Market Power: Collusion and Horizontal Mergers (1)

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Estimating cost functions without using cost data

Rosse 1970, Econometrica.

- During the 1960s and 1970s, IO economists were building methods to estimate cost functions. Why?
  - Return to scale,
  - Learning by doing,
  - Efficient scale, etc.
- At the same time, many papers tried to test the SCP paradigm using **accounting** data.
- For instance, cross-industry comparisons were conducted to estimate the "causal" effect of concentration on profitability or prices:

$$\text{Profits}_{jt} = \alpha + \beta \text{Concentration}_{jt} + \gamma X_{jt} + u_{jt}$$

- Critics started pointing out that,
  1. Market structure is not exogenous,
  2. Accounting costs $\neq$ economic costs.

Estimating cost functions without using cost data

- **This paper:** Combine economic theory assumptions with prices and output data to estimate **economic** marginal cost functions.
- Among the first papers in the "New Empirical Industrial Organization" literature.

Structural Econometrics Methods in IO

- Structural econometrics modelling? (See Reiss and Wolak (2007))
  - **Definition:** The use of economic theory to develop mathematical statements about how observable "endogenous" variables, y, are related to observable "explanatory" variables, and unobservable variables.
  - As opposed to *reduced-form* econometrics modeling, which is interested in measuring the impact of *exogenous* changes in the environment on endogenous outcomes.
- Unlike most other applied-micro fields, empirical IO relies heavily on structural econometrics modeling techniques:
  - This difference is mostly due to the type of questions that IO researchers are interested in.
  - Example: The equilibrium effect of mergers have in theory large *spillover* effects on all firms active competing in the same market.
  - See the recent debate between Angrist and Pischke (2010) and Nevo and Whinston (2010).
  - See also a similar debate in Labor: Rosenzweig and Wolpin (2000) and Angrist and Krueger (2001).

Functional Form Assumptions

- Consider only the one output y_j example.

$$p_j = \alpha_0 + \alpha x_j - \alpha_2 y_j + u_j$$
$$\mathrm{mc}_j = \beta_0 + \beta_1 z_j + \beta_2 y_j + v_j$$

- Assumptions:

$$E(u) = E(v) = 0$$
$$E(u \cdot v) = 0$$
$$E(x \cdot u) = E(x \cdot v) = 0$$
$$E(z \cdot u) = E(z \cdot v) = 0$$

  The last two corresponds to "short-run" assumptions: Quality and other sunk product characteristics are fixed in the short run.
- Problems:
  - mc_j is unobserved.
  - How can we estimate the return to scale parameter β_2?

Conduct Assumption

- **Assumption:** Each local newspaper is a local monopolist and chooses y_j to maximize profits.
  - Note: The paper also model advertising and news space.
- Equilibrium condition:

$$\mathrm{MR}_j - \mathrm{MC}_j = e_j \tag{1}$$

where e_j is a mean-zero optimization/specification error.

- With linear demand and marginal-cost functions:

$$\alpha_0 + \alpha_1 x_j - 2\alpha_2 y_j + v_j = \beta_0 + \beta_1 z_j + \beta_2 y_j + v_j + e_j$$
$$\leftrightarrow p_j = \beta_0 + \beta_1 z_j + (\alpha_2 + \beta_2) y_j + \underbrace{v_j + e_j - u_j}_{=w_j}$$

Where, $E(w_j \times (x_j, z_j)) = 0$

Identification and Estimation

- GMM set-up (not in the paper):
  - Theoretical and empirical moment conditions:

$$E(u_j \times (x_j \sim z_j)) = 0 \Longrightarrow \frac{1}{n}\sum_j u_j \times (x_j \sim z_j) = 0$$

$$E(w_j \times (x_j \sim z_j)) = 0 \Longrightarrow \frac{1}{n}\sum_j w_j \times (x_j \sim z_j) = 0$$

  - Identification?
    - ★ Rank conditions: MC function is identified as long as z_j contains exogenous variables not included in x_j to identify the demand curve (and vice-versa).
  - More generally, demand and supply relations can take non-linear forms:

$$y_j = f(x_j, p_j, u_j|\alpha)$$
$$p_j = g(y_j, x_j, w_j|\beta)$$

- **Takeaway:** If firms are optimizing (i.e. conduct), observed actions reveal the implicit opportunity cost of production. This leads to a (now) standard revealed-preference estimation strategy.

What about oligopoly markets?

- Under a particular *conduct* assumption, the same insight can be extended to markets with more than one firm:
  - **Symmetric Cournot:**

$$P(q_{i,t}, q_{-i,t}) + P'(q_{i,t}, q_{-i,t})q_{i,t} = MC(q_{i,t})$$

$$\leftrightarrow P(Q_t) = MC(Q_t) - \frac{1}{n_t}P'(Q_t)Q_t \quad \text{[Summing across } i\text{]}$$

  - **Asymmetric Cournot:**

$$P(q_{i,t}, q_{-i,t}) + P'(q_{i,t}, q_{-i,t})q_{i,t} = MC_i(q_{i,t})$$

$$\leftrightarrow P(Q_t) = \frac{1}{n}\sum_i MC_i(q_{i,t}) - \frac{1}{n_t}P'(Q_t)Q_t \quad \text{[Summing across } i\text{]}$$

  - **Bertrand:**

$$P(Q_t) = MC(Q_t)$$

  - **Collusion:**

$$P(Q_t) + P'(Q_t)Q_t = MC(Q_t)$$

Supply Relations Estimation

- MC is identified under specific conduct assumptions. What identifies firms' conduct?
- Most oligopoly models can be nested into a general **supply relation** equation:

$$P(Q_t) = MC(Q_t) - \theta P'(Q_t)Q_t$$

  where $\theta \in (0, 1)$ is a measure of market-power (i.e. conduct parameter).
- Examples:
  - $\theta = 0$: Bertrand
  - $\theta = 1/n$: Cournot
  - $\theta = 1$: Monopoly

Two Justifications

1. Can be used to test particular models (e.g. $H_0 : \theta = 1/n$).
2. Theoretical foundation for $\theta \in (0, 1)$: The conjectural variation model
   - CV equilibrium:

$$\max_{q_i} \quad P\left(q_i + \sum_{j \neq i} Q_j(q_i), X\right) q_i - C_i(q_i, Z)$$

$$P(Q, X) + q_i P'(Q, X) \underbrace{\left(1 + \sum_{j \neq i} \frac{\partial Q_j(q_i)}{\partial q_i}\right)}_{1+r} - C_i'(q_i) = 0$$

   - Averaging across firms: $P_m + QP'_m(Q, X_m)\theta - \overline{MC}(Q_m, Z_m) = 0$ where $\theta = \frac{1}{n}(1 + r)$.
   - The conduct parameter then corresponds to the "average" conjecture in the industry:
     - ★ Bresnahan (1989): "IF the conjectures are constant over time and collusion breakdowns are infrequent, θ measures the average collusiveness of conduct"

Identification of Market Conduct

- **Example:** Linear demand/cost (symmetric)
  - Functional forms:

$$P(Q_t) = \alpha_x x_t - \alpha_q Q_t + u_t$$

$$MC(Q_t) = \beta_z z_t + \beta_q Q_t + v_t$$

  - Two estimating equations:

$$\begin{aligned} \text{Demand:} \quad & P_t = \alpha_x x_t - \alpha_q Q_t + u_t \\ \text{Supply relation:} \quad & P_t = z_t \beta_z + (\beta_Q + \theta \alpha_q) Q_t + v_t \end{aligned}$$

  - **Negative result:** The industry conduct parameter is not identified, even with all the necessary exclusion restrictions.
- Why? The linearity of demand implies that the *supply relation* between q_t and p_t is confounded with the possibility of a non-linear cost function.
- **Note:** This also implies that estimates of the pass-through of cost shocks onto prices **are not** sufficient to test for market-power (unless we assume a constant MC function).

Lack of Identification in a Figure

- When $P(q_t)$ is linear, variation in x_t induces parallel shifts:

$$P(q_t) = x_t\alpha_x - \alpha_q Q_t + u_t$$

- The implied change from E_1 to E_2 can be explained by collusion or competition.

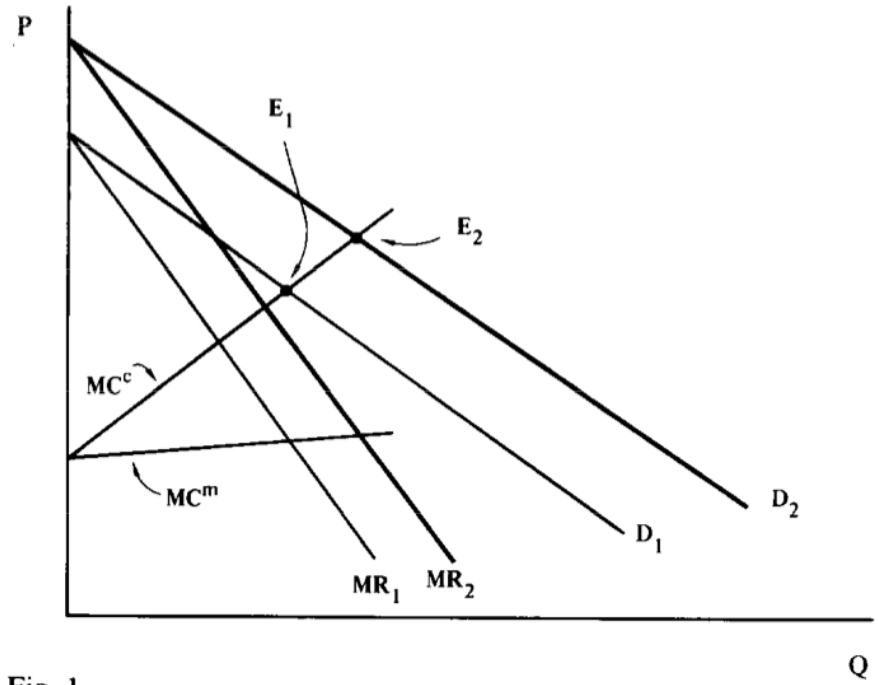


Fig. 1.

Source: Bresnahan (1982).

Relevant Source of Variation

- This is not the case when we can observe demand **rotation**.
- Example:

$$P(q_t) = x_t\alpha_x - \alpha_q y_t Q_t + u_t$$

- The implied a change from E_1 to E_3 (caused by y_t) can only be explained by collusion.

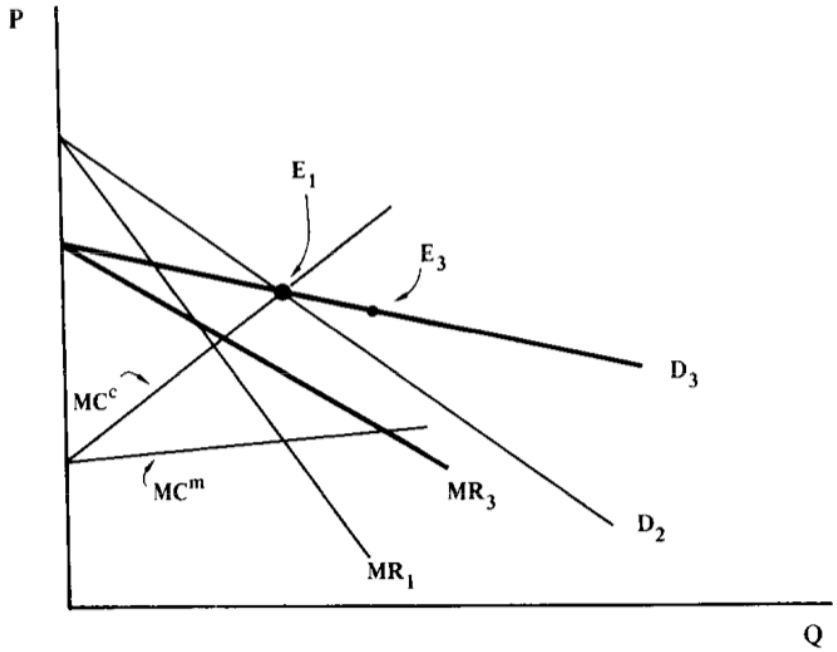


Fig. 2.

Source: Bresnahan (1982).

Application: Sugar cartel

- **Source:** Genesove and Mullin (1998)
- **Historical notes:**
  - Industry organized as Trust in 1887.
  - Between 1887 and 1911, the industry alternated between periods of collusion, and price war episodes triggered by the entry and expansion of outside firms.
  - The trust was dismantled in 1911 by the US government.
- **Objective:** Validate the conduct estimation approach by comparing predicted and observed estimates of marginal costs, under **known** conduct.

Direct measure of market-power

- Linear production technology:

$$\mathrm{MC}_t = c_t = c_0 + kP_{\mathrm{raw},t}$$

  where $k = 1.075$ (i.e. inverse rate of transformation).
- Intercept: $c_0 \in (0.16, 0.26)$ from industry documents.
- Optimality condition:

$$\theta = \eta(P)\frac{P - c}{P}$$

$$P(c) = \frac{-c\eta(P)}{\theta - \eta(P)}$$

- Conduct = elasticity adjusted Lerner index.

Step 1: Demand estimation

- Functional form:

$$Q_t(P) = \beta_t(\alpha_t - P)^{\gamma_t}$$

  Where β_t, and α_t or γ_t are allowed to vary by season (third quarter).
- Instrument: Cuban imports (i.e. closest substitute).
- Demand elasticity:

$$\eta_t(P) = \beta_t\gamma_t(\alpha_t - P)^{\gamma_t - 1}\frac{P}{\beta_t(\alpha_t - P)^{\gamma_t}} = \frac{\gamma_t P}{(\alpha_t - P)}$$

- This leads to the following pricing relation:

$$P(c,\theta) = \frac{-c\eta(P)}{\theta - \eta(P)} \Leftrightarrow L_\eta = \frac{P-c}{\eta(P)P} = \theta$$

- For instance, in the log-linear case: $P(c,\theta) = \frac{c\gamma}{\theta+\gamma}$.

Step 2: Direct conduct estimates

TABLE 4 **Demand for Refined Sugar, Derived Estimates**

	(1) Quadratic	(2) Linear	(3) Log-Linear	(4) Exponential	(5) Lerner Index
$P^M(c)$: *High Season* = 0	$2.57 + .67c$	$2.91 + .5c$	$1.97c$	$1.89 + c$	
$P^M(c)$: *High Season* = 1	$3.96 + .67c$	$3.96 + .5c$	$10.1c$	$3.85 + c$	
$P(c;\theta)$: *High Season* = 0	$\frac{7.72\theta}{2+\theta} + \frac{2}{2+\theta}c$	$\frac{5.82\theta}{1+\theta} + \frac{1}{1+\theta}c$	$\frac{2.03}{2.03-\theta}c$	$1.89\theta + c$	
$P(c;\theta)$: *High Season* = 1	$\frac{11.88\theta}{2+\theta} + \frac{2}{2+\theta}c$	$\frac{7.91\theta}{1+\theta} + \frac{1}{1+\theta}c$	$\frac{1.10}{1.10-\theta}c$	$3.85\theta + c$	
η at Full sample mean					
High Season = 0	2.18	2.24	2.03	2.13	
High Season = 1	1.03	1.04	1.10	1.05	
Adjusted Lerner index, L_η					**(Unadjusted)**
Mean	.099	.107	.095	.097	.054
Standard Deviation	.097	.118	.083	.089	.045
Standard Error	.024	.028	.021	.022	.0046

- P^M should be around \$4.80 in low seasons, and \$5.90 in high seasons (versus \$3.99 and \$4.14 in reality).
- The price increase during high seasons is too small.

Step 3: Conduct parameter estimation

- Supply relation (linear model):

$$P_t = \frac{\alpha_t \theta + c_0}{1+\theta} + \frac{k}{1+\theta} P_{\text{raw},t} + u_t$$

- Using the Cuban imports as IV for the price of raw can sugar, yields the following moment condition:

$$E\left[(1+\theta)P_t - \alpha_t \theta - c_0 - k P_{\text{raw},t} | Z_t\right] = 0$$

  where $\alpha_t = \alpha_{\text{low}} 1(t = \text{Low season}) + \alpha_{\text{high}} 1(t = \text{High season})$.
- Identification of θ:
  - **Assumption:** Unobserved changes in firms' conduct (i.e. $u_t = \Delta\theta_t + e_t$) are independent of IVs.
  - This is a difficult assumption to satisfy
    - ★ E.g: Price wars during booms.
    - ★ Corts (1999): Correlation between "conduct changes" and demand shocks invalidates standard instruments (downward bias)

Key result: θ is under-estimated

TABLE 7 **NLIV Estimates of Pricing Rule Parameters**

	Linear		Direct Measure
	(1)	(2)	(3)
$\hat{\theta}$	.038 (.024)	.037 (.024)	.10
$\hat{c}_o$	.466 (.285)	.39 (.061)	.26
$\hat{k}$	1.052 (.085)		1.075

Alternative Approach: Bounds on market power

- Market conduct tests a la Bresnahan suffer from (at least) two critics:
  - Requires knowledge of demand curve: Functional form assumptions can invalidate the results
  - Necessitates variation in the **slope** of the demand curve (somewhat arbitrary)
- Sullivan (1985) and Ashenfelter and Sullivan (1987) construct an **upper bound** on the degree of market power.
  - **Null hypothesis:** Monopoly.
  - Minimal assumptions on demand and cost functions
  - Exploits observed (exogenous) shocks to marginal cost
  - **Key requirement:** Shock must be separable (e.g. tax shock)

Model Set-up

- **Notation:**
  - Homogenous goods: $P(Q) = P\left(\sum_j q_j\right)$ and $P'(q) < 0$.
  - Heterogeneous cost functions: $C_j(q)$ with $C_j'(q) \geq 0$.
  - Excise tax: $C_j(q) = C_j(q) + tq$, where $C_j(q)$ is time-invariant.
- Profit maximization condition given tax level t:

$$P\left(q(t)\right) + q_i(t) \underbrace{P'\left(q(t)\right)}_{=P'(t)/q'(t)} \theta = C_i'\left(q_i(t)\right) + t$$

$$\frac{P(t) - t - \mathrm{mc}_i(t)}{\theta} + q_i(t)\frac{P'(t)}{Q'(t)} = 0$$

  Where $Q(t) = \sum_i q_i(t)$, $Q'(t) = dQ/dt$, and $P'(t) = dP(t)/dt$.
- θ is a market "conjecture": $\partial Q^*/\partial q_i$.
  - Cournot conjecture: $\theta = 1$
  - Collusion conjecture: $\theta = n$.

Necessary Conditions

- Necessary equilibrium condition for conduct θ:

$$\frac{P(t) - t - c}{\theta} + q_i(t)\frac{P'(t)}{Q'(t)} \geq 0, \quad \forall c < \text{mc}_i(t)$$

- Aggregating at the market level, this gives a lower bound on the number of equivalent Cournot competitors:

$$n^*(t) = \sum_i \frac{1}{\theta_i} \geq n^*(t, c) = \frac{-P'(t)Q(t)}{(P(t) - t - c)Q'(t)}, \quad \forall c < \text{mc}_i(t)$$

- Why is it useful?
  - RHS depends only on observed variables ($P(t)$ and $Q(t)$), and reduced form pass-through rates (i.e. $P'(t)$ and $Q'(t)$).
  - If $P'(t) > 0$ and $Q'(t) < 0$, $n^*(t, 0)$ provides a useful lower bound on the industry conduct.
  - Allow to reject the monopoly model, but not the perfect competition assumption.

Application: Pass-through of cigarettes tax

- Parametric reduced-form equations:

$$q_{is}(t) = \exp\left(\kappa_{is}^1 + g^1 t + h^1 (t - \bar{t})^2\right)$$

$$p_{is}(t) = \kappa_{is}^2 + g^2 t + h^2 (t - \bar{t})^2$$

  - κ_{is}^j controls for State FEs and time-trends.
  - Estimated by OLS.
- **Results:**
  - $q'(t) = -2.93$: Consistent with the theory (i.e. tax increases marginal cost).
  - $p'(t) = 1.089$: Reject Bertrand with constant mc (i.e. complete pass-through).
  - $n^*(t, c = 0) = 2.88$: Significantly different from 1.
  - Easily reject the monopoly model. The observed pass-through rates are consistent with a fairly important level of competition.

Collusion and Price Wars

- Textbook models of tacit collusion predict stable prices, and off-equilibrium cheating.
- In most known cases of implicit or explicit collusions, we observe alternating periods of high/low markups, price wars, cheating, etc.
- There are two ways of modeling markup fluctuations in models of **tacit** collusion:
  - **Imperfect information:** Price wars discipline cartel members price cuts are not fully observed (see Stigler, Green & Porter, Abreu, Pearce & Stachetti).
  - **Demand fluctuations:** Collusive prices must adjust to reflect higher temptation to cheat when demand is high (see Rotember and Saloner).
- Price wars, or more generally, *equilibrium* cheating behavior are still phenomena that we don't understand very well (good research topic!).

Rotemberg and Saloner (1986): Price Wars During Booms

- Empirical regularity: In many oligopolistic industries, prices or markups are **counter-cyclical**
  - Cement (Rotemberg and Saloner 1986), refined sugar (Genesove and Mullin 1998), gasoline (Borenstein and Shepard 1996).
- **Interpretation:** Cheating is more tempting when demand is high.
- Simple model:
  - Homogeneous duopoly with symmetric firms and constant marginal cost.
  - Demand is stochastic:
    - ⋆ With probability $1/2$ demand is **low**, $q = D_1(p)$.
    - ⋆ With probability $1/2$ demand is **high**, $q = D_2(p)$.
  - Harshest punishment: Bertrand-Nash forever.
  - Equilibrium selection: Pareto outcome (i.e. joint profit maximization).

Equilibrium Conditions

- Equilibrium prices $\{p_1, p_2\}$ solve:

$$\begin{aligned} \max_{p_1,p_2} \quad & \pi_1(p_1) + \pi_2(p_2) \\ \text{s.t.} \quad & V_s^{\text{deviation}} \leq V_s^{\text{coop}}(p_1, p_2), \quad \forall s = 1, 2. \end{aligned}$$

  where $V_s^{\text{coop}}(p_1, p_2) = \frac{\pi_s}{2} + \frac{\delta}{1-\delta}\left(\frac{\pi_1(p_1)}{4} + \frac{\pi_2(p_2)}{4}\right)$, and $V_s^{\text{deviation}} = \pi_s(p_s)$ (i.e. undercutting).

- Alternatively, IC constraints can be written as:

$$\text{IC}_s: \quad \frac{\pi_s(p_s)}{2} \leq \delta V(p_1, p_2) = \frac{\delta}{1-\delta}\left(\frac{\pi_1(p_1)}{4} + \frac{\pi_2(p_2)}{4}\right)$$

- Since $\pi_1(p) < \pi_2(p)$, only the **second** IC is relevant (i.e. collusion is more difficult when demand is high).
  - **Implication:** $p_1 = p_1^m$ maximizes joint discounted profits

Equilibrium Conditions: Two Cases

1. IC_2 does not bind: $p_2 = p_2^m$ and $p_1 = p_1^m$.
   The incentive constraint implies:

$$\pi_2^m \leq \frac{\pi_2^m}{2} + \frac{\delta}{1-\delta}\left(\frac{\pi_1^m}{4} + \frac{\pi_2^m}{4}\right) \text{ or } \delta \geq \frac{2\pi_2^m}{3\pi_2^m + \pi_1^m}$$

   Therefore, the lower-bound on the discount factor lives between $1/2$ (i.e. Bertrand case), and $2/3$ (i.e. zero demand in state 1).

2. Low discount factor case: $\delta \in \left(1/2, \frac{2\pi_2^m}{3\pi_2^m + \pi_1^m}\right)$
   - In this case, "full" collusion is not enforceable and IC_2 binds.
   - The cartel must lower prices during high demand periods.
   - Boom period prices is found by solving IC_2:

$$\frac{\pi_2(p_2^*)}{2} = \delta V(p_1^m, p_2^*)$$

Price Wars During Boom?

- **Caveat 1:** The model does not really predict "price-wars", since deviations are not observed in equilibrium.
  - RS = Theory of *countercyclical* markups.
- **Caveat 2:** To test the prediction in the data, we need to be careful. Case 2 does not imply that $p_2^* < p_1^m$. The predictions is about lowering the prices *relative* to the monopoly price (i.e. $p_2^* < p_2^m$).
  - Need to condition on demand/cost state variables.
- **Caveat 3:** When demand shocks are not IID, the predictions can be reversed.
  - Important: Demand is expected to be low in the (near) future if it is very high today.
  - See Harrington and Haltiwanger (1991)

Collusion With Secret Price Cuts

- The idea that imperfect monitoring and secret price cuts cause price wars dates back to Stigler.
  - **First formalization:** Green and Porter (1984)
- Here I follow the example in Tirole (1988), which considers the pricing-game example.
- **Set-up:**
  - Demand is stochastic:
    - ⋆ With probability α demand is **zero**
    - ⋆ With probability $1 - \alpha$ demand is $D(p) > 0$.
  - Demand and competing prices are unobserved: Firms earn zero profit if their opponent cut their prices, OR if there is no demand.
  - Signal extraction problem: Rival's price cut and low demand state are observationally equivalent

Mechanism: Recurrent Price Wars

- Collusive mechanism:
  - Collusive phase: both firms charge p^m
  - Punishment trigger: If one firm makes zero **sales**, firms enter a punishment phase
  - Punishment: Bertrand prices for $T \leq \infty$, and the game reverts to a collusive state
- Value functions:

$$\begin{aligned} \text{Collusion:} \quad & V^+ = (1-\alpha)(\pi^m/2 + \delta V^+) + \alpha\delta V^- \\ \text{Punishment:} \quad & V^- = \delta^T V^+ \end{aligned}$$

Rearranging those terms gives the following expression for V^+:

$$V^+ = \frac{(1-\alpha)\pi^m/2}{1-(1-\alpha)\delta - \alpha\delta^{T+1}}$$

Note: V^+ is decreasing in T.

Equilibrium Conditions

- Incentive constraint:

$$\text{IC}^+: \quad V^+ \geq (1-\alpha)(\pi^m + \delta V^-) + \alpha\delta V^-$$

$$\text{Or, } \delta(V^+ - V^-) \geq \pi^m/2$$

- The optimal collusive agreement is a punishment lenght T^*:

$$\begin{aligned} \max_T \quad & V^+ \\ s.t. \quad & V^+ \geq (1-\alpha)(\pi^m + \delta V^-) + \alpha\delta V^+ \end{aligned}$$

- **Tradeoff:** Since price wars occur with positive probability in equilibrium (i.e. α), punishments are costly and cannot be too long. On the other hand, a short punishment increase the incentive to secretly cut prices.
- **Implication:** Price wars occur during periods of low demand (opposite as RS).

Porter (1983): A study of cartel stability

- Study empirically the Green & Porter model of collusion under uncertainty:
  - Assume that the data is generated from a variant of the model (i.e. no deviations in the data),
  - Take as given the mechanism chosen by the cartel (i.e. $\bar{p}$ and T),
  - **Goal:** Measure the profits of collusion **and** test for the presence of price wars (equilibrium).
- **Empirical problem:** Punishment/Collusion regimes are unobserved to the econometrician.

Brief history of the JEC

- Legal and public cartel formed in 1879.
- Control railroad eastbound shipments from Chicago to the East coast.
- Historical evidence that the cartel used "temporary" price cuts to punish rumors of cheating by a member.
- Firms set rates individually and privately.
- Volume transported was surveyed weekly by the JEC.
- Prices are monitored only imperfectly, and firms only observed aggregate market shares.
- Recurrent price war episodes were documented by economic historians.

Functional Forms: Demand and Supply

- Market demand function:

$$\log Q_t = \alpha_0 + \alpha_1 \log p_t + \alpha_2 L_t + U_{1t}$$

  where L_t is a dummy equal to one when the Great Lakes were open (i.e. close substitute).
- Cost function:

$$C_i(q_{it}) = a_i q_{it}^{\delta} + F_i$$

  for $i = 1, ..., N$.
- Industry supply relation:

$$p_t = \begin{cases} \frac{1}{1+\theta\alpha_1} D Q_t^{\delta-1} & \text{If } I_t = \text{Collusion} \\ D Q_t^{\delta-1} & \text{If } I_t = \text{Price war} \end{cases}$$

  where $D = \delta(\sum_i a_i^{1/1-\delta})^{1-\delta}$ is the productivity-weighted marginal-cost parameter if firms split the market based on a_i.
- Conduct parameter: θ measures the collusive markup relative to the punishment phase.

Econometrics Model

- Empirical supply relation equation:

$$p_t(1 + \theta_t/\alpha_1) = DQ_t^{\delta-1}$$
$$\log p_t = \beta_0 + \beta_1 \log Q_t + \beta_2 S_t + \beta_3 I_t + U_{2t}$$

  where $\beta_0 = \log D$, S_t controls for entry and acquisitions, $\beta_1 = \delta - 1$, I_t is equal to one if the industry is in cooperative mode, and $\beta_3 = -\log(1 + \theta_{\text{coop}}/\alpha_1)$
- Econometric problem: I_t is a latent variable.
- Stochastic assumptions:
  - Cost and demand shocks: $(U_{1t}, U_{2t}) \sim N(0, \Sigma)$
  - Price war regimes (i.e. trigger):

$$I_t = \begin{cases} 1 & \text{With probability } \lambda \\ 0 & \text{With probability } 1 - \lambda \end{cases}$$

  - Log-Likelihood function of sequence of outcomes Y_t:

$$l(Y_1, ..., Y_T) = \prod_t \log(h(Y_t|I_t = 1)\lambda + h(Y_t|I_t = 0)(1 - \lambda))$$

Key Results

- The model with "hidden" regimes fits the data best.
  - Price wars occur in "equilibrium"
- Estimate of $\beta_3 = 0.545$: Prices are $\approx 50\%$ higher in the collusive phase.
- If we assume that $\theta_{\text{punish}} = 0$, the estimated value of $\theta \approx 1/3 < 1$ (i.e. close to Cournot).

Fit: Reported *vs* Estimated Regimes

TABLE 5 Index of Cartel Nonadherence[1]

Year	MacAvoy[2]	Reported[3]	Estimated[4]
1880	26	0.00	0.00
1881	14	0.67	0.44
1882	18	0.06	0.21
1883	6	0.10	0.00
1884	16	0.58	0.40
1885	10	0.77	0.67
1886[5]	15	0.50	0.06

What triggers price wars?

Source: Ellison (1994)

- Extends the original Porter model:
  - Introduce serial correlation in the demand shock
  - Incorporate state variables in the price war regime probability:

$$\Pr(I_t = 1|It, Z_t) = \frac{\exp(\gamma W_t)}{1 + \exp(\gamma W_t)}$$

  - Price war triggers: Introduce demand shifters in the W_t
- **Results:**
  - Find a greater degree of collusion.
  - Regimes are not independent of each other.
  - Unanticipated demand shock enters **negatively** in the price war trigger probability (i.e. $\neq$ RS).
  - The RS story is not supported in this data-set.
  - Find evidence of "two-type" of hidden regimes: (i) regular price wars, and (ii) large unobserved demand shock (e.g secret price cut).

Price Leadership and Collusion

- **Motivation:** An old theory of oligopoly pricing is based on the idea firms face a *kinked residual demand curve* (Stigler 1947)
- **Definition:** If firms expect rivals to match perfect price reductions, but not price increases, the residual demand has a *kink* at p_{t-1}. This is a source of *nominal price rigidity*, that originates from the **conduct** of an industry.
- Stigler identifies two types of price leadership that can increase or decrease the occurrence of nominal price rigidities:
  - **Dominant firm:** Larger firm sets the price and allow rivals to sell what they which at that price (standard view - no kink)
  - **Barometer firm:** Firm that (by convention) first announces p_{t+1}, that are followed by the rest of the industry (relevant for rigidity and collusion)
- **Recent empirical papers:**
  - Clark and Houde (2013): "Collusion between asymmetric retailers"
  - Byrne and de Roos (2017): "Learning to coordinate"
  - Chillet (2017): "Gradually Rebuilding a Relationship"

Clark and Houde (2013): Collusion between asymmetric retailers

- In June 2008 Competition Bureau announced price-fixing charges against a number of gasoline station owners/operators in Victoriaville, Thetford Mines, Magog and Sherbrooke
- Violation of Section 45 of the Canadian Competition Act
  - Newspaper in June 2004
  - Inquiry trigger: The *Vicky Nollet* story
  - Wire-tapping: 2005-2006
  - Investigation was announced on May 29th 2006.
- Legal charges and guilty pleas
  - 14 companies and 38 individuals were charged.
  - 4 companies and 10 individuals, including four of the 5 major players, have pleaded guilty.
  - Fines: \$90,000 to \$1,850,000 for companies, and \$5,000 to \$50,000 for individuals (+1 year in jail for some).

The target markets

PLAYERS	Characteristics	Sherbooke /Magog	Thetford -Mines	Victoriaville	Total
Bilodeau-Shell	Organizer/ Wholesaler	0	4	4	8
Bourassa-Olco	Organizer/ Wholesaler	9	0	0	9
Canadian-Tire	Hardware	3	0	1	4
Goulet	Informant	0	0	1	1
Couche-Tard	Conv.-store	13	2	3	18
Maxi	Grocery	0	0	1	1
Petro-T	Wholesaler	5	2	1	8
Ultramar	VI + LPG	18	3	2	23
Other	Independent	32	12	12	56
Total		80	23	25	128
Population		147,427 /23,880	40,486	25,704	

Institutional Details

- **Bertrand-like competition:** Price-setting oligopoly with (i) little spatial differentiation, (ii) good price information, (iii) no-capacity constraints.
- **Firm asymmetries:**
  - Heterogenous costs: Size, amenities, and vertical-contracts.
  - Network size: Roughly 50% of stores are part of multi-product networks, and 50% are independent price-setters.
- **Price-floor regulation:**
  - Discourage aggressive pricing,
  - Prevent firms from setting prices below terminal price (rack),
  - Most stores have marginal-costs **below** the floor,
  - Government can raise minimum margin to 3 cpl following price-wars.

Collusion with asymmetric firms

- **Example:**
  - Homogenous products duopoly: $D(p_L, p_H) = 1 - \min\{p_L, p_H\}$.
  - Two sources of asymmetries:
    - ★ Time-invariant cost: $c_H > c_L = 0$
    - ★ Two network sizes: $n_H > n_L = 1$
- **Claim:** Collusion is more difficult if c_H or n_H are large.
  - IC of type L with cost asymmetries:

$$\text{IC}_L: \quad \frac{(1-\bar{p})\bar{p}}{2(1-\delta)} \geq (1-\bar{p})\bar{p} + \frac{\delta}{1-\delta}(1-c_H)c_H$$

$$\rightarrow \delta \geq \frac{1}{2}\frac{\pi^{\text{coll.}}}{\pi^{\text{coll.}} - \pi^{\text{comp.}}} = \bar{\delta}(c_h) \text{ and } \partial\bar{\delta}/\partial c_H > 0$$

  - IC of type H with network size asymmetries:

$$\text{IC}_H: \quad \frac{1}{1+n_H}\frac{(1-\bar{p})\bar{p}}{(1-\delta)} \geq (1-\bar{p})\bar{p} + 0$$

$$\rightarrow \delta \geq 1 - \frac{1}{(1+n_H)} = \bar{\delta}(n_H) \text{ and } \partial\bar{\delta}/\partial n_H > 0$$

How to sustain collusion in this context?

- Standard solutions in the asymmetric cartels literature
  - Side-payments
  - Market share division (e.g. Bae ('87) and Harrington ('91))
  - Ex.: Quotas, "buy-back" programs, exclusive territories, knockout auctions, etc.
- Not implementable in homogenous price-posting retail markets:
  - Firms do not control where consumers shop
  - Common price $\Rightarrow$ Equal market share
- Price leadership: (i) high-cost firm leads price increases, and (ii) low-cost firm leads price decreases. (i.e. inter-temporal transfers).
  - Recurrent price differences between firms allow firms to "transfer" sales from "weak" to "strong" players
  - **Definition:** By strong player, we refer to firms who have less to gain from collusion. WTP for collusion $= NPV^{coll} - NPV^{punish}$.

Key features the collusive arrangement

1. Organizational structure of the cartel
2. Pricing dispersion patterns
3. Coordinated price increases
4. Coordinated price decreases

1. Organization of the cartel

- **Cartel leader** [barometers]
  - Large lessee retailer (multi-store)
  - Partially integrated: Wholesale & distribution
- **Low-cost firms** [market leaders]
  - Ultramar: VI & low-price guarantee policy
  - High volume retailers: Company-owned big-box retailing chain (i.e. Canadian-Tire, Maxi)
- **Followers**
  - Two types:
    - ⋆ *Active:* Share monitoring efforts with leader.
      Main player: Couche-Tard.
    - ⋆ *Passive:* Follow the directives of the leader
- **Dissidents**
  - Independently owned stations
  - Either "low-cost" independents, or differentiated location

2. Collusive pricing – 2002-2006

Key features:

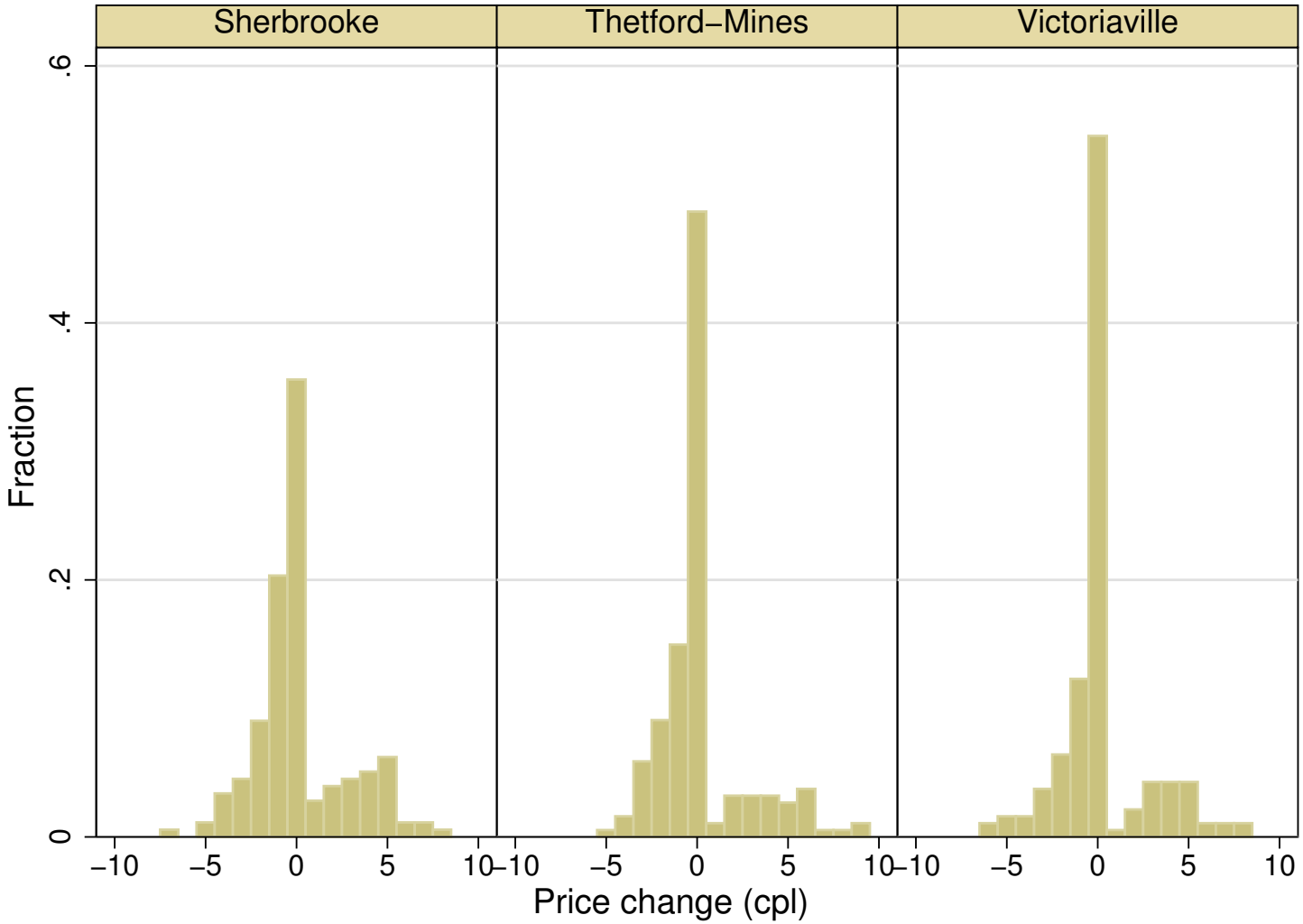
- Infrequent and large price increases
- Frequent periods of sticky prices
- Small price cuts + discrete price grid
- Price changes $\neq$ Cost changes (i.e. variable markup)
- Small and stable price dispersion

Analogous to *Edgeworth cycles* common in other gasoline markets:

- Castanias & Johnson (1994), Eckert (2002), Noel (2007), Wang (2009), Byrne and de Roos (2017).

Distribution of weekly price changes – 2002-2006

Takeaway: Sticky-prices and asymmetric adjustments



Distribution of Prices

Market name	N	Freq. Mode	Freq. Min	Median Mode-Min	Median Range	Median # Prices
Sherbrooke	60	0.864	0.651	0	2.7	4
Thetford-Mines	13	0.5	0.461	0.5	0.5	2
Victoriaville	24	0.877	0.083	2	2.5	3

3. Coordinated price increases

- **Key feature:** Firms coordinate the magnitude and the sequence of move
- **Communication patterns**
  - Leader chooses a price increase, and communicates with followers
  - Then contact low-cost stations: Big-box retailers and Ultramar
- **Typical information shared**
  - Followers asked to raise their prices **simultaneously** at t_0
  - Low-cost stations are told to raise their prices by time t_1
- **Dual role of communication**
  - Monitoring the behavior of followers to detect laggers
  - Negotiating with low-cost stations to ensure their participation

Distribution of communications over time

Successful price increases in Victoriaville

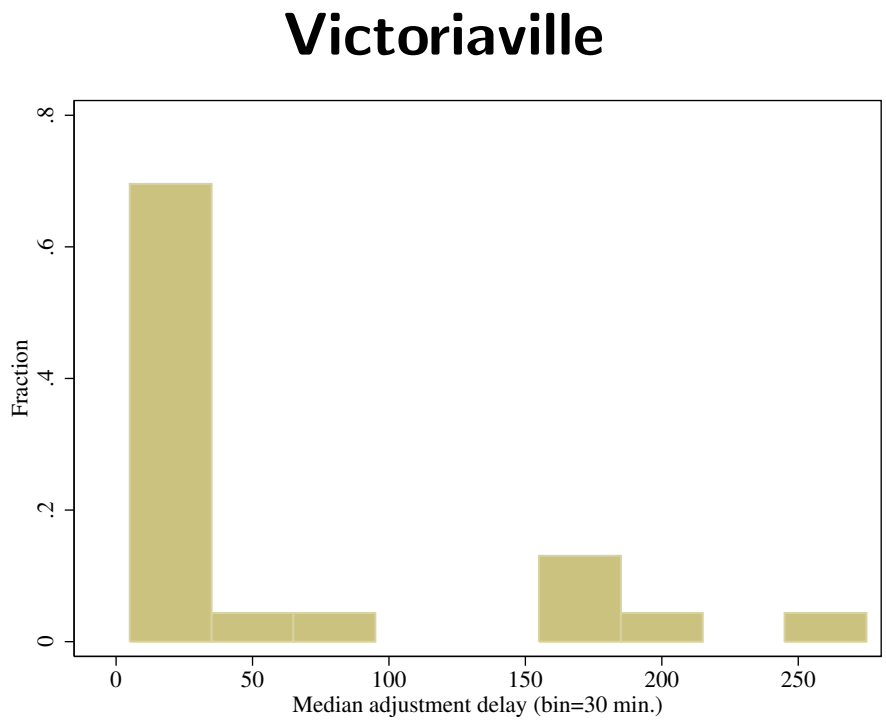
Timing:

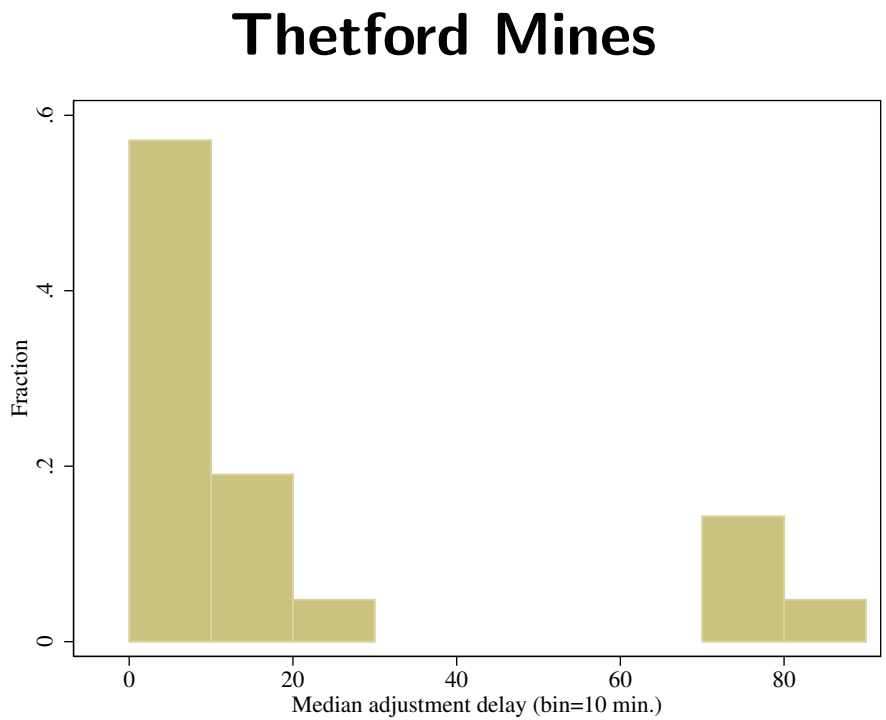
- $t = 0$: time of the first price change
- $t \in (-120, 0)$: Initial phone calls deciding on a target price
- $t \geq 0$: Monitoring and negotiations

		Share of contacts received in time grid (min.)						
Player types	Number of contacts rcv./send	≤ -120	-60	0	60	120	180	≥ 240
Follower	20/25	0.09	0.10	0.51	0.01	0.07	0.04	0.17
Leader	19/28	0.03	0.16	0.19	0.16	0.14	0.03	0.29
Couche-Tard	9/7	0.25	0.19	0.38	0.00	0.06	0.00	0.13
Dissident	6/2	0.00	0.27	0.09	0.36	0.00	0.09	0.18
Ultramar/big-box	11/3	0.00	0.08	0.04	0.29	0.25	0.08	0.25

Notes: A contact is defined as a sequence of phone calls between two individuals. The contact time corresponds to the time of the first phone calls, and is expressed relative to the time of the first recorded price change. Each entry is calculated by averaging over all successful price increases in Victoriaville.

Distribution of price adjustment delays





4. Coordinated price decreases

- Price cuts are almost always initiated by Ultramar
  - Low-price-garantee (LPG) policy creates a natural coordination device,
  - And provide an effective monitoring.
- Communication patterns:
  - Ultramar unilaterally cuts prices by 1 cpl (i.e. no communication)
  - After a price cut is observed, the Leader begins a round of communication:
    - ★ About half of followers are contacted
    - ★ Messages: Automatic price-match
    - ★ No delays or retaliation

Distribution of communications over time

Price decreases in Victoriaville

Timing:

- $t = 0$: time of the first price change
- $t \in (-120, 0)$: Initial phone calls warning of an upcoming price cut (not from Ultramar)
- $t \geq 0$: Diffusion of information

		Share of contacts received in time grid (min.)						
Player labels	Number of contacts receive/send	≤ -120	-60	0	60	120	180	≥ 240
Follower	10/9	0.10	0.00	0.49	0.27	0.05	0.04	0.05
Leader	7/12	0.06	0.00	0.70	0.13	0.04	0.00	0.08
Couche-Tard	4/3	0.14	0.07	0.54	0.07	0.04	0.04	0.11
Dissidents	3/0	0.14	0.00	0.57	0.29	0.00	0.00	0.00
Ultramar/big-box	2/2	0.00	0.00	0.75	0.19	0.00	0.00	0.06

What is the cost the first-mover?

- **Québec City price-war:** Virtually all 283 stations posted prices at the floor between Feb. and December 2000
- **Data:** Daily volume for 32 EKO stations (Aug.-Dec.)
- **Price variation:** 20% of prices $>$ min (e.g. relenting)
- **Dependent variable:** Log volume.

VARIABLES	Week & Store FEs	Week & Store FEs
$1(0 < P_j - \min(P_j) \leq 2)$	-0.259***	-0.249***
	(0.0273)	(0.0327)
$1(P_j - \min(P_j) \geq 2)$	-0.468***	-0.421***
	(0.0244)	(0.0288)
$1(0 < P_j - \min(P_j) \leq 2)$ X Large stations		-0.0314
		(0.0534)
$1(P_j - \min(P_j) \geq 2)$ X Large stations		-0.140***
		(0.0449)

- Consistent with kinked-demand story...

Takeaway 1: Monitoring costs are important

- Implementation of coordinated price increase is costly...

  Leader cost = Monitoring + Prosecution + First-mover sales losses

- Without effective monitoring efforts, incentive to cheat on timing would be important.
- Imperfect monitoring = Prisoner dilemma problem
  - Secret delays:
    - ★ Leader announce $p_t > p_{t-1}$
    - ★ Followers face a *prisoner dilemma*: (i) delay action (e.g. not answer the phone), or (ii) raise price immediately.
  - Same is true on the way down:
    - ★ No incentive to delay, but "preempt" a coordinated price cut

Takeaway 2: Simple pricing rules and infrequent price adjustments facilitate collusion

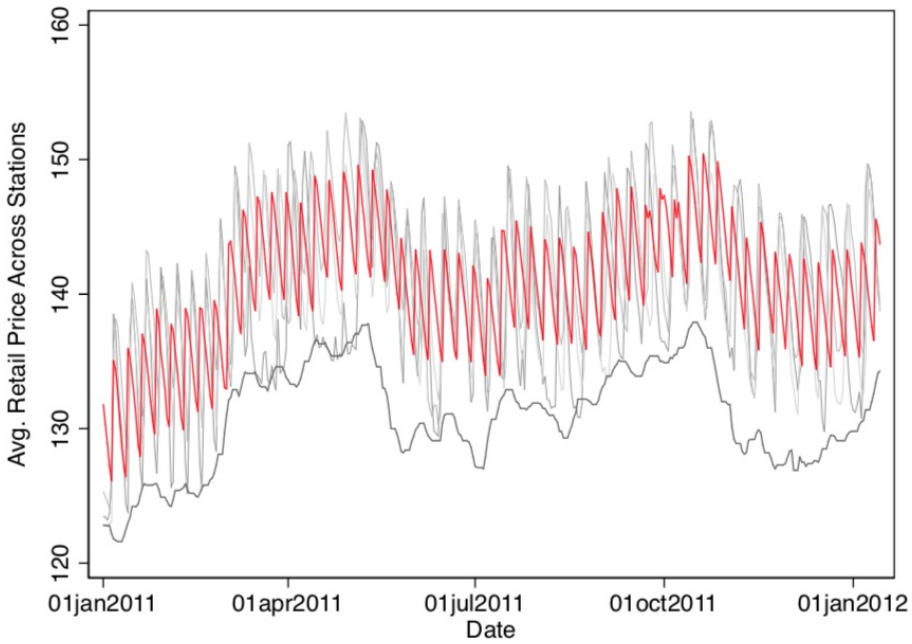
- Constant markup rule is unattractive
  - Require frequent price changes
  - Raise monitoring costs and tightened IC of leader(s)
- Solution: Infrequent price changes. How?
  - Overshooting: Achieve large transfers (demand accumulation)
  - Small price cuts: easily observed/monitored by LPG firm (price decrease leader)
  - Sticky prices: Increase time between transfers
- Pricing-cycle is similar to "menu-cost" models of price adjustments (e.g. $[S, s]$ rule)

Byrne and de Roos (2017): Learning to coordinate

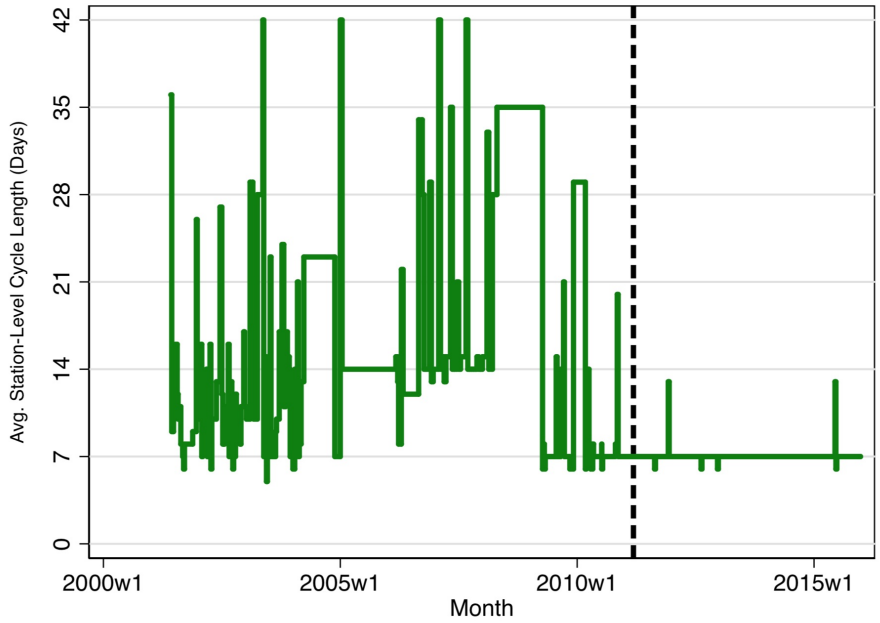
- In 2001, the Western Australia's state government introduced a price transparency regulation. What does it do?
  - Next day's price must be announced before 2pm
  - This price is valid for 24hrs (from 6am)
- First-order effect of the regulation: Mis-pricing is *very* costly (24hrs delays)!
- **Market:** Perth's gasoline retail market
  - Integrated retailers: BP, Caltex, Mobil, and Shell
  - Grocery store chains: Coles and Woolworths

Time-series: Price Cycles

Prices and costs in 2011
across 4 australian cities



The collapse of
cycle lenghts in Perth



- **Note:** Red = Perth (other cities are not price regulated).
- Prior to 2010, prices and profits margins were more unstable in Perth than in other cities.

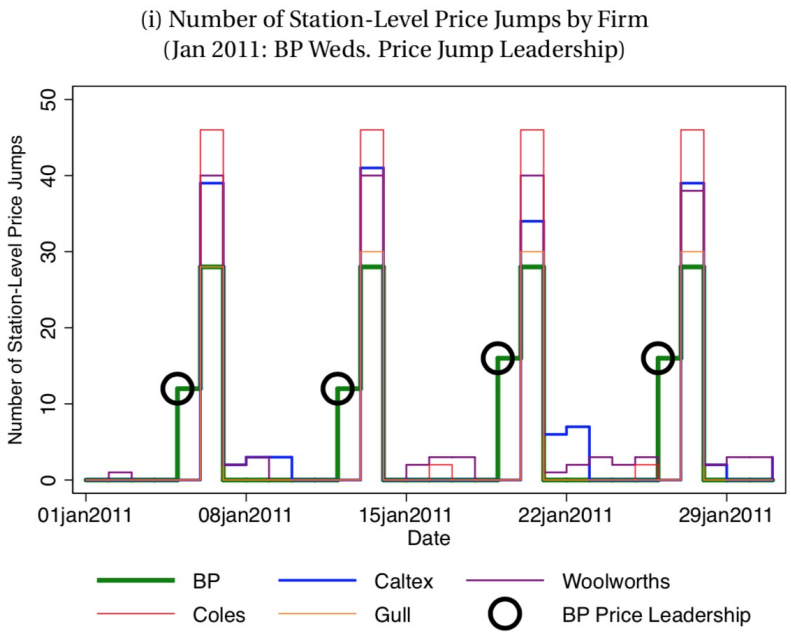
Key features of the price adjustment strategy

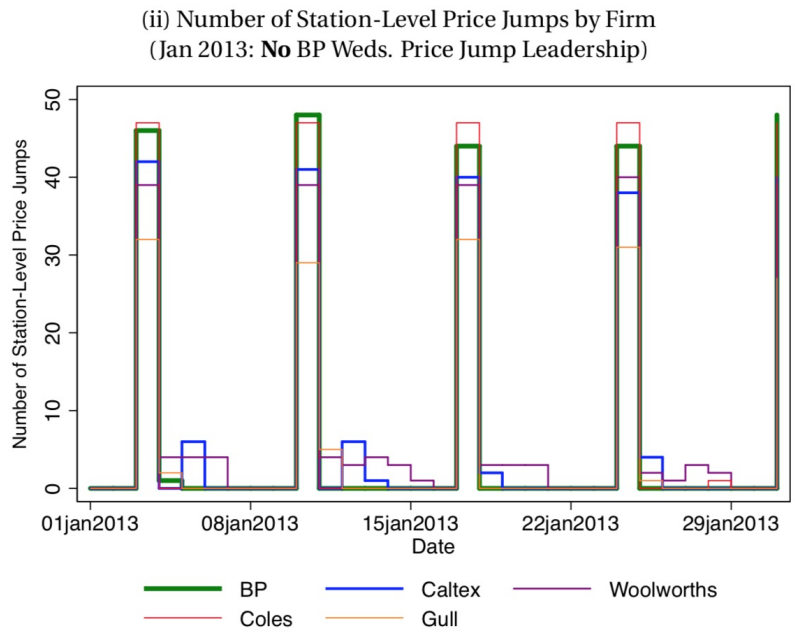
- Starting in 2010, firms coordinated on the following pricing rule:
  1. Thursday price *jump*
  2. Daily price cuts by 2 cpl
  3. Cycle length = 7 days
- The size of price increase is determined by expected margins at the bottom of the cycle:

$$p_{t+7} = p_t - 12 \geq E(c_{t+7})$$

- **Implications for profits:** Prices change every day, but profit margins are determined by the Thursday price.
- **Coordination problem:** How to determine the Thursday price given the constraints imposed by the price-posting regulation?

Pricing cycles with and without leadership

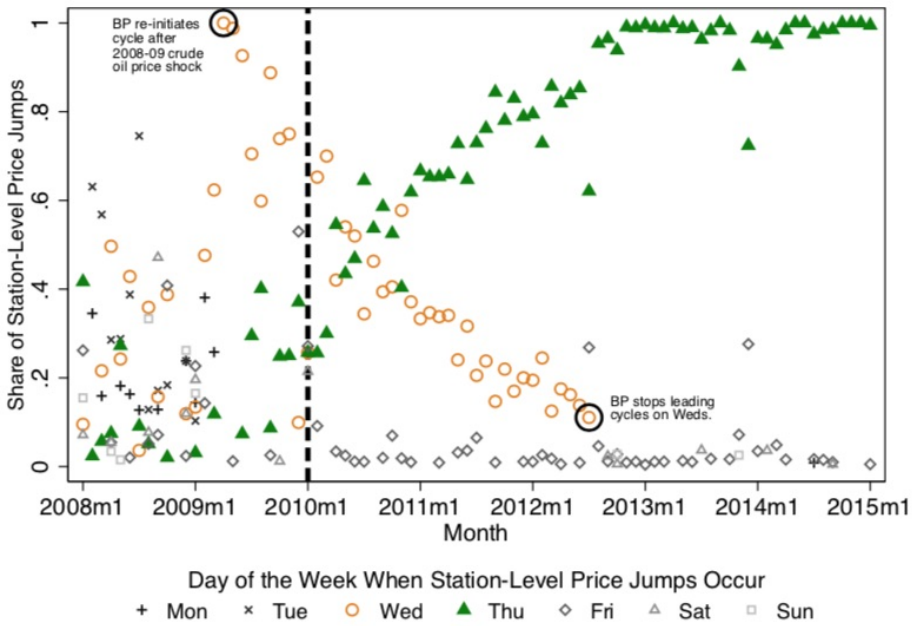




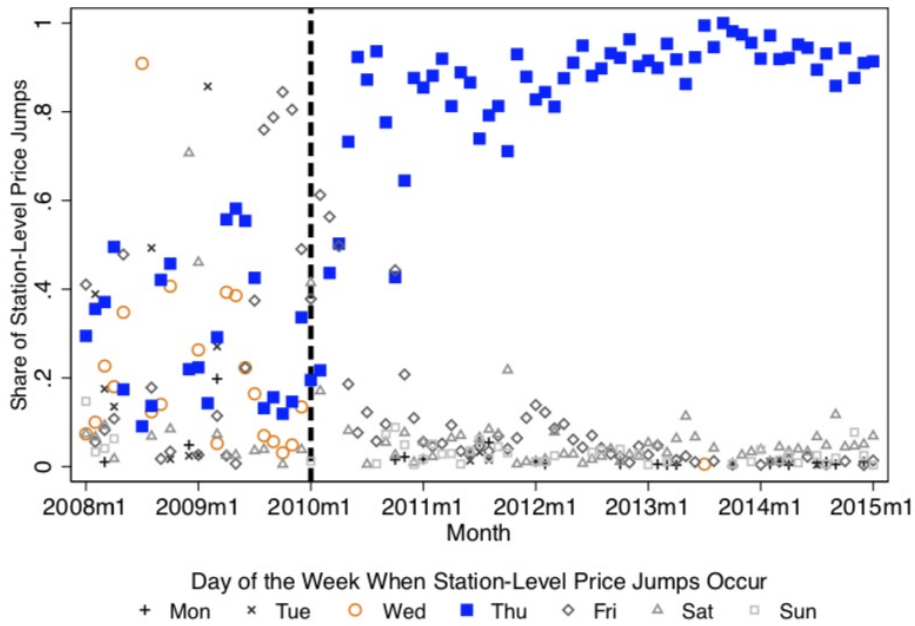
- The strategy was implemented gradually, with BP taking a **price leadership** role
  - **Sequential-move period:** BP (largest network) "jumps" first on Wednesday (give up market share), and rivals price match on Thursday
  - **Simultaneous-move period:** All major chains "jump" simultaneously on Thursday to re-start the cycle

Transition period (1): BP gradually decreasing its share of stations moving first on Wednesday

(i) Share of **BP** Station-Level Price Jumps by Day of the Week and Month

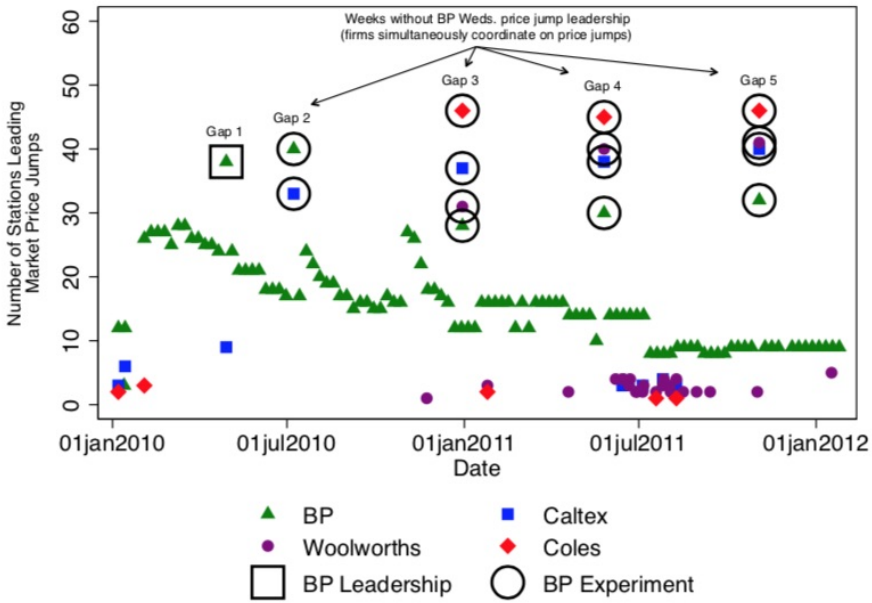


(ii) Share of **Caltex** Station-Level Price Jumps by Day of the Week and Month

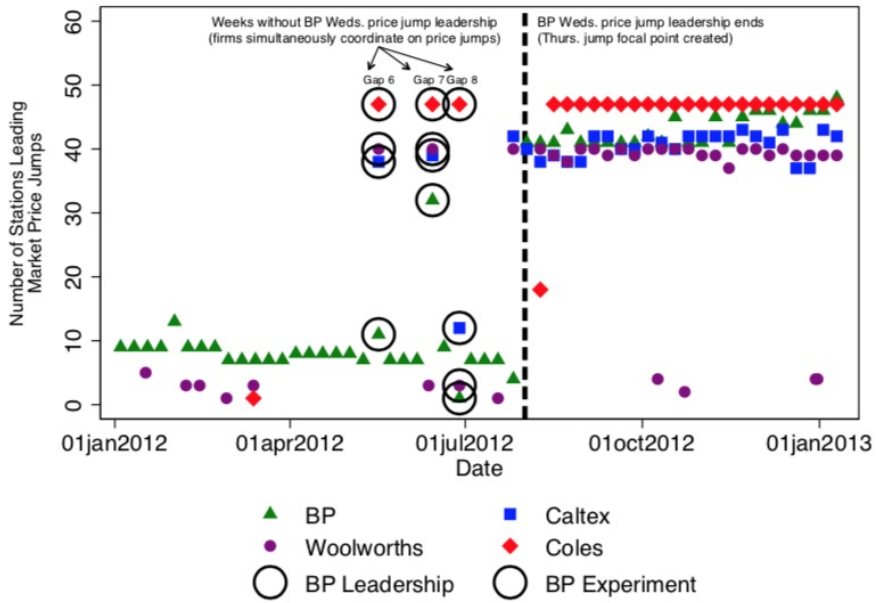


Transition period (2): BP periodically experiments with Thursday price jumps (signals to rivals)

(i) Number of Stations Leading Market Price Jumps by Firm
Jan 2009 – Jan 2012

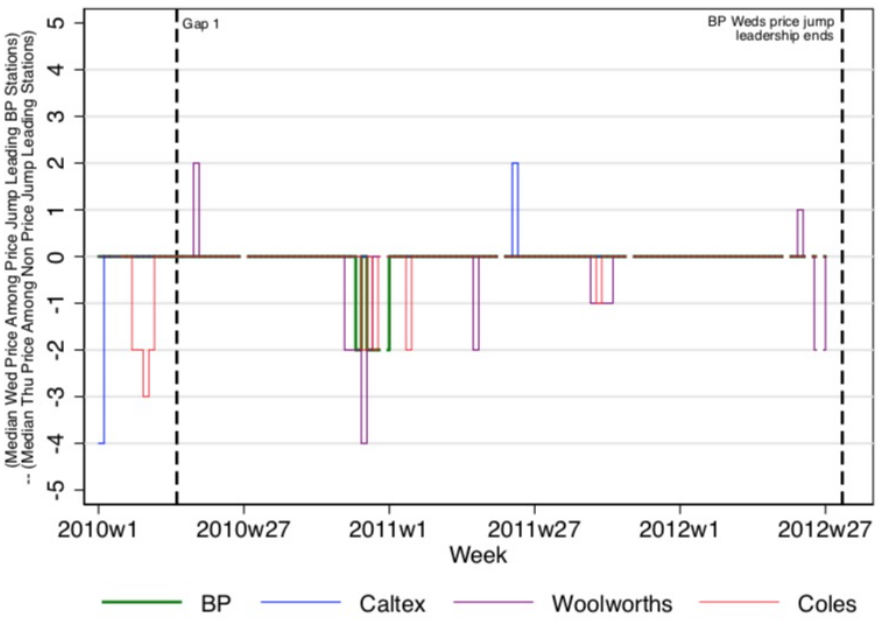


(ii) Number of Stations Leading Market Price Jumps by Firm
Jan 2012 – Jan 2013

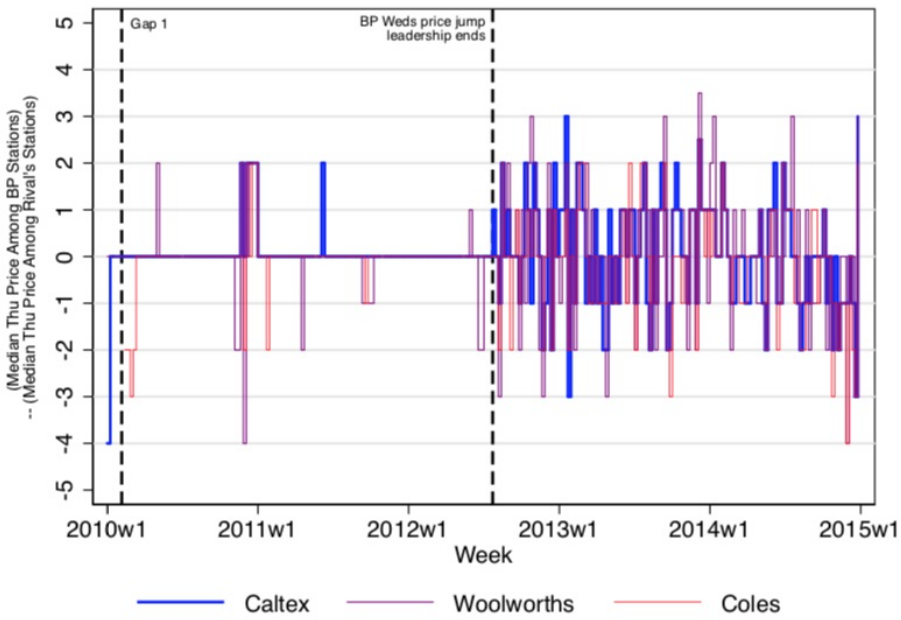


Simultaneous equilibrium: Coordination Problems on Thursday Prices

(i) Difference Between Median **Wed.** Price Among Price Jump Leading BP Stations and Median **Thu.** Price Among Non-Leading Stations



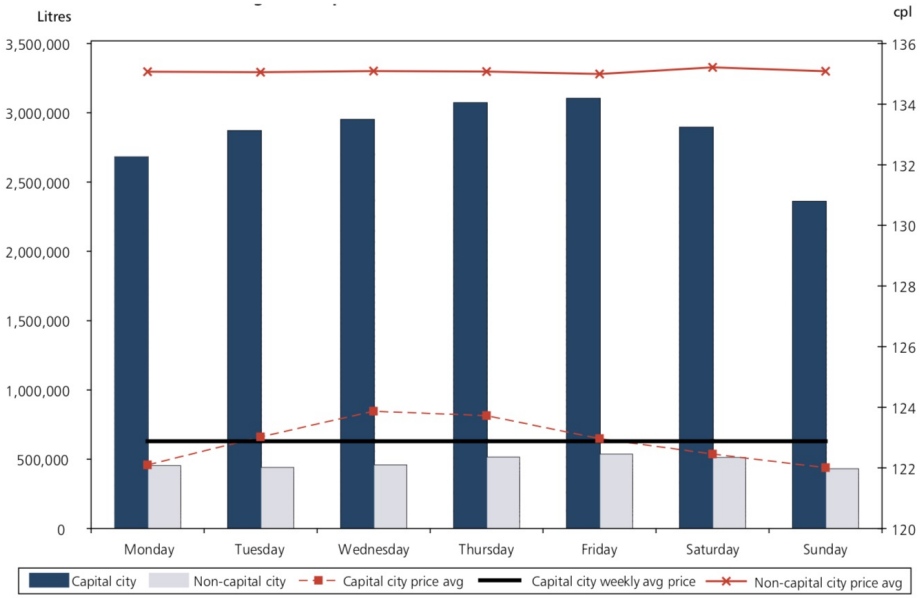
(ii) Difference Between Median **Thu.** Price Among All BP Stations and Median **Thu.** Price Among Rival Stations



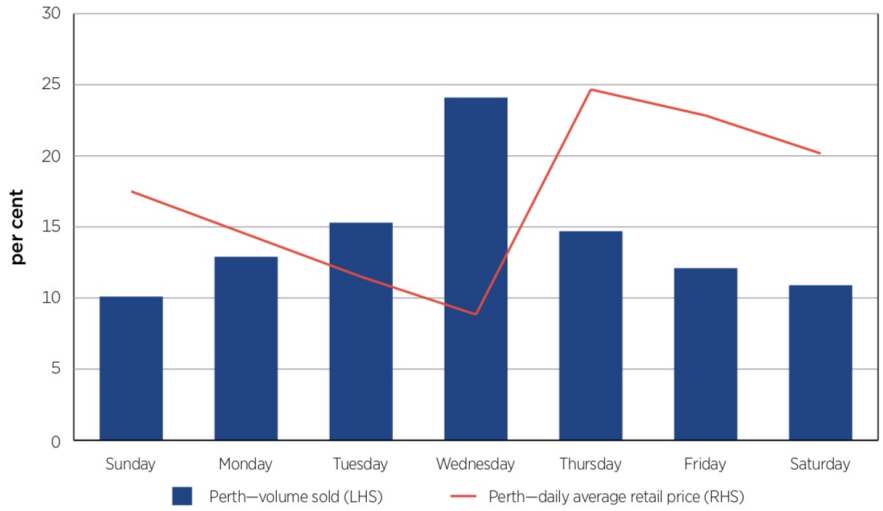
- **Takeaway:** The role of the first-mover is important to provide stability and information on the collusive price.

Implication for consumers?

Period: 2003-2004



Period: 2013-2014



- Within-week cycle $\approx$ Price discrimination device between informed and uninformed consumers (e.g. Airline tickets)
- **Implication 1:** This implies that it is very costly to move first in this market (25% of sales on Wednesday!).
- **Implication 2:** The fact that informed consumers sort on Wednesday substantially reduce the coordination cost of Thursday (i.e. mispricing does not lead to zero profits)

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