

# Pricing and Firm Conduct in California's Deregulated Electricity Market

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# The Problem Of Market Power In CA

- Ability to raise prices above marginal cost by withholding output
- BBW (2000) find evidence of market power
- This paper:
  - Use different data for 1998-99 to look for corroborating evidence
  - Question: Is the observed market power unilateral/static or collusion/dynamic?

# How the Market Worked in 1998-99

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- Generation restructured in 1998: utilities divested fossil-fueled plants to 6 firms
- Generators sold energy through:
  1. Day-ahead market - PX
  2. Real-time market - ISO
  3. Very limited block forward sales
- Uniform-price auction
- Price varies across transmission zones if congestion

Table 1: Fossil Generation Post-Divestiture Market Structure  
 (54% of capacity in California)

Firm	Capacity (MW)	Pct Capacity
AES	3921	22%
Reliant	3698	21%
Duke	3343	19%
Southern	3130	18%
Dynegy	2871	16%
PG&E	570	3%
Thermo Ecotek	274	2%

# Pricing Games Yielding Market Power

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- Unilateral or Static Market Power
  - Firms ignore interdependence
  - Firms take others' behavior as given and decide how to maximize profit
- Joint or Dynamic Market Power (Collusion)
  - Firms recognize interdependence
  - Follow supergame trigger strategy
  - Note: No “smoke-filled rooms” required

# Why Is the Distinction Important for Policy?

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- If static,
  - New entry / further divestiture will mitigate market power
- If dynamic (collusion),
  - Tacit collusion potentially punishable under antitrust law
  - Asymmetric divestiture may mitigate collusion
  - Collusion less likely under pay-as-bid vs. uniform-price auction?

# Data

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## Sources

- Unit-level hourly output data (EPA's CEMS) from Apr '98 to Dec '99
- Unit-level marginal cost from natural gas spot prices, heat conversion factors, and variable O&M; constant up to capacity

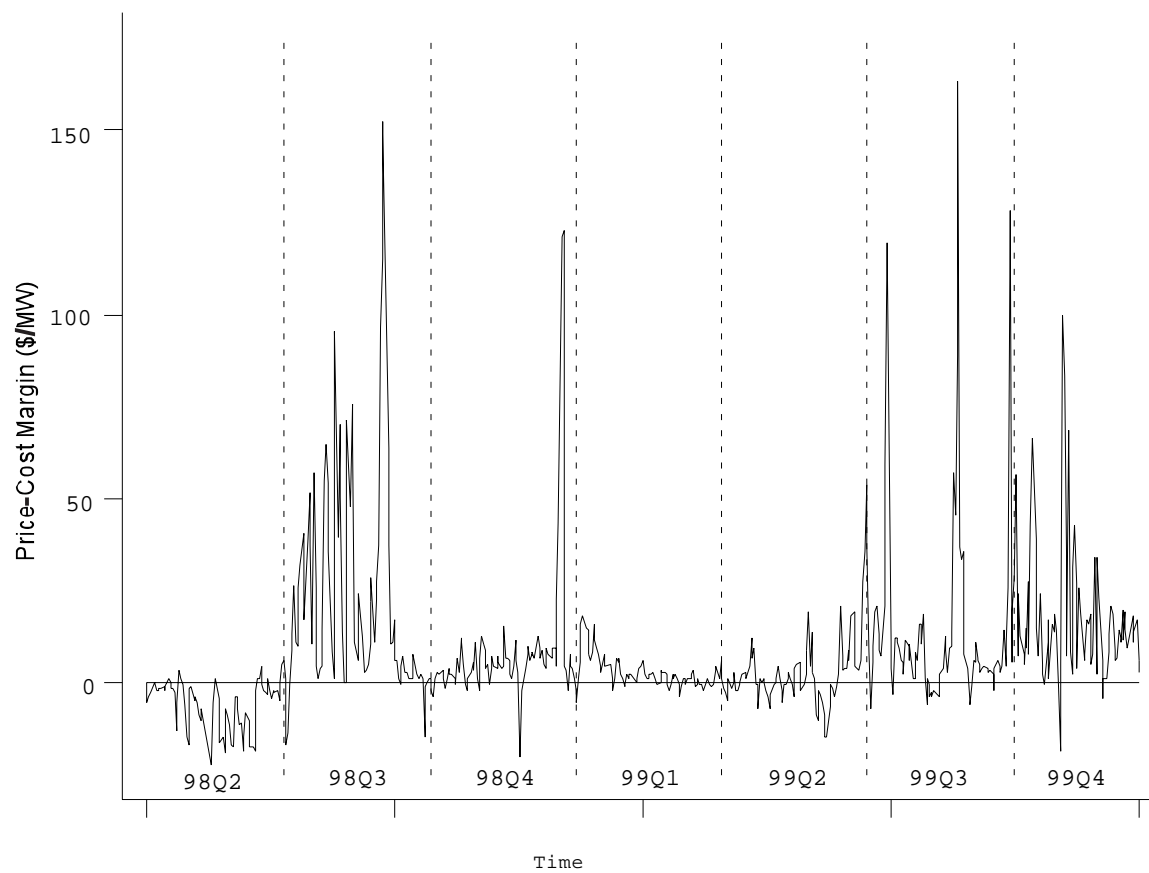
Calculating firm  $i$ 's price-cost margin:

- $P_{it}$  = PX zonal price
- $MC_{it} = \max_j \{MC_{ijt}\}$  where  $j$  indexes firm  $i$ 's units operating with "excess" capacity
- $q_{it}$  = firm  $i$ 's total fossil output in its zone

## Caveats

- EPA data cover 91% of thermal capacity (though only 68% of Dynegy)
- Do not observe partial outages
- Output measure can be too high (out-of-market calls) or too low (small peaking plants)

Figure 1: Average Hour 18 Firm Margins Over the Sample



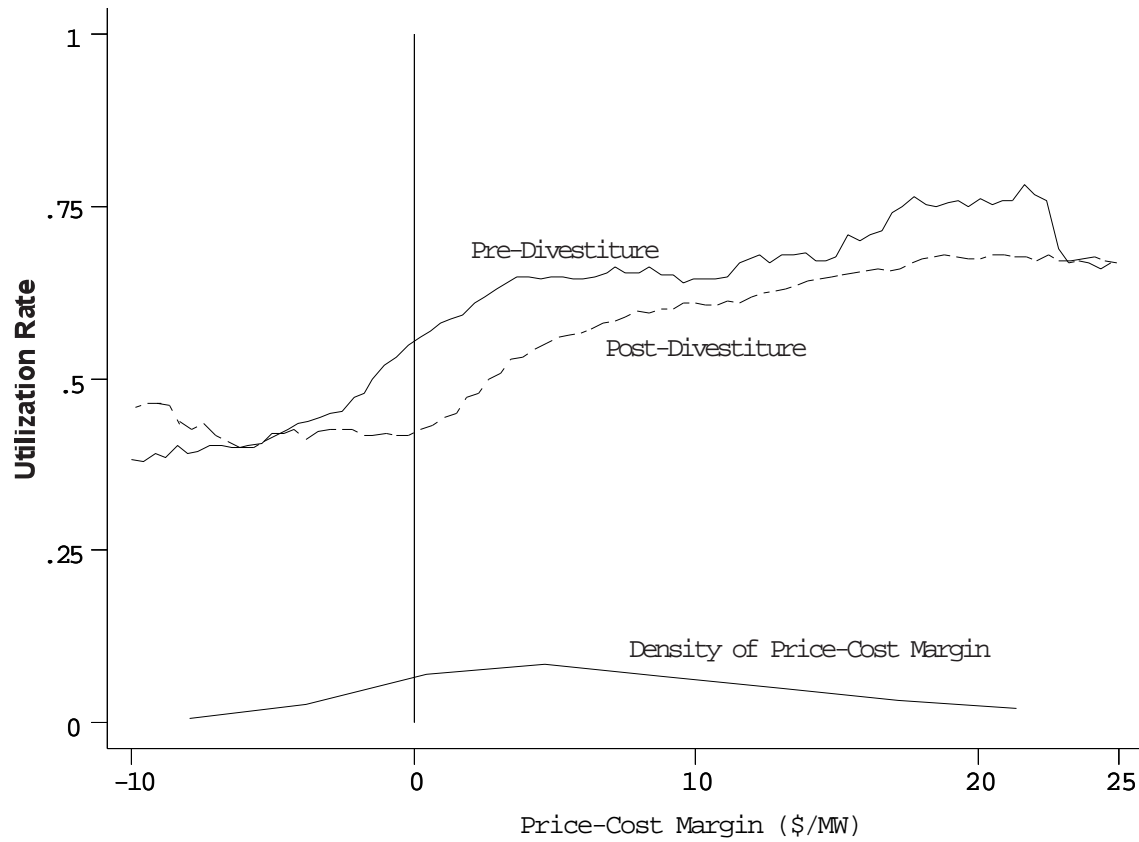
## Hour 18 Price-Cost Margins When Firms Not at Capacity

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Firm	% time NOT at capacity	Price-Cost Margin (\$/MW)					Mean Lerner
		Mean	Median	St Dev	Min	Max	
Southern	99	15.68	10.08	23.36	-14.28	164.62	.23
Reliant	91	13.70	6.82	23.73	-25.41	161.91	.21
Duke	91	10.73	3.79	22.41	-20.13	166.00	.15
AES	99	9.94	3.62	23.75	-26.91	162.85	.05
DukeSouth	86	9.37	4.55	21.46	-29.05	115.67	.02
Dynegy	100	8.36	2.17	23.20	-31.23	160.38	.02

⇒ Not Price-Takers

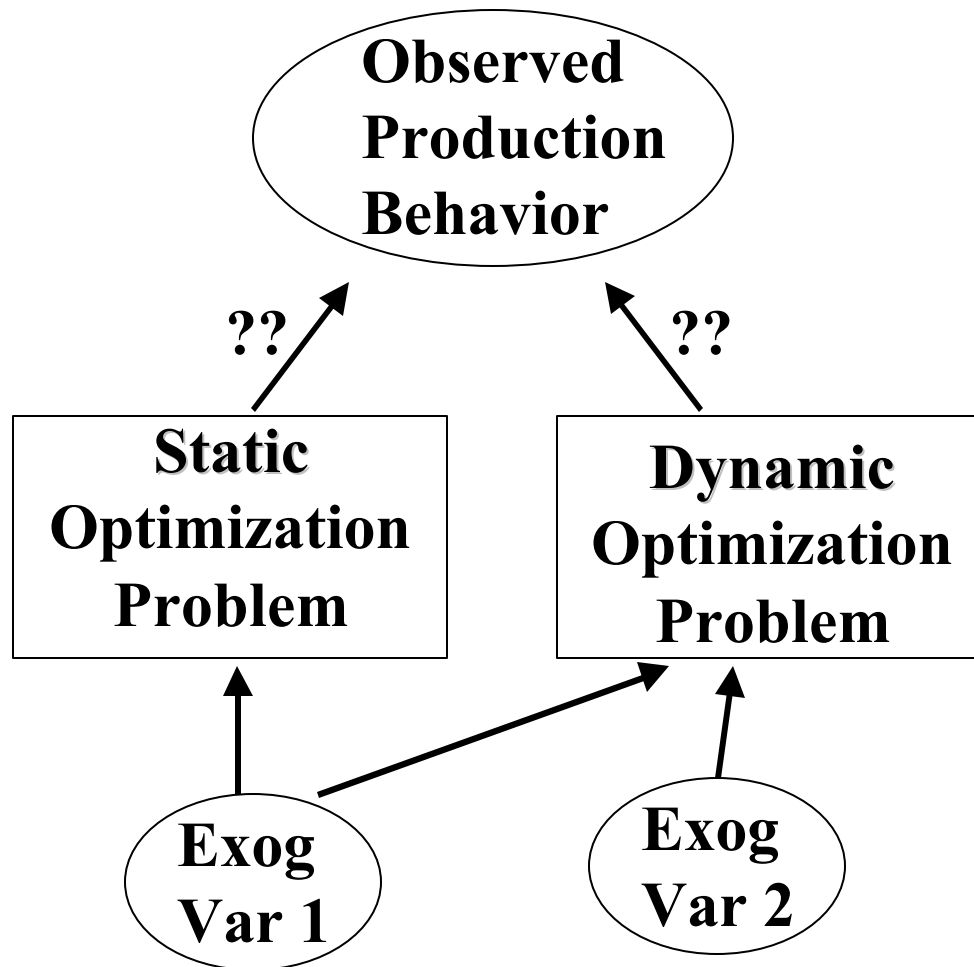
Figure 2: Unit Utilization Rates Pre- and Post-Divestiture



Note: Kernel regression estimates for units in all hours 18 in which the unit was operating. The full range of outcomes is truncated to make the figure clearer but these outcomes rarely occur (see the density estimates). In truncated outcomes with very low margins, units tend to utilize more capacity after divestiture whereas the opposite holds for truncated outcomes with high margins.

# Approach #1: Is Production Consistent with Static or Dynamic Market Power?

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# Approach #1: Setup

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- “Thought experiment” model of the firms’ choice of output:

Static Model: (Cournot)

$$\begin{aligned} \max_{q_t} \text{ Individual Profit } (q_t) \\ \text{s.t. } q_t \leq \text{capacity} \end{aligned}$$

Dynamic Model: (Efficient Tacit Collusion)

$$\begin{aligned} \max_{Q_t} \text{ Joint Profit } (Q_t) \\ \text{s.t. } \text{Deviation Profit } (Q_t) + \text{Future Punishment Profits} \\ \leq \text{Current Collusive Profits } (Q_t) + \text{Future Collusive Profits} \end{aligned}$$

High expected future demand  $\Rightarrow$  Changes future punishment & collusive profits  
 $\Rightarrow$  Changes current behavior  
(Rotemberg/Saloner and Haltiwanger/Harrington)

Firm deviates from collusion  $\Rightarrow$  Observe low shares & trigger punishment regime  
 $\Rightarrow$  Changes current behavior  
(“Green/Porter with cheating”)

- Do changes in expected future demand or lagged shares affect output today?  
If yes, some dynamic behavior.

# Approach #1: Implementation

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- Analyze: Firm utilization rates of available capacity with  $P > MC$  in Hour 18
- Determinants of Utilization Rates ( $q_{it}/AvailCapacity_{it}$ )
  - Cost-Based
    - \* Ramping Constraints ( $RAMP_{TIME}$ )
    - \* Current Demand ( $CURR\_DEM$ )
  - Static Market Power
    - \* Hourly Firm Size ( $SHARE\_PROF\_CAP$ )
    - \* Current Demand ( $CURR\_DEM$ )
  - Dynamic Market Power
    - \* Expected Future Demand ( $E_t[D_{t+1\ month}]/D_t$ )
    - \*  $\Delta$  Lagged Share ( $MAG\_LAG\_SHARE_t$ )
  - Day of Week and Firm Fixed Effects

Dependent Variable: Firm Hour 18 Utilization Rate of Available Profitable Capacity				
Variable	(1)		(2)	
	Estimate	Std. Err.	Estimate	Std. Err.
RAMPTIME (hours)	-0.041	0.005	-0.040	0.011
CURR_DEM (MW)	-7.14E-05	1.07E-04	-1.11E-04	6.26E-05
CURR_DEM <sup>2</sup> (MW)	2.66E-09	3.02E-09	3.59E-09	1.72E-09
CURR_DEM <sup>3</sup> (MW)	-2.52E-14	2.81E-14	-3.21E-14	1.63E-14
SHARE_PROF_CAP	-0.118	0.039	—	—
” *1998Q2	—	—	-0.190	0.066
” *1998Q3	—	—	-0.011	0.357
” *1998Q4	—	—	0.023	0.065
” *1999Q1	—	—	-0.145	0.057
” *1999Q2	—	—	-0.111	0.122
” *1999Q3	—	—	0.000	0.061
” *1999Q4	—	—	-0.347	0.098
MAG_ΔLAG_SHARE	0.002	0.003	—	—
” *1998Q2	—	—	-0.041	0.050
” *1998Q3	—	—	-0.012	0.011
” *1998Q4	—	—	-0.001	0.002
” *1999Q1	—	—	0.003	0.007
” *1999Q2	—	—	0.001	0.003
” *1999Q3	—	—	0.004	0.006
” *1999Q4	—	—	0.002	0.004
$E_t[D_{t+1\text{month}}]/D_t$	-0.231	0.181	—	—
” *1998Q2	—	—	-0.239	0.182
” *1998Q3	—	—	-0.325	0.152
” *1998Q4	—	—	-0.281	0.195
” *1999Q1	—	—	-0.334	0.181
” *1999Q2	—	—	-0.256	0.179
” *1999Q3	—	—	-0.237	0.233
” *1999Q4	—	—	-0.062	0.181
N	2248		2248	
$\hat{\rho}$	0.66		0.61	

AR(1) error model with White standard errors.  
Firm and day fixed effects included but not shown.

# Interpreting Comparative Static Results

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- Generally consistent with static pricing games
- Weak evidence of *forward-looking* dynamic pricing but no evidence of *backward-looking* dynamic pricing
- Market power roughly consistent with direct price-cost margins
  - 1998Q3 - consistent with *forward-looking* dynamic pricing
    - \* Not robust to alternative defn's of expected future demand
  - 1998Q4 - Not explained by firm size; possibly by demand
  - 1999Q1 - has low margins but evidence of static capacity withholding
    - \* 1 stdev  $\uparrow$  in share of profitable capacity  $\Rightarrow$  2.8%  $\downarrow$  in utilization
  - 1999Q4 - strong evidence of capacity withholding
    - \* 1 stdev  $\uparrow$  in share of profitable capacity  $\Rightarrow$  2.5%  $\downarrow$  in utilization

## Approach #2: Estimate Firm Conduct

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- Derive shape of firms' "supply functions" under static & dynamic pricing
- Use data to estimate actual "supply functions"



Do actual supply relations "look like" the theorized static or dynamic one?

## “Supply Function” Under Static Market Power

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Firm  $i$  maximizes one-period profits by choosing quantity *s.t.* a capacity constraint:

$$\max_{q_i} [Price(q_i + q_{others}) - MC_i(q_i)] \cdot q_i \quad s.t. \quad q_i \leq Capacity_i$$

$$\Rightarrow Price(q_i^* + q_{others}) - MC_i(q_i^*) + \theta_i \cdot \frac{dP}{dq} \cdot q_i^* - \lambda_i^* = 0$$

where  $\theta_{it}$  = how much firms consider effect of revenue from other sales

$\theta_{it} = 0 \Rightarrow$  perfect competition

$\theta_{it} = 1 \Rightarrow$  static market power (Cournot)

# Model of Behavior Under Static and Dynamic Pricing

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- Static: Choose  $q_{it}$  to maximize profit s.t. capacity constraint
- Dynamic: Choose joint  $Q_t$  to maximize *joint* profit s.t. incentive compatibility constraint
- General First-Order Condition at Firm Level:

$$Price(q_{it}^* + q_{otherst}) - MC_i(q_{it}^*) - \lambda_{it}^* = -\theta_{it} \frac{dP}{dQ_t} q_{it}^* + \frac{\mu_t^*}{1 + \frac{\mu_t^*}{N}} \frac{d\pi^{br}}{dQ_t}$$

$H_1$ : No Market Power:  $\theta_{it} = 0, \mu_t^* = 0, \lambda_{it}^* \geq 0$

$H_2$ : Static Market Power:  $\theta_{it} = 1, \mu_t^* = 0, \lambda_{it}^* \geq 0$

$H_3$ : Dynamic Market Power:  $\theta_{it} = N, \mu_t^* \geq 0$

# Static Estimation

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- Demand for Power from Strategic Firms:

$$Q_{strat}^D(p) \equiv Q_{total}^D - Q_{fringe}^S(p)$$

where fringe  $\equiv$  Nuke, Hydro, Indep, Imports, Fringe Gas

$$\ln Q_{fringe}^S = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln GasPrSouth_t + \beta_3 \ln GasPrNorth_t + \beta_4 \ln tempD65neigh_t + \beta_5 DAYDUM_t + \beta_6 MONDUM_t + v_t \quad (7)$$

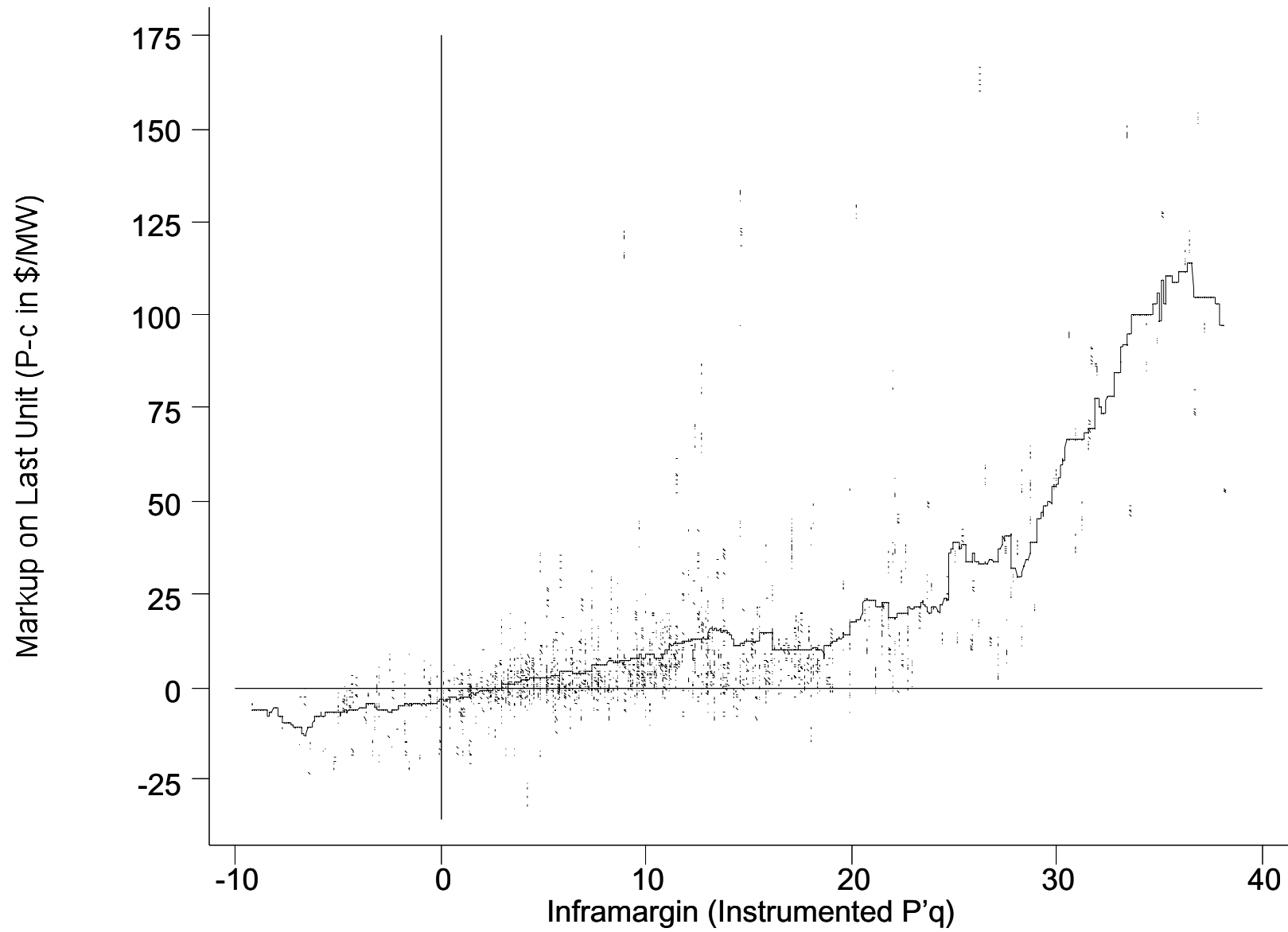
- Static Supply Relation:

$$(P - MC)_{it} = \lambda \cdot CAPBIND_{it} + \frac{\theta}{\beta_1 Q_{fringe}^S} \cdot q_{it} + \epsilon_{it} \quad (8)$$

Estimate (7) and each firm's (8) instrumenting with total perfectly inelastic demand

# Static Estimation Results

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## **Static Conduct Parameter Estimates**

	4 Firm Market*		5 Firm Market**	
	Estimate	Std Error	Estimate	Std Error
<i>Overall:</i>	1.07	0.09	0.89	0.07
<i>By Firm:</i>				
Southern	--	--	1.32	0.11
Reliant	1.12	0.11	0.72	0.07
Duke	1.16	0.11	0.75	0.07
AES	0.88	0.08	0.85	0.08
Dynegy	4.70	0.47	0.92	0.11

\* = 7/1/98-4/15/99

\*\* = 4/16/99-12/18/99

# Evidence Against Dynamic Pricing

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- Supply relation approximately ray through MC intercept
- Dynamic Supply Relation:

$$(P - c)_{it} = \lambda \cdot CAPBIND_{it} + \frac{\theta}{\beta_1} \frac{P_t}{Q_{fringe,t}^S} \cdot q_{it} + \frac{\mu_t^*}{1 + \frac{\mu_t^*}{N}} \frac{d\pi^{br}}{dQ_t} + \epsilon_{it} \quad (81)$$

Dynamic Market Power:  $\theta_{it} = N$ ,  $\mu_t^* \geq 0$

Dynamic Conduct Parameters  $\theta$  by Quarter

Quarter	Estimate	Std Error
98Q3	0.433	0.100
98Q4	0.163	0.080
99Q1	0.066	0.024
99Q2	0.251	0.057
99Q3	0.352	0.093
99Q4	0.145	0.042

# Conclusions

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- Direct evidence of market power
- Comparative static and behavioral models consistent with *static* pricing for most of 1998-99
- Some evidence of *forward-looking* dynamic pricing during summer 1998
- Future application: What's Going on in 2000? Behavior or costs?

