Downstream Price Effects of Upstream Monopolization in Active Pharmaceutical Ingredient Markets

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I. Motivation

Low cost ratio of API in FPP (downstream)

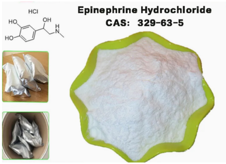
Packaging

Transportation

Storage

Tax

¥4/1ml:1mg



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¥7,500/kg ¥0.35/pcs ¥0.02/1ml

¥0.0075/mg

I. Motivation

Rising pharmaceutical price

- Cartel among drug makers (Cuddy, 2020; Clark et al, 2022)
- New perspective:
  - Substantial number of antitrust cases in API
  - Downstream effects of upstream monopolization
  - Administrative price formation

Identifying downstream price effects

- Administrative penalty announcements
- Synthetic control process for counterfactual prices
  - Abadie and Gardeazabal (2003)
- **Differential FPP price effects**
- **Bargaining-based mechanism** and **structural estimation**
  - Grennan (2013)

I. Motivation

Reduced-form findings

- Downstream price effect: **77.4%** average increase
- Price effects and FPP market structures
  - **114% smaller** where CR1 > 0.4, **198% higher** for CR1 ≤ 0.4 and CR2 > 0.6 (relatively symmetric duopoly markets)
- Likelihood of API monopolization
  - **4 times higher** in **balanced duopolistic** markets

A Nash-in-Nash framework to model drug pricing

- Players: government and drug makers
  - Competitive FPPs lack the ability (small bargaining power)
  - Exclusive FPPs lack the incentive
- **API monopolization events alter the disagreement points**

Go to model

I. Motivation

Highlights

- Theory of **vertical relationships**
- Complex pharmaceutical system in China
- Policy guidance
  - Antitrust scrutiny
  - Health authority
  - Industrial policy: subsidy in value chain

Roadmap

- Institutional background
- Data
- Reduced-form evidence
- Bargaining model
- Structural estimation

II. Background

Antitrust ecforcement

- State/Provincial AMR initiates investigation (triggered by reports or surveillance)
- Gather evidence
  - E.g., contracts, internal documents, business data
- Assess enterprises' alleged behaviors
- Issue **administrative penalty announcements**
  - Involved enterprises, type and duration, key evidence, forfeiture and fine, . . .
  - Disclose to the public
  - Mark the close of the case

II. Background

API monopolization cases

APIs Involved	Ann. M.	Case Dur.	# Firm	Viol.	Penalty
Promethazine Hydrochloride	2011.11	2011.6	2	A	7.030
Ligustrazine Hydrochloride	2015.01	Unknown	2	A	Unknown
Allopurinol	2015.10	2013.10-2014.3	2	A	0.439
Estazolam	2016.07	2015.1-2016.5	3	C	2.604
Phenol	2016.11	2014.2-2015.12	2	A	0.500
Methyl Salicylate	2017.01	2015.1-2015.12	1	A	2.210
Isoniazid	2017.07	2014.12-2017.7	2	A	0.444
Glacial Acetic Acid	2018.12	2017.10-2018.12	3	C	12.834
Chlorpheniramine	2018.12	2018.2-2018.12	2	A	12.431
Calcium Gluconate	2020.04	2015.8-2017.12	3	A	325.5
Bromhexine Hydrochloride	2020.11	2015.9-2016.12	1	A	2.474
Batroxobin	2021.01	2019.11-2020.6	1	A	100.7
Fluocinolone Acetonide	2021.04	2008-2013, 2017.5-2019.12	3	C	50.778
Camphor	2021.06	2018.3-2019.12	3	C	16.88
Phenol	2021.10	2014.2-2017.3	1	A	11.045
Pralidoxime Chloride	2021.11	2018.3-2019.12	1	C	6.58
L-Carnitine	2023.01	2018.11-2019.6	1	C	133
Epinephrine	2023.05	2016.6-2019.7	2	A and C	320
Iodized Oil	2023.11	2016.6-2020.3	1	A	1.564

II. Background

Pharmaceutical system in China

- Pricing: nationally negotiated prices (300), volume-based bidding (400), **independently pricing under regulation** (90%+)
- Procurement: provincial platform
  - Institutions act as **price taker**
  - **0-markup** rate in public hospital
- Payment: BMIP (part A/B)
  - Low average elasticity
- Policy shock: overall impacts
  - Case-sepecific effects: average across cases

III. Data

Firm-level panel

- Chemical drugs, public hospital, provincial platforms, 2013-Q1 to 2021-Q2
- 20 representative cities
- "Market": an API (general name)
- "Drug": a strength of an API-form (product name)

Processing

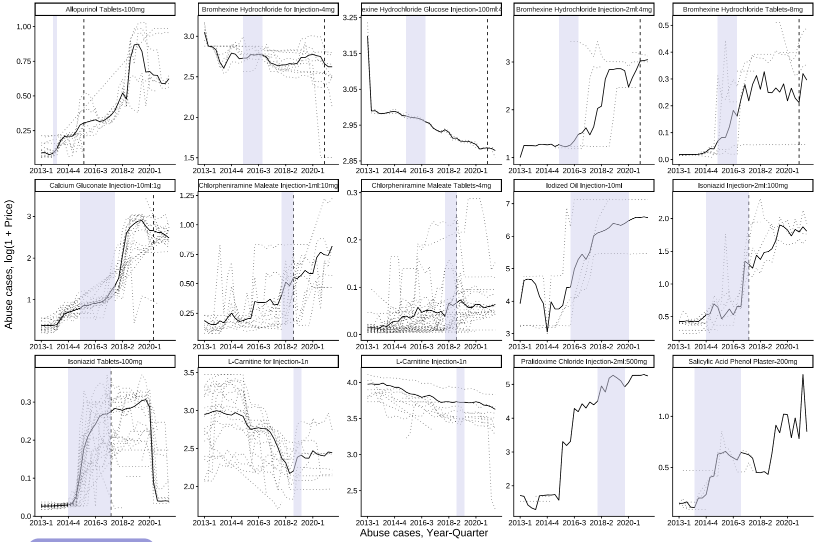
- Exclude vertically integrated firms
- Market concentration indicators
- Aggregate to drug-national level (Abadie et al, 2010)
- 24 treated drugs with balanced panel

III. Data

Descriptive statistics

	Stat	Qty	Amt	Price	N^f	HHI	CR1	CR2	CR3
Treated	mean	2,793,709	10,229,300	30.680	1.892	0.447	0.548	0.727	0.826
#. Obs	sd	6,371,893	22,914,666	88.914	1.925	0.307	0.277	0.227	0.177
812	min	100	65	0.013	1.000	0.101	0.155	0.310	0.441
#. drug	median	653,208	1,579,294	3.832	1.000	0.340	0.479	0.742	0.894
24	max	35,866,881	142,506,397	730.431	14.000	1.000	1.000	1.000	1.000
Full treated	mean	1,713,554	6,704,183	27.364	1.620	0.570	0.657	0.805	0.878
#. Obs	sd	5,025,119	18,120,674	75.089	1.571	0.334	0.291	0.219	0.164
1,401	min	1	4	0.013	1.000	0.101	0.155	0.310	0.441
#. drug	median	58,913	409,958	5.231	1.000	0.527	0.676	0.895	0.984
60	max	35,866,881	142,506,397	730.431	14.000	1.000	1.000	1.000	1.000
Control	mean	917,250	6,793,604	177.917	1.937	0.562	0.663	0.824	0.893
#. Obs	sd	3,980,272	23,131,687	4063.481	1.921	0.296	0.254	0.189	0.144
193,862	min	1	1	0.004	1.000	0.035	0.078	0.153	0.201
#. drug	median	48,064	494,503	10.783	1.000	0.501	0.650	0.884	0.965
8,182	max	110,609,593	925,624,326	710571.727	36.000	1.000	1.000	1.000	1.000
Pool	mean	922,964	6,792,962	176.836	1.935	0.562	0.663	0.824	0.893
#. Obs	sd	3,989,294	23,099,570	4048.902	1.919	0.296	0.255	0.189	0.144
195,263	min	1	1	0.004	1.000	0.035	0.078	0.153	0.201
#. drug	median	48,128	494,170	10.688	1.000	0.501	0.650	0.884	0.965
8,242	max	110,609,593	925,624,326	710571.727	36.000	1.000	1.000	1.000	1.000

III. Data



Counterfactuals

III. Data

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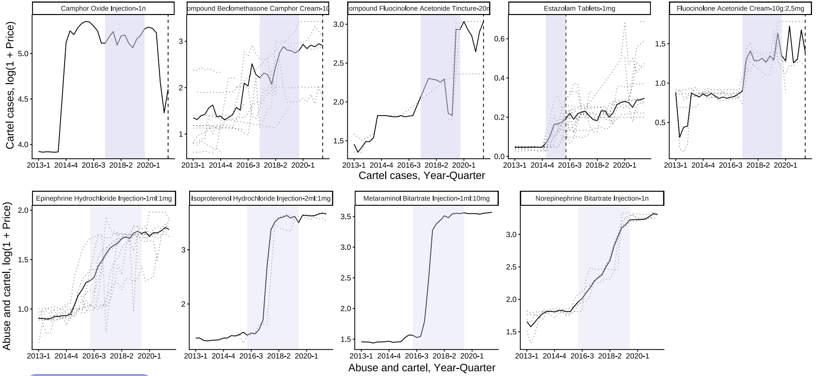


Counterfactuals

IV. Reduced-form Evidence

Counterfactuals: **ATT**

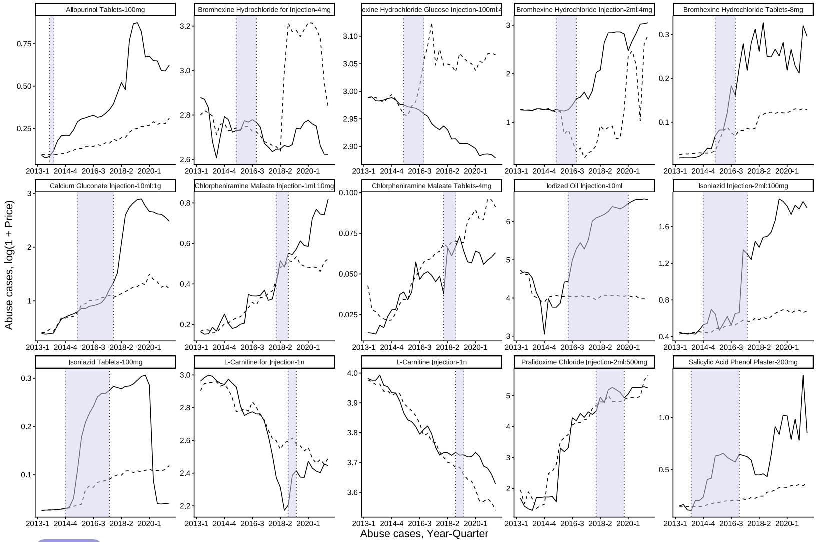
- "Weighted avg": $\hat{P}_{1t}^{N} = \sum_{j=2}^{J+1} w_j P_{jt}$
  - $w_j \geq 0$ and $\sum_{j=2}^{J+1} w_j = 1$
- Optimal unit weights: $\min_{\mathbf{W} \in \Lambda_J} \|\mathbf{X}_1 - \mathbf{X}_0 \mathbf{W}\|_V$
- Optimal predictor weights:

$$\min_{\mathbf{V} \in \Lambda_k} \left(\mathbf{P}_1 - \mathbf{P}_0 \mathbf{W}^*(\mathbf{V})\right)' \left(\mathbf{P}_1 - \mathbf{P}_0 \mathbf{W}^*(\mathbf{V})\right)$$

Synthetic control process

- Treatment span: case duration
- Donor pool: minimum 100 Mahalanobis distance
  - $\sqrt{\left(\mathbf{X}_j - \mathbf{X}_0\right)' \mathbf{\Sigma}^{-1} \left(\mathbf{X}_j - \mathbf{X}_0\right)}$
- drug-quarter level predictors: N^f, CR1, CR2, CR3, HHI, price
- drug level predictors: total sales Qty and Amt

IV. Reduced-form Evidence



Trend

IV. Reduced-form Evidence

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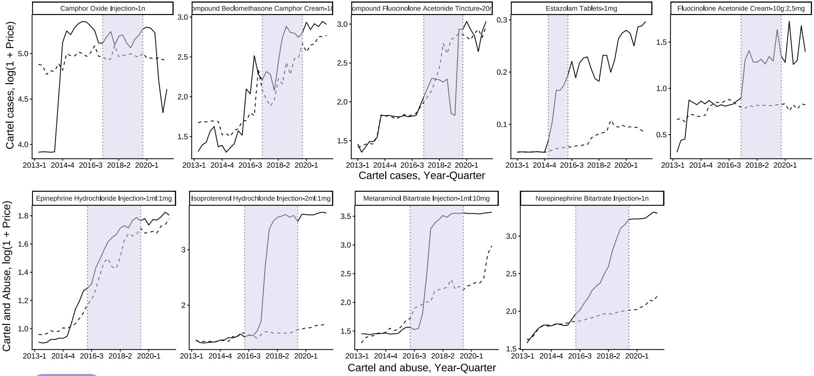

Trend

- Placebo test confirms robustness

IV. Reduced-form Evidence

Average downstream price effect (Cunningham et al, 2021)

$$\log P_{jt} \propto \delta D_j^{up} + D_j^{up} \times (\beta_1 D_j^{syc} + \beta_2 D_{jt}^m + \beta_3 D_j^{syc} \cdot D_{jt}^m) + \gamma' \mathbf{Z}_{jt} + \lambda_t + \lambda_j$$

- 24 treated units $\mathbf{P}_1^j$, 24 counterfactuals $\hat{\mathbf{P}}_1^j$
- 8,218 control units: self-selection issues
- $D_j^{up} = 1$: treated or counterfactual
- $D_j^{syc} = 1$: counterfactual
- $D_{jt}^m = 1$: treated/counterfactual unit during its case period
- β_3: **ATT**
- $\mathbf{Z}_{jt}$: N_{jt}^f and $\log Q_{jt}$
- λ: time and product fixed effect

IV. Reduced-form Evidence

Average downstream price effect

	$\log P_{jt}$		
	Full	Top 20	Top 10
D_j^{up}	-0.788*	-0.777*	-0.750*
	(0.264)	(0.275)	(0.273)
$D_j^{up} \times D_j^{syc}$	0.133	0.090*	0.076
	(0.079)	(0.037)	(0.045)
$D_j^{up} \times D_{jt}^{m}$	0.975***	0.945***	0.948***
	(0.149)	(0.159)	(0.159)
$D_j^{up} \times D_j^{syc} \times D_{jt}^{m}$	-0.690***	-0.703***	-0.774***
	(0.115)	(0.137)	(0.150)
N_{jt}^{f}	-0.004	-0.004	-0.004
	(0.010)	(0.010)	(0.010)
$\log Q_{jt}$	-0.051***	-0.051***	-0.051***
	(0.006)	(0.006)	(0.006)
Prod. FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
#Obs	195,303	195,303	195,303
DF.Residual	190,616	190,616	190,616
R^2	0.94	0.94	0.94
Adj. R^2	0.938	0.938	0.938

IV. Reduced-form Evidence

Price effects and FPP market structures

$$P_{jt}/P_{jt}^{syc} - 1 \propto 100 \times \mathrm{MS}_{jt} + \bar{P}_j^{pre} + N_{jt}^f + \mathrm{Dur}_j + \mathrm{Viol}_j + \lambda_t + \lambda_a$$

- 24 Treated units and 24 counterfactuals during case period
- MS indices: CR1, CR2, CR3, and CR-cutoffs
- $\bar{P}_j^{pre}$: average price prior to the case
- Dur_j: duration
- Viol_j: dummy for cartel/abuse
- λ: time and API fixed effect

IV. Reduced-form Evidence

Price effects and FPP market structures

	$P_{jt}/P_{jt}^{syc}-1$					
	(1)	(2)	(3)	(4)	(5)	(6)
N_{jt}^{f}	0.159	0.141	0.130	0.177	0.188	0.173
	(0.133)	(0.131)	(0.140)	(0.131)	(0.129)	(0.128)
Duration_j	-0.055	0.120	-0.118	-0.145	-0.337	-0.365
	(0.303)	(0.303)	(0.319)	(0.293)	(0.305)	(0.298)
$\bar{P}_j^{pre}$	-0.019***	-0.013***	-0.010*	-0.022***	-0.024***	-0.023***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
$\text{CR1}_{jt} > 0.4$					-1.144**	
					(0.546)	
$\text{CR1}_{jt} \leq 0.4, \text{CR2}_{jt} > 0.6$						1.982***
						(0.712)
$100 \times \text{CR1}_{jt}$	0.060***					
	(0.007)					
$100 \times \text{CR2}_{jt}$		0.097***				
		(0.011)				
$100 \times \text{CR3}_{jt}$			0.125***			
			(0.019)			
$100 \times \text{HHI}_{jt}$				0.054***	0.062***	0.059***
				(0.006)	(0.007)	(0.006)
Cartel case	-1.124	-2.922*	-2.350	-0.603	0.728	0.112
	(1.546)	(1.610)	(1.779)	(1.479)	(1.596)	(1.473)
Abuse case	3.916***	4.074***	4.761***	4.300***	4.841***	5.071***
	(1.012)	(0.990)	(1.047)	(0.980)	(1.004)	(1.000)
G.N. FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
#Obs	214	214	214	214	214	214
DF.Residual	173	173	173	173	172	172
R^2	0.719	0.727	0.689	0.73	0.737	0.741
Adj. R^2	0.653	0.664	0.617	0.667	0.674	0.68

IV. Reduced-form Evidence

Likelihood of API monopolization

$$\log\left(\frac{\Pr(D^m_{jt}=1)}{1-\Pr(D^m_{jt}=1)}\right) \propto \mathrm{MS}_{jt} + N^f_{jt} + \lambda_t + \lambda_c$$

- Full sample (60 treated drugs), logit regression
- MS classifier
- λ: time and major-category fixed effect
- Between-group log-odds ratio differences, avg. across periods

IV. Reduced-form Evidence

Likelihood of API monopolization

	$\Pr(D^m_{jt}=1)$			
	(1)	(2)	(3)	(4)
$I(\mathrm{CR1}_{jt} > 0.4)$	-0.722**			
	(0.355)			
$I(\mathrm{CR2}_{jt} > 0.6, \mathrm{CR1}_{jt} < 0.4)$		-0.463		
		(0.479)		
$I(\mathrm{CR2}_{jt} > 0.5, \mathrm{CR1}_{jt} < 0.3)$			1.003	
			(0.831)	
$I(\mathrm{CR3}_{jt} > 0.6, \mathrm{CR2}_{jt} < 0.5)$				1.463***
				(0.558)
N^f_{jt}	-0.227*	-0.161	-0.176	-0.177
	(0.138)	(0.145)	(0.148)	(0.146)
#Obs	126,257	126,257	126,257	126,257
DF.Residual	126,220	126,220	126,220	126,220
R^2	0.071	0.066	0.067	0.068
Adj. R^2	0.057	0.052	0.053	0.054
Cate. FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
AIC	4,811.471	4,837.389	4,831.49	4,829.184

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V. A Bargaining Theory

Primitives

- Bargaining between FPP firms and the government
- Supply: industry association for n firms; no cost
- Demand: inelastic unit demand with size Q; reservation price W

Initial Nash bargaining

- $P_0 = \arg\max_P (W - P)^{1-\alpha} P^{\alpha}$
- Disagreement points are 0
- Bargaining power of firms: $\alpha(n) \in [0, 1]$ with $\alpha'(n) < 0$
- Initial price $P_0 = \alpha W$
  - reaches its maximum $\bar{P} = \alpha(1)W$ at $n = 1$

V. A Bargaining Theory

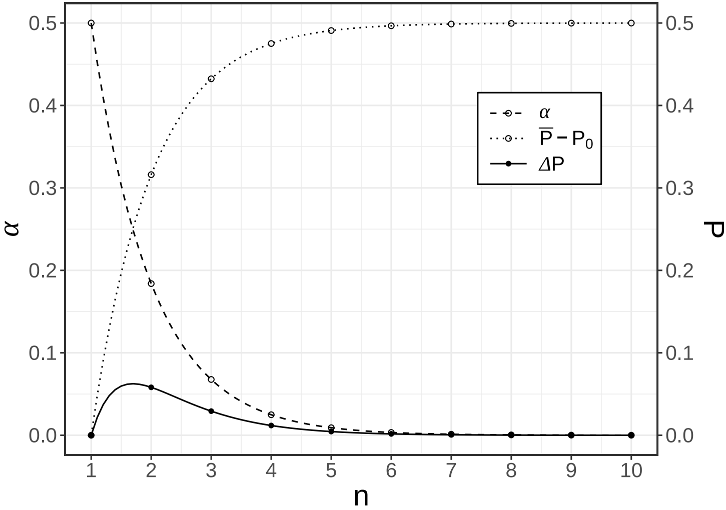
API monopolization $\Rightarrow$ downstream re-bargaining

- Disagreement point for firms: P_0
- Disagreement point for government: $\bar{P}$
- $P_1 = \arg\max_P \left[(W-P)-(W-\bar{P})\right]^{1-\alpha}\left[P-P_0\right]^{\alpha}$
- Re-bargaining price $P_1 = P_0 + \alpha(\bar{P}-P_0)$

Downstream price effect: $\Delta P = P_1 - P_0$

- Downstream ability: $\alpha(n) = Ae^{-(n-1)}$ with $A \in [0,1]$, decreasing with n
- Downstream incentive: $\bar{P}-P_0$, increasing with n
- $\Delta P'(n) = \alpha'(n)(\bar{P}-P_0) - \alpha(n)P_0'(n) = AW\alpha'(n)(1-2e^{-(n-1)})$
  - inverted-U shape with threshold at $n=2$

V. A Bargaining Theory



V. A Bargaining Theory

Main takeaway:

- Cost shifts contribute little to downstream price increase
- Firms' **bargaining power** increases with market concentration
- **Disagreement point** changes in re-bargaining

Structural-form evidence

- Data reflects NiN equilibrium between downstream firms and the government
- Given parameterized bargaining power $\Rightarrow$ disagreement point $\uparrow$

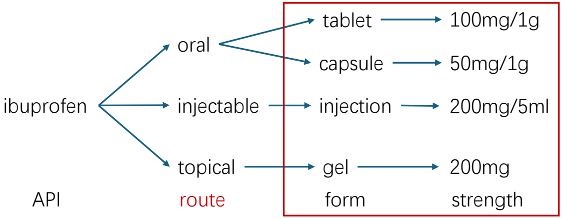
VI. Structural Estimation

(WIP) Nash-in-Nash framework *à la* Grennan (2013)

- Y-Q t, city c, API (general name) $a \Rightarrow$ “market” $m = a \times c \times t$
- Drug j: a strength of an API-form (product name) of firm f

Primitives

- Government (on behalf of *all* hospitals) and firms negotiate uniform prices p_{jm} in each m
- Doctors (on behalf of patients i w/ indication a in ct) choose $j \in J_m$
- Demands are independent across m; doctors perceive substitution only among j



VI. Structural Estimation

Demand side: nested logit model

- Utility of the doctor for patient i: $u_{ijm} = \delta_{jm} + \varepsilon_{ijm}$
- $\delta_{jm} = \theta_{jm} - \theta^P p_{jm} + \mathbf{X}'_{jm}\theta^X + \xi_{jm}$
- $\varepsilon_{ijm} = \epsilon_{igm} + (1-\sigma)\epsilon_{ijm}$, with g = route
- Aggregated demand share: $s_{jm} = \int_{\mathcal{A}_{jm}} dF(\varepsilon)$

Outside option

- Market size: all **patients** with indication a in ct
- Demographic: N_{ct}; incidence×treatment rate ρ_m is unavailable
- $s_{jm} \times \rho_m = q_{jm}/N_{ct}$

$$\ln\left(\frac{q_{jm}}{Q_m}\right) - \ln\left(\rho_m \frac{N_{ct}}{Q_m} - 1\right) = \delta_{jm} + \sigma \ln\left(s_{m,j|g}\right) \tag{1}$$

- $\rho_m = \rho_{ac} \times \rho^0_{ac}$, with $\rho^0_{ac} = \frac{\max_t Q_{act}}{\min_t N_{ct}}$

VI. Structural Estimation

Demand side estimation: $\Theta^D = (\theta, \sigma, \rho)'$

1. Given $\rho \Rightarrow$ LHS in eq (1)
2. 2SLS estimator: $\mathbb{E}(\mathbf{Z}^{D\prime}\boldsymbol{\xi}) = 0 \Rightarrow \hat{\theta}$, $\hat{\sigma}$

$$\text{LHS}_{jm}(\rho_m) = \sigma \ln\left(s_{m,j|g}\right) + \theta_{jm} - \theta^P p_{jm} + \mathbf{X}'_{jm}\theta^X + \xi_{jm}$$

3. GMM estimator: $\hat{\rho} = \arg\min_\rho(\boldsymbol{\xi}'\mathbf{Z}^D)(\mathbf{Z}^{D\prime}\mathbf{Z}^D)^{-1}(\mathbf{Z}^{D\prime}\boldsymbol{\xi})$

Demand IVs:

- BLP-style (city-level LOO mean)
  - $J_{at}^{-1}\sum_{j'\in a\backslash j} C_{j't}^{-1}\sum_{c'\neq c}$: $p_{j'ac't}$, $s_{ac't,j'|g}$, $\frac{q_{j'ac't}}{Q_{ac't}}$
- Demographic: $J_{at}^{-1}\sum_{j'\in a\backslash j} C_{j't}^{-1}\sum_{c'\neq c}\ln(\rho^0_{ac'}\frac{N_{c't}}{ac't}) \times p_{j'ac't}$
- Time: 1 quarter lag
- Interaction and square terms

VI. Structural Estimation

One-to-many NiN: the government vs. multi-product firms

$$\forall j, m: \quad \max_{\{p_{jm}\}_{j \in J_{fm}}} (W_m - W_{fm}^d)^{b_{Gm}} (\sum_{j \in J_{fm}} \Pi_{jm} - \Pi_{fm}^d)^{b_{fm}} \tag{2}$$

- Social welfare: $W_m = \sum_k \int_{\mathcal{A}_{km}} \frac{u_{ikm}}{\theta^p} dF(\varepsilon)$
  - $\partial W_m / \partial p_{jm} = -q_{jm}$
- Profit: $\Pi_{jm} = q_{jm}(p_{jm} - c_{jm})$
- Disagreement point:
  - Government: $W_{fm}^d = \sum_{k \setminus J_{fm}} \int_{\mathcal{A}_{km}} \frac{u_{ikm}}{\theta^p} dF(\varepsilon)$
  - Firm: Π_{fm}^d

VI. Structural Estimation

Bargaining power based on Shapley value

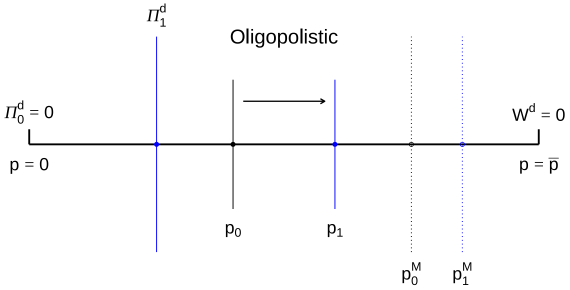
$$\frac{b_{fm}}{b_{hm}} = \frac{\tilde{\Delta}_{fm}}{\tilde{\Delta}_{hm}} = \frac{\tilde{W}_m - \tilde{W}^d_{fm}}{\tilde{W}_m - \tilde{W}^d_{hm}}; \quad \frac{b_{fm}}{b_{Gm}} = \frac{\tilde{\Delta}_{fm}}{\tilde{W}_m \cdot \nu} \tag{3}$$

- s.t. $b_{Gm} + \sum_f b_{fm} = 1, \;\; \nu > 0$
- $\tilde{x}_t = x_{t-1}$
- Competitive: $\tilde{\Delta}_{fm} = 0 \Rightarrow b_{Gm} = 1$
- Monopoly: $\tilde{W}^d_{fm} = 0 \Rightarrow b_{Gm} = \frac{\nu}{1+\nu} \in (0,1)$

F.O.C.

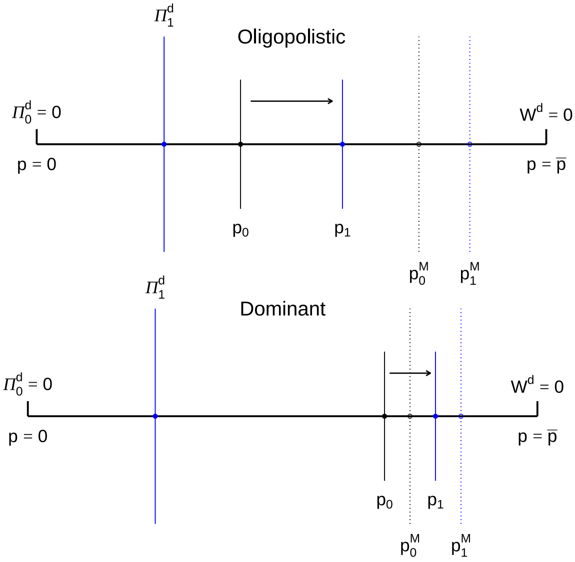
$$\frac{b_{fm}}{b_{Gm}} = \frac{\sum_{k\in f} \Pi_{jm} - \Pi^d_{fm}}{W_m - W^d_{fm}} \left[1 + \sum_{k\in f} \frac{\partial q_{km}}{\partial p_{jm}} (p_{km} - c_{km}) \right]^{-1} \tag{4}$$

VI. Structural Estimation

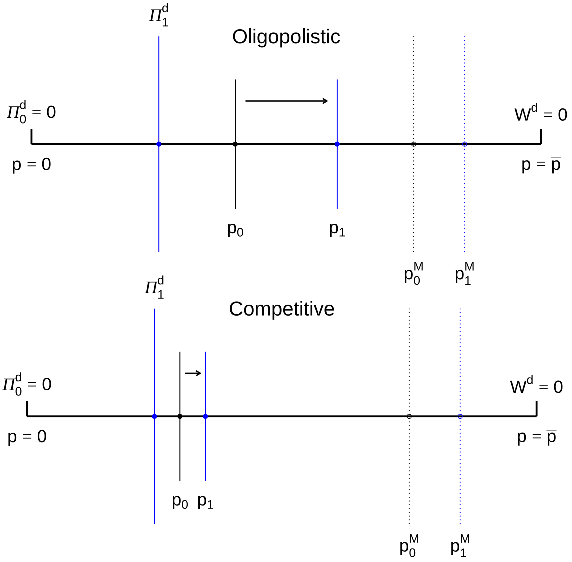


- Single-product firm
- $\bar{p}$, $W^d = 0$; p^M, fully monopolized
- w/o API mono., $\Pi_0^d = 0$; w/ API mono., $\Pi_1^d > \Pi_0^d$
- Concavity of Nash product: $p_1 - p_0 > p_1^M - p_0^M$
- Concentration $\Rightarrow$ bg. power $\uparrow$, $\bar{p} - p_0 \downarrow$

VI. Structural Estimation



VI. Structural Estimation



VI. Structural Estimation

Estimation

$$\Pi_{fm} - \frac{b_{fm}}{b_{Gm}} \left(W_m - W_{fm}^d\right) \left[1 + \sum_{k \in f} \frac{\partial q_{km}}{\partial p_{jm}} \left(p_{km} - c_{km}\right)\right] = \Pi_{fm}^d \quad (5)$$

- API-level marginal cost: $c_{km} = \gamma_a + \gamma_{at}^{\text{case}}$
- City-level government f.e.: $\nu = \nu_c$
- $\text{LHS}_{jm}(\mathbf{s}_m, \mathbf{p}_m; \theta, \gamma, \nu) = \Pi_{at}^d + \mu_{jm}$, with

$$\Pi_{at}^d = \begin{cases} \Pi_a^d, & \text{case}_{at} = 1 \\ 0, & \text{o.t.w.} \end{cases}$$

- Supply side instruments: $\mathbb{E}(\mathbf{Z}^{S\prime} \boldsymbol{\mu}) = 0 \Rightarrow \hat{\Pi}^d$
- GMM estimator: $(\hat{\gamma}, \hat{\nu})' = \arg\min(\boldsymbol{\mu}' \mathbf{Z}^S)(\mathbf{Z}^{S\prime} \mathbf{Z}^S)^{-1}(\mathbf{Z}^{S\prime} \boldsymbol{\mu})$

VII. Concluding Remarks

- API cases have led to an average downstream price increase of 77.4%
- The price effect is 114% lower in single-dominant downstream markets and 198% higher in symmetric duopoly markets
- The odds ratio of API mono. is 48.6% of the average with single-dominated downstream, while 431.9% with balanced duopolistic downstream.
- We suggest that API mono. events alter the disagreement points, representing a vertical relation beyond double marginalization