Bargaining in B2B Markets

Guest Lecture for Penn PhD IO, Fall 2017

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A Little About Me

(Biomedical) Industrial Engineering

- Bioceramics research
- CPG manufacturing
- Leadership consulting

Strategy & Economics (research, teaching, consulting)

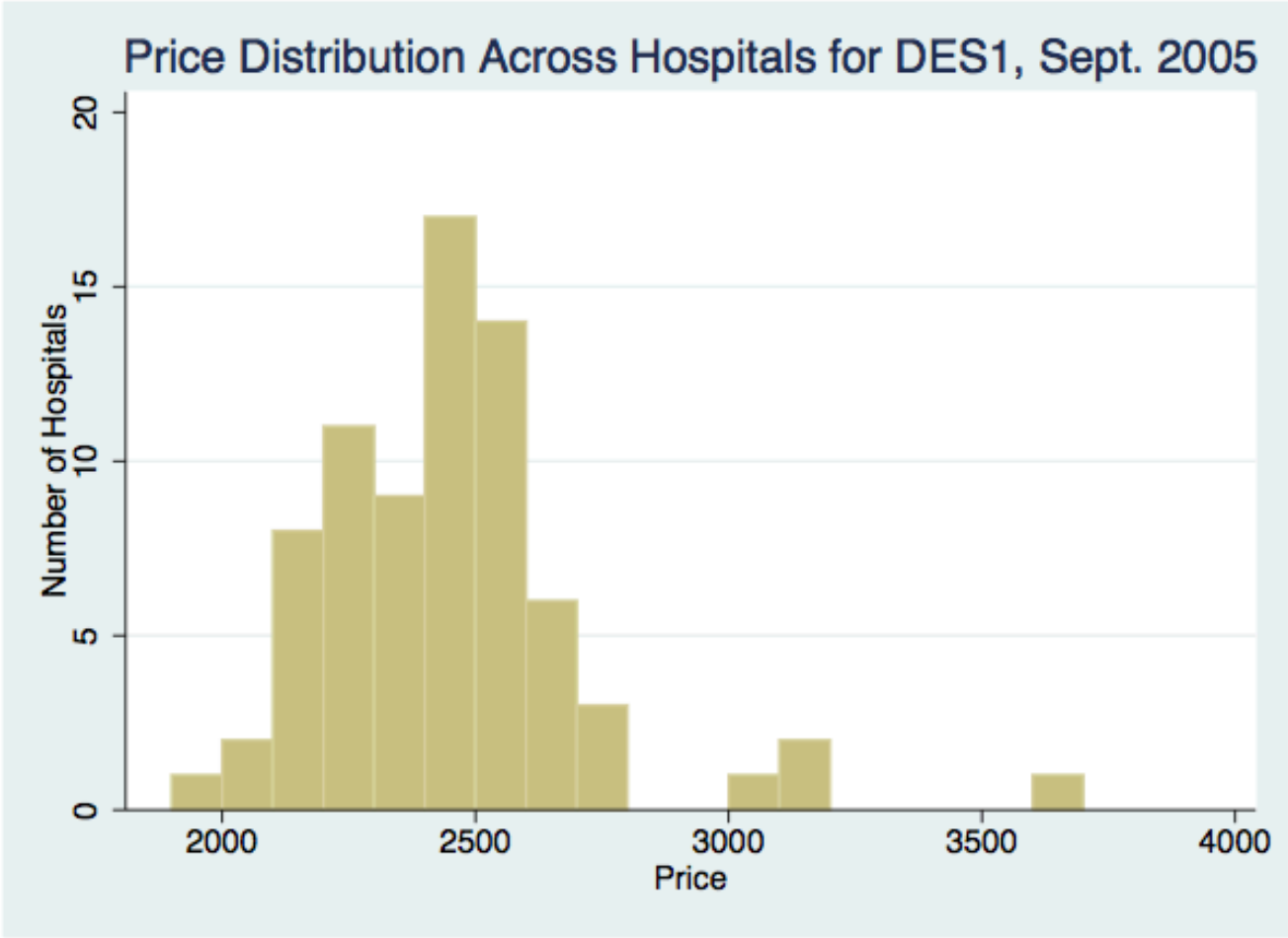
- Empirical Industrial Organization and Competitive Strategy
- Incentives, Bargaining, and Transparency in Hospital Input Pricing
- Medical Device Regulation, Adoption, and Diffusion
- Physician-Industry Ties
- (Healthcare) Entrepreneurship and Marketing/Commercialization

Today: Empirical Bargaining Research

- Huge parts of the world economy: B2C haggling; B2B contracting (auctions and/or bargaining)
- Tons of theory; very little empirics (but changing)
- Full information case extends oligopoly framework (Crawford & Yurukoglu 2012; Grennan 2013; Gowrisankaran et al 2014)
- Asymmetric information cases more varied (Sieg 2000; Keniston 2011; Larsen 2014; Backus et al 2016; Grennan & Swanson 2016; Silveira 2016)
- Search/contracting an important current area (Ho and Lee 2016a&b; Crawford et al 2016; Grennan & Swanson 2017)

Price Discrimination and Bargaining:
Empirical Evidence from Medical Devices
(Grennan 2013, *AER*)

Different Hospitals Pay Different Prices (for the exact same product)



Inter-Quartile Range = \$310/stent $\rightarrow$ \$300,000/year/hospital

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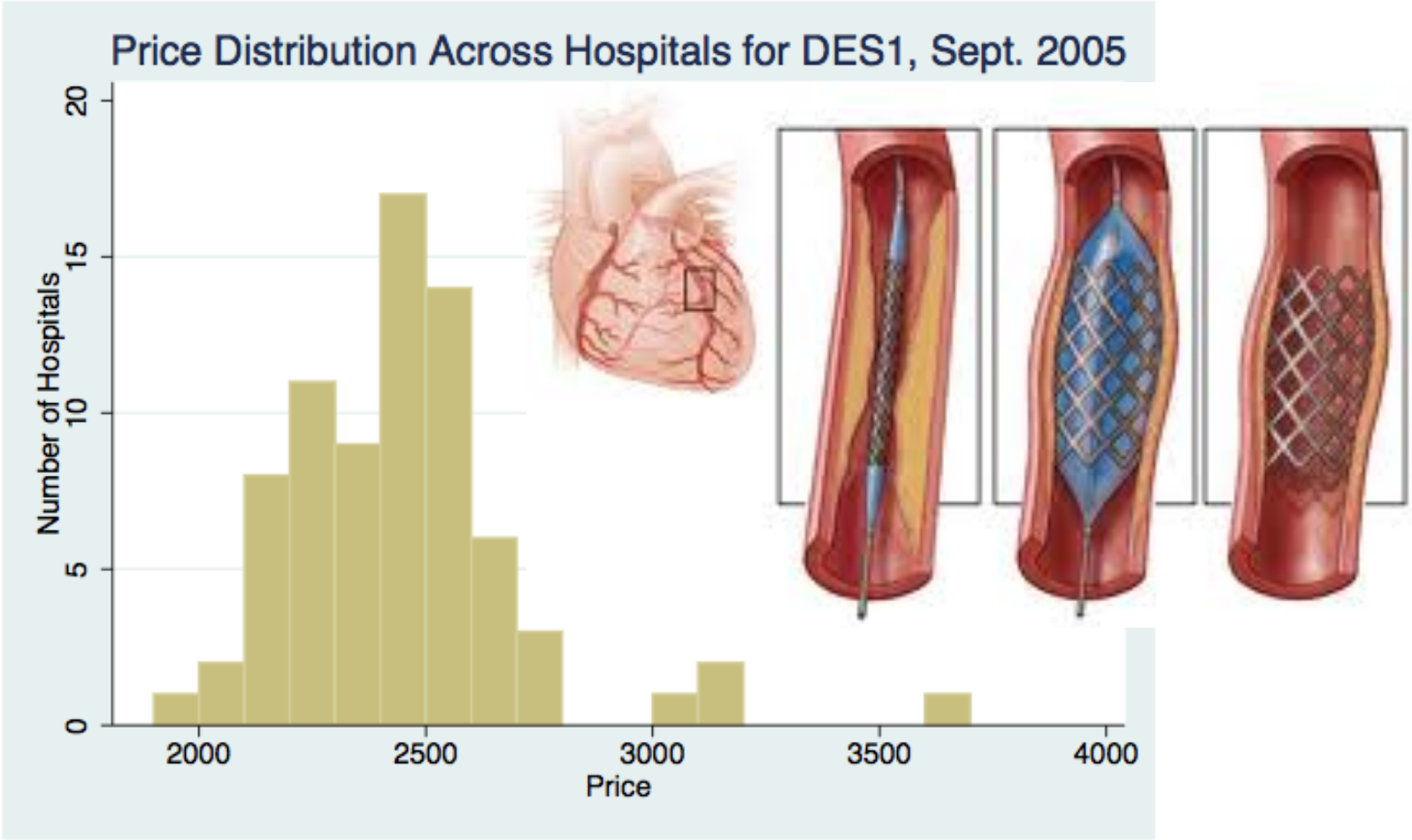


Inter-Quartile Range = \$310/stent → \$300,000/year/hospital

Research Questions

RQ: What happens under more uniform pricing?

- Do hospital mergers, GPOs, transparency $\downarrow$ prices?
- It's not clear . . .

[Dranove & Lindrooth 2003; Burns & Lee 2008; Kyle & Ridley 2007]

RQ0: What explains this price variation?

- demand $\rightarrow$ price discrimination with oligopoly

[Holmes 1989; Corts 1998; Hastings 2008; Villas-Boas 2009]

- allowing for bargaining

[Dranove et al 2008; Dafny 2010; Crawford & Yurukoglu 2011]

Panel Data Over Hospitals and Time

Unbalanced panel: all stents, 96 U.S. hospitals, Jan. '04 - Jun. '07 (10,098 stent-hospital-months) [Millenium Research Group *Marketrack* survey]

Product Data:

Year	Month	Hospital	Product	Manufacturer	Quantity	Price
2004	January	001	BMS9	Mfr1	7	1050
⋮						
2007	June	096	DES2	Mfr4	41	2500

Hospital Data:

Year	Month	Hospital	State	Public	Teaching	Diagnostic
2004	January	001	Arkansas	0	1	283
⋮						

The Model

(STAGE 1) Pricing: bargaining and competition

$\mathbf{p}(\mathbf{wtp}, \mathbf{c}, \mathbf{ba})$ for all stents at each hospital for contract period

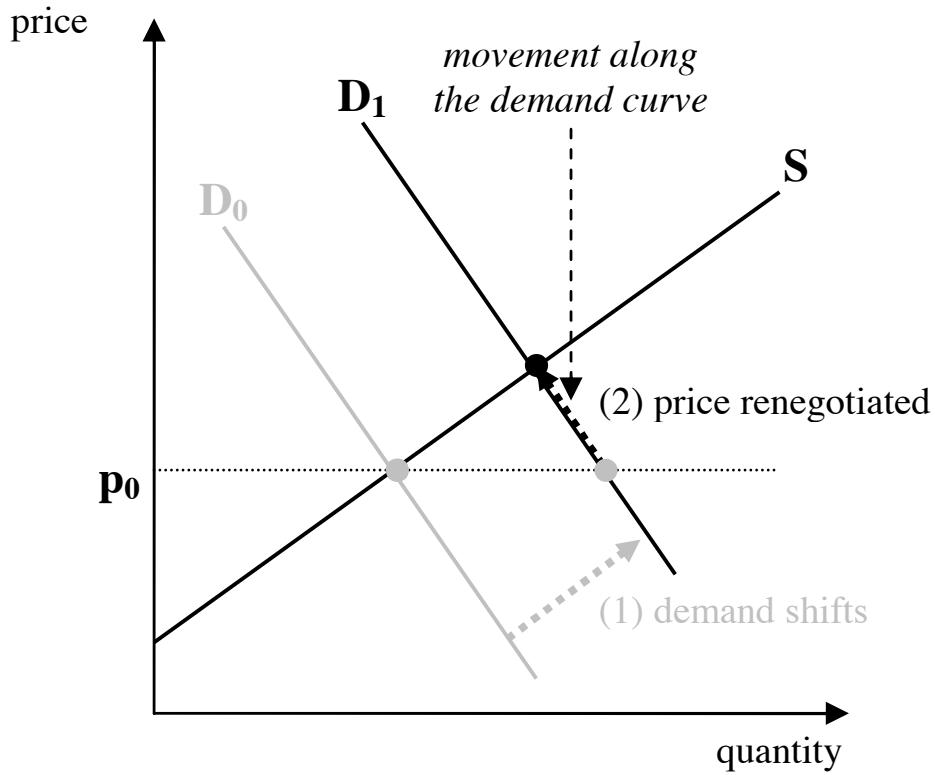
(STAGE 2) Demand: patients arrive; doctors choose

$\mathbf{q}(\mathbf{p}, \mathbf{wtp})$ for all stents at each hospital for each month

- hetero across hospitals; across patients/doctors within hospital
- random coefficients discrete choice model

  [McFadden 1978; Berry, Levinsohn, & Pakes 1995; Nevo 2001]
- bargaining introduces new sources of identification

Demand Identification with Negotiated Prices



Instruments for negotiated prices:

- p_{jht-1} by "sticky price" mechanism
- $\bar{p}_{k \neq jht-1}$ proxy for bargaining ability; other stent demand shifts

Pricing Model: Bargaining and Competition

Incorporate cost/demand/competition (range) and bargaining ability.

Nash Equilibrium of bilateral Nash Bargaining problems

[THEORY: Cremer & Riordan 1987; Horn & Wolinsky 1988; de Fontenay & Gans 2007]

[EMPIRICS: Crawford & Yurukoglu 2011; Dranove, Satterthwaite, & Sfekas 2011]

$$\max_{p_j} \underbrace{[\pi_j(p)]^{b_j(h)}}_{\text{mfr profits}} \underbrace{[\pi_h(p) - d_{jh}]^{b_h(j)}}_{\text{h profits with mfr - h profits w/out mfr}} \qquad \forall j \in \mathcal{J}_h$$

- d_{jh} : hospital h disagreement point—not contracting with stent j
- $b_j(h)$: stent j bargaining ability (vs. hospital h)
- $b_h(j)$: hospital h bargaining ability (vs. stent j)

Pricing Equation from Model

$$\underbrace{p_{jh} - c_{jh}}_{\text{margin}} = \underbrace{\frac{b_j(h)}{b_j(h) + b_h(j)}}_{\text{bargaining abilities}} \underbrace{\left\{ \left(1 + \overbrace{\frac{\partial q_{jh}}{\partial p_{jh}} \frac{p_{jh} - c_{jh}}{q_{jh}}}^{\text{adjust for } q \text{ dependent on } p} \right) \overbrace{\frac{\pi_h - d_{jh}}{q_{jh}}}^{\text{"Added Value" of } j} + p_{jh} - c_{jh} \right\}}_{\text{surplus up for negotiation}}$$

Empirical specification:

$$p_{jht} = \underbrace{\gamma_j}_{\text{cost}} + \underbrace{\frac{\beta_j}{\beta_h} \nu_{jht}}_{\text{bargaining abilities}} \underbrace{\widetilde{AV}_{jht}}_{\text{demand estimates}}$$

Parameter Estimates: Sources of Price Variation

	Price Data		Cost Est.	Barg. Ratio Est.		Added Value Est.	
	mean ($)	s.d. ($)	mean ($)	mean	s.d.	mean ($)	s.d. ($)
BMS4	1006	175	34	0.33	0.07	2980	254
			(79)	(0.04)	(0.004)	(327)	(25)
BMS5	926	191	34	0.32	0.07	2807	155
			(79)	(0.10)	(0.006)	(313)	(13)
BMS6	952	156	34	0.31	0.05	2993	291
			(79)	(0.06)	(0.004)	(321)	(28)
BMS7	1035	174	34	0.35	0.07	2899	248
			(79)	(0.02)	(0.004)	(314)	(21)
BMS8	1063	338	34	0.36	0.10	2809	222
			(79)	(0.04)	(0.01)	(310)	(18)
BMS9	1088	224	34	0.34	0.08	3171	403
			(79)	(0.01)	(0.005)	(341)	(31)
DES1	2508	317	1103	0.35	0.08	4298	463
			(286)	(0.02)	(0.004)	(389)	(26)
DES2	2530	206	1103	0.36	0.06	4317	472
			(286)	(0.02)	(0.002)	(390)	(30)

September 2005 only. BMS1-3 have exited the market. Standard errors clustered at hospital level.

What Determines Bargaining Abilities?

Regress $\ln(\frac{\beta_j}{\beta_h}\nu_{jht})$ on firm dummy variables:

- $R^2 = 0.41$
- estimates of β_j and β_h, for all j and h

Uniform Pricing: What Would Happen?

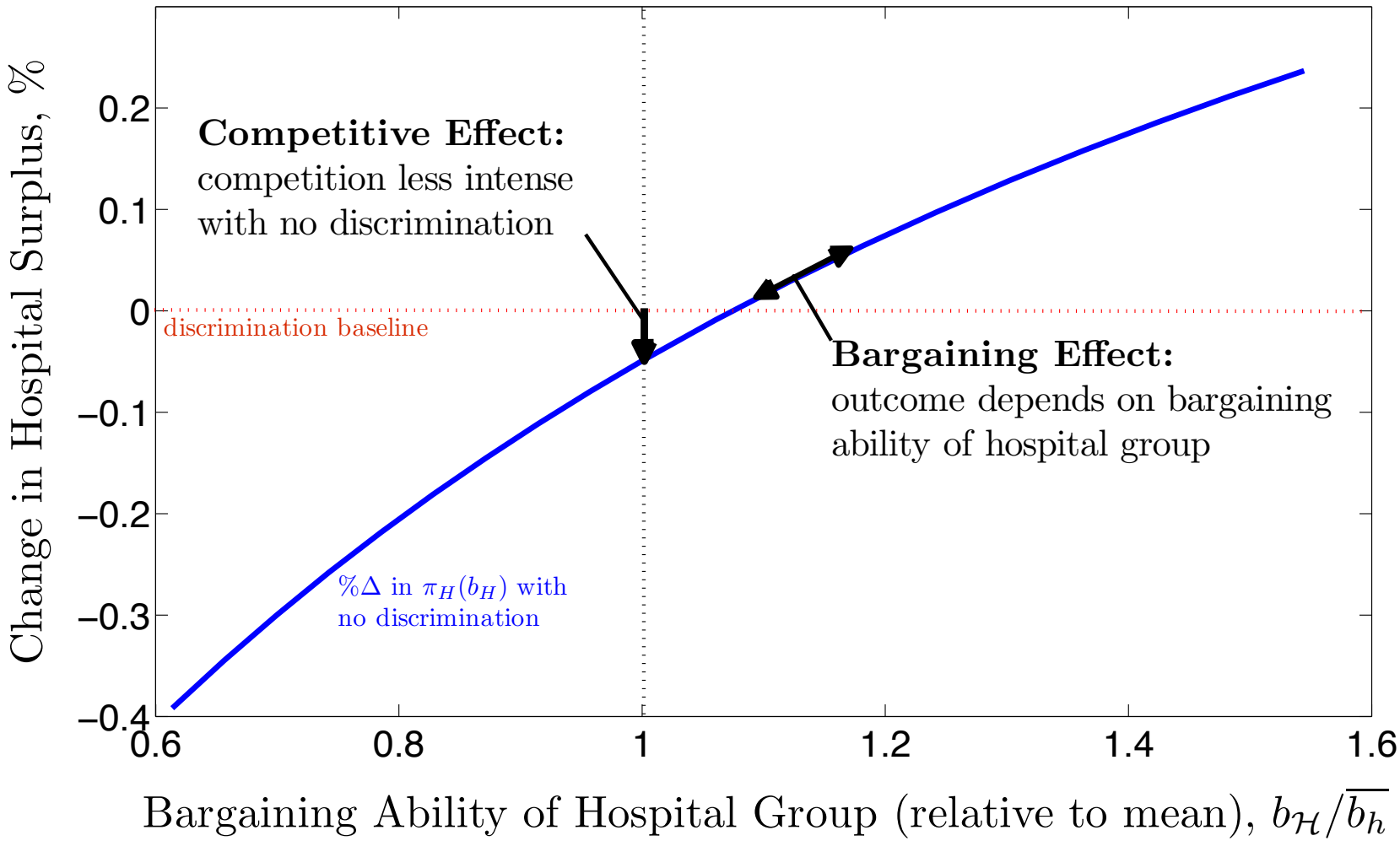
$$\max_{p_j} \underbrace{\left[\sum_h \pi_{jh}(p)\right]^{b_j}}_{\text{mfr j } \textbf{total} \text{ profits}} \underbrace{\left[\sum_h \pi_h(p) - d_{jh}(p)\right]^{b_{\mathcal{H}}}}_{\textbf{all} \text{ h profits}} , \forall j$$

- demand aggregated over hospitals

  [Holmes 1989; Corts 1998; Hastings 2008; Villas-Boas 2009]

- $b_{\mathcal{H}}$ allows for collective bargaining

Why GPOs May Not Benefit Hospitals



Takeaways

GPOs, Hospital Mergers, and Stent Prices:

- Competition more intense with non-uniform prices
- Bargaining ability of "merged" group important

Further Research:

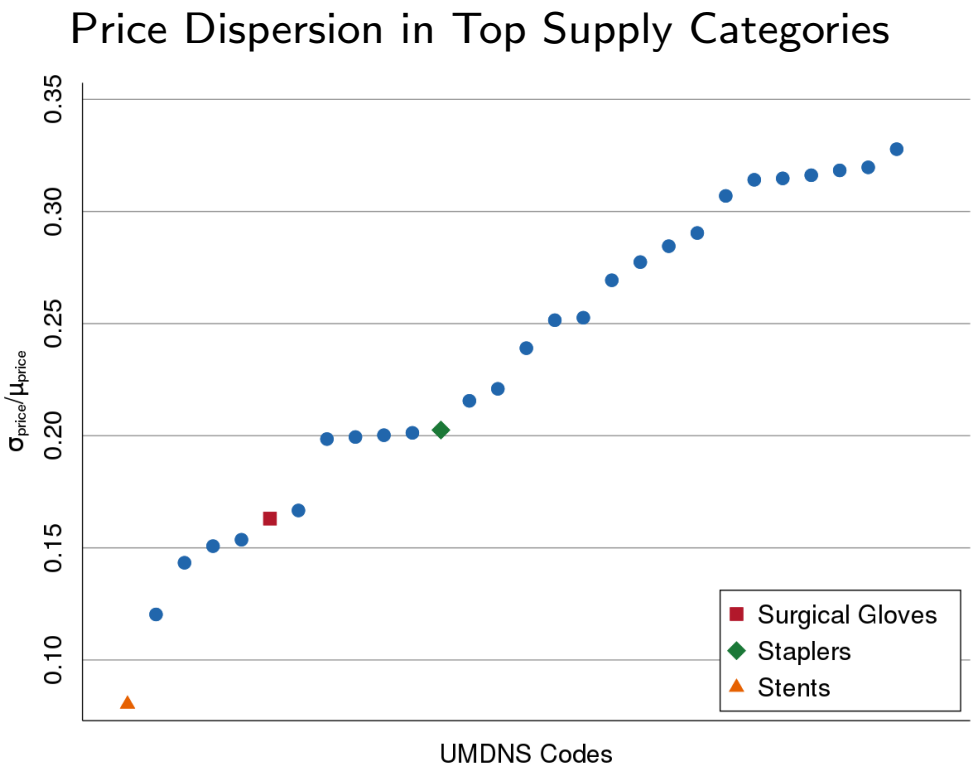
- Determinants of bargaining ability?
- Entry and the "cost" of medical technology in the longer-run?

Transparency and Negotiated Prices:
The Value of Information in Hospital-Supplier Bargaining

(Grennan & Swanson 2016, *RnR@ JPE*)

Hospitals Pay Different Prices for the Same Inputs

1. What causes this variation in prices across buyers?
2. How does it differ across product markets?



- Supply costs direct to profit margin ($\overline{OpMarg_{h,2013}} = 3.1\%$)
- Supplies in data $\approx$20% hospital 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
    [Syverson 2004; Chipty Snyder 1999]
  - Relative bargaining skill, effort, and information
    [Goldberg 1996; Scott Morton et al 2011; Crawford Yurukoglu 2012; Grennan Swanson 2016]
  - Contract structure – rebates, nonlinear contracts, bundling

- **Search/diligence/contracting** cost to buyer, supply concentration, obfuscation
  [Stigler 1961; Sorensen 2000; Hortacsu Syverson 2004; Jin Leslie 2006; Ellison Ellison 2009; Allen et al 2013, 2014, 2017; Ghili 2017; Ho Lee 2017]

RQ: Will *Information* Decrease Prices?

1. Policymakers seem to think it will for medical devices:
   "To the extent that prices of medical devices are not disclosed, the ability of hospitals to bring price information to bear in negotiations is clearly limited." – King (Ind-ME)
2. B2B markets: increasing number of "information intermediaries" as benchmarking data easier to collect, access, and analyze
3. Economic theory and empirical evidence unclear:
   - information/search in B2C $\Rightarrow$ lower prices, higher quality
     [Sorensen 2000; Jin Leslie 2006; Hendricks et al. 2012; Bronnenberg et al. 2014]
   - information/search in B2C bargaining $\Rightarrow$ lower prices
     [Zettelmeyer et al. 2006; Scott Morton et al. 2011]
   - B2B bargaining $\Rightarrow$ other buyers' prices may not matter
     [Crawford Yurukoglu 2012; Grennan 2013, 2014; Gowrisankaran et al. 2014; Ho Lee 2015; Lewis Pflum 2015]

Outline for Today's Talk

1. Data: Hospital purchase orders (16% of US, 2009-14)
2. Theory: How might information affect bargaining?
3. Research design: Hospitals with and without information
   - difference-in-differences and triple differences
4. Results: (How) does information affect negotiated prices?
   - prices $\searrow$ for previously high-priced hospitals
     - larger effects for high-quantity hospitals imply cost of using info
   - evidence suggests asymmetric information mechanism
   - 26% of "potential" savings achieved
5. Next paper(s): product categories, hospital data, claims data

Data Set: Hospital Purchase Orders

Data

- all purchase orders issued $\sim$ 16% of US hospitals, 2009-14
- *today:* stents only (important product, simple contracts)

▸ Evidence on Standardization

Benchmarking Information "Treatment"

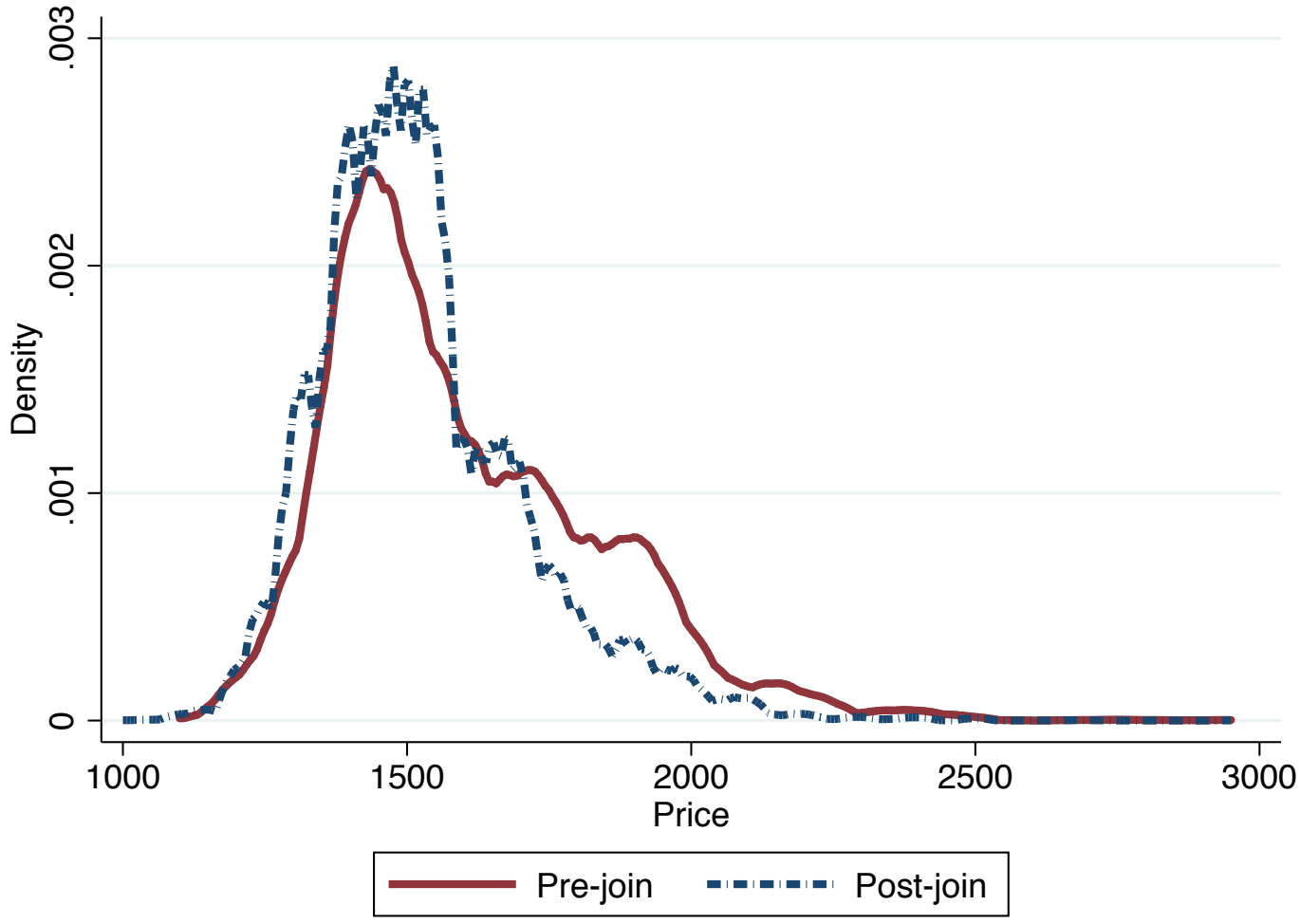
- online database allows members to benchmark purchasing
- *basic interface:* "potential savings" (mean and min)
- *buried data:* transaction-level data, all products

Useful Variation

- twelve month retrospective upon joining; monthly thereafter
- "clickstream" of member login activity
- new product entry: exogenous variation in information
- place in distribution pre-join: price and quantity

Raw Evidence of Treatment Effects

Price Distribution Pre-/Post-Join



Rubinstein (1982)
Complete Information Benchmark

Single buyer with discount factor $\delta^B \in (0,1)$ and seller δ^S make alternating offers to split surplus $V = wtp - c$:

$$p^{CI} = c + \delta^S \frac{1-\delta^B}{1-\delta^B\delta^S} V$$

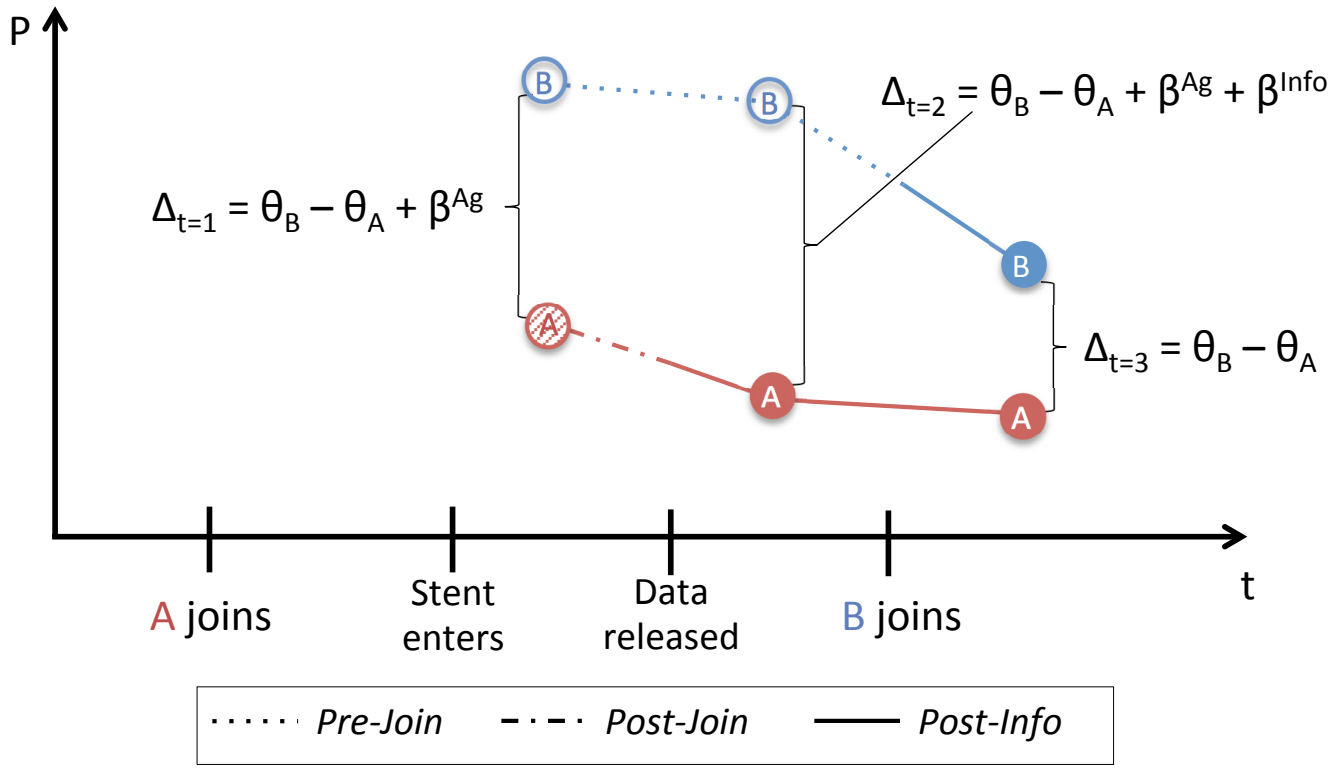
Foundation of theory and empirical work [Binmore et al 1983; Horn Wolinsky 1988; Collard-Wexler et al 2014; Crawford Yurukoglu 2012; Grennan 2013, 2014; Gowrisankaran et al 2014; Ho Lee 2015] :

- "discount factors" proxy impatience, laziness, fear of breakdown, etc.
- maps into Nash Bargaining with multiple buyers and sellers

Where might information matter?

1. Asymmetric information: hospitals have uncertainty about supplier δ^S
2. Agency: δ^B a function of purchasing manager's (unobserved) effort

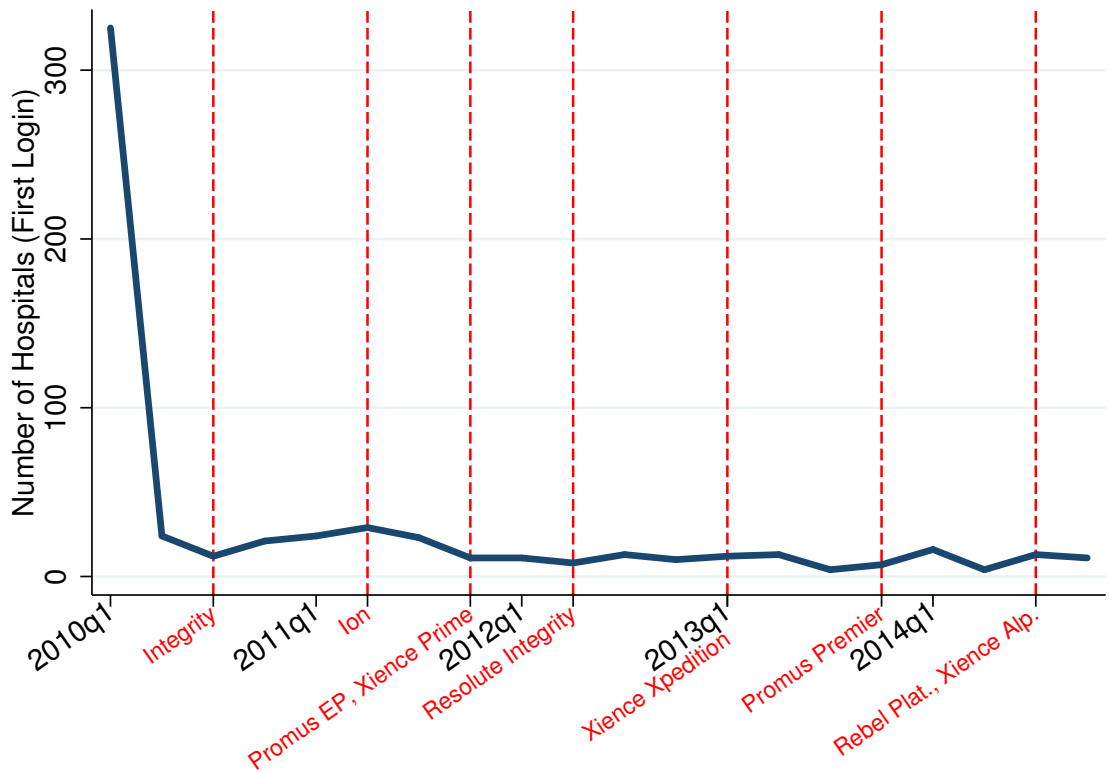
Research Design 2/2: New Product Entry



- New product introduction provides *two* information treatments
  - no benchmarking data for first few months, so asymmetric information cannot explain differences between initial prices
  - bias from join timing would be in β^{Ag}

Hospitals Joining Database and Product Entry

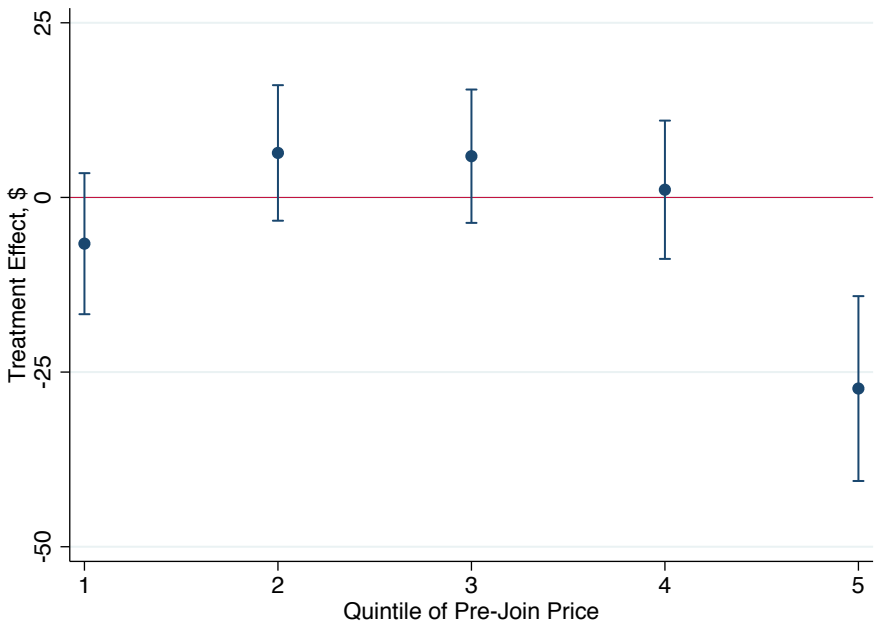
- After 1Q2010, $\sim$ 14 sample hospitals join each quarter
- Nine entry events to shock information availability



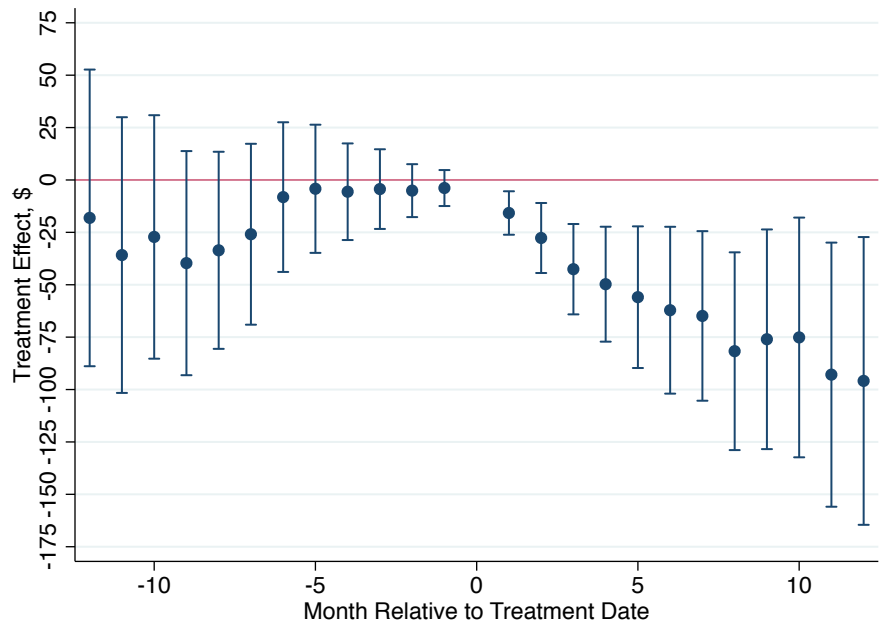
▸ Observations Relative to New Product Entry

TEs Across Price Distribution

- ATE of information small and noisy ▸ Event Study
- TE only significant in highest price quintile, at -$27
- TE for top price quintile: no pre-trend, post- decreasing to -$102



(a) $\beta^{Info}_{quintile^p}$



(b) $\sum_{qtr=-12}^{+12} \beta^{Info,mo}_{quintile^p=5}$

Quantifying the Sources of Price Dispersion:

Evidence from Hospital Procurement

(Grennan & Swanson 2017)

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Why Do We Care About Price Dispersion?

- Price dispersion linked to market power, and thus efficiency
- Further unpack determinants of firm productivity and size heterogeneity
  [De Loecker 2011; Hottman et al 2016]
- Welfare implications depend on underlying economic mechanisms
  - E.g.: Transparency policies and information intermediaries can affect asymmetric information in bargaining [Grennan & Swanson 2016] 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 l
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 provider
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]

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.

Outline of Today's Talk

1. Institutional detail: hospital purchasing
   - "Exposure" to multi-category vendors to separately identify search vs. demand
2. Data: ∼20% of US hospitals , 2009-15
   - (p, q) 2 million SKUs in 3,000+ categories, monthly
3. Structural empirical model and estimation:
   - assume $\mathcal{J}_h^{purch} = \mathcal{J}_h^{search} \subseteq \mathcal{J} = \cup_h \mathcal{J}_h^{purch}$
   - Demand: $\mathcal{J}_h^{purch}$+ Discrete-choice utility $\rightarrow$ preferences
   - Supply: $\mathcal{J}_h^{purch}$+ Demand + Nash-in-Nash bargaining $\rightarrow$ supplier costs, relative bargaining weights
   - Search: $\mathcal{J}_h^{purch}$+ Demand + Supply + Moment inequalities inspired by search theory $\rightarrow$ search/contracting costs
4. Results: decomposing sources of price dispersion (and welfare implications)

Model: Primitives and Timing

fix this to allow for selection that X^e will correct

Products $j = 0, 1, ..., J \in \mathcal{J}$ via Vendors $v = 1, ..., V$ to Hospitals $h = 1, ..., H$.

Timing of search, pricing, demand:

1. Hospital h has ex-ante beliefs about:

   Preferences $\theta_h + \theta_{jt} + \xi^o_{hjt} + \xi^u_{hjt}$ (unknown $\xi^u_{hjt} \sim N(0, \sigma_\xi)$)
   Costs of production/distribution $mc_j = X^{mc}_j \gamma$ (known)
   Bargaining $\frac{\beta_{jt}}{\beta_h} \nu_{hjt}$ (unknown $\ln(\nu_{hjt}) \sim N(0, \sigma_\nu)$)
   Search costs $sc_{hjt} = X^{sc}_{hjt} \phi$ (known)

2. Hospital choice set $\mathcal{J}_{ht}$ determined by search process
3. $\{\xi^u_{hjt}\}, \{\nu_{hjt}\}$ learned and contract prices determined $p_{hjt}(mc_j, \mathcal{J}_{ht}, \theta_{hjt}, \beta_{hjt})$.
4. Quantities realized $q_{hjt}(\mathcal{J}_{ht}, p_{hjt}, \theta_{hjt})$.

Search: Challenges and Potential Solutions

- Allowing for various sources of heterogeneity across products in (beliefs about) preferences θ_j, bargaining β_j, and search sc_j seem important for fitting the data and intuitions about agent information/behavior
- Repeat purchases from $\mathcal{J}_{ht}^{search}$, so composition matters
  (similar to optimal retailer assortment or portfolio choice)
- Unless small $|\mathcal{J}|$, computability of (optimal) search model relies on *ordering* of products not changing (too much) with the size/composition of $\mathcal{J}_{ht}^{search}$
  - Undirected search or directed search with single dimension of product-specific heterogeneity (IO/marketing)?
  - Reduced-form "matching" function (labor/trade)?
  - Assume (non-optimal) algorithm of how hospitals search?
- Our approach: moment inequalities based on weak 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 $\mathcal{J}_{ht}^{purch}$ provide upper bounds on search costs:

- Must have been worth searching at some stage (if $\mathcal{J}_{ht}^{purch} \subseteq \mathcal{J}_{ht}^{search}$)
- For substitutes, weakest assumption comes from value vs. outside good :

$$E_{\xi}[AV_{jht}(\theta_{jt}, \theta_h, \xi_{jht}; \emptyset] \geq sc_{jht}$$

- Can further weaken by assuming optimistic beliefs $\xi_{jht} = \max_{ht} \xi_{jht}$

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

- Must not have been worth searching (if $\mathcal{J}_{ht}^{purch} = \mathcal{J}_{ht}^{search}$)
- For substitutes, weakest assumption comes from value vs. full choice set :

$$E_{\xi}[AV_{jht}(\theta_{jt}, \theta_h, \xi_{jht}; \mathcal{J}_t] \leq sc_{jht}$$

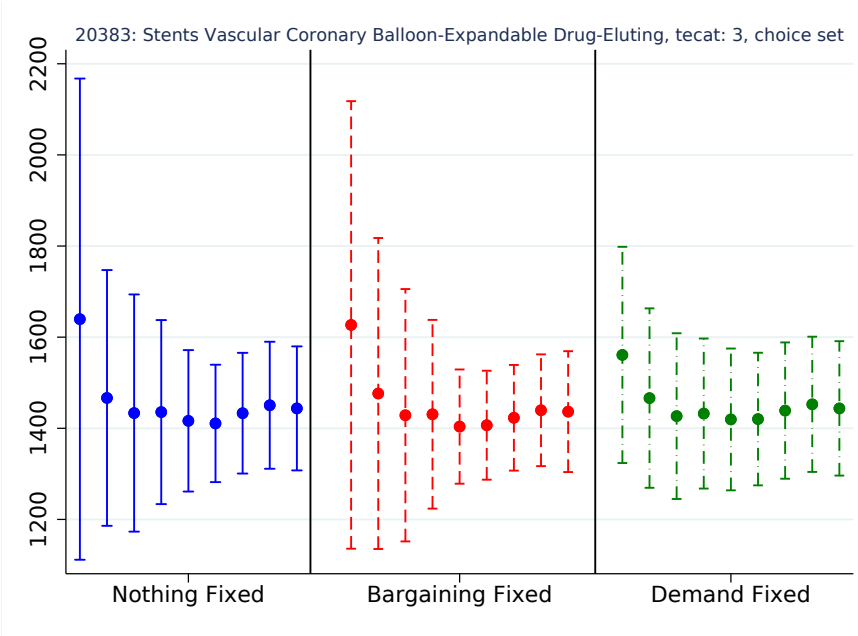
- Can further weaken by assuming pessimistic beliefs $\xi_{jht} = \min_{ht} \xi_{jht}$
- Can weaken bite of $\mathcal{J}_{ht}^{purch} = \mathcal{J}_{ht}^{search}$ by using weakest bound for each ht

Quantifying the Sources of Price Variation

The pricing equation has an intuitive decomposition:

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

Figure: **Price distribution across hospitals vs. same $\tilde{\mathcal{J}}_{ht}$ (t fixed)**



(a) Stents

Quantifying the Sources of Price Variation

Table: **Decomposing Variation in Prices and Markups**

	$p_{\mathcal{J}^{(2)}}$		$p^{-\sigma_B}_{\mathcal{J}^{(2)}}$		$p^{-\sigma_D}_{\mathcal{J}^{(2)}}$		$p_{\mathcal{J}^{(*)}}$		$\lvert\mathcal{J}^{(*)}\rvert$	$\lvert\mathcal{J}_h\rvert$	
	μ	$\frac{\sigma}{\mu}$	$\%\mu$	$\%\frac{\sigma}{\mu}$	$\%\mu$	$\%\frac{\sigma}{\mu}$	μ	$\frac{\sigma}{\mu}$		μ	$\frac{\sigma}{\mu}$
Commodity											
Needles	\$0	0.76	0.91	0.95	1.11	0.91	\$0	0.66	3	6	0.54
Drapes Surgical	\$4	0.68	0.80	0.56	0.98	0.97	\$3	0.27	4	8	0.62
Average	\$21	0.61	0.91	0.61	0.94	0.74	\$29	0.45	4	12	0.45
Other Medical / Surgical											
Screws Bone	\$74	0.65	1.00	1.01	0.76	0.48	\$119	0.19	10	31	0.58
Guide Wires	\$26	0.54	0.91	0.49	1.01	1.37	\$21	0.50	3	27	0.59
Average	\$823	0.55	0.93	0.77	0.88	0.70	\$756	0.40	5	20	0.48
Physician Preference Item											
Defibrillator/Cardio	\$23,007	0.14	0.96	0.82	0.89	0.80	\$21,604	0.15	5	3	0.39
Prostheses Joint Hip	\$2,450	0.51	0.99	0.68	0.95	0.82	\$1,961	0.47	3	29	0.57
Stents Vascular Coro	\$1,624	0.31	0.99	0.94	0.95	0.33	\$1,466	0.17	3	4	0.40
Average	\$3,818	0.54	0.95	0.80	0.89	0.57	\$3,524	0.34	5	16	0.48

Takeaways and Future Directions

Takeaways:

- Price dispersion large for both buyer preference and commodity hospital inputs – policy interest growing due to information/analytics and cross-market mergers (outside of healthcare as well)
- Extensive panel data + Exposure and info IV + Model of demand/bargaining/search $\rightarrow$ identify frictions underlying price dispersion for a wide variety of hospital supply markets

Future directions:

- Text $\rightarrow$ product characteristics (demand and cost)
- Many research questions require an explicit model of (not-quite-optimal) search
- Pass-through to cost of care requires pairing with claims data and device-procedure crosswalk