rossi, 1995; Ellickson and Misra, 2008; Hwang, Bronnenberg, and Thomadsen, 2010; Anderson, Nakamura, Simester, and Steinsson, 2012)

- **Uniform Pricing** (McMillan, 2007; Nakamura, 2008; Dobson and Waterson, 2008)

- **Local demand and pricing** (Kaplan and Menzio, 2014; Beraja, Hurst, and Ospina, 2014; Stroebel and Vavra, 2015;)

- **Behavioral Firms** (Matsa, 2011; Mahon and Zwick, 2014; Bloom and van Reenen, 2012-; Cavallo, Cavallo, and Rigobon, 2014)
Outline

1. Data
2. Motivating Facts
3. Model
4. Evidence on Model
Data

- Kilts Center Nielsen RMS retail scanner data
  - Revenue and units sold for UPC $u$ in week $t$, for store $i$
  - 53 grocery retailers with at least 10 stores each
  - 8,375 stores that meet our criteria
Data

- Data extraction criteria
  - Select 12 high-revenue modules (product category):
    - Canned Soup
    - Cookies
    - Cat Food (wet type)
    - Candy (chocolate)
    - Coffee (ground/whole bean)
    - Orange Juice (refrigerated)
    - Soft Drinks (carbonated)
    - Toilet Paper
    - Bleach
    - Paper Towels
    - Toothpaste
    - Yogurt
  - Within each (module, year), select UPC with top coverage *across all chains*
    - Reese’s Peanut Butter Cups for “Candy (chocolate)”
    - Campbell’s Cream of Mushroom Soup for “Canned Soup”
Sample Products
Outline

1. Data

2. Motivating Facts

3. Model

4. Evidence on Model
Motivating Facts

- Chain 79: locations of 1,027 stores
Motivating Facts

- Chain 79 price table for OJ

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>$12,500</td>
<td>3.390</td>
<td>3.79</td>
<td>3.00</td>
<td>3.00</td>
<td>3.26</td>
</tr>
<tr>
<td>VA</td>
<td>$21,000</td>
<td>3.288</td>
<td>3.79</td>
<td>3.00</td>
<td>3.00</td>
<td>3.79</td>
</tr>
<tr>
<td>DE</td>
<td>$24,000</td>
<td>3.293</td>
<td>3.79</td>
<td>3.02</td>
<td>3.02</td>
<td>3.79</td>
</tr>
<tr>
<td>MD</td>
<td>$29,000</td>
<td>3.300</td>
<td>3.79</td>
<td>3.03</td>
<td>3.18</td>
<td>3.67</td>
</tr>
<tr>
<td>SC</td>
<td>$36,000</td>
<td>3.300</td>
<td>3.79</td>
<td>3.00</td>
<td>3.00</td>
<td>3.79</td>
</tr>
<tr>
<td>MD</td>
<td>$48,500</td>
<td>3.302</td>
<td>3.79</td>
<td>3.02</td>
<td>3.00</td>
<td>3.79</td>
</tr>
</tbody>
</table>
Motivating Facts: Visualizing Prices

- Challenge: Show pricing across stores, over time, for different products

- This paper: Color-coded plots of price
  - Plot $\ln(\text{price in store } i, \text{ week } t) - \ln(\text{average yearly price across chains})$
  - Example: 0.1 indicates price 10% higher than in avg. store
  - Darker colors are higher price
  - Blank if no price

- Each row is a store $i$, stores sorted by measure of store-level income, 250 stores in a chain
- Each column is a week $t$
Motivating Facts

- Majority of Chains display largely uniform pricing (e.g., chain 79)
- Plenty of price variation over time (sales)
- Almost no variation across stores
Motivating Facts

- Same chain, multiple UPCs, same 50 stores for each UPC
Motivating Facts

- Another example of largely uniform pricing
Motivating Facts

- Small number of other chains: Separate by geography.
- Rigid pricing within a region: Chain 9
Motivating Facts

- Separate by geography. Links indicate similar pricing
Motivating Facts

- Finally, few chains: Individualized pricing. Example: Chain 827
Motivating Facts

- Finally, few chains: Individualized pricing. Example: Chain 827
Motivating Facts

• How similar are prices across stores in same chain?
• Two main measures of price similarity b/w stores 1 and 2:
  1. (Low-frequency) Absolute difference in log quarterly prices
     (quarterly prices = unweighted average weekly logP in each quarter)

  2. (High-frequency) Weekly correlation in demeaned log prices
     (demeaning at store-year-UPC level)

• Additional measure:
  • Share of identical prices (up to 1 percent difference in prices)
    \[
    \frac{|p_{u,t}^1 - p_{u,t}^2|}{\frac{1}{2}(p_{u,t}^1 + p_{u,t}^2)} \leq 0.01
    \]
    • \(u\) denotes a UPC, \(t\) denotes a non-missing week

• Measures computed by UPC, then averaged across 12 UPCs
  (except for correlation, computed with all modules together)
Motivating Facts

- 346k within-chain pairs
- High similarity of prices along each of 3 measures
- BUT maybe prices are similar also across chains
Motivating Facts

• 1.5m between-chain pairs
• Much larger difference in pricing along each of 3 measures
Motivating Facts: Within vs. Between Chains

- Perhaps the between-retailer pairs in the previous slide were too heterogeneous
- Compare store pairs in the same DMA only
- Same results
Motivating Facts: Within vs. Between Chains

- Stronger test of rigid pricing:
- Compare stores across DMAs (not in same advertising area)
- Compare stores with different income (top-third-of-income store & bottom-third-of-income store)
- Similar pattern of rigidity
Motivating Facts: Price difference decomposition

- How does it differ across chains?
- Plot two main measures, average at chain level

Each observation is a retailer
Labels indicate retailer_code and colors indicate same parent_code
Motivating Facts: Robustness

- Robustness 1. Top-Seller vs. Other Goods
- Maybe only for top-selling UPC (loss leader features)? No

*Quarterly Abs Diff of Log Prices*

Top Constant Products vs. Sales Rank 20 Fixed Products

Average of all modules
Labels indicate retailer_code and colors indicate parent_code
Motivating Facts: Robustness

- **Robustness 2. Negotiation with Brands.** Brands demand uniform pricing (Anderson et al. 2014)
- Identify by chain highest-selling *generic* in 11 modules

![Graph showing quarterly absolute difference of log prices between top constant products and top selling generics.]

*Average of all modules. Labels indicate retailer_code and colors indicate parent_code.*
Motivating Facts: Robustness

• Additional Robustness:

• Robustness 3. High-price vs. Low-price Items
  • Maybe only for low-price items (which are top-sellers)
  • Same result for high price-per-unit items in modules

• Robustness 4. Only Grocery Retail Chains?
  • 5 Drug Stores Chains, 360 stores
  • Same results
Outline

1. Data
2. Motivating Facts
3. Model
4. Evidence on Model
Model

- Under monopolistic competition firm maximizes
  \[ \Pi = p(q)q - C(q) \]
  - Assumption 1: constant marginal costs \( C(q) = cq \)
  - Assumption 2: constant-elasticity demand: \( q = kp^{-s_i} \), elasticity \( s_i \) varying by store \( i \)

- Optimal pricing. Store \( i \) set \( p_i^* \):
  \[
  p_i^* = \frac{s_i}{s_i - 1}c \quad \text{or} \quad \log(p_i^*) = \log\left(\frac{s_i}{(s_i - 1)}\right) + \log c
  \]

- Testable with measure of elasticity \( s_i \)
Model

- **Loss from Rigid Pricing.** Suppose firm sets rigid price at (not necessarily optimal price)

\[ \bar{p} = \frac{s}{s_1 - 1} c \]

- What are the losses? Denote \( M = s / (s - 1) \)

- Percentage profit loss

\[ \frac{\Pi_i - \bar{\Pi}}{\bar{\Pi}} = \frac{s_1 - 1}{s_i - 1} \left( \frac{M}{M_i} \right)^s - 1 \]

- Expression depends uniquely on elasticities \( s \)
Model: Elasticity

- Est. elast. $\eta_i$ by store $i$: $\log Q_{i,u,t} = \alpha_i + \eta_i \log P_{i,u,t} + \gamma_i X_{i,u,t} + \epsilon_{i,u,t}$
- $X$ is a vector of upcXyear and upcXweek of year dummies
- Estimated elasticities $\eta_i$ measured with error
- Empirical shrinkage procedure:
  - Divide sample into 1$^{st}$ half and 2$^{nd}$ half of each year
  - Estimate for each store $i \eta_i^1$ and $\eta_i^2$
  - Choose $\rho$ to min $\sum_i MSE_i = ((1 - \rho)\eta_i^1 + \rho \overline{\eta}_1 - \eta_i^2)^2 \rightarrow \hat{\rho} = .1239$
  - Apply $\hat{\rho}$ to elasticity on entire sample: $\widehat{\eta}_i = (1 - \hat{\rho})\eta_i + \hat{\rho} \overline{\eta}$

 ![MSE vs. Shrinkage Parameter](image1)

 ![Raw vs. Shrinked Elasticity](image2)

- Constant $\beta$ and fixed 4 products.
- 1st half of each year shrunk using second half of each year.
Model: Elasticity

- Validation of Elasticities I: Estimated with precision
- Distribution of standard error of elasticity $\eta_i$
Model: Elasticity

- Validation of elasticities II: linearity of logQ on logP
- Partial out $X$ from logQ and logP, binscatter of residuals

Residuals of logQ and logP

All stores, all modules

Each store is represented by approximately $468 \times 12 = 5,616$ observations
Model: Elasticity

- Validation of elasticities III: relate to store-level income measure
Outline

1. Data

2. Motivating Facts

3. Model

4. Evidence on Model
Evidence on Model: Price v. Elasticity

- Within chain relationship (demeaning by chain) of:
  - Average log price for store $i$ (averaged across weeks & UPCs)
  - Elasticity for store $i$

1. Clear statistical relationship
2. Small coefficient economically

- Does it differ depending on price centralization?
Evidence on Model: Price v. Elasticity

- Split chains by price correlation measure
- Slope mostly due to chains with less rigid pricing
Evidence on Model: Price v. Elasticity

- Return to model: Log price vs. price elasticity
- Within-Chain, compare to level predicted by model (assume constant marginal cost across stores within chain)

- Slope much flatter than in model
Evidence on Model: Price v. Elasticity

- What about between chain? (No attention rigidity)
- Compute average price and average elasticity across all stores in a chain (assume equal marginal cost in all chains)

- Slope noisy, but comes closer to slope in model
Evidence on Model: Price v. Elasticity

- Empirical response to elasticity much lower than model predicted response
- Especially true for within-chain response

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) OLS Within Chain Price</th>
<th>(2) OLS Between Chain Price</th>
<th>(3) Model Median Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity</td>
<td>0.0126*** (0.00361)</td>
<td>0.0266* (0.0140)</td>
<td>0.1916</td>
</tr>
<tr>
<td>Constant</td>
<td>0.0715* (0.0420)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>7,824</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.061</td>
<td>0.052</td>
<td></td>
</tr>
<tr>
<td>Chain FE</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1
Evidence on Model: Possible Explanations

- Wrong model / estimates
  - Elasticity measure not correct (e.g., substitution or short-run vs. long-run)
  - Instrument for elasticity
  - Richer competitive interactions (not today)

- Managerial Costs
  - Fixed costs of price setting
  - Managerial inertia or attention

- Other
  - Fairness constraints
Evidence on Model: Possible Explanations

- **Wrong model / estimates**
  - Elasticity measure not correct (e.g., substitution or short-run vs. long-run)
  - Instrument for elasticity
  - Richer competitive interactions (not today)

- **Managerial Costs**
  - Fixed costs of price setting
  - Managerial inertia or attention

- **Other**
  - Fairness constraints
Evidence on Model: Price v. Elasticity

- Instrument elasticity with local demographics: income
  - Match to Nielsen Homescan dataset of consumers
  - Compute income per capita of (5-digit) ZIP code of residence for all consumers shopping in store $i$
  - Weighted average of income measure for consumers shopping at store $i$, weighted by trips taken to store $i$

- Instrument likely biases price-elasticity slope upward if also (pos.) correlated with marginal cost (e.g., land cost)
Evidence on Model: Price v. Elasticity

- **First stage: within and between chain**

  ![Graph showing store-level and retailer-level first stage](image)

- **We pool the within and between variation in the first stage:**

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Shrunken Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income ($10,000s)</td>
<td>0.160***</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.278***</td>
</tr>
</tbody>
</table>

  Observations: 7,824
  R-squared: 0.124

  Standard errors clustered by parent_code

  *** p<0.01, ** p<0.05, * p<0.1
Evidence on Model: Price v. Elasticity

- Reduced form: price on income
  - Very flat relationship *within* chain
  - Steeper relationship *between* chains
Evidence on Model: Price v. Elasticity

- **IV results:**
  - Within-chain slope is still one order of magnitude flatter
  - Between-chain slope is as predicted by model

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) OLS Within Chain Price</th>
<th>(2) OLS Between Chain Price</th>
<th>(3) Model Median Price</th>
<th>(4) IV Within Chain Price</th>
<th>(5) IV Between Chain Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity</td>
<td>0.0126*** (0.00361)</td>
<td>0.0266* (0.0140)</td>
<td>0.1916</td>
<td>0.0318** (0.0126)</td>
<td>0.257*** (0.0854)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.0715* (0.0420)</td>
<td></td>
<td></td>
<td></td>
<td>0.716*** (0.233)</td>
</tr>
<tr>
<td>Observations</td>
<td>7,824</td>
<td>53</td>
<td>7,824</td>
<td>7,824</td>
<td>7,824</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.061</td>
<td>0.052</td>
<td>0.099</td>
<td>0.274</td>
<td></td>
</tr>
<tr>
<td>Chain FE</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1
Evidence on Model: Possible Explanations

- **Wrong model / estimates**
  - Elasticity measure not correct (e.g., substitution or short-run vs. long-run)
  - Instrument for elasticity
  - Richer competitive interactions (not today)

- **Managerial Costs**
  - Fixed costs of price setting
  - Managerial inertia or attention

- **Other**
  - Fairness constraints
Evidence on Model: Managerial Costs

- Managerial costs ("behavioral firms", e.g., Bloom and Van Reenen):
  - Managers find it too costly/too hard to solve pricing problem across stores in a chain
  - Almost uniform pricing *within* a chain
  - Approximate correct pricing *between* chains

- Puzzle:
  - Why *positive* (if flat) slope also within chain?
  - Not predicted with fixed cost of inattention

- How large would the managerial costs be?
Evidence on Model: Managerial Costs

- Using elasticities, compute profit losses from centralized pricing
- Loss in profit is function of dispersion of elasticities
- About 1% assuming no fixed costs (understates loss)
- Do chains with higher losses respond more?

**Weekly Corr of LogP vs. Lost Profits**
Shrunk Elasticity

**Quarterly Abs Log Diff vs. Lost Profits**
Shrunk Elasticity

- Elasticity floor of 1.2 used in calculating lost profits
- Each observation is a retailer
- Size of marker proportional to number of stores in retailer
- Regression line with analytic weights (SE clustered by parent_code): -4.7969 (2.8664)
- Regression line with analytic weights (SE clustered by parent_code): 0.3944 (0.4867)
Conclusion

- Retail firms respond little to local demand
  - Robust to product choice, chain, and sector
  - Some response to price elasticity, but small magnitude
  - Thus, they appear to forgo profit opportunities

- Explanations?
  - Could be managerial attention cost
  - BUT need to explain positive slope

  - Could be fairness constraint
  - BUT is it plausible in US grocery sector?

- In any case, important fact to contend with
Evidence on Model: Explanations

- Possible explanation: *Pricing Inertia*
- Implication 2: Tailored pricing more likely for items with larger revenue (if fixed cost of tailored pricing)
Evidence on Model: Explanations

- Possible explanation: *Pricing Inertia*
  - Implication 3: Chains likely to learn over time
  - Not much evidence for this
Evidence on Model: Price v. Elasticity, by Chain

- Notice: Most chains have no slope: Chain 117

Parent Code 117 by State

Line of best fit coef (robust SE): 0.0056 (0.0037). R-squared = 0.00773
Evidence on Model: Price v. Elasticity, by Chain

- Some chains though have clear slope: Chain 50
Evidence on Model: Price v. Elasticity, by Chain

- Some chains have clear slope: Chain 236
Evidence on Model: Price vs. Elasticity, by Chain

- Other chains have intercepts by region: Chain 32