Diagnosing Price Dispersion

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Hospitals Pay Different Prices for the Same Inputs

RQ1: What causes this variation in prices across buyers?
RQ2: How does it differ across product markets?

Figure: Price Dispersion in Top Supply Categories

- Supply costs direct to hospital profit margin ($\overline{OpMarg}_h, 2013 = 3.1\%$)
- Supplies in data $\approx 23\%$ hospital operating costs
Why Does the “Law of One Price” Fail?

- **Demand** preference heterogeneity
  - End-user (and institutional) preferences over characteristics, price, brands

- **Supply** cost, bargaining, and contracting heterogeneity
  - Distribution costs, geography, and size
    [Chipty Snyder 1999; Syverson 2004; Salz 2017]
  - Relative bargaining skill, effort, and information
    [Goldberg 1996; Scott Morton et al 2011; Crawford Yurukoglu 2012; Grennan Swanson 2016]
  - Contract structure – nonlinear contracts, bundling, exclusion
    [Bonnet Dubois 2015; Ghili 2017; Ho Lee 2018; Liebman 2018]

- **Search/diligence/contracting** cost to buyer
Why Do We Care About Price Dispersion?

- Price dispersion linked to market power → efficiency (B2B ⇒ misallocation of hospital supplies + downstream pass-through to health care costs)

- Welfare implications depend on underlying economic mechanisms
  - E.g.: Information can affect bargaining and/or search costs
    
    **Amazon poised to deliver disruption in medical supply industry**
    
    By Alex Krailo | June 10, 2017

    Amazon is on the healthcare industry’s doorstep. The e-commerce giant continues to transform virtually every segment of the economy as it leverages its massive distribution network to deliver logistical harmony. With a stronghold on the consumer market, Amazon is eying the business-to-business segment as it builds its seller base. Soon, that familiar smiling brown box will make its way from porches to providers’ front doors and that may make for some disgruntled medical supply distributors.

    **E.g.:** Consolidation across product markets by hospital suppliers can lower search/distribution costs and raise quality, but also increase market/bargaining power [Lewis & Pflum 2014, 2016; Dafny et al 2017; Schiraldi et al 2017]

    **Becton Dickinson To Acquire C.R. Bard For $24 Billion**
    
    Apr. 24, 2017 1:03 PM ET

    Becton Dickinson is buying C.R. Bard for $24 billion in cash and stock.

    The large deal will transform BDX by adding Bard’s cancer, vascular and urology business lines and potential strategic and cross-selling opportunities.

- Further unpack determinants of firm productivity, size, markups across different product markets [De Loecker 2011; Hottman et al 2016; De Loecker Eeckhout 2017]
Outline of Today’s Talk

1. Institutional Context: Hospital Purchasing of Medical/Surgical Supplies
2. Data: Hospital Purchase Orders
3. Model, Research Design, and Estimation
4. Results: Sources of Price Dispersion and Market Power
Institutional Context: Hospital Purchasing of Medical/Surgical Supplies

Data: Hospital Purchase Orders

Model, Research Design, and Estimation

Results: Sources of Price Dispersion and Market Power
Hospital administrators generate choice set... perhaps with input from providers. Providers choose products from choice set to treat patients. Vendors (and administrators) potentially active across categories in hospital; some "far away" with unrelated providers and sales forces.

Institutional Context: Medical/Surgical Supplies

Vendors/products (e.g. coronary stents)

Hospital service unit (e.g. catheter lab)

Administrators

Providers

Patients
Institutional Context: Medical/Surgical Supplies

- **Hospital administrators** generate choice set
- Providers choose products from choice set to treat patients
- Vendors (and administrators) potentially active across categories in hospital; some “far away” with unrelated providers and sales forces

## Diagram

- **Hospital service unit** (e.g. catheter lab)
- **Vendors/products** (e.g. coronary stents)
- **Administrators**
  - solicit vendor proposals
  - due diligence on quality
  - negotiate contracts
- **Providers**
- **Patients**
Institutional Context: Medical/Surgical Supplies

- Administrators
  - solicit vendor proposals
  - due diligence on quality
  - negotiate contracts
- Providers
- Patients

Hospital service unit (e.g. catheter lab)

Vendors/products (e.g. coronary stents)

- Hospital administrators generate choice set
- ... perhaps with input from providers
Institutional Context: Medical/Surgical Supplies

Vendors/products (e.g. coronary stents)

Hospital service unit (e.g. catheter lab)

Administrators
- solicit vendor proposals
- due diligence on quality
- negotiate contracts

Providers
- product usage decisions
- revenue/surplus generated

Patients

Hospital administrators generate choice set
... perhaps with input from providers

Providers choose products from choice set to treat patients
Institutional Context: Medical/Surgical Supplies

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- solicit vendor proposals
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Providers
- product usage decisions
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Patients
Institutional Context: Hospital Purchasing of Medical/Surgical Supplies

Data: Hospital Purchase Orders

Model, Research Design, and Estimation

Results: Sources of Price Dispersion and Market Power
Data: Hospital Purchase Orders

- Benchmarking database of all purchase orders issued $\sim 20\%$ of US hospitals, 2009-15 ($\sim 30\%$ more large and western hospitals than AHA sample)
- $(p, q)$ 2 million SKUs in 3,000+ categories, monthly
- Challenges: transactions vs. contracts; SKUs vs. products and characteristics; market size estimation

|                      | $N_h$ | $\text{Spend} \, $1000s | $p$  | $\mu$ | $\sigma$ | $|J|$ | $|J_h|$ | $\mu$ | $\sigma$ | $P[j^* \in J_h]$ | $P[j^* = j^*_h]$ |
|----------------------|-------|--------------------------|------|-------|----------|------|--------|-------|----------|-----------------|-----------------|
| **Non PPI**          |       |                          |      |       |          |      |        |       |          |                 |                 |
| Bone Nails           | 470   | $175$                    | 1,404| 0.15  |          | 149  | 15     | 0.46  |          | 0.77            | 0.21            |
| Trocars              | 593   | $60$                     | 40   | 0.18  |          | 204  | 7      | 0.54  |          | 0.29            | 0.11            |
| Sutures              | 647   | $16$                     | 8    | 0.14  |          | 450  | 11     | 0.57  |          | 0.23            | 0.11            |
| **Average(24)**      | 441   | $109$                    | 394  | 0.13  |          | 144  | 7      | 0.54  |          | 0.34            | 0.16            |
| **Physician Preference Item** |       |                          |      |       |          |      |        |       |          |                 |                 |
| Pacemakers           | 357   | $534$                    | 4,376| 0.11  |          | 53   | 11     | 0.42  |          | 0.90            | 0.32            |
| Drug Eluting Stents  | 314   | $1,028$                  | 1,571| 0.05  |          | 9    | 4      | 0.36  |          | 0.81            | 0.40            |
| Acetabular Hip Prosth. | 458  | $265$                    | 1,418| 0.23  |          | 143  | 17     | 0.56  |          | 0.71            | 0.30            |
| **Average(6)**       | 324   | $383$                    | 1,951| 0.13  |          | 95   | 10     | 0.50  |          | 0.61            | 0.26            |
Data: Hospital Purchase Orders

- PPI vs. non: PPIs used less, but price and total spend higher
- Price variation across hospitals substantial for all product categories
- Evidence of search costs and/or preference heterogeneity for nearly all categories; more in non-PPI (where preference heterogeneity less likely)

|                  | Nh  | Spend  | p   | |J| | |Jh| |P[j*∈Jh]| |P[j*≡j*]|
|------------------|-----|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                  |     | $1000s | $    | µ  | σ   | µ   | σ   |     |     |     |     |
| Non PPI          |     |        |      |     |     |     |     |     |     |     |     |
| Bone Nails       | 470 | $175   | $1,404 | 0.15 | 149 | 15 | 0.46 | 0.77 | 0.21 |
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Price $p_{jht}$ and Hospital Size, etc.

Little (if any) price variation explained by hospital characteristics (size, public, teaching, etc.) based on hospital effects from: $p_{jht} = \alpha_{jt} + \alpha_h + e_{jht}$
Choice Sets $\mathcal{J}_{ht}$ and Other Spend $Z_{v_{jht}}^{\text{far}_j}$

$j \in \mathcal{J}_{ht}$ predicted by percent hospital spend with vendor in other, far categories:

$$1\{j \in \mathcal{J}_{ht}\} = \alpha_{jt} + \alpha_{v_j, hrr_h} + \alpha_h + \alpha_{\text{far}} 1\{Z_{v_{jht}}^{\text{far}_j} > \text{median}\} + e_{jht}$$
Other Spend $Z_{vht}^{far}$, Choice Sets $\mathcal{J}_{ht}$, and Prices $p_{jht}$

Bargaining model “test”: Nash-in-Nash w/ no exclusion $\Rightarrow \frac{\partial p}{\partial |\mathcal{J}_{ht}|} < 0$

$$p_{jht} = \alpha_{jt} + \alpha_{v_{j},hrr} + \alpha_{|\mathcal{J}|} |\mathcal{J}_{ht}| + \alpha_{far} 1\{Z_{v_{j}ht}^{far} > \text{median}\} + e_{jht}$$

β_{far} and exclusion “test”
Institutional Context: Hospital Purchasing of Medical/Surgical Supplies

Data: Hospital Purchase Orders

Model, Research Design, and Estimation

Results: Sources of Price Dispersion and Market Power
Model Overview: Primitives, Timing, and Challenges

PRICING
\[ p_{hj}(\gamma_{hj}, \theta_h(J), J_h, \beta_h(J)) \]

DEMAND
\[ q_{hj}(J_h, \theta_h(J_h), p_h(J_h)) \]

SEARCH
\[ J_h(\psi_h, \theta_h(J), \beta_h(J)) \]

Model Timing
1. Search
2. Pricing
3. Demand
Model – Math

For a given UMDNS Category: Products $j = 0, 1, \ldots, J \in \mathcal{J}$ via Vendors $v = 1, \ldots, V$ to Hospitals $h = 1, \ldots, H$ in Years $t = 2009, \ldots, 2015$:

1. Hospital $h$ has ex ante beliefs regarding brand $j$ and time $t$ defined by:
   - Preferences $\theta_{jt} + \theta_{vj,hrr} + \theta_{h} + \xi_{jht}^o + \xi_{jht}^u$ (unknown $\xi_{jht}^u \sim N(0, \sigma_{\xi})$)
   - Costs of production/distribution $mc_{jh} = X_{jh}\gamma$ (known)
   - Bargaining $\frac{\beta_{jt}}{\beta_{h}} \nu_{jht}$ (unknown $\ln(\nu_{jht}) \sim N(X_{jht}^{info}\beta_{info}, \sigma_{\nu})$)
   - Search costs/frictions $X_{jht}^{sc}\psi + \mu_{jht}$ (known)

2. Hospital consideration set $\mathcal{J}_{ht}$ determined, and $\{\xi_{jht}^u\}, \{\nu_{jht}\}$ realized via search/contracting process.

3. Contract prices $p_{jht}(mc_{j}, \mathcal{J}_{ht}, \theta_{jht}, \beta_{jht})$ determined.

4. Quantities $q_{jht}(\mathcal{J}_{ht}, p_{jht}, \theta_{jht})$ realized.

Identification challenges:

- supply and demand: price may be a function of $\xi_{jht}^o + \xi_{jht}^u$
- search and demand: choice set may be a function of $\xi_{jht}^o$
Model Overview: Primitives, Timing, and Challenges

Solving Backwards
1. Demand $\theta_h$
2. Pricing
3. Search

PRICING
$p_{hj}(\gamma_{hj}, \theta_h(J), J_h, \beta_h(J))$

DEMAND
$q_{hj}(J_h, \theta_h(J_h), p_h(J_h))$

SEARCH
$J_h(\psi_h, \theta_h(J), \beta_h(J))$
Identification Challenge: Search and Demand

Problem: Choice set determined by search + contracting process

- Search + contracting process likely incorporates preferences, including $\xi_{jht}^o$ [observed to hospital, unobserved to econometrician]
- Analogous to selection problem in labor economics [Heckman 1979; Powell 1994]

Solution: Control function $E[\xi_{jht}^o | j \in J_{ht}]$ using reduced form search model

$$1\{j \in J_{ht} \} = \alpha_{jt}^s + \alpha_{vj,h}^s + \alpha_{h}^s + f(Z_{vj,ht}^{far}; \alpha_{far}^s) + e_{jht}^s$$

- Instrument: exposure to vendor in other “far away” categories
- Intuition: proxy for administrator search/contracting cost shifters Analogous to [Hausman (1996); Nevo (2001)]: prices in other markets
- Exclusion restriction: exposure of $h$ to $v_j$ in “far away” categories ($Z_{vj,ht}^{far}$) only affects $s_{jht}$ via choice set
Model Overview: Primitives, Timing, and Challenges

Solving Backwards
1. Demand $\theta_h$
2. Pricing
3. Search

PRICING
$p_{hj}(\gamma_{hj}, \theta_h(J), J_h, \beta_h(J))$

DEMAND
$q_{hj}(J_h, \theta_h(J_h), p_h(J_h))$

SEARCH
$J_h(\psi_h, \theta_h(J), \beta_h(J))$
Identification Challenge: Pricing and Demand

Classic problem: price a function of unobservable determinants of demand

Solution: instruments from Grennan & Swanson (2018) – price renegotiations after hospitals join benchmarking information service

\[ p_{jht} = \alpha_{jt}^p + \alpha_{v_j,hrr_h}^p + \alpha_{h}^p + Z_{jht}^{info} \alpha_{info}^p + e_{jht}^p \]

where \( Z_{jht}^{info} = \) interactions \( (1_{\{postjoin_{jht}\}}, 1_{\{q_{jht}>p75(q)\}}, 1_{\{p_{jht}>p80(p)\}}) \)
Demand and Supply: Details and Estimation

Faced with situation/patient/provider $i$ in hospital $h$ in month $t$, choose product $j \in J_{ht}$ so that:

$$\ln \left( \frac{S_{jht}}{S_{0ht}} \right) = \lambda_g \ln \left( \frac{S_{jht}}{S_{ght}} \right) + \theta_h + \theta_{jt} - \theta^P p_{jht} + \theta^{IMR} \frac{\phi(Z_{jht}^s \hat{\alpha}^s)}{1 - \Phi(Z_{jht}^s \hat{\alpha}^s)} + \xi_{jht}$$

Suppose price for hospital $h$, product $j$ determined by Nash bargaining, in Nash equilibrium with other products in $J_{ht}$:

$$p_{jh} = mc_j + \frac{b_j(h)}{b_j(h) + b_h(j)} \left[ \left( 1 + \frac{\partial q_{jh}}{\partial p_{jh}} \frac{p_{jh} - mc_j}{q_{jh}} \right) \frac{\pi_h(J_h) - \pi_h(J_h \setminus j)}{q_{jh}} + p_{jh} - mc_j \right]$$

- $\frac{\partial q_{jh}}{\partial p_{jh}}$ and $\pi_h(\cdot)$ are functions of demand estimates
- let $mc_{jht} = X_{jht}^{mc} \gamma$ (for now $mc_j = \gamma \min_{ht} = (p_{jht})$)
- let $b_{jt}(h) = e^{\beta_{jt} - \beta_h - Z_{jht}^{Info} \beta^{Info} + \nu_{jht}}$
- GMM joint estimation supply and demand
Model Overview: Primitives, Timing, and Challenges

Solving Backwards
1. Demand $\theta_h$
2. Pricing $\gamma_{hj}, \beta_h$
3. Search $\psi_h$

PRICING
$p_{hj}(\gamma_{hj}, \theta_h(J), J_h, \beta_h(J))$

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$q_{hj}(J_h, \theta_h(J_h), p_h(J_h))$

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Demand and Bargaining Estimates

- $\theta^p \Rightarrow$ PPIs less price sensitive (levels and relative)
- margins $\frac{p-mc}{p} \approx 18-77\%$
- bargaining share to vendor $B \approx 1-42\%$ (lower for commodities)

<table>
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<th></th>
<th>$p$</th>
<th>$\lambda$</th>
<th>$\theta^p$</th>
<th>$AV^{CS}$</th>
<th>$\frac{p-mc}{p}$</th>
<th>$B$</th>
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<tr>
<td>Pacemakers</td>
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<td>$0.21$</td>
<td>-0.390</td>
<td>$3,369$</td>
<td>$0.15$</td>
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Quantifying the Sources of Price Variation 1/2

Cut for time: search/contracting cost estimation using moment inequalities

- Complex problem with no “shortcuts”: similar to optimal portfolio choice, hospital network formation, etc. (and large product/vendor space $\mathcal{J}$)
- Use fact that products are substitutes to generate bounds based on $(\emptyset, \mathcal{J})$, robust to different models of choice set formation
- Mostly point identified; $\approx 10\%$ of price

Search/Contracting Cost Estimation and Results

Decomposition exercise: fix $t = 2014$, compute counterfactual $(p, q)$

1. for $\mathcal{J}_{ht}$, with bargaining $-\sigma_B$ and demand $-\sigma_D$ heterogeneity removed
2. for $\mathcal{J}_t$ (no search/contracting frictions)

\[
p_{jh} - mc_j = \beta_{jh} \underbrace{\text{AV}_{jh}(\theta; \mathcal{J}_h)}_{\text{Bargaining Demand & Search}}
\]
bargaining drives more hetero (than demand) across hospitals
eliminating search/contracting frictions lowers prices some, but mostly increases CS via more/better products

<table>
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<th>$E[CS(J_t) - CS(J_{ht})]$</th>
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<td>0.15</td>
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<td><strong>Average(24)</strong></td>
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<td>Drug Eluting Stents</td>
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<td><strong>Average(6)</strong></td>
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<td>0.14</td>
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Takeaways and Future Directions

Takeaways:
- Extensive panel data + Exposure and Info IV + Model of demand/bargaining/search → identify frictions underlying price dispersion (and markups) for a wide variety of hospital supply markets
- Search frictions meaningful, but markups mostly product differentiation (bargaining important to keep prices down)
- Price dispersion across hospitals 12% demand; 88% bargaining (average across 30 product categories)

Future directions:
- This paper: vendors, costs($q$), and “dynamics” via $t - 1$ data
- Many research questions require full (not-quite-optimal) search model
- Pass-through to cost of care requires pairing with claims data and device-procedure crosswalk
Appendix
Monte Carlo Evidence

- Endogenous consideration set: LPM or probit

\[
\begin{pmatrix}
\epsilon_{\text{search}} \\
\xi^0_{\text{demand}}
\end{pmatrix}
\sim
N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix}
\sigma_1^2 & \rho \\
\rho & \sigma_2^2
\end{pmatrix}\right)
\]

Note: Non-random (endogenous) search. True search model: linear probability model.

(a) **LPM**

(b) **Probit**
Price $p_{jht}$ and Teaching

Little (if any) price variation explained by hospital characteristics (size, public, teaching, etc.) based on hospital effects from: $p_{jht} = \alpha_{jt} + \alpha_h + e_{jht}$
Price $p_{jht}$ and Size

\[
\ln(p_{jht}) = \alpha_{jt} + \alpha^{\text{beds}} \ln(beds_{jht}) + e_{jht}
\]
Other Spend $Z_{vht}^{far}$, Choice Sets $J_{ht}$, and Prices $p_{jht}$

Bargaining model test: Exclusion $\Rightarrow \frac{\partial p}{\partial |J_{ht}|} > 0$; $\frac{\partial p}{\partial |J_{search}^{|}}} < 0$ (all else equal)

$p_{jht} = \alpha_{jt} + \alpha_{v_{j},hrr_{h}} + \alpha |J| |J_{ht}| + \alpha^{far} 1\{Z_{v_{j},ht}^{far} > median\} + e_{jht}$

(proxy for $|J_{search}^{|}$)
Search: Challenges and Potential Solutions

- Repeat purchases from $\mathcal{J}_{ht}$, so composition matters, similar to optimal retailer assortment or portfolio choice ($\Rightarrow$ no Weitzman (1979))

- Preferences, bargaining, search costs likely heterogeneous across products ($\Rightarrow$ no Chade and Smith (2006))

- Thus, computation of optimal search models difficult for large $|\mathcal{J}|$

- Our approach: moment inequalities based on weaker/stronger search assumptions
  1. Very weak assumptions are still informative
  2. Adding inequalities based on stronger assumptions $\Rightarrow$ identical results to full search model with those assumptions
  3. Computationally tractable because expected benefits of search computed prior to search cost estimation
Search Cost Estimation with Moment Inequalities

Products in $\mathcal{J}_{ht}$ provide upper bound on search costs:

- Assume $\mathcal{J}_{ht} \subseteq \mathcal{J}_{ht}^{search}$. Then $j \in \mathcal{J}_{ht}$ worth searching.
- For substitutes, weakest assumption comes from value vs. outside good:

$$E_\xi[AV_{jht}(\theta_{jt}, \theta_{h}, \xi_{jht}; \emptyset)] \geq sc_{jht} = \psi_0 + \psi^Z Z_{hv_{jht}}$$

- Can further weaken with optimistic beliefs $\xi^O_{jht} = \max_{ht} \xi_{jht}$

Products in $\mathcal{J}_t \setminus \mathcal{J}_{ht}$ provide lower bound on search costs:

- Assume $\exists j \in \mathcal{J}_t \setminus \mathcal{J}_{ht}^{search}$. Then $j$ not worth searching.
- For substitutes, weakest assumption comes from value vs. full choice set:

$$E_\xi[AV_{jht}(\theta_{jt}, \theta_{h}, \xi_{jht}; \mathcal{J}_t)] \leq sc_{jht} = \psi_0 + \psi^Z Z_{hv_{jht}}$$

- Can further weaken by assuming pessimistic beliefs $\xi^O_{jht} = \min_{ht} \xi_{jht}$
- Take minimum of such bounds over potential $j \in \mathcal{J}_t \setminus \mathcal{J}_{ht}$
Search Cost Estimation with Moment Inequalities

Products in $\mathcal{J}_{ht}$ provide upper bound on search costs:

- Assume $\mathcal{J}_{ht} \subseteq \mathcal{J}_{ht}^{\text{search}}$. Then $j \in \mathcal{J}_{ht}$ worth searching
- For substitutes, weakest assumption comes from value vs. outside good:
  \[
  E_\xi[AV_{jht}(\theta_{jt}, \theta_{h}, \xi_{jht}; \emptyset)] \geq sc_{jht} = \psi^0 + \psi^Z Z^s_{hv_{j,t}}
  \]
- Can further weaken with optimistic beliefs $\xi^o_{jht} = \max_{h,t} \xi_{jht}$

Products in $\mathcal{J}_t \setminus \mathcal{J}_{ht}$ provide lower bound on search costs:

- Assume $\exists j \in \mathcal{J}_t \setminus \mathcal{J}_{ht}^{\text{search}}$. Then $j$ not worth searching
- For substitutes, weakest assumption comes from value vs. full choice set:
  \[
  E_\xi[AV_{jht}(\theta_{jt}, \theta_{h}, \xi_{jht}; \mathcal{J}_t)] \leq sc_{jht} = \psi^0 + \psi^Z Z^s_{hv_{j,t}}
  \]
- Can further weaken by assuming pessimistic beliefs $\xi^o_{jht} = \min_{h,t} \xi_{jht}$
- Take minimum of such bounds over potential $j \in \mathcal{J}_t \setminus \mathcal{J}_{ht}$
mostly point identified (at $\bar{\xi}$); $\simeq 10\%$ of price

vendor spend in other categories sometimes matters ($\simeq 1\%$)

<table>
<thead>
<tr>
<th></th>
<th>$\psi^0$</th>
<th>$\psi_{\text{far}}$</th>
<th>$\psi^{t-1}$</th>
<th>$Z_{\text{far}}$</th>
<th>$1{t-1}$</th>
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<tbody>
<tr>
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<td>$\mu$</td>
<td>$\sigma$</td>
<td>$\mu$</td>
<td>$\sigma$</td>
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<tr>
<td><strong>Non PPI</strong></td>
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<tr>
<td>Bone Nails</td>
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<td>-0.0</td>
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<td>-0.0</td>
<td>-0.0</td>
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<td>0.50</td>
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<tr>
<td>Sutures</td>
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<td>-4.5</td>
<td>-1.6</td>
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<td>0.46</td>
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<td><strong>Physician Preference Item</strong></td>
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<tr>
<td>Pacemakers</td>
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<td>0.6</td>
<td>0.08</td>
<td>0.42</td>
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<tr>
<td>Drug Eluting Stents</td>
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<td>-2.8</td>
<td>-29.3</td>
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<td>0.31</td>
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<tr>
<td>Average(6)</td>
<td>186.3</td>
<td>0.1</td>
<td>-5.2</td>
<td>0.06</td>
<td>0.42</td>
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