Dynamic Competition

Glenn Ellison

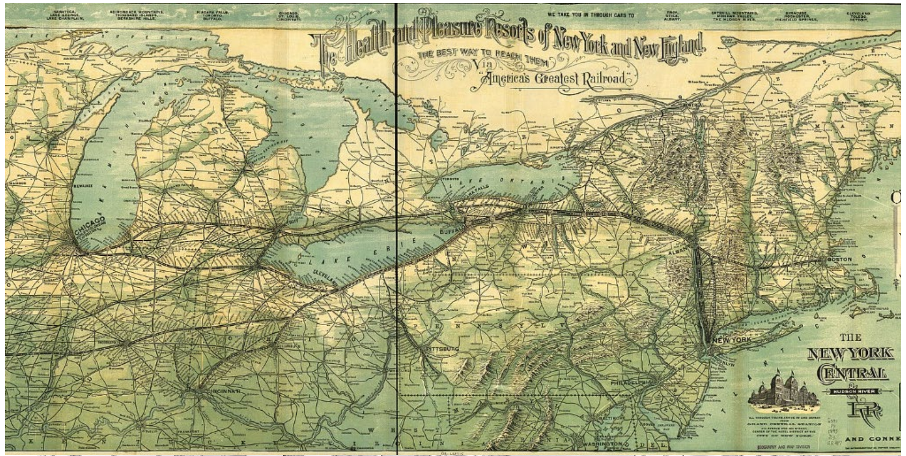
Porter, "A Study of Cartel Stability: The Joint Executive Committee, 1880-1886," *BJE* 1983

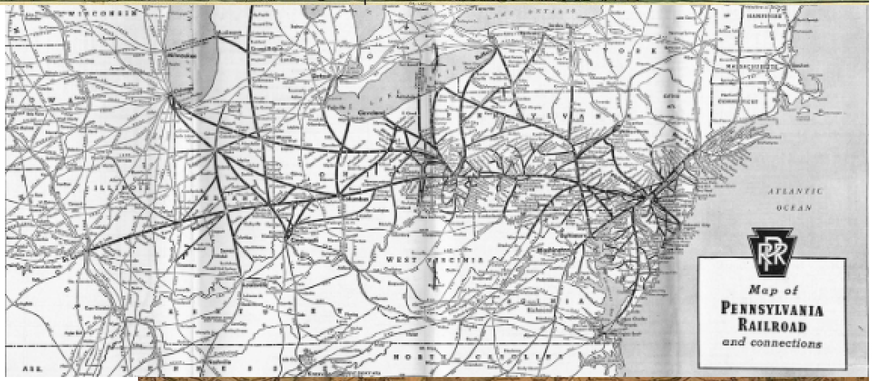
Railroads were very important in the 1880s, representing a large portion of the capitalization of the US stock market.

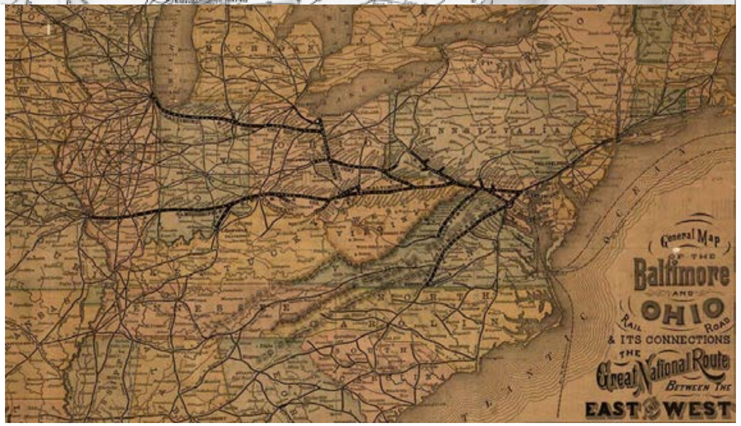
They struggled with keeping prices high enough to recoup the fixed costs of building tracks.

Porter studies a legal cartel which controlled rail traffic between Chicago and the East Coast.

- The cartel initially had three members.
- It hired the premier cartel consultant of the day, Albert Fink, to organize its operations.
- Among other things, Fink collected detailed data on the shipments out of Chicago on each road.







Maps from top to botton:
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Image is in the public domain. Library of Congress, Geography and Map Division.

Porter, "A Study of Cartel Stability"

Some other background:

- Then, as now, grain production was concentrated in the Midwest.
- Grain was shipped to the East Coast to feed urban populations there and in Europe.
- Grain could also be shipped (more cheaply) via the Great Lakes. Prior to global warming, however, the Straits of Mackinac were impassible for several months in the winter, leaving railroads as the only option.

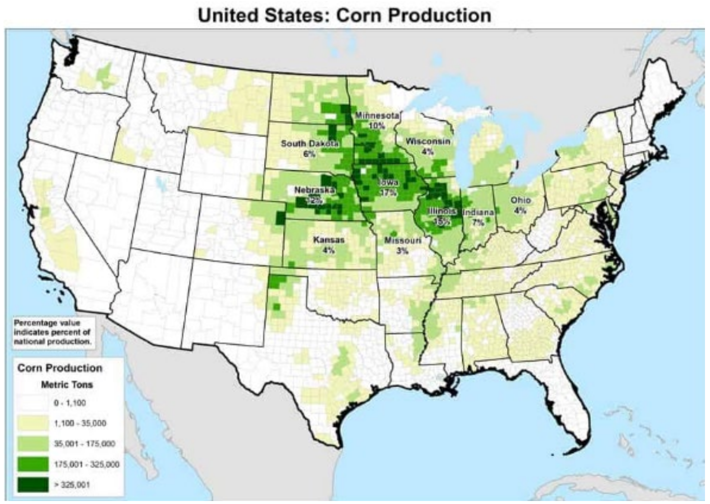
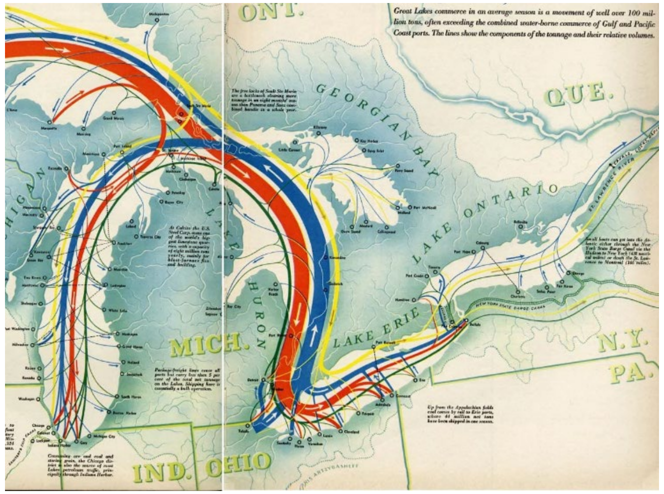


Image is in the public domain. U.S. Department of Agriculture



Porter, "A Study of Cartel Stability"

Porter was interested in the possibility that the JEC was a Green-Porter-style cartel in which price wars were used to deter deviations from collusive prices.

Assume that demand takes the form

$$log(Q_t) = \alpha_0 - \alpha_1 log(p_t) + \alpha_2 LAKES_t + \tilde{u}_{1t}$$

dummy variable for whether the lakes were navigable---an exogenous shift in demand

Porter, "A Study of Cartel Stability"

Assume that prices are chosen according to : $\frac{p-mc}{p} = -\frac{\theta}{\varepsilon},$

- $\theta_t = \theta_c$ in cooperative periods
- $\theta_t = \theta_w$ during price wars

We would expect that θ_c would be somewhat less than 1 and θ_w would be close to 0.

If we assume that marginal costs are of the form $mc_t = \gamma_0 Q_t^{\beta_1} e^{\tilde{u}_{2t}}$, then

$$\frac{p-\gamma_0 Q^{\beta_1} e^{\tilde{u}_2}}{p} = \frac{\theta}{\alpha_1} \quad \Rightarrow \quad p = \frac{\gamma_0 Q^{\beta_1} e^{\tilde{u}_2}}{1-\frac{\theta}{\alpha_1}}$$

Porter, "A Study of Cartel Stability"

$$\frac{p-\gamma_0 Q^{\beta_1} e^{\tilde{u}_2}}{p} = \frac{\theta}{\alpha_1} \;\Rightarrow\; p = \frac{\gamma_0 Q^{\beta_1} e^{\tilde{u}_2}}{1-\frac{\theta}{\alpha_1}}$$

Taking logs, this gives us a supply curve of the form

$$log(p_t) = \beta_0 + \beta_1 log(Q_t) + \beta_2 I_t + \tilde{u}_{2t}$$

where $\beta_0 \equiv \log(\gamma_0) - \log(1-\frac{\theta_w}{\alpha_1})$ and

$$\beta_2 \equiv \log\left(1-\frac{\theta_w}{\alpha_1}\right) - \log\left(1-\frac{\theta_c}{\alpha_1}\right)$$

dummy variable for being in cooperative phase of cartel, shift in supply

Porter, "A Study of Cartel Stability"

The key takeaway is that with the functional form for demand Porter assumes, the Green-Porter model of cartels suggest supply should also have a log-linear form.

This gives a simple supply-demand system:

$$log(Q_t) = \alpha_0 - \alpha_1 log(p_t) + \alpha_2 LAKES_t + \tilde{u}_{1t}$$

$$log(p_t) = \beta_0 + \beta_1 log(Q_t) + \beta_2 I_t + \tilde{u}_{2t}$$

Note that *LAKES* excluded from supply and cooperative phase indicator, *I,* is excluded from demand. These will provide the instruments we need to identify the system.

Porter, "A Study of Cartel Stability"

Porter's dataset contains 328 weekly observations.

- Q: total shipments of grain
- P: official price (would not reflect secret price cuts)
- *LAKES:* dummy equal to 1 if Great Lakes were open for shipping
- PO: price war dummy based on newspaper accounts

Porter, "A Study of Cartel Stability"

Porter estimates the model in two ways:

Approach #1: Assume I_t is observable using PO.
We then have a standard simultaneous equation model.
We can use $LAKES_t$ as an instrument for Q_t in the supply equation.
We can use I_t as an instrument for P_t in the demand equation.

Approach #2: Assume I_t is an unobserved Bernoulli random variable with mean λ.
We then have a simultaneous equation version of a switching regressions model. This model is not identified under general distributional assumptions. But we can estimate the demand parameters and λ (parameter describing relative probability of regimes) by MLE if we assume that the shocks are normally distributed.

Porter, “A Study of Cartel Stability”

TABLE 3 Estimation Results*

Variable	Two Stage Least Squares (Employing *PO*) Demand	Two Stage Least Squares (Employing *PO*) Supply	Maximum Likelihood (Yielding *PN*)** Demand	Maximum Likelihood (Yielding *PN*)** Supply
C	9.169 (.184)	−3.944 (1.760)	9.090 (.149)	−2.416 (.710)
LAKES	−.437 (.120)		−.430 (.120)	
GR	−.742 (.121)		−.800 (.091)	
DM1		−.201 (.055)		−.165 (.024)
DM2		−.172 (.080)		−.209 (.036)
DM3		−.322 (.064)		−.284 (.027)
DM4		−.208 (.170)		−.298 (.073)
PO/*PN*		.382 (.059)		.545 (.032)
TQG		.251 (.171)		.090 (.068)
R^2	.312	.320	.307	.863
s	.398	.243	.399	.109

Prices are estimated to be substantially higher in cooperative phase.

If $\theta_0 = 0 \rightarrow \hat{\theta}_1 = 0.336$ (approx Cournot). My paper suggests α is larger so $\hat{\theta}_1 = 0.85$)

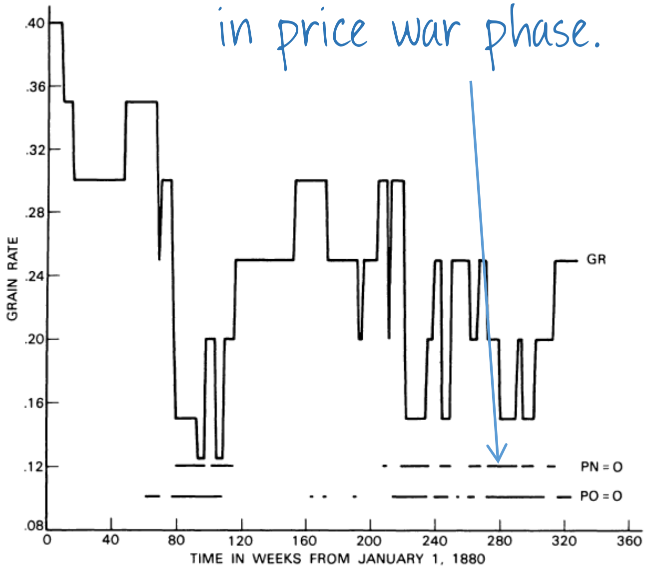
Switching regression model fits better than using the reported price wars

TABLE 4 Price, Quantity, and Total Revenue for Different Values of *LAKES* and *PN**

Price	*LAKES* 0	*LAKES* 1
PN 0	.1673	.1612
1	.2780	.2679
Quantity	***LAKES* 0**	***LAKES* 1**
PN 0	38680	25904
1	25775	17261
Total Revenue**	***LAKES* 0**	***LAKES* 1**
PN 0	129423	83514
1	143309	92484

* Computed from the reduced form of the maximum likelihood estimates of Table 3, with all other explanatory variables set at their sample means.
** Total Revenue = 20 (Price × Quantity), to yield dollars per week.

FIGURE 1
PLOT OF GR, PO, PN AS A FUNCTION OF TIME



About 28% of weeks are in price war phase.

Ellison, "Theories of Cartel Stability and the JEC," *RJE*, 1994

The paper views the JEC as providing opportunities to examine additional predictions of the Green-Porter model: Porter shows that there are two pricing regimes, but it does not show that price wars are contiguous periods that follow suspicious demand realizations.

The main exercise is an estimation of a modified version of Porter's model.

- Demand is as in Porter with serially correlated demand shocks $u_{1t} = \rho u_{1,t-1} + v_{1,t}$.
- Supply is as in Porter with unobserved I_t.
- Regime transitions are assumed to follow a first order Markov process.

$$\Pr(I_{t+1}|I_t, W_t) = \frac{e^{\gamma W_t}}{1 + e^{\gamma W_t}}$$

Ellison, "Theories of Cartel Stability and the JEC"

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$$\Pr(I_{t+1}|I_t, W_t) = \frac{e^{\gamma W_t}}{1 + e^{\gamma W_t}}$$

Several alternative specifications of W_t are examined.

- W_t constant is Porter model
- Including $W_t = I_t$ allows for first-order Markov structure to see if price wars are contiguous periods.
- The primary interest is in specifications that include (interacted with $I_t = 1$), several variables that could have been regarded as suspicious demand patterns: whether any firm had an unusually large market share, whether any firm had an unusually small market share, and whether aggregate demand was unexpectedly high.

Ellison, "Cartel Stability"

1. Strong serial correlation
2. Similar to Porter effect of I_t
3. More elastic demand (implies θ closer to monopoly)
4. Price wars are continuous periods.

TABLE 2 The "Standard" Model

Demand: $\log Q_t = \alpha_0 + \alpha_1 \log P_t + \alpha_2\, LAKES_t + \alpha_{3-14}\, SEASXX_t + U_{1t}$

Price: $\log P_t = \beta_0 + \beta_1 \log Q_t + \beta_2 I_t + \beta_{3-6}\, DMx_t + U_{2t}$

Regimes: $\text{Prob}\{I_{t+1} = 1 \mid I_t, Z_t\} = \dfrac{e^{\gamma W_t}}{(1 + e^{\gamma W_t})}$

Variable	"Standard" Model Estimate	"Standard" Model Standard Error	No Serial Correlation Estimate	No Serial Correlation Standard Error
Demand				
CONSTANT	7.677	1.882	9.019	.361
log *P*	−1.802	1.287	−.843	.193
LAKES	−.009	.112	−.460	.348
*SEAS*1	−.103	.086	−.117	.157
*SEAS*2	.146	.145	.167	.180
*SEAS*3	.147	.138	.149	.166
*SEAS*4	−.011	.157	.145	.242
*SEAS*5	−.315	.165	.062	.164
*SEAS*6	−.550	.179	.077	.170
*SEAS*7	−.446	.198	.081	.176
*SEAS*8	−.504	.194	−1.116	.374
*SEAS*9	−.395	.165	.048	.185
*SEAS*10	−.545	.164	.102	.191
*SEAS*11	−.521	.180	.085	.304
*SEAS*12	−.397	.173	.183	.241
Supply				
CONSTANT	−4.764	1.863	−5.649	9.461
log *Q*	.306	.178	.398	.928
*DM*1	−.154	.075	−.211	.124
*DM*2	−.246	.064	−.283	.160
*DM*3	−.317	.076	−.373	.242
*DM*4	−.198	.119	−.419	.422
I_t	.637	.104	.660	.406
Regimes				
CONST. (I_t = 1)	3.675	.474	3.661	.513
CONST. (I_t = 0)	−2.641	.404	−2.620	.476
Other				
σ_1	.290	.061	.396	.029
σ_{12}	−.007	.004	−.045	.142
σ_2	.160	.045	.191	.313
U_{1t-1}	.832	.085		
Log-likelihood	181.0		37.2	

Ellison, "Theories of Cartel Stability and the JEC"

TABLE 3 Causes of Price Wars

Regimes: $\text{Prob}\{I_{t+1} = 1 \mid I_t = 1, Z_t\} = \frac{e^{\gamma W_t}}{(1 + e^{\gamma W_t})}$

	Model					
Parameter	1	2	3	4	5	6
CONSTANT	4.63 (.77)	4.36 (.77)	3.95 (1.30)	2.96 (.66)	4.43 (.81)	4.35 (.90)
*BIGSHARE*1	−.77 (.49)					
*BIGSHARE*2		−.46 (.39)				
BIGSHAREQ			−.21 (1.06)			
SMALLSHARE				.66 (.89)		
V_{1t}					−4.15 (2.64)	−5.00 (3.15)
U_{1t}						1.17 (1.15)

* Note: Estimated standard errors in parentheses.

1. Unusually large share for some firm causes price wars

2. Unanticipated low demand causes price wars

The significance is only marginal, though, and the triggers are not sufficiently powerful to deter deviations.

Ellison, "Theories of Cartel Stability and the JEC"

The paper also looks for evidence of:

- Rotemberg-Saloner effects: Finds little evidence of countercyclical markups or more frequent price wars.

- Secret price cuts: Finds evidence that suggests there were some. Our inability to identify strong triggers of price wars could reflect that the JEC was not a sufficiently well designed cartel.

  Could also be that price war start dates are misidentified and/or I missed some stronger trigger. Not asking what happens if one imposes that punishments are strong enough to deter collusion was a missed opportunity.

Noel, "Edgeworth Price Cycles: Evidence from the Toronto Retail Gasoline Market," *JIE* 2007

Noel collected twice-daily prices from 22 Toronto gasoline stations over a 131 day period and finds striking evidence of Edgeworth-like price cycles.

Part of Mike's thesis as a student at MIT, and a nice example of a self-collected data set.

He had his girlfriend, who lived in Toronto at the time, note the price of gasoline at several gas stations on her way to and from work every day.

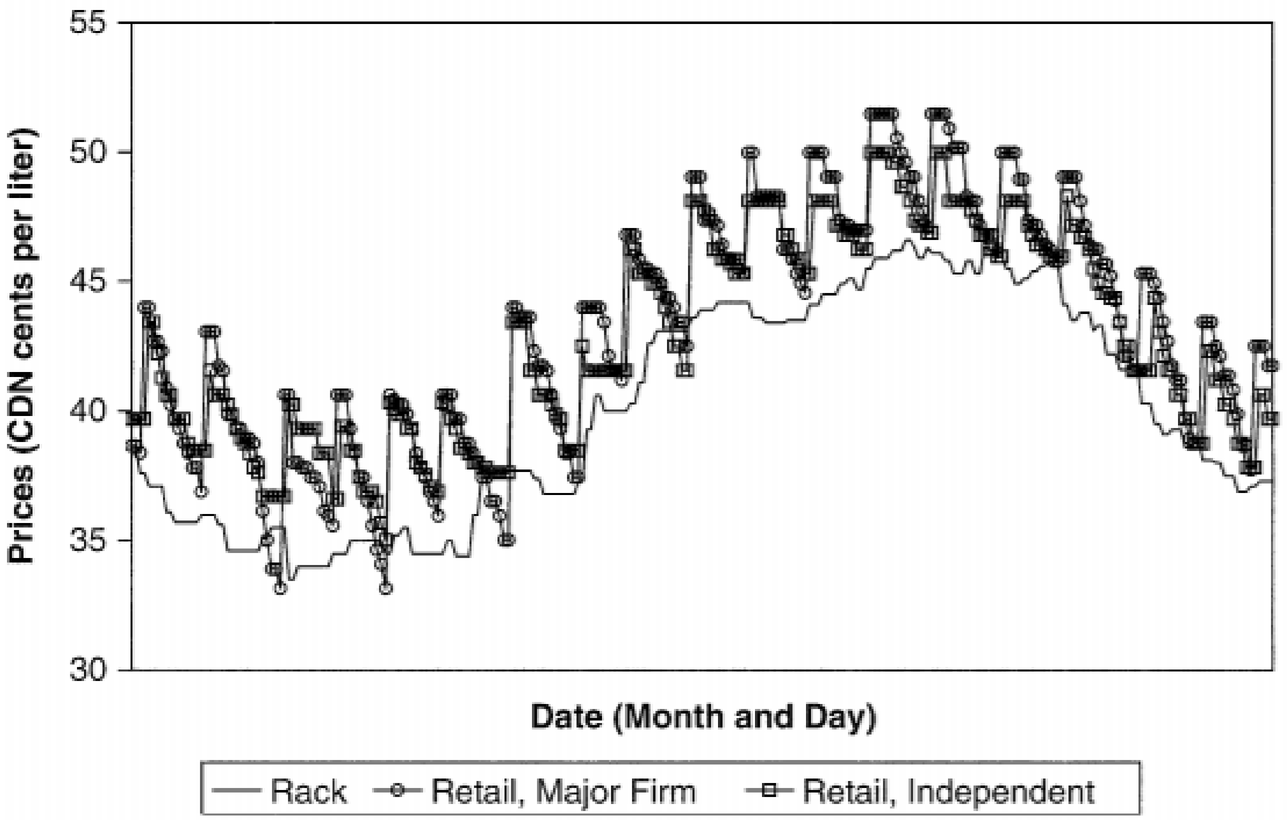
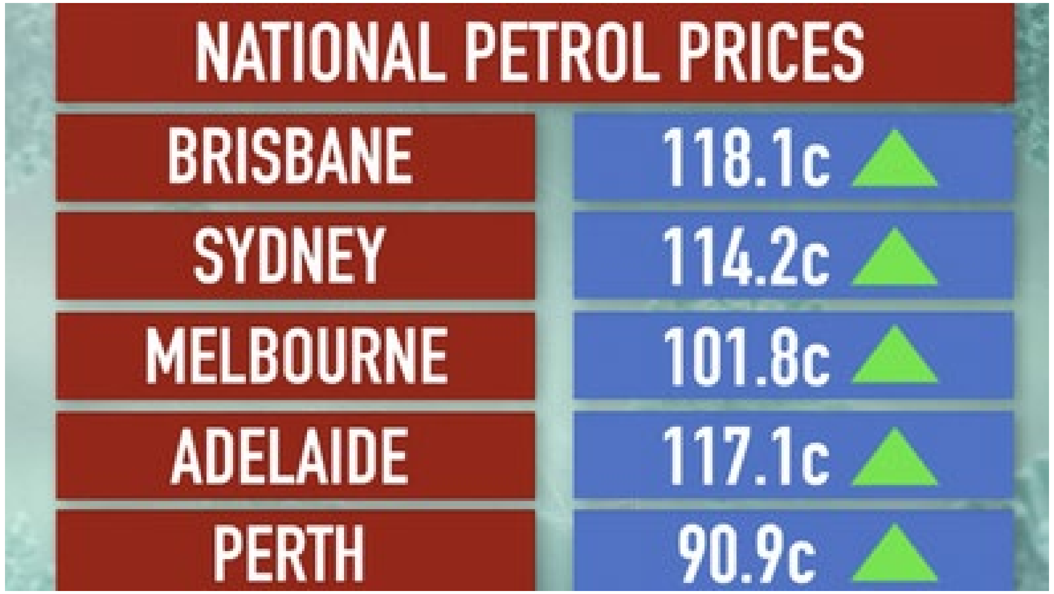


Figure 1
Retail Prices (Major Firm, Independent Firm) and Rack Price

Wang, "(Mixed) Strategy in Oligopoly Pricing: Evidence from Gasoline Price Cycles Before and Under a Timing Regulation," *JPE* 2009.

Wang studies gasoline pricing in Perth, Australia from 1999-2003.



Wang, "Gasoline Price Cycles"

Wang studies gasoline pricing in Perth, Australia from 1999-2003. The market has four major chains, two independent chains, and some smaller firms. Three aspects of the market make it attractive to study.

1. Edgeworth cycles were present.
2. A regulatory change intended to stop cycling took effect on January 1, 2001. It required that firms submit to a government website the price they would charge the next day by 2pm.
3. Data was available from a variety of sources.
   - Daily prices from 2001-2003 were available from the government website.
   - A credit card company provided hourly prices for the 6 months prior to the legal change for a number of stations.
   - Wholesale prices were available from two stations and via a formula indexing BP's prices to the Singapore price.

Wang, "Gasoline Price Cycles"

Wang again finds striking evidence of price cycling both before and after the implementation of the new regulation.

Before

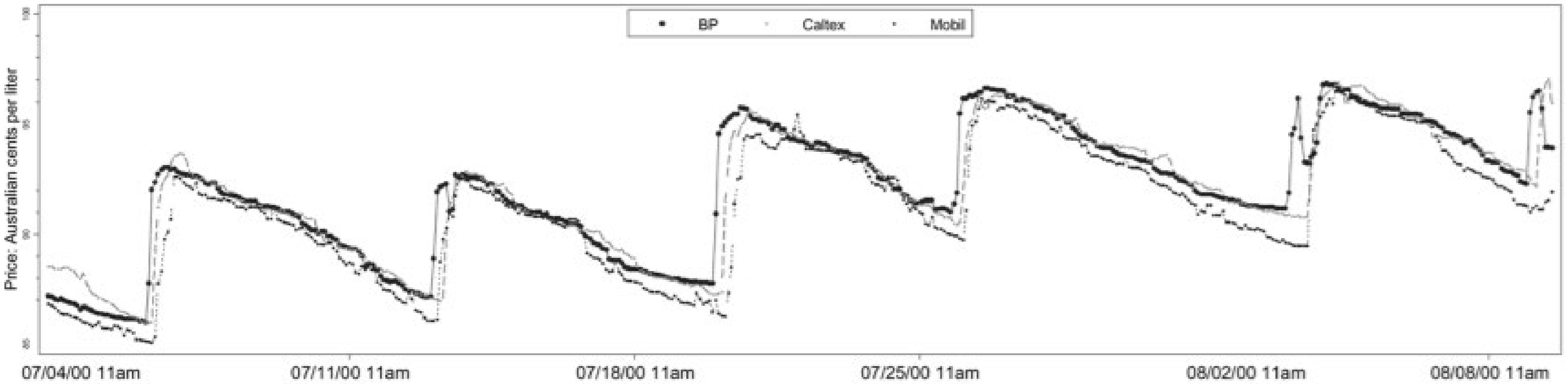


FIG. 1.—Hourly brand average gasoline prices over six cycles before the law

After

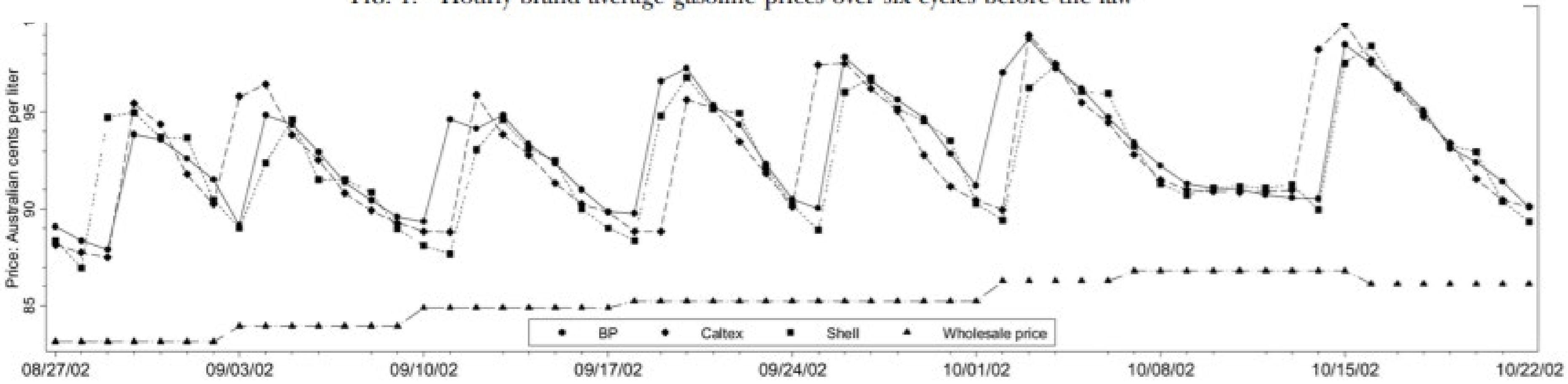


FIG. 2.—Daily brand average gasoline prices over seven cycles under the law

Wang, “Gasoline Price Cycles”

The paper provides a lot of detailed observations that can help us think about how Edgeworth cycle work and come about.

1. Before the regulation, the cycles had a distinctive pattern. BP would raise prices at some point between 11am and 2pm on a T, W, or Th. Caltex (the largest firm) would follow within 2-3 hours, Shell within 3-4 hours, and others in a day or two.
2. The regulatory change disrupted the cycles, but they reemerged within 4 months.
3. The pattern of leadership changes after the regulation. Caltex takes on a co-equal role and Shell sometimes leads.
4. A model of independent mixing at the bottom of the cycle fits the data fairly well. Mixing probabilities appear to depend on who raised prices first in the previous cycle (with some alternation).
5. Average markups are mostly unaffected except for during the first few weeks of the law.

Brown and MacKay, "Competition in Pricing Algorithms," *AEJ: Micro* 2022

Brown and MacKay provide descriptive evidence on pricing algorithms.

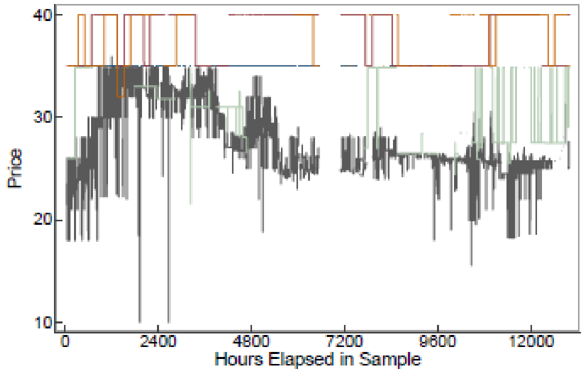
The dataset was constructed in a simple way: they scraped prices hourly from five websites (perhaps Amazon, Walmart, Target, CVS, and Walgreens) for all package sizes of seven allergy drugs (Allegra, Benedryl, Claritin, Flonase, Nasacort, Xyzal, and Zyrtec).

Prices were collected hourly from April 10, 2018 through October 1, 2019.

There is clear heterogeneity in practices across websites:

- Retailer A (Amazon?) changes prices 1.89 times per day. B changes prices 0.28 times per day. C, D, and E change prices once per month or less.
- Price levels differ.

(a) Xyzal, Tablets, 80 Count

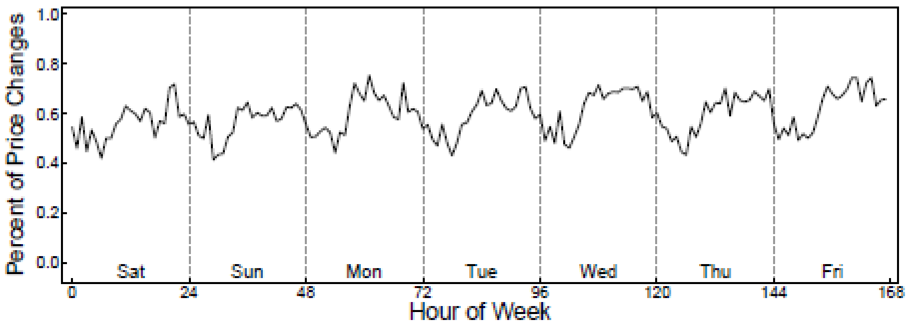


Brown and MacKay, “Competition in Pricing Algorithms,” *AEJ: Micro* 2022

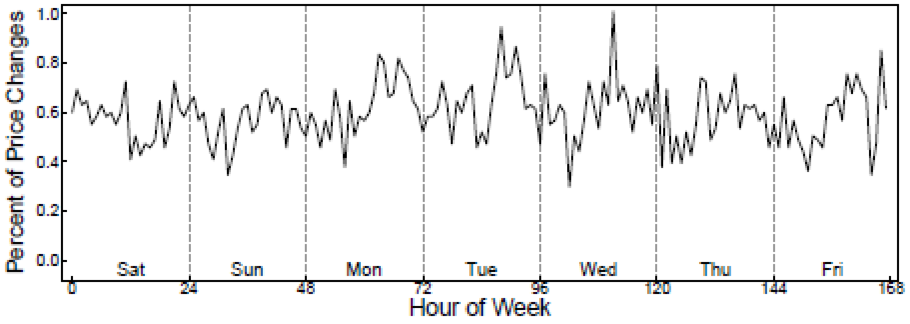
Observations:

1. Three firms mostly update prices on a schedule. Firm C updates at some point between 3am and 6am ET daily. Firms D and E update just after midnight on Sunday. Firms A and B update continuously.

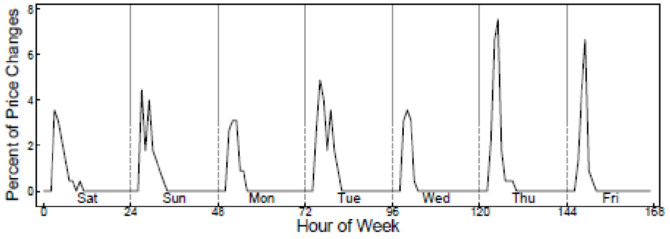
(a) Retailer *A*



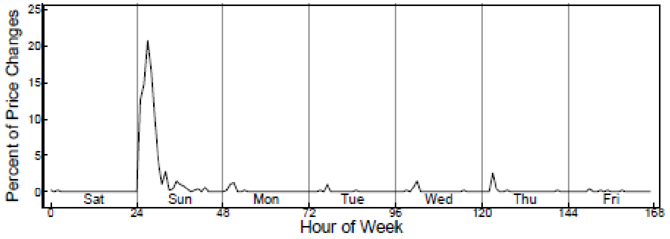
(b) Retailer *B*



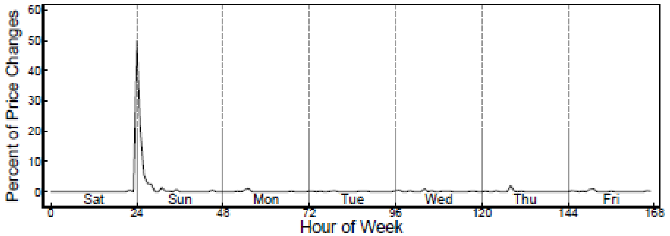
(c) Retailer *C*



(d) Retailer *D*



(e) Retailer *E*

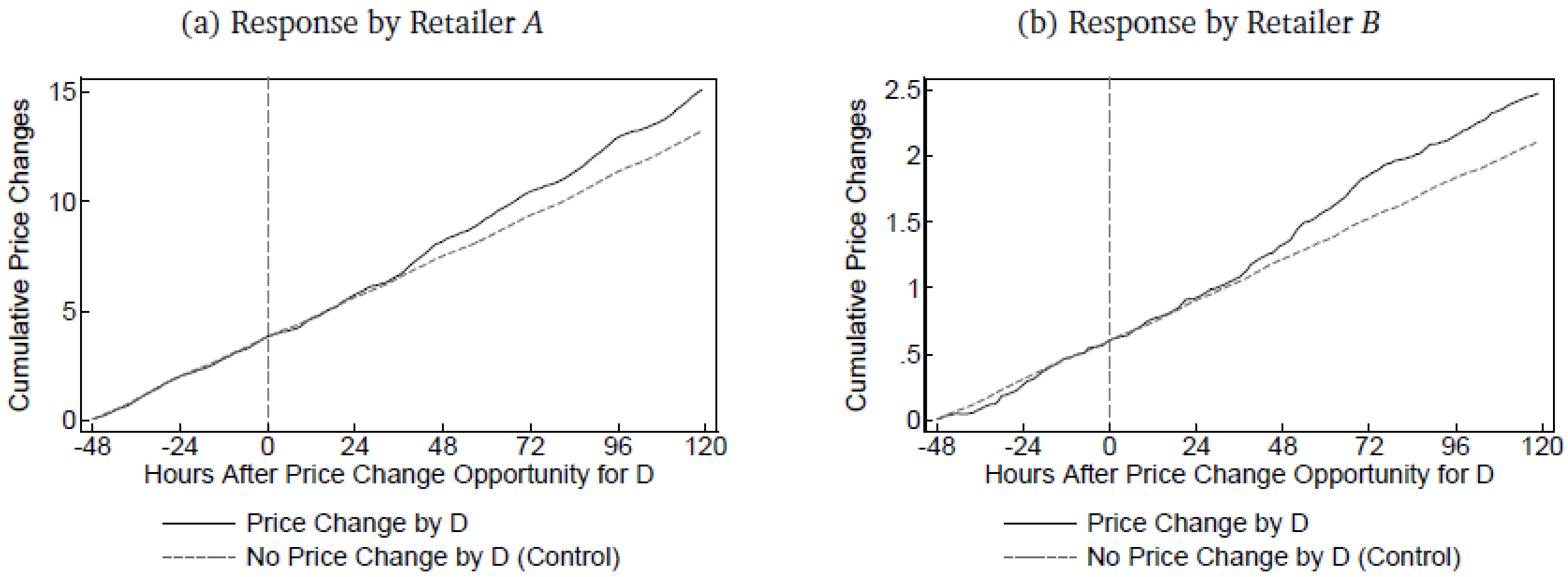


Brown and MacKay, "Competition in Pricing Algorithms," *AEJ: Micro* 2022

Observations:

2. The algorithms of firms A and B are affected by whether D and E changes their prices, but are only responding with a 36+ hour lag.

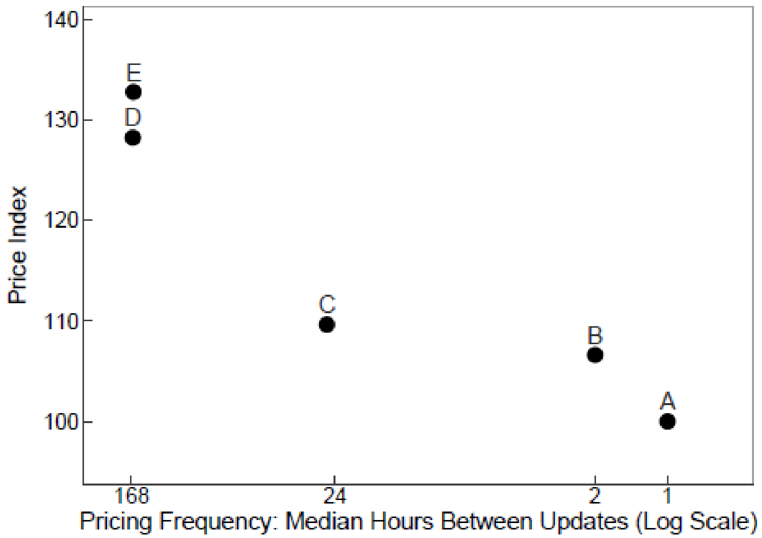
The analysis compares weeks when D does and does not change on Sunday morning taking D's changes as exogenous.



Brown and MacKay, "Competition in Pricing Algorithms," *AEJ: Micro* 2022

Observations:

3. The firms changing prices more frequently are setting lower prices.



Motivated by these findings, the paper then has a long theory section (and a calibration) examining the Markov equilibria of a model where one firm is able to change its prices N times as frequently as another.

The slow firm becomes a disadvantaged Stackelberg leader. Both firms price above the static NE with the fast firm undercutting and earning higher profits.

Next week's topic is entry.

Monday's lecture will be theory including a lot of textbook material.

See you then!