Diagnosing Price Dispersion

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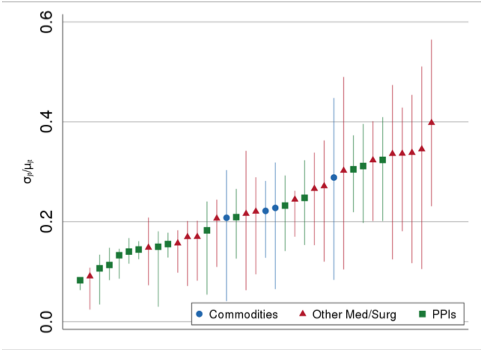
Hospitals Pay Different Prices for the Same Inputs

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 ≈23% hospital operating costs

Why Does the "Law of One Price" Fail?

- **Demand** preference heterogeneity
  - End-user (and institutional) preferences over characteristics, price, brands
    [McFadden 1978; Ho 2008; Bronnenberg et al. 2012, 2014; Grennan 2013, 2014]
- **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
  [Stigler 1961; Sorensen 2003; Hortacsu Syverson 2004; Jin Leslie 2006; Allen et al 2013, 2014, 2017; Fong Lee 2013; Salz 2017]

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 Kacik | 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: Medical/Surgical Supplies

Vendors/products (e.g. coronary stents)

Boston Scientific

Abbott Vascular

Medtronic

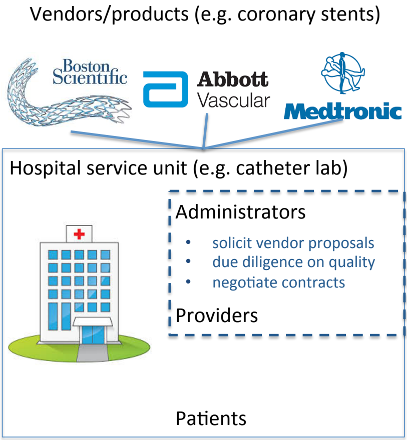
Hospital service unit (e.g. catheter lab)

Administrators

Providers

Patients

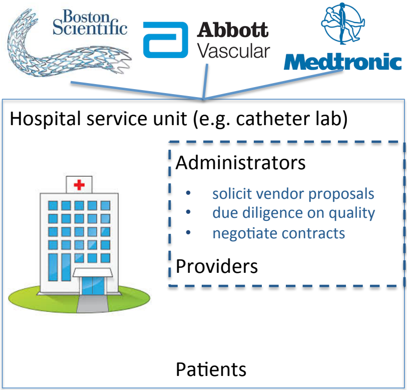
Institutional Context: Medical/Surgical Supplies



- Hospital administrators generate choice set

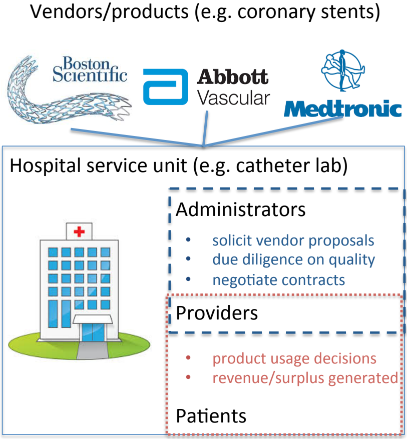
Institutional Context: Medical/Surgical Supplies

Vendors/products (e.g. coronary stents)



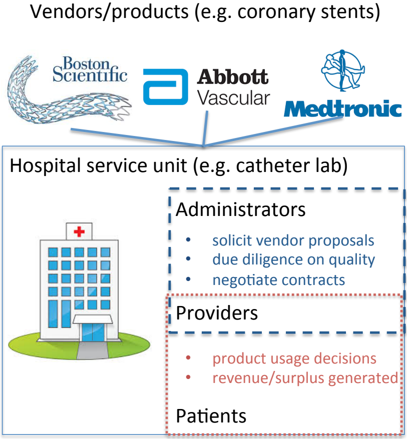
- Hospital administrators generate choice set
- ... perhaps with input from providers

Institutional Context: Medical/Surgical Supplies



- Hospital administrators generate choice set
- ... perhaps with input from providers
- Providers choose products from choice set to treat patients

Institutional Context: Medical/Surgical Supplies



- 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

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	Spend	p		$\lvert\mathcal{J}\rvert$	$\lvert\mathcal{J}_h\rvert$		$P[j^* \in \mathcal{J}_h]$	$P[j^* = j_h^*]$
		\$1000s	μ	$\frac{\sigma}{\mu}$		μ	$\frac{\sigma}{\mu}$		
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)

	N_h	Spend	p		$\lvert\mathcal{J}\rvert$	$\lvert\mathcal{J}_h\rvert$		$P[j^* \in \mathcal{J}_h]$	$P[j^* = j_h^*]$
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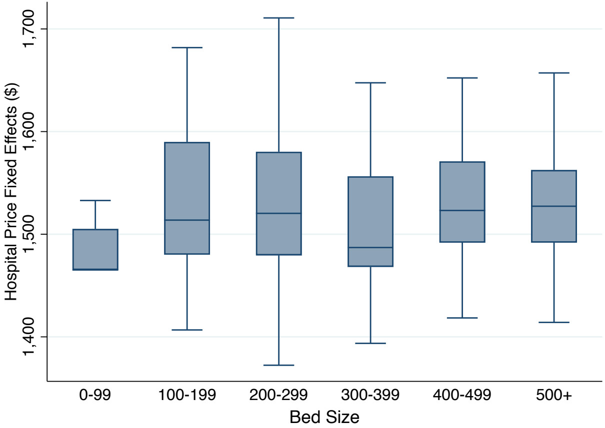
Price p_{jht} and Hospital Size, etc.

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



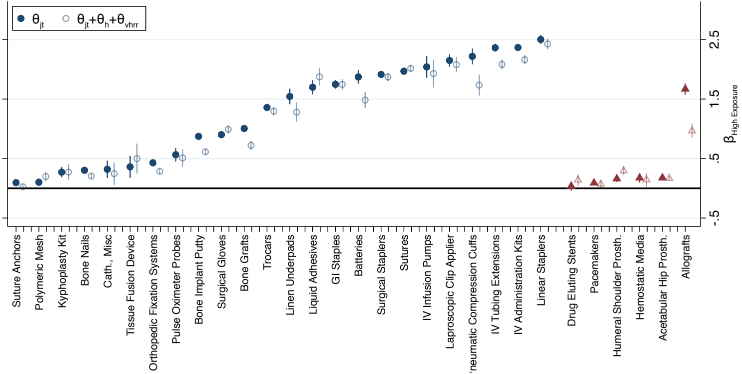
p and other hospital characteristics

Across all UMDNS

Choice Sets $\mathcal{J}_{ht}$ and Other Spend $Z^{far_j}_{v_j ht}$

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

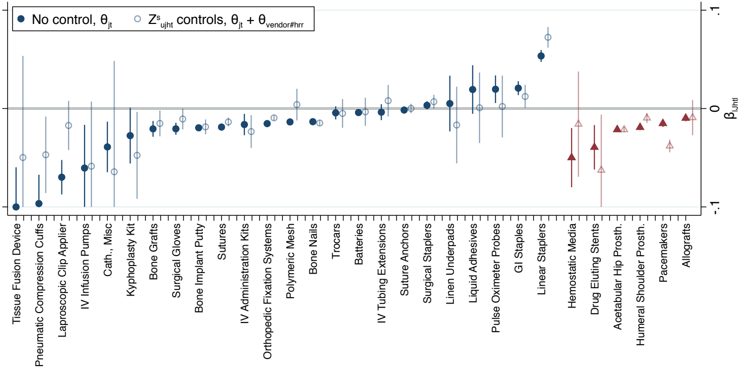
$$1\{j \in \mathcal{J}_{ht}\} = \alpha_{jt} + \alpha_{v_j,hrr_h} + \alpha_h + \alpha^{far} 1\{Z^{far_j}_{v_j ht} > median\} + e_{jht}$$



Other Spend Z^{far}_{vht}, Choice Sets $\mathcal{J}_{ht}$, and Prices p_{jht}

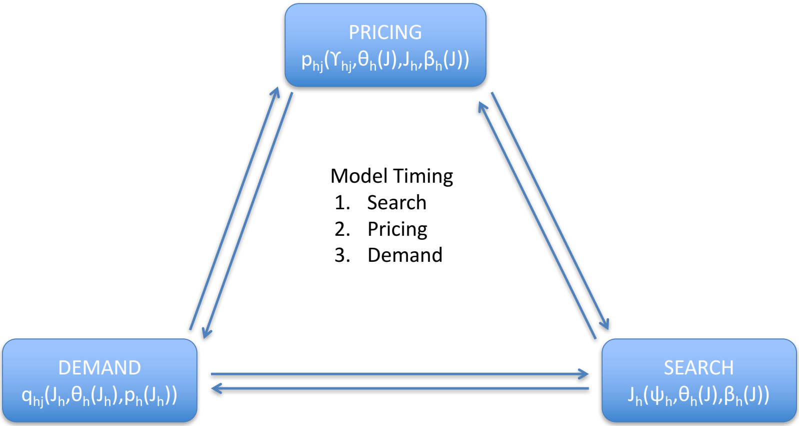
Bargaining model "test": Nash-in-Nash w/ no exclusion $\Rightarrow \frac{\partial p}{\partial |\mathcal{J}_{ht}|} < 0$

$$p_{jht} = \alpha_{jt} + \alpha_{v_j, hrr_h} + \alpha^{|\mathcal{J}|} |\mathcal{J}_{ht}| + \alpha^{far} \underbrace{1\{Z^{far_j}_{v_j ht} > median\}}_{\text{proxy for } |\mathcal{J}^{search}_{ht}|} + e_{jht}$$



β^{far} and exclusion "test"

Model Overview: Primitives, Timing, and Challenges



Model – Math

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

1. Hospital h has ex ante beliefs regarding brand j and time t defined by:

   Preferences $\theta_{jt} + \theta_{v_j,hrr_h} + \theta_h + \xi^o_{jht} + \xi^u_{jht}$ (unknown $\xi^u_{jht} \sim N(0, \sigma_\xi)$)

   Costs of production/distribution $mc_{jh} = X_{jh}\gamma$ (known)

   Bargaining $\frac{\beta_{jt}}{\beta_h}\nu_{jht}$ (unknown $\ln(\nu_{jht}) \sim N(X^{info}_{jht}\beta^{info}, \sigma_\nu)$)

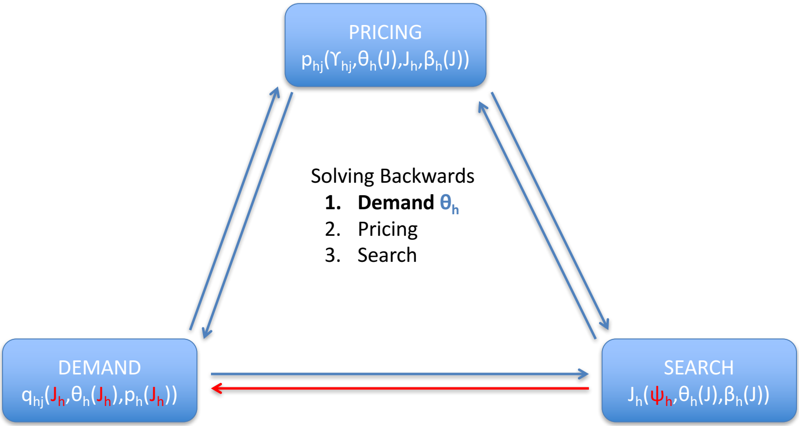
   Search costs/frictions $X^{sc}_{jht}\psi + \mu_{jht}$ (known)

2. Hospital consideration set $\mathcal{J}_{ht}$ determined, and $\{\xi^u_{jht}\}, \{\nu_{jht}\}$ 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 $\xi^o_{jht} + \xi^u_{jht}$
- search and demand: choice set may be a function of ξ^o_{jht}

Model Overview: Primitives, Timing, and Challenges



Identification Challenge: Search and Demand

Problem: Choice set determined by search + contracting process

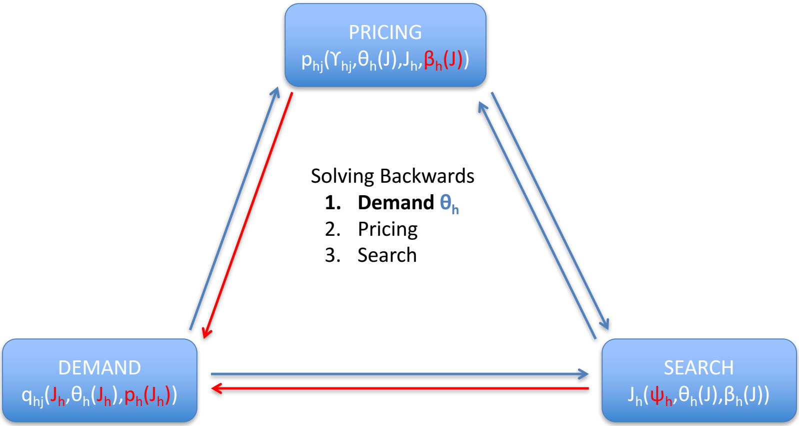
- Search + contracting process likely incorporates preferences, including ξ^o_{jht}
  [observed to hospital, unobserved to econometrician]
- Analogous to selection problem in labor economics
  [Heckman 1979; Powell 1994]

Solution: Control function $E[\xi^o_{jht} | j \in \mathcal{J}_{ht}]$ using reduced form search model

$$1\{j \in \mathcal{J}_{ht}\} = \alpha^s_{jt} + \alpha^s_{v_j, hrr_h} + \alpha^s_h + f(Z^{far_j}_{v_j ht}; \alpha^s_{far}) + e^s_{jht}$$

- 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 ($Z^{far_j}_{v_j ht}$) only affects s_{jht} via choice set

Model Overview: Primitives, Timing, and Challenges



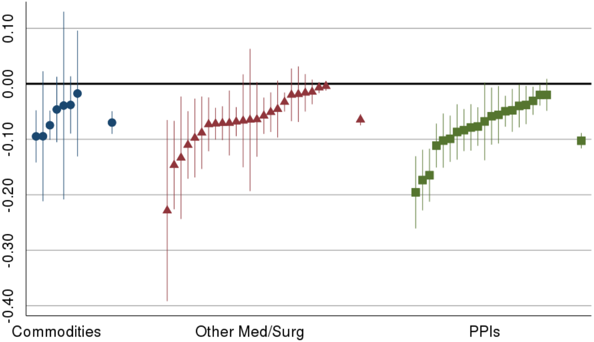
Identification Challenge: Pricing and Demand

Classic problem: price a function of unobservable determinants of demand

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

$$p_{jht} = \alpha^p_{jt} + \alpha^p_{v_j,hrr_h} + \alpha^p_h + Z^{info}_{jht}\alpha^p_{info} + e^p_{jht}$$

where Z^{info}_{jht} = 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 $j \in \mathcal{J}_{ht}$ so that:

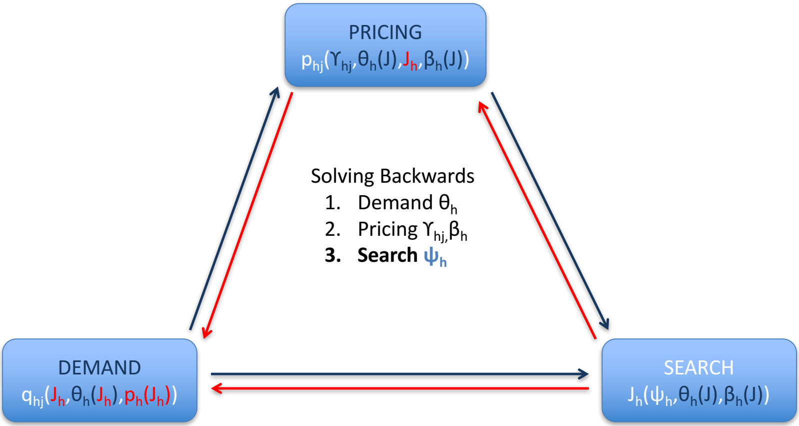
$$\ln\left(\frac{s_{jht}}{s_{0ht}}\right) = \lambda_g \ln\left(\frac{s_{jht}}{s_{ght}}\right) + \theta_h + \theta_{jt} - \theta^p p_{jht} + \theta^{IMR}\frac{\phi(Z^s_{jht}\hat{\alpha}^s)}{1-\Phi(Z^s_{jht}\hat{\alpha}^s)} + \xi^u_{jht}$$

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

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

- $\frac{\partial q_{jh}}{\partial p_{jh}}$ and $\pi_h(\cdot)$ are functions of demand estimates
- let $mc_{jht} = X^{mc}_{jht}\gamma$ *(for now $mc_j = \gamma \min_{ht} = (p_{jht})$)*
- let $\frac{b_{jt}(h)}{b_{ht}(j)} = e^{\beta_{jt}-\beta_h-Z^{Info}_{jht}\beta^{Info}+\nu_{jht}}$
- GMM joint estimation supply and demand

Model Overview: Primitives, Timing, and Challenges



Demand and Bargaining Estimates

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

	p		λ	θ^p	AV^{CS}		$\frac{p-mc}{p}$		B	
	μ	$\frac{\sigma}{\mu}$		$*1000$	μ	$\frac{\sigma}{\mu}$	μ	$\frac{\sigma}{\mu}$	μ	$\frac{\sigma}{\mu}$
Non PPI										
Bone Nails	$1,404	0.15	0.09	-0.330	$1,893	0.12	0.61	0.09	0.32	0.23
Trocars	$40	0.18	0.18	-7.609	$95	0.09	0.31	0.36	0.13	0.56
Sutures	$8	0.14	0.16	-24.815	$33	0.03	0.20	0.38	0.05	0.53
Average(24)	$394	0.13	0.22	-20.443	$788	0.09	0.37	0.24	0.14	0.40
Physician Preference Item										
Pacemakers	$4,376	0.11	0.33	-0.086	$4,697	0.12	0.77	0.04	0.42	0.15
Drug Eluting Stents	$1,571	0.05	0.38	-0.789	$613	0.22	0.19	0.22	0.33	0.30
Acetabular Hip Prosth.	$1,418	0.23	0.00	-0.404	$1,816	0.20	0.42	0.31	0.27	0.51
Average(6)	$1,951	0.13	0.21	-0.390	$3,369	0.15	0.44	0.17	0.24	0.31

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; $\simeq 10\%$ 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)

$$p_{jh} - mc_j \quad = \quad \underbrace{\beta_{jh}}_{\text{Bargaining}} \quad \underbrace{AV_{jh}(\theta; \mathcal{J}_h)}_{\text{Demand \& Search}}$$

Quantifying the Sources of Price Variation 2/2

- bargaining drives more hetero (than demand) across hospitals
- eliminating search/contracting frictions lowers prices some, but mostly increases CS via more/better products

	$\mathcal{J}_{ht}$				$\mathcal{J}_{t}$				
	p		$p^{-\sigma_B}$	$p^{-\sigma_D}$	$p_{[w=q(\mathcal{J}_{ht})]}$		$p_{[w=q(\mathcal{J}_{t})]}$		$E[CS(\mathcal{J}_t) - CS(\mathcal{J}_{ht})]$
	μ	$\frac{\sigma}{\mu}$	$\%\frac{\sigma}{\mu}$	$\%\frac{\sigma}{\mu}$	μ	$\frac{\sigma}{\mu}$	μ	$\frac{\sigma}{\mu}$	
Non-PPI									
Bone Nails	\$1,441	0.15	2.7	101.0	\$1,436	0.15	\$1,437	0.07	\$2,803
Trocars	\$36	0.19	3.0	101.9	\$36	0.19	\$35	0.08	\$125
Sutures	\$8	0.15	1.0	101.8	\$8	0.15	\$7	0.06	\$36
Average(24)	\$396	0.13	14.1	109.8	\$393	0.12	\$378	0.07	\$939
Physician Preference Item									
Pacemakers	\$4,203	0.12	20.3	101.4	\$4,131	0.12	\$4,216	0.07	\$6,896
Drug Eluting Stents	\$1,504	0.06	30.2	103.0	\$1,493	0.06	\$1,522	0.04	\$632
Acetabular Hip Prosth.	\$1,426	0.22	1.4	101.5	\$1,424	0.22	\$1,395	0.13	\$2,700
Average(6)	\$1,905	0.14	18.5	103.7	\$1,888	0.14	\$1,855	0.07	\$4,622

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:

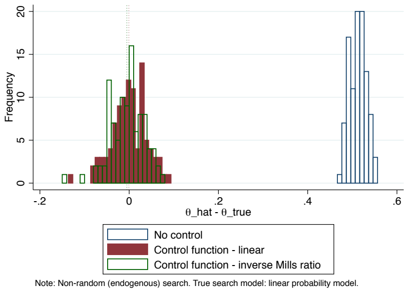
- This paper: vendors, costs(q), and "dynamics" via $t-1$ data
- Many research questions require full (not-quite-optimal) search model
- Pass-through to cost of care requires pairing with claims data and device-procedure crosswalk

Appendix

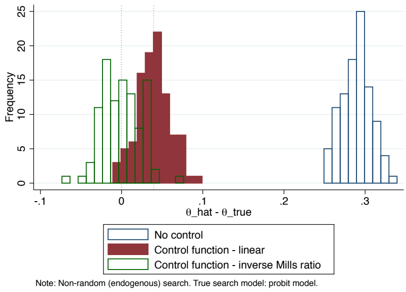
Monte Carlo Evidence

- Endogenous consideration set: LPM or probit

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



(a) *LPM*



(b) *Probit*

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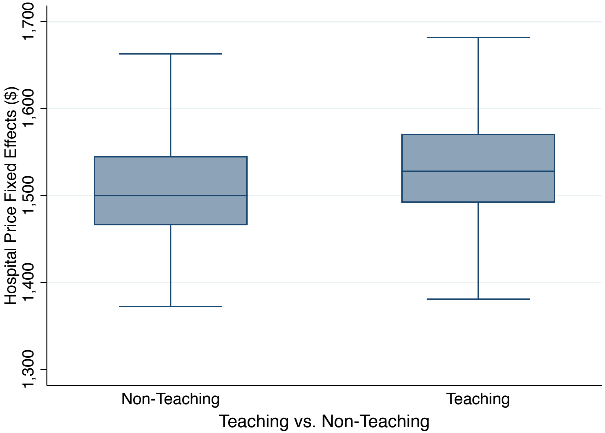
Price p_{jht} and Teaching

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



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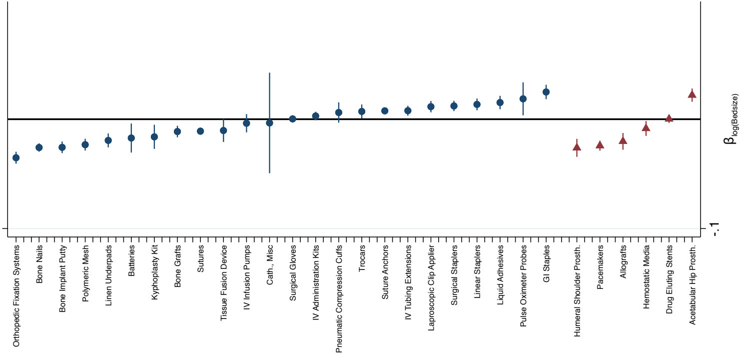
Price p_{jht} and Size

$$\ln(p_{jht}) = \alpha_{jt} + \alpha^{beds} \ln(beds_{jht}) + e_{jht}$$



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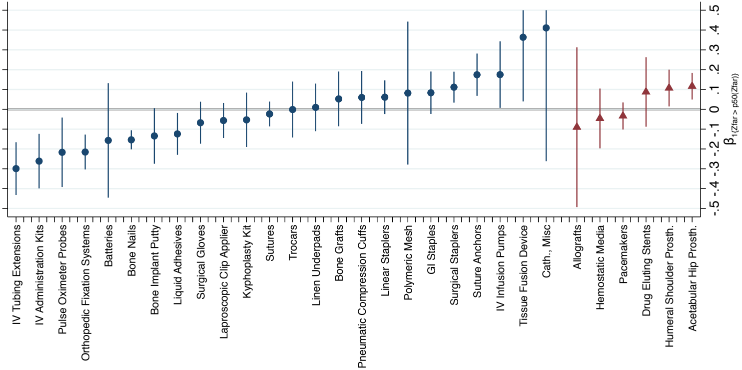
Other Spend Z^{far}_{vht}, Choice Sets $\mathcal{J}_{ht}$, and Prices p_{jht}

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

$$p_{jht} = \alpha_{jt} + \alpha_{v_j,hrr_h} + \alpha^{|\mathcal{J}|}|\mathcal{J}_{ht}| + \alpha^{far} \underbrace{1\{Z^{far_j}_{v_j ht} > median\}}_{\text{proxy for } |\mathcal{J}^{search}_{ht}|} + e_{jht}$$



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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 :

$$E_{\xi}[AV_{jht}(\theta_{jt}, \theta_h, \xi_{jht}; \emptyset)] \geq sc_{jht} = \psi^0 + \psi^Z Z^s_{hv_j t}$$

- 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 :

$$E_{\xi}[AV_{jht}(\theta_{jt}, \theta_h, \xi_{jht}; \mathcal{J}_t)] \leq sc_{jht} = \psi^0 + \psi^Z Z^s_{hv_j t}$$

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

$$E_{\xi}[AV_{jht}(\theta_{jt}, \theta_h, \xi_{jht}; \emptyset)] \geq sc_{jht} = \psi^0 + \psi^Z Z^s_{hv_jt}$$

- 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 :

$$E_{\xi}[AV_{jht}(\theta_{jt}, \theta_h, \xi_{jht}; \mathcal{J}_t)] \leq sc_{jht} = \psi^0 + \psi^Z Z^s_{hv_jt}$$

- 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/Contracting Cost Estimates

- mostly point identified (at $\bar{\xi}$); $\simeq$ 10% of price
- vendor spend in other categories sometimes matters ($\simeq$ 1%)

	ψ^0	ψ^{far}	ψ^{t-1}	Z^{far}		$1\{t-1\}$	
				μ	σ	μ	σ
Non PPI							
Bone Nails	31.7	0.0	-0.0	0.15	0.11	0.39	0.34
Trocars	1.9	-0.0	-0.0	0.09	0.08	0.50	0.31
Sutures	0.2	0.0	-0.0	0.09	0.08	0.49	0.30
Average(24)	39.2	-4.5	-1.6	0.10	0.08	0.46	0.30
Physician Preference Item							
Pacemakers	134.9	-0.1	0.6	0.08	0.07	0.42	0.33
Drug Eluting Stents	617.4	-2.8	-29.3	0.04	0.04	0.44	0.31
Acetabular Hip Prosth.	45.0	-0.0	-0.0	0.08	0.07	0.43	0.33
Average(6)	186.3	0.1	-5.2	0.06	0.06	0.42	0.32

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