Welfare Effects of Buyer and Seller Power

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Motivation: Competitive Effects of Buyer Power

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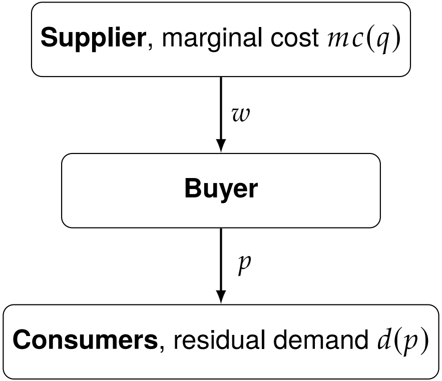
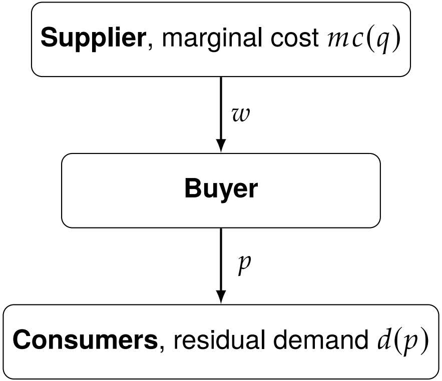
When are buyer & seller power anti-competitive or pro-competitive?

Stylized Framework



- Single supplier and buyer
- Supplier sells q units to buyer at w
- Buyer sells q to consumers at p

Stylized Framework: Classical Monopsony



- $mc'(q) > 0$
- $d'(p) = 0$
- Seller chooses supply $q(w)$
- Buyer chooses w
- Inefficiency: buyer exercises monopsony power when setting w

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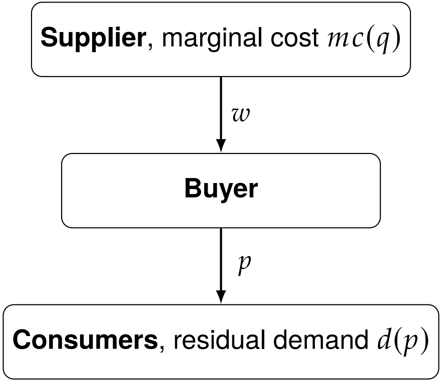

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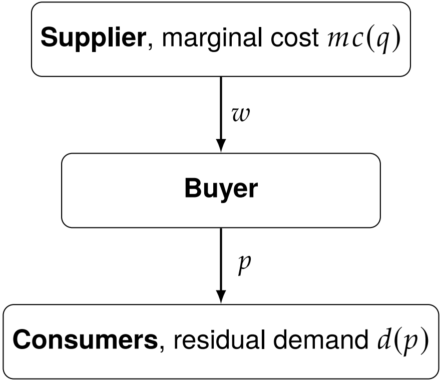
Examples:

- Robinson (1969); Card, Cardoso, Heining, Kline (2018); Berger, Herkenhoff, Mongey (2022)

Stylized Framework: Sequential Monopoly



- $d'(p) < 0$
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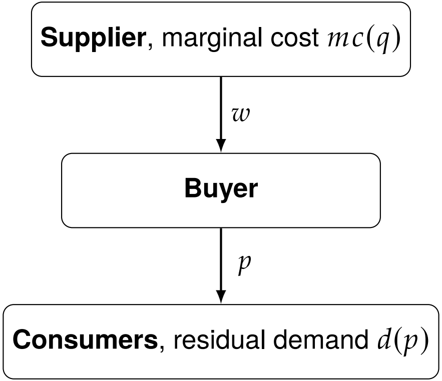

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Examples:

- Grennan (2013), Ho and Lee (2017); Crawford, Lee, Whinston, Yurukoglu (2018); Hosken, Larson-Koester, Tarragin (2023)

This Paper

Unified framework that accommodates both monopsony and monopoly distortions

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- Increasing marginal cost of seller $mc'(q) \geq 0$, decreasing demand curve of buyer $d'(p) \leq 0$
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- Conduct (monopsony or monopoly) is endogenously determined
- Nests most commonly used vertical models in the literature

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Application to coal procurement of power plants from coal mines

- ERCOT ISO (Texas) market, 2005-2015
- Rich data on upstream + downstream cost curves
- Observe transacted wholesale prices + contract information

Contribution to the Literature

1. **Empirical models of bargaining**
   - Ho, Lee (2017); Crawford, Lee, Whinston, Yurukoglu (2018); Collard-Wexler, Gowrisankaran, Lee (2019); Alviarez, Fioretti, Kikkawa, Morlacco (2022), Hosken, Larson-Koester, Tarragin (2023) ;

→ These assume downstream picks p (or q), double marginalization due to upstream monopoly power

Contribution to the Literature

1. **Empirical models of bargaining**

2. **Monopsony/oligopsony models:**
   - Prager & Schmitt (2021); Arnold (2019); Berger, Hasenzagl, Herkenhoff, Mongey, & Posner, (2023)

   $\longrightarrow$ These assume upstream chooses its supply, double marginalization due to downstream monopsony power.

Contribution to the Literature

1. **Empirical models of bargaining**

2. **Monopsony/oligopsony models:**

3. **Countervailing power:**

   - Galbraith (1954), Hemphill & Rose (2018); Barrette, Gowrisankaran, Town (2022), Loertscher & Marx (2022)

   $\longrightarrow$ We allow for countervailing power in complete-information Nash-in-Nash bargaining models

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1. **Empirical models of bargaining**

2. **Monopsony/oligopsony models:**

3. **Countervailing power:**

4. **Vertical conduct inference:**
   - Bonnet & Dubois (2010), De Loecker & Scott (2015), Atkin, Blaum, Fajgelbaum, Ospital, 2024

   → Rather than testing for conduct in equilibrium, we present a model in which vertical conduct is a function of the model primitives

Model Primitives

Seller u and buyer d negotiate over **linear contract** w.

- Profits: $\pi_d = [p(q) - w]q$, $\pi_u = [w - c(q)]q$. Zero disagreement payoff.

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Notation:

- $mc(q) \equiv \frac{\partial(c(q)q)}{q}$, $mr(q) \equiv \frac{\partial(p(q)q)}{q}$
- $0 \leq \beta \leq 1$: bargaining power of buyer, 'buyer power'

Possible Conduct Types

Two possible types of ‘vertical conduct’:

‘Monopolistic bargaining’ (‘mpl’):

$$\begin{cases} \max_{w} (\pi_u)^{(1-\beta)} (\pi_d)^{\beta} \\ \max_{q} \pi_d \end{cases} \rightarrow (q^{mpl}, w^{mpl})$$

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We will compare to, but do not allow for, **joint profit maximization (‘jpm’):**

$$q^{jpm} = \arg\max_{w,q} (\pi_u)^{(1-\beta)} (\pi_d)^{\beta} \qquad \rightarrow (q^{jpm}, w^{jpm})$$

Timing Assumptions

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Input price bargaining and quantity decision happen simultaneously:

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Input price bargaining and quantity decision happen simultaneously:

1. Upstream and downstream observe $c(.), p(.), \beta$
2. Upstream **or** downstream choose q, simultaneously they bargain over w

Extension: Sequential Model

Alternatively, consider sequential model:

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This nests often-used models:

	Monopolistic	**Monopsonistic**
$\beta = 0$	Sequential monopoly	Seller makes TIOLI offer (w, q)
$\beta = 1$	Buyer makes TIOLI offer (w, q)	Classical monopsony

Result 1: Existence of Equilibrium

Result ‘Nash-in-Nash’ (Horn & Wolinsky, 1988) equilibrium: equilibrium conditions

- $c'(q) = 0$: equilibrium only exists under **monopolistic conduct**
- $d'(p) = 0$: equilibrium only exists under **monopsonistic conduct**
- $c'(q) > 0, d'(p) < 0$: Equilibrium exists under both monopolistic **and** monopsonistic conduct

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Denote $q^{mps}(\beta), q^{mpl}(\beta)$ as equilibrium output under each conduct

Result 2: How does Equilibrium Quantity Changes with Buyer Power

Result: $q'(\beta)$ depends on conduct: $\dfrac{\partial q^{mpl}(\beta)}{\partial \beta} \geq 0, \dfrac{\partial q^{mps}(\beta)}{\partial \beta} \leq 0$

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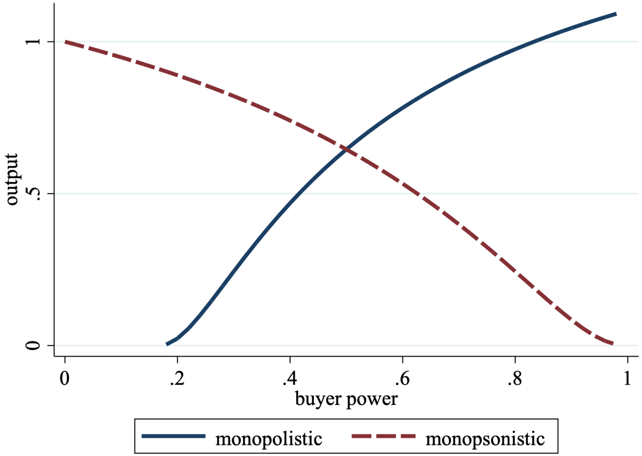
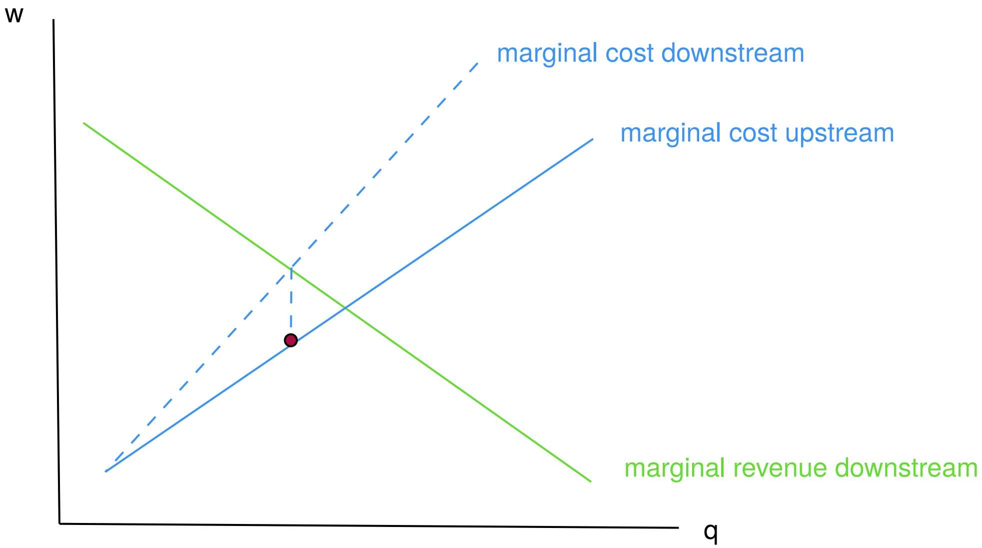


Intuition: Monopsony



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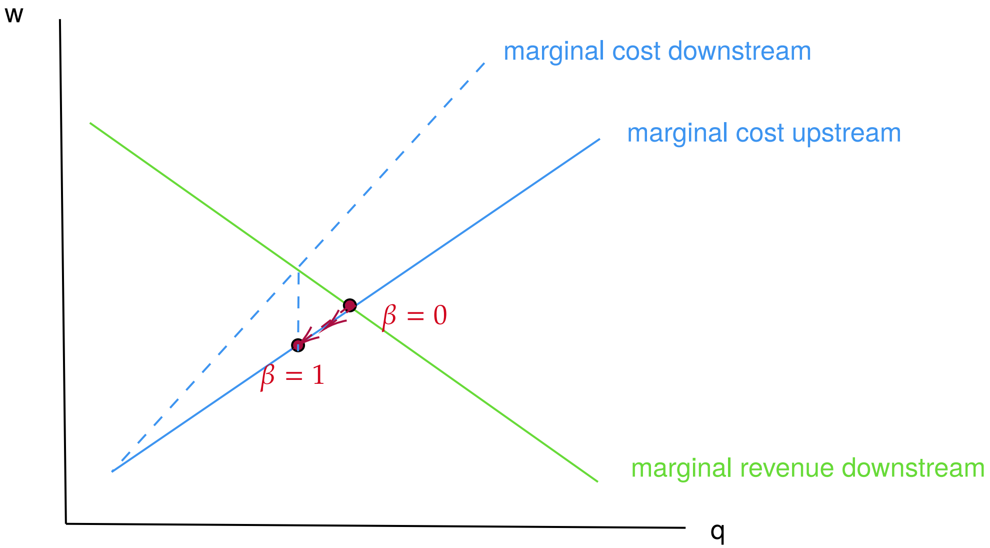

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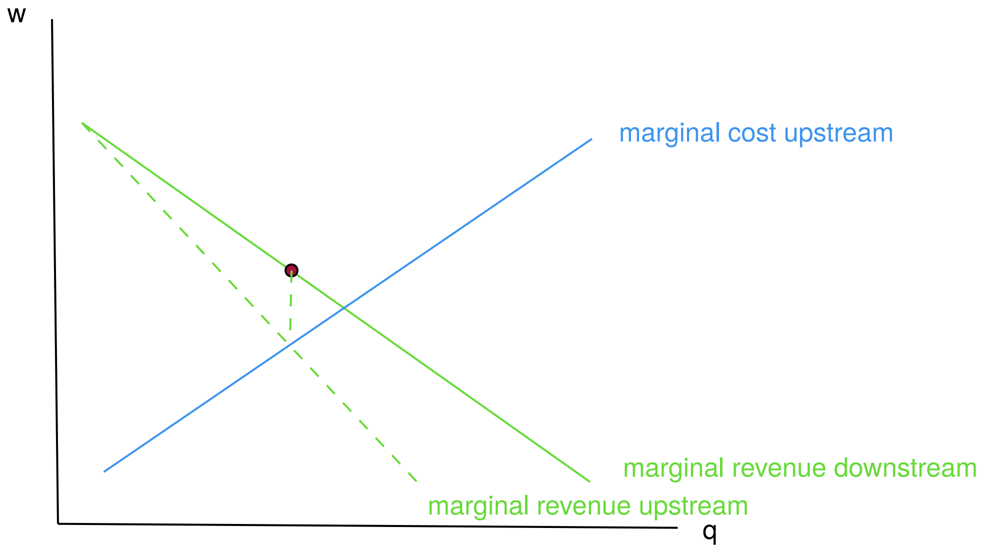

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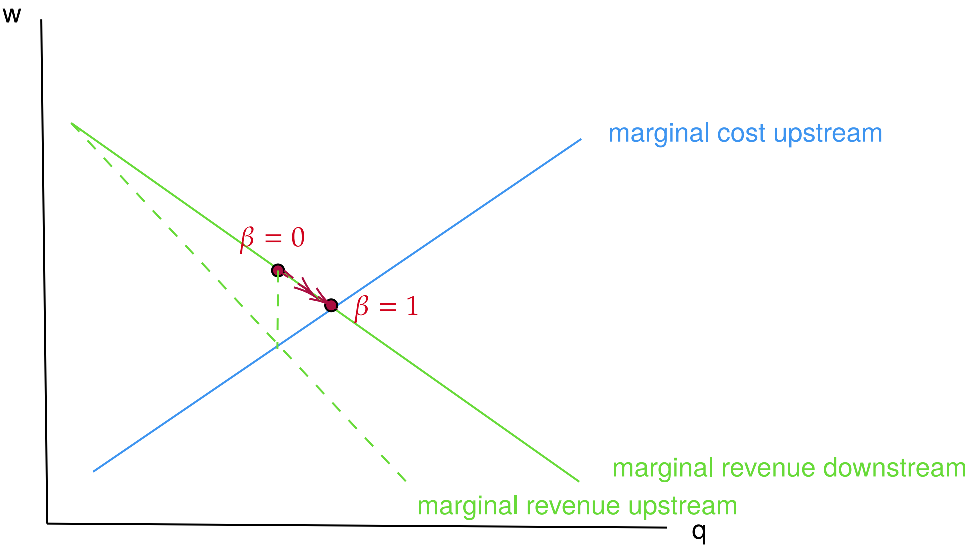

Result 3: Output-Maximizing Bargaining Parameter

Result: There exists $\beta^* \in [0, 1]$ such that $q^{mps}(\beta^*) = q^{mpl}(\beta^*) = q^{jpm}$.

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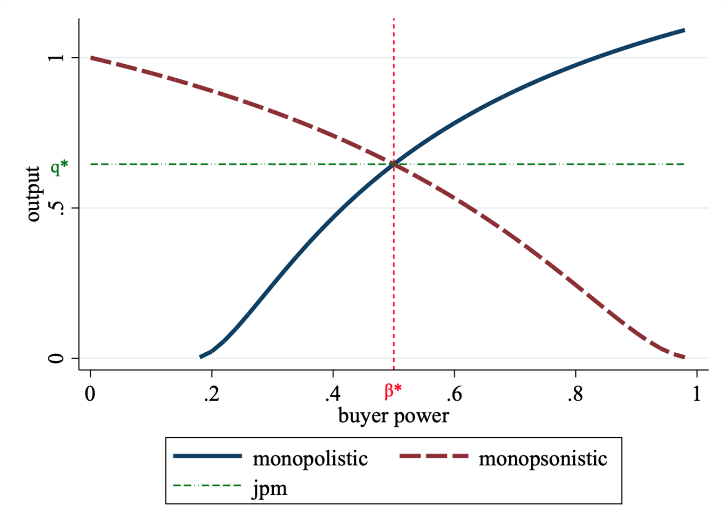

Assumption: Non-negative markups and markdowns

We do not want to impose a vertical conduct assumption (monopolistic/monopsonistic)

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Instead, we impose two **additional assumptions:**

- $w \geq mc(q)$ (A1)
- $w \leq mr(q)$ (A2)

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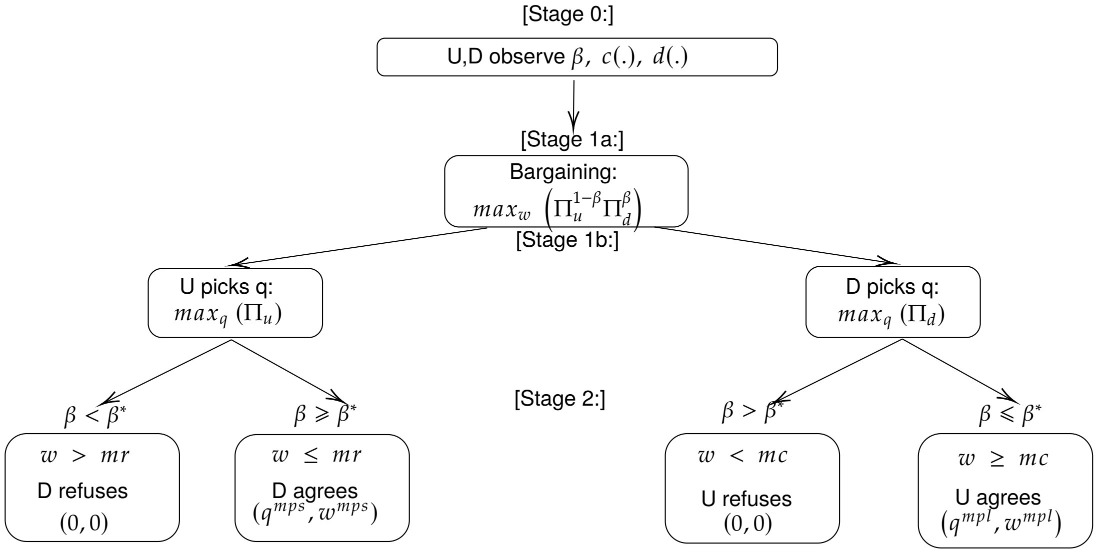
This has two relevant implications:

- Output bounded by q^{jpm} (testable)
- Output-setting party cannot improve by moving to JPM

Game tree



[Stage 0:]
U,D observe $\beta,\ c(.),\ d(.)$
[Stage 1a:]
Bargaining:
$max_w\ \left(\Pi_u^{1-\beta}\Pi_d^{\beta}\right)$
[Stage 1b:]
U picks q:
$max_q\ (\Pi_u)$
D picks q:
$max_q\ (\Pi_d)$
[Stage 2:]
$\beta < \beta^*$
$\beta \geqslant \beta^*$
$\beta > \beta^*$
$\beta \leqslant \beta^*$
$w\ >\ mr$
D refuses
$(0,0)$
$w\ \leq\ mr$
D agrees
(q^{mps}, w^{mps})
$w\ <\ mc$
U refuses
$(0,0)$
$w\ \geq\ mc$
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(q^{mpl}, w^{mpl})

Result 4: Unique Vertical Conduct

Theorem Under assumptions (A1), (A2), there is a unique Nash-in-Nash equilibrium for each bargaining parameter β: monopolistic if $\beta < \beta^*$, monopsonistic if $\beta > \beta^*$.

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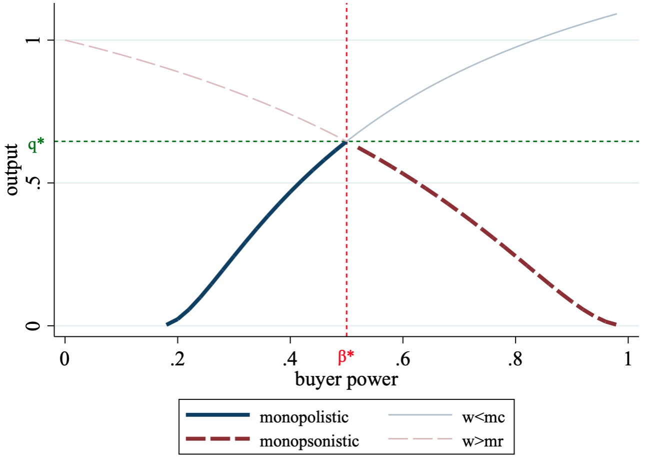
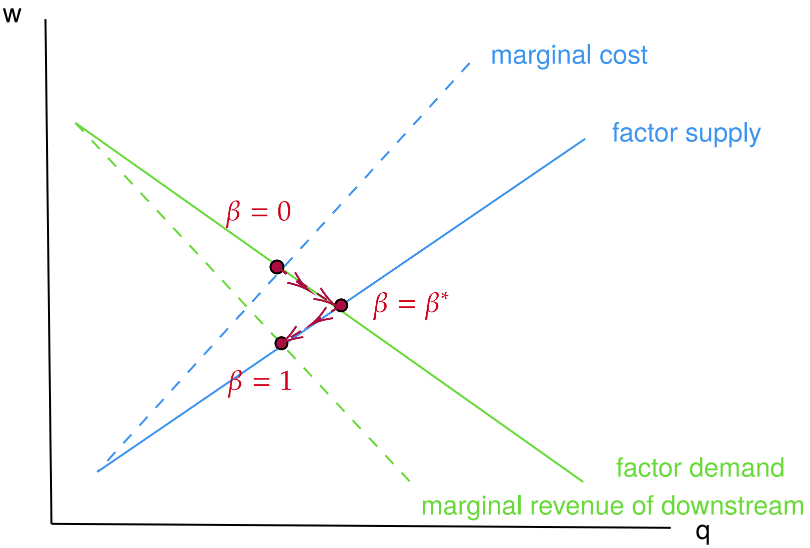


Intuition: Buyer *and* Seller Power



Vertical Conduct: Determinants

β^* is a function of cost and demand curvature:

$$\beta^* = \frac{-p'(q^*)}{c'(q^*) - p'(q^*)}$$

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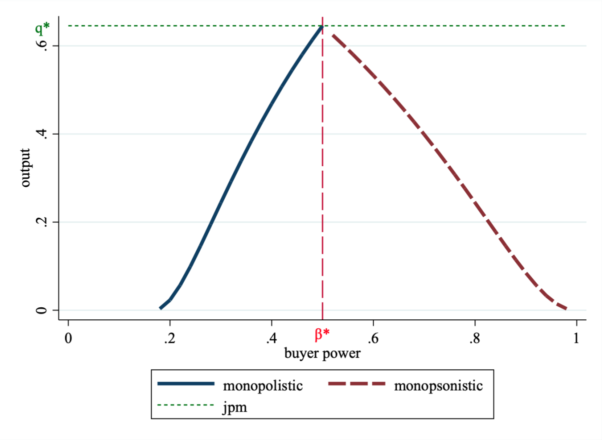
- More inelastic demand $(-p'(q^*) \uparrow) \longrightarrow \beta^* \uparrow$
- Steeper marginal cost curve $(c'(q^*) \uparrow) \longrightarrow \beta^* \downarrow$
- $\beta^* = 0$ if fully elastic residual demand, $\beta^* = 1$ if constant marginal cost

Deadweight Loss



Parametrization

Deadweight loss as soon as $\beta \neq \beta^*$:

- **Buyer** power-induced if $\beta > \beta^*$
- **Seller** power-induced if $\beta < \beta^*$

Generalizations

- **Multiple buyers** that compete à la Cournot
  - # Competitors $\Rightarrow \beta^* \downarrow$ Cournot results
  - Increased competition makes residual demand curve more elastic
  - This increases the range of β values for which monopsonistic conduct occurs in equilibrium
- **Sequential model**
  - First bargaining, then output decision (as in Ho & Lee, 2019)
  - Results generalize, $q'(\beta)$ less steep, i.e. lowers deadweight losses Sequential model results
- **Non-zero disagreement payoffs**
  - Baseline: fix disagreement payoffs, vary β
  - Alternative: fix β, vary disagreement payoff of buyer ('z') & seller ('y')
  - Results generalize: $q(z-y)$ is inverted V-function Disagreement payoff results
- **Alternative supergame** with JPM option Game tree

Takeaways

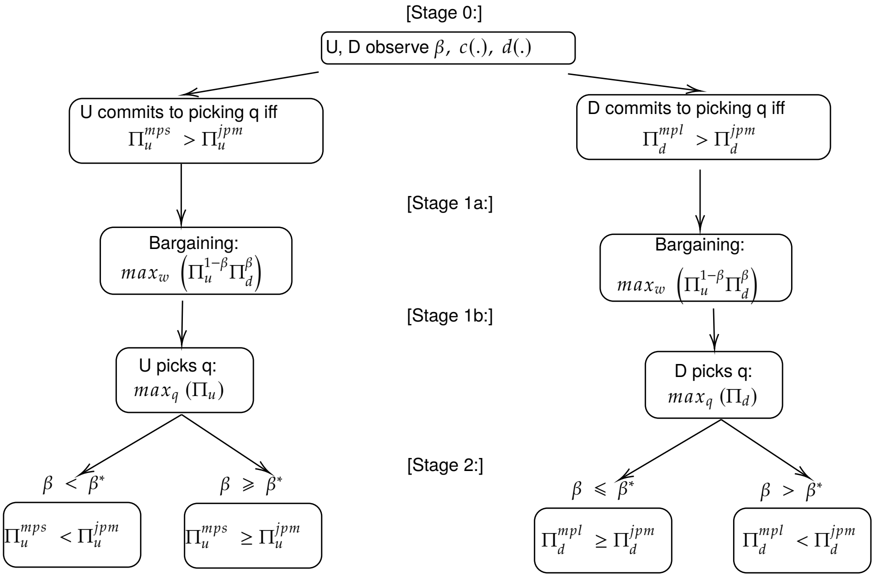
Consumer welfare losses of buyer / seller power depend on:

- shape of the marginal cost curve (upstream)
- shape of the demand curve (downstream)
- level of the bargaining parameter

Output is maximized when bargaining power is in the interior, except in extreme cases

Empirical question, requires knowledge of market primitives

Alternative Game tree



back

Empirical Application: Coal Procurement in ERCOT

- Study wholesale coal market in the US
- Focus on coal-fired power plants in the **ERCOT** ISO
- Objective: quantify deadweight loss, decompose into buyer and seller power
- Ideal empirical setting:
  - Transaction-level wholesale prices and quantities are observed
  - Upward sloping marginal cost of mining companies
  - Estimate upstream and downstream marginal cost curves using rich cost data

Data

1. **Power Plant Data**: EPA, EIA, Velocity Suite, ERCOT
   - Hourly fuel consumption and generation
   - Fuel Type, Capacity, Location, Ownership
   - Hourly nodal prices

Data

1. **Power Plant Data**: EPA, EIA, Velocity Suite, ERCOT

2. **Coal Mine Data**: Mine Safety and Health Administration, Coal Cost Guide, Velocity Suite
   - Quarterly production of coal mines
   - Variable and fixed cost by mine type, hourly wages at the county level
   - Ownership and mergers and acquisitions

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1. **Power Plant Data**: EPA, EIA, Velocity Suite, ERCOT

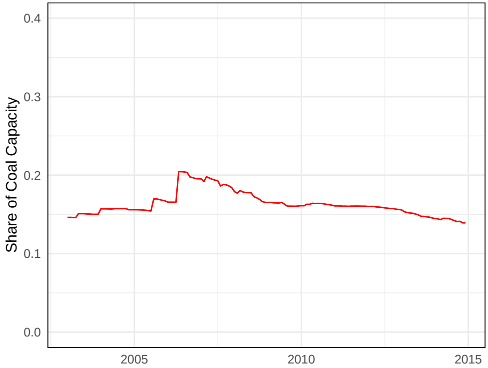
2. **Coal Mine Data**: Mine Safety and Health Administration, Coal Cost Guide, Velocity Suite

3. **Coal Transaction Data**: Velocity Suite (based on EIA data)
   - Monthly coal shipment with prices, quantities and coal type
   - Contract duration
   - Transportation mode and transportation cost

Summary Statistics

	Upstream	Downstream
	Unit Characteristics	
# of Units (Plant or Mine)	25	9
# of Firms	9	3
# of Units per Firm	2.51	2.88
Avg. # of Trade Partners	22.09	2.65
Avg. Share of Largest Partner	0.42	0.53
	Transaction Characteristics	
Average Fob Price (per mmtbu)	-	0.85
Contract Duration (year)	-	1.42
% Spot	-	0.04
% Railroad	-	0.77

Ercot Market



- Ercot market is ideal empirical setting
  - No import and export
  - Most power plants are not regulated
  - Availability of nodal prices
- Stable coal capacity share between 2005 and 2015
- Existing evidence of market power

  (Hortacsu and Puller, 2008 ; Hortacsu et al, 2015)

Empirical Model: Roadmap

Empirical model requires the following primitives

- **Mining Firm Supply Curves**
  - Production function: Aggregate marginal cost of individual mines at the firm level
- **Downstream Demand Curve**
  - Cournot Model: Assume power plants compete a la Cournot to estimate residual demand curves
- **Transactions and Disagreement Payoffs**
  - Transaction Data: Whole prices and quantities, use spot prices to estimate disagreement payoff

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- With these primitives estimate bargaining model and bargaining weights, quantify welfare loss
- Define welfare as consumer surplus. Can adjust for externalities (e.g. environmental).

Estimating Mining Supply Function

- A mining firm u consists of a portfolio of mines $i(u)$
- Estimate Leontief production function in labor and non-labor inputs
- Mine i that produce q_i has the following marginal cost curve (quantities in terms of heat input)

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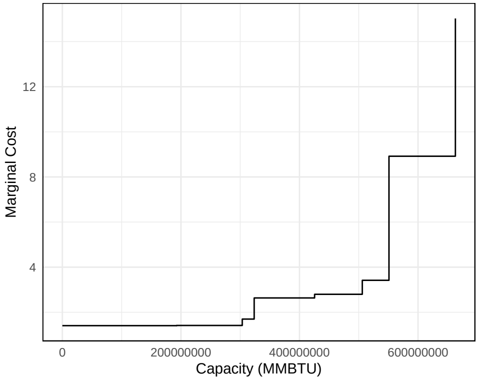
$$\underbrace{c_i}_{\text{marginal cost}} = \frac{\overbrace{h_i l_i}^{\text{Labor cost}} + \overbrace{p^v v_i}^{\text{Non-labor variable costs}}}{\underbrace{q_i}_{\text{production}}} \text{ if } q_i < cap_i$$

- **Supply curve of mining firm**: rank mines by increasing c_i, add start-up costs of idle mines
  $c_u = \{c_1, c_2 + I_2, c_3 + I_3 \ldots\}$

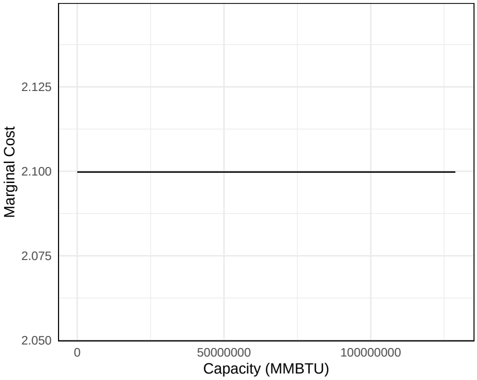
estimation details

Mining Supply Curves: Examples

Vistra Energy (2015)



Westmoreland Coal Company (2015)



Power Plant Cost Curve

- Each power company d consists of a portfolio of power plants
  - Potentially different fuels (nuclear, gas, coal renewable)
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Production technology for power plant j:

$$\underbrace{q_j^e}_{\text{electricity output}} = \underbrace{q_j^c}_{\text{heat input}} / \underbrace{\lambda_j}_{\text{heat rate}}$$

Marginal cost of each power plant:

$$c_j(q_j^e) = q^c \lambda_j \underbrace{w}_{\text{coal price per mmbtu}}$$

- w^c = fob price + transportation cost

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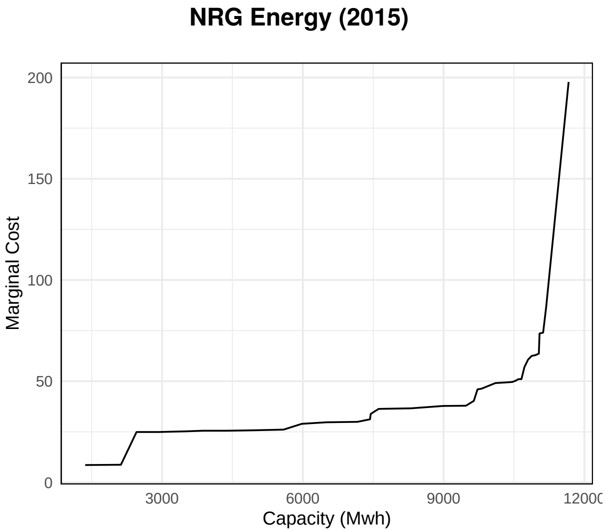
- Cost curve of power firm is the aggregation of individual marginal cost from lowest to highest

Power Plant Cost Curve: Example



Modeling Electricity Market: Cournot Competition

- We impose **Cournot competition** to model electricity market
  - (Borenstein et al., 1995; Borenstein and Bushnell, 1999 ; Puller, 2007)
- Market includes **fringe and strategic firms**
  - Fringe (competitive) firms: Small market share firms (less than 5% capacity) and regulated firms.
  - Strategic (Cournot) firms: Large firms compete à la Cournot
  - The market definition is an ISO (ERCOT)

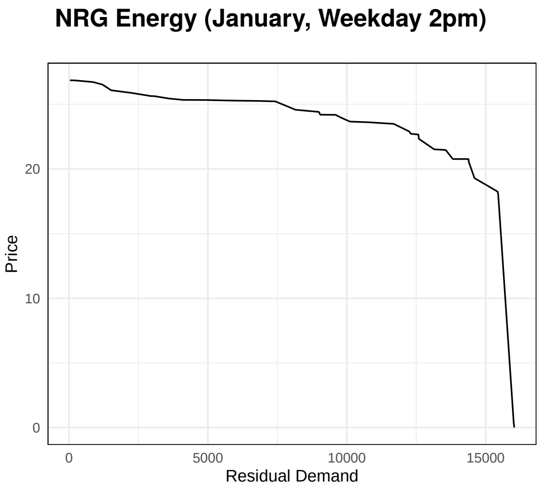
Modeling Electricity Market: Cournot Competition

- We impose **Cournot competition** to model electricity market
  - (Borenstein et al., 1995; Borenstein and Bushnell, 1999 ; Puller, 2007)
- Market includes **fringe and strategic firms**
  - Fringe (competitive) firms: Small market share firms (less than 5% capacity) and regulated firms.
  - Strategic (Cournot) firms: Large firms compete à la Cournot
  - The market definition is an ISO (ERCOT)
- Strategic firms face the following demand curve every hour t

$$\underbrace{Q^D_{\text{strat}}(P_t)}_{\text{Strategic demand at price } P_t} = \underbrace{Q^D_{\text{total}_t}}_{\text{Inelastic demand at hour t}} - \underbrace{Q^S_{\text{fringe}}(P_t)}_{\text{Supply from fringe firms at price } P_t}$$

- Supply elasticity of fringe firm determines the residual demand curve for strategic firms

Electricity Demand: Example



- Estimate residual demand for every month-hour-(weekend/weekday) combination
- Use average fringe supply and demand to estimate firm's expected residual demand curve
- Aggregate hourly residual demand curves to yearly level

Modeling Electricity Market: Cournot Competition

- Strategic firm d chooses quantity in period t to maximize profit subject to a capacity constraint:

$$\max_{q_{dt}} \left(P(q_{dt} + q_{-dt}) \cdot q_{dt} - C_{dt}(q_{dt})\right) \quad \text{s.t.} \quad q_{dt} \leq k_{dt}$$

- The annual profit of the power company is

$$\Pi_d = \sum_t \pi_{dt}(q_{dt}, q_{-dt})$$

Solving the Model

We solve the model for every contracting pair-year using the estimated primitives

- (i) electricity demand curve at downstream firm
- (ii) coal mining marginal cost curve of upstream firm

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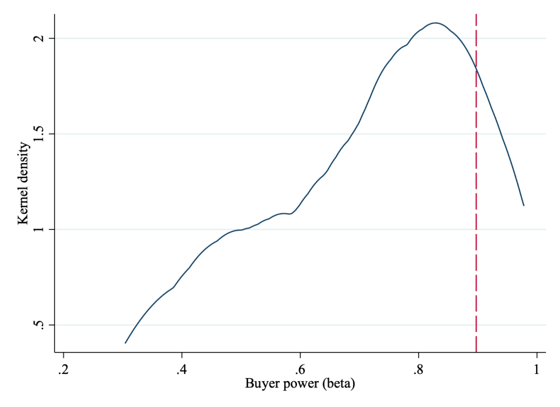
Estimation Procedure

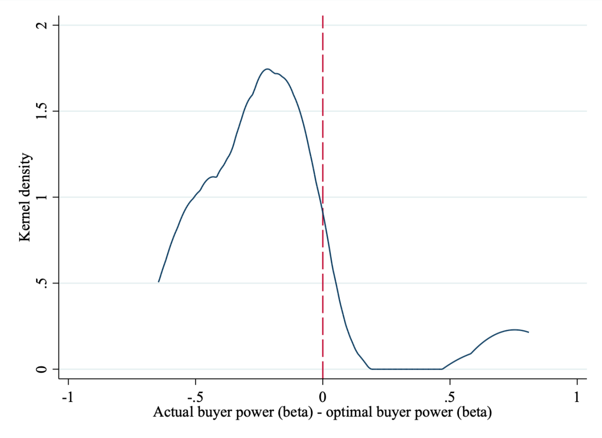
1. Solve equilibrium (q, p, w) under monopsonistic and monopolistic conduct to form payoff functions
2. For each $\beta \in (0, 1)$, form coal demand and supply curve under monopolistic and monopsonistic bargaining equilibrium conditions
3. Estimate β as value that rationalizes observed w
4. Compare β to β^*, $q(\beta)$ to $q(\beta^*)$

Buyer Power: Estimates



- Power plants relatively more bargaining power than mines
- Output-maximizing bargaining parameter around 0.9
- Mines still have too much bargaining power, deadweight loss mostly due to double marginalization

Actual vs. Output-Maximizing Buyer Power



Counterfactuals

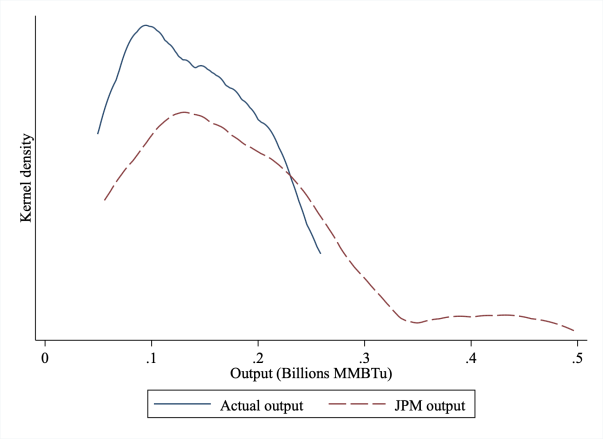
Today:

1. First best: Comparison between actual conduct and joint profit maximization (first best), in terms of Q, CS, DS, US. Upper bound on the potential gains from eliminating seller + buyer power

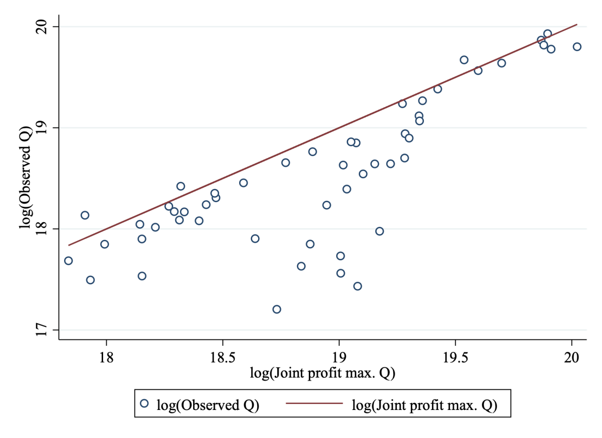
In progress:

2. Vertical merger: Compute how far β is from β^* in vertically integrated plants on average. How close to first best can we get by vertically integrating?
3. Horizontal mergers between D: depending on whether $\beta > \beta^*$ or $\beta < \beta^*$, we can get closer or further from the first best
4. Horizontal mergers between U: same, but opposite effect as mergers between D.

Deadweight Loss



Deadweight Loss



Deadweight Loss

Deadweight loss	Amount (Billion $)	% of Total Loss
Total	$9.05 (5.11%)	-
Due to Monopsony	$1.56	17.29%
Due to Monopoly	$7.48	82.71%

Conclusion

We extend Nash-in-Nash bargaining models to allow for either monopsony or monopoly conduct and distortions

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We find that the relative distortions of buyer and seller power depend on

- Curvatures of the upstream marginal cost and downstream residual demand
- Level of the bargaining parameter

Conclusion

We extend Nash-in-Nash bargaining models to allow for either monopsony or monopoly conduct and distortions

We find that the relative distortions of buyer and seller power depend on

- Curvatures of the upstream marginal cost and downstream residual demand
- Level of the bargaining parameter

Applying model to study coal fuel procurement in the ERCOT ISO, we find that

- A deadweight loss of 5.11% the total output.
- 83% of DWL due to seller power, 17 due to buyer power

Appendix

Parametrization

Consumer demand for q:

$$q(p) = p^{\eta}$$

Cost curve of U:

$$c(q) = q^{\psi}$$

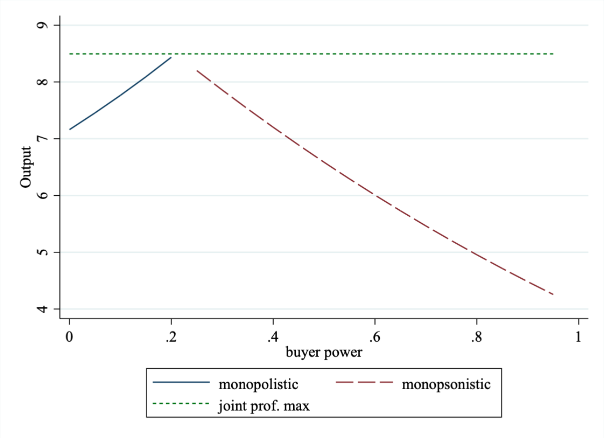
Solve for equilibrium using

- $\eta = -6$
- $\psi = 0.25$
- $\beta \sim \mathcal{U}[0, 1]$,

Back to conduct

More elastic demand

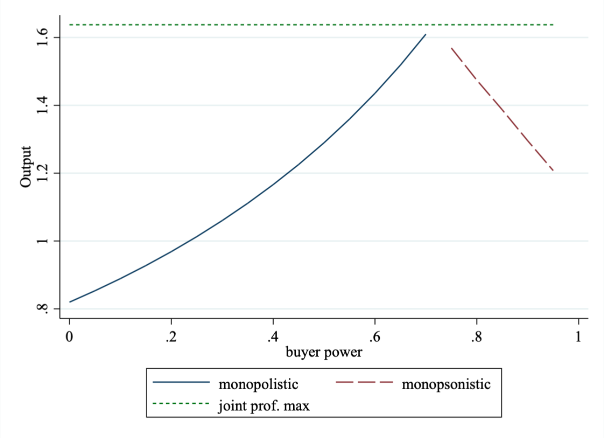
Let $\eta = -20$, rather than $\eta = -6$



back to slides graph with inelastic demand

More inelastic demand

Let $\eta = -3$, rather than $\eta = -6$



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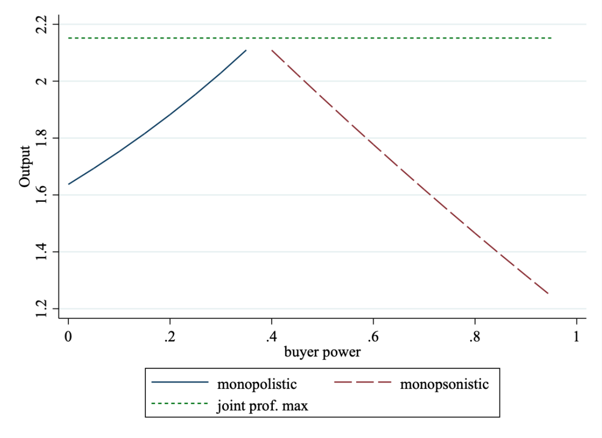
More elastic supply

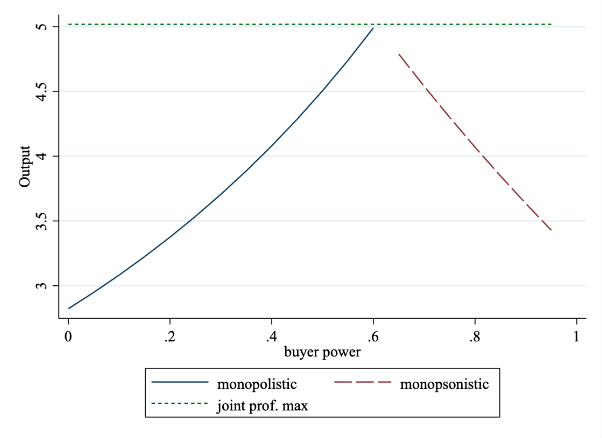
Let $\psi = 0.5$ rather than $\psi = 0.25$:



back to slides   graph with inelastic supply

More elastic marginal costs curve

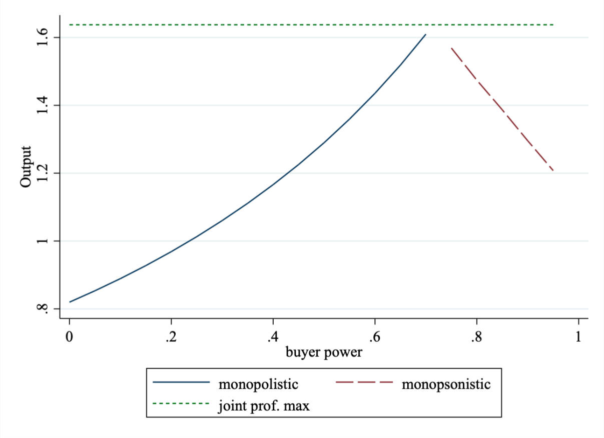
Let $\psi = 0.15$ rather than $\psi = 0.25$:



back to slides

More inelastic demand

Let $\eta = -3$, rather than $\eta = -6$

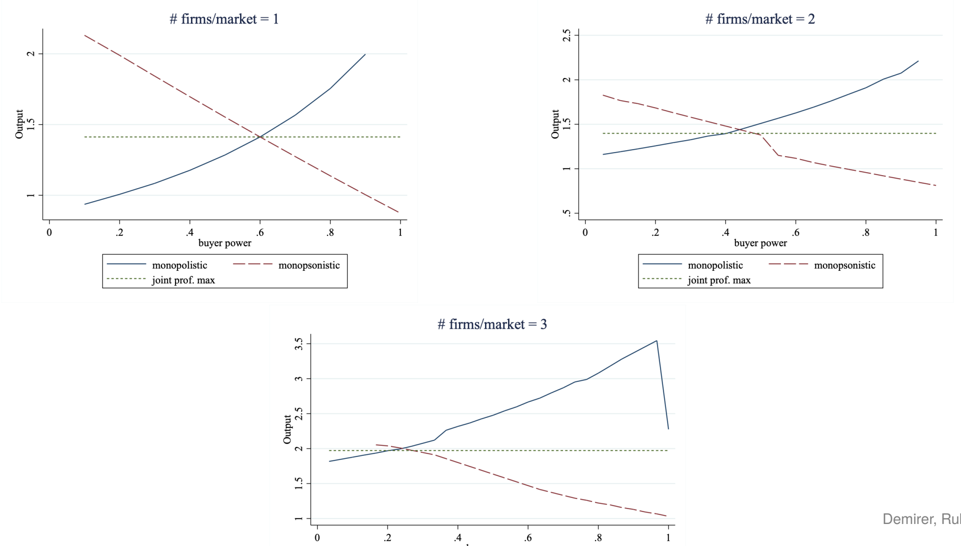


back to slides

Cournot competition

$\eta = -3$, $\psi = 0.25$, 1 to 3 firms

back to slides



Coal Mining Production Model Estimation

- Mines m characterized by 'type' $\boldsymbol{\theta}_m$: (capacity, vein thickness, technology)

- Coal Cost Guide: $\gamma_{\boldsymbol{\theta}_m} = \frac{p^v v}{hl}$

$$\Rightarrow c_m = h_m \frac{l_m}{q_m}(1 + \gamma_{\boldsymbol{\theta}_m}) + v_m(cap_m - q_m) \text{ if } q_m \leq cap_m$$

- Estimate $c_m - v_m(cap_m - q_m)$ by cap_m, then find v_{cap_m} by linear interpolation

back to main slide deck

Bargaining model

- **Monopolistic bargaining:**

$$\begin{cases} \max\limits_{Q_d^e} \pi_d(Q_d^e, W_d) \\ \max\limits_{W_{kl}} \left[\left(\pi_d(Q_d^e, W_d) - \pi_d(\tilde{Q}_d^e, W_{u,-d}) \right)^{\beta_{ud}} \left(\pi_u(Q_u^c, W_u) - \pi_u(\tilde{Q}_u^c, W_{u,-d}) \right)^{1-\beta_{ud}} \right] \end{cases}$$

- **Monopsonistic bargaining:**

$$\begin{cases} \max\limits_{Q_u} \pi_u(Q_u^c, W_u) \\ \max\limits_{W_{kl}} \left[\left(\pi_d(Q_d^e, W_d) - \pi_d(\tilde{Q}_d^e, W_{u,-d}) \right)^{\beta_{ud}} \left(\pi_u(Q_u^c, W_u) - \pi_u(\tilde{Q}_u^c, W_{u,-d}) \right)^{1-\beta_{ud}} \right] \end{cases}$$

back to main slide deck

Equilibrium conditions

- Each pair ij forms a contract $\mathbb{C}_{ij} \in C_{ij}$, no agreement is $\mathbb{C}_0$
- Given all contracts $\mathbb{C} \equiv \{\mathbb{C}_{ij}\}$, downstream profit is $\Pi_j^d(\mathbb{C})$, upstream $\Pi_i^u(\mathbb{C})$
- Set of contracts with non-negative gains to trade for i and j is:

$$C_{ij}^{+}(\mathbb{C}_{-ij}) \equiv \{\mathbb{C}_{ij} \in C_{ij} : [\Pi_j^d(\mathbb{C}_{ij}, \mathbb{C}_{-ij}) - \Pi_j^d(\mathbb{C}_0, \mathbb{C}_{-ij})\}] \geq 0$$

$$\text{and } [\Pi_j^u(\mathbb{C}_{ij}, \mathbb{C}_{-ij}) - \Pi_j^u(\mathbb{C}_0, \mathbb{C}_{-ij})\}] \geq 0$$

next slide

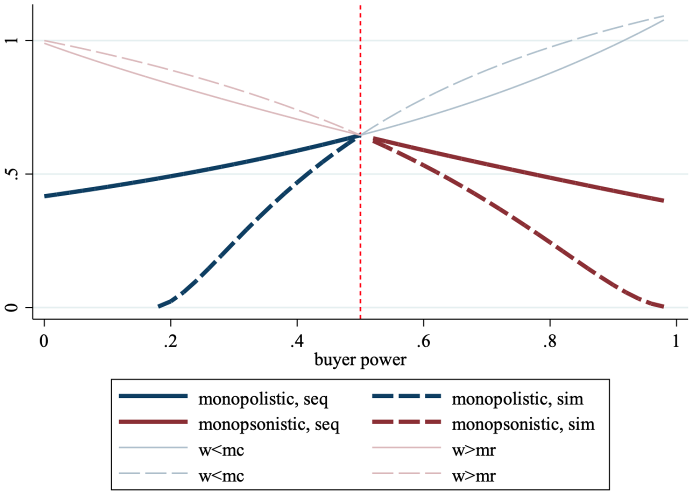
Nash-in-Nash bargaining equilibrium

$\hat{\mathbb{C}} \equiv \{\hat{\mathbb{C}}_{ij}\}$ is a **Nash-in-Nash equilibrium** if:

(i)$\forall i, j$ such that $\hat{\mathbb{C}}_{ij} \neq \mathbb{C}_0$:
$$\{\hat{\mathbb{C}}_{ij}\} \in \arg\max[\Pi_j^d(\{\{\mathbb{C}_{ij}\}, \{\hat{\mathbb{C}}_{-ij}\}\}) - \Pi_j^d(\{\{\mathbb{C}_0\}, \{\hat{\mathbb{C}}_{-ij}\}\})]^{b_{ij}}$$
$$x[\Pi_i^u(\{\{\mathbb{C}_{ij}\}, \{\hat{\mathbb{C}}_{-ij}\}\}) - \Pi_i^u(\{\{\mathbb{C}_0\}, \{\hat{\mathbb{C}}_{-ij}\}\})]^{1-b_{ij}}$$

(ii) $\forall i, j$ such that $\hat{\mathbb{C}}_{ij} = \mathbb{C}_0$, there is no contract in $C_{ij}^+(\mathbb{C}_{-ij})$ that gives strictly positive gains from trade to both i and j. back to main slide deck

Simultaneous vs. sequential model

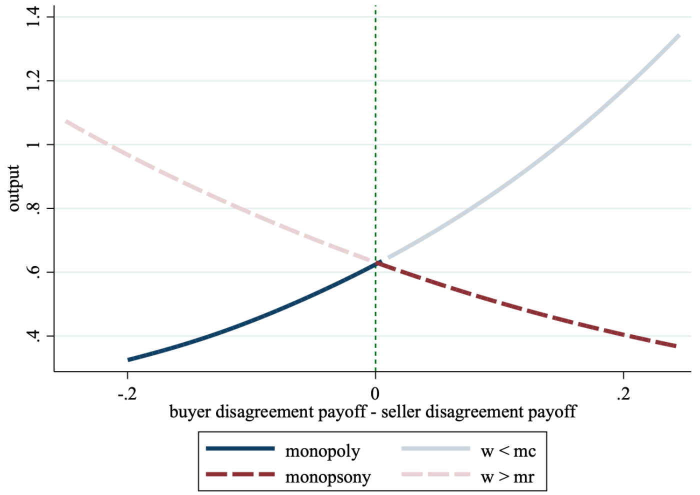


Parametrization

back to main deck

Non-zero disagreement payoffs

$$\pi^u = (w - c(q - y)q \; , \quad \pi^d = (p(q) - w - z)q$$



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