2. Notes on Strategic Games, Strategic Interaction

2.1. Overview

- **Strategic Cooperative behavior**

Carlton and Perloff (2000), chapters 5,6 and 11.

Antitrust, Carlton and Perloff (2000), chapter 19.

- **Supergames**

- *Repeated games and collusion, Tirole (1989) chapter 6.*

Fluctuating Demand: Rotemberg and Saloner (1986) JSTOR link

Cyclical Demand: Haltiwanger and Harrington (1991) JSTOR link

Empirical paper: Reading for Topic "Dynamic Pricing", Borenstein and Shepard (1996) , Assignment, please read for next lecture.

- *Repeated games with Asymmetric information*

Green and Porter (1984) JSTOR link

Empirical papers:

Reading for Topic:"Cartel/Price Wars", Porter (1983)

Reading for Topic:"Cartel Collusion/Repeated Games with Asymmetric Information", Ellison(1994)(optional)

- **More on identification of oligopoly models.**

2.2. Strategic Behavior

References: Lecture notes on factors that facilitate collusion, Carlton and Perloff (2000), chapters 5,6 and 11.Antitrust, Carlton and Perloff (2000), chapter 19.

° Strategic Behavior are actions that are taken with the objective of increasing firm's profits.

° These actions aim at manipulating the market environment:
- Other existing firms or by possible entrants
- Beliefs of consumers and of existing and potential rivals
- Technology and costs of firms and entry costs

° **Non-cooperative strategic behavior (next set of notes)** encompasses actions of one firm that wants to increase its profits by improving its position relative to its rivals

to harm its rivals

to benefit itself

Cooperative strategic behavior are actions that increase the profits of all firms by reducing competition and by reducing uncertainty about each other.

These can take the form of explicit agreements as well as non explicit

- Practices that facilitate collusion
    -

- **<u>The role of Courts:</u>**

Sometimes the above practices may be engaged not to decrease competition but for efficiency reasons. Sometimes such practices are done in the context of a large number of firms where collusion can be difficult.

Example 1: Information exchange, where an Open Competition Plan was voluntarily joined by 465 lumber mills. There, price and quantity data are collected and disseminated. Such exchange has been found not to have anticompetitive impact on output and price.

Example 2: Advance notice of price changes that are reached by insistence of the buyers (to plan better) but not the firms themselves (to facilitate collusion)

- **<u>Factors that affect collusion</u>**

1. elasticity of demand facing the cartel
2. expectation of severe punishment
3. monitoring and organizational costs
4. Stable environments
5. homogeneity of good
6. Repeated Interactions, finite horizon?

2.3. Supergames

References: Tirole, chapter 6, Rotemberg and Saloner (1986), Haltiwanger and Harrington (1991), Borenstein and Shepard (1996) , Green and Porter (1984), Empirical papers: Porter (1983); Ellison(1994)(optional).

• Supergames = repeated games & collusion

Does the repeated interaction allow firms to sustain equilibria for the dynamic game which are more cooperative than the equilibria we obtain from "one shot"/ static game?

• Supergame is a special case of Dynamic Games
where each period the same game is repeated
we'll repeat the Bertrand game

• 2 firms, same constant marginal costs, homogeneous goods, choose prices. Perfect information.
• A strategy in a repeated game: what price to choose given previous history (previous set prices). Let the information set at time t be τt= { P_1, τi, P_2, τ} t=1 τ=2
• T finite:
Solved by backward induction/recursion=> unique equilibrium is Pt=mc
Each firm $\max_{p_{it}} \pi_i (p_{it\backslash} p_{jt})$

$$D_{it} = 0 \quad if \quad p_{it} > p_{jt}$$

$= D(p_{it}) /2$ if $p_{it}=p_{jt}$
$=D(p_{it})$ if $p_{it}<p_{jt}$

- **T finite**. Why p_t=mc $\forall$t
In the last period $p_{1T}=p_{2T}$ =mc. In the T-1 period the profits of π_T=0 regardless of decision in the T-1 period, so period T-1 is again a 'stand alone' period , therefore, $p_{1,T-1}=p_{2,T-1}$=mc, etc…

- The assumption that makes this result is that there is zero robability of playing after period T.
- If probability of playing after period T >0 even if small $\Longrightarrow$
Possible to support higher prices than mc!

T infinite Infinitely repeated games
It is possible to sustain p>mc ! we can sustain p$\in$[c,p^m].

- Grim Strategy / Trigger pricing

Consider the following strategy: (2 firms)
$p_{i,0}=p^m$, i=1,2 , where pm is the monopoly price
$p_{i,t}= p^m$ if $\forall \tau<t$, $p_\tau=(p^m,p^m)$
mc , otherwise. Plays mc <u>forever</u> if one person deviates once.

Can we support p^m ?
Compare discounted profits from deviating with the profits from collusion.
<u>Deviating in period T</u> : $\pi_T = (p^m - \varepsilon - c) \bullet D(p^m - \varepsilon) = \pi_T^m$
$\pi_t = 0$, t=T+1,T+2,…

<u>Not Deviating :</u> Shares monopoly profits forever $\frac{\pi^m}{2} + \delta \frac{\pi^m}{2} + \delta^2 \frac{\pi^m}{2} + \dots$

A firm will <u>not</u> deviate if $\pi^m < \frac{\pi^m}{2}(1 + \delta + \delta^2 + \dots) = \frac{\pi^m}{2} \bullet \frac{1}{1-\delta} \Leftrightarrow$

if δ>1/2 then it's possible to sustain $p_t=p^m$ $\forall$t

<u>Folk Theorems</u>

For the repeated price game, any pair of payoffs (π^1, π^2) such that $\pi^1 > 0$ and $\pi^2 > 0$ and $\pi^1 + \pi^2 \le \pi^m$ is a per-period equilibrium payoff for δ sufficiently large.

- For large enough δ we can sustain π>0.

2.4. Fluctuating Demand

Rotenberg and Saloner(1986)

-Simple version: homogeneous good, 2 firms, symmetric, set prices
-2 states of nature: s=1, D1(p) with probability=1/2
s=2, D2(p) with probability =1/2
where D2(p)>D1(p)
-Demand is independent over time, that is, high demand today does not say anything about demand tomorrow, implying iid demand shock. In the example above demand takes two values, for simplicity.
-In each period all firms observe state of demand before choosing prices.

-Question again: Can we sustain p>mc?

- Strategies given s:

- Deviation profits:

-Now note that the incentives to deviate are higher in high demand periods.

-So for collusion to be sustained in the high demand state s=2:

So what is $\mathbf{p}_2$ such that collusion works?

$\max\limits_{p_1,p_2}[E(\pi)]$ s.t. no firms want to deviate for all states

$$\max_{p_1,p_2} V = \underbrace{[.5*\pi_1(p_1)/2 + .5*\pi_2(p_2)/2]}_{E(\pi)}$$

s.t. (i) $\pi_1(p_1)/2 \leq E(\pi)\delta/(1-\delta)$ (redundant)

(ii)$\pi_2(p_2)/2 \leq E(\pi)\delta/(1-\delta)$ (binding)

so set $\underbrace{p_1 = p_1^m}_{\text{because } \max \pi_1(p_1)/2}$ and p_2 s.t. $\pi_2(p_2)/2 = [\pi \underbrace{{}_1(p_1^m)/4 + \pi_2(p_2)/4}_{p_2 \in [c, p_2^m]}]\delta/(1-\delta)$

and constraint (ii) is less restrictive.

Note: It is possible to have $p_2^m < p_1^m$

$\Longrightarrow$Countercyclical pricing: charge p_1^m during low demand periods and below p_2^m when high demand (price war).

How does iid assumption on demand affect results? $\rightarrow$Lets relax it next...

1 Relaxing demand i.i.d. assumptions:

Cyclical Demand Haltwinger and Harrington(1991)

Deterministic demand cycles:

1.0.1 $\mathbf{D}_t(p)$ are increasing until $\mathbf{t} \leq \mathbf{t}'$

$\mathrm{D}_t(p)$ are decreasing until cycle is complete.

Repeated game:

$\forall t$, same number of firms, costs, symmetric firms , homogenous goods.

Punishments as before = revert to Nash-Bertrand, $\pi_i = 0\ \forall i$

Conclusions:

–For equal current demand, the point when demand is falling will be more difficult / less able to sustain collusion than at the point at which demand is rising.

–2 Forces:

-Higher demand makes it more profitable to deviate

-Falling demand lowers punishment

$\Longrightarrow$ when demand is high and falling it is that monopoly prices are hardest to maintain so prices fall.

$\Longrightarrow$ $(p - mc)$ =margins respond positively to changes in expected demand, given current demand.

This is the theoretical testable implication of this model!

2 Dynamic Pricing in Retail Gasoline

Borenstein and Shepard, RAND, 1996

-Don't impose a structure. Reduced form paper

Question: Is pricing of retail gasoline consistent with predictions of Rothenberg-Saloner (Haltiwanger and Harrington_ type of models?

Collusion=means here implicit collusion supported by repeated interactions

PCM=price cost margins

Theory-3 predictions

1. General conclusion: collusive margins will respond to anticipated changes in cost and demand

2. Controlling for current demand, price cost margin will increase when expected (future-near) demand increases.

3. Controlling for current input prices, PCM decreases if input price increases.

Here, reduced form approach

They don't distinguish theories (like in Ellison structural paper next).

Given the coefficients, what do we get from them?

Data:

Panel data 43 cities (they abstract from intra-city competition), 72 months,

retail price, wholesale price=marginal cost , quantities

$\Longrightarrow$margin=(retail-wholesale) price

-Differentiated product, mostly by location

-known seasonal changes -in demand (figure 2), in wholesale prices (figure 1)

-margins=retail-terminal price (figure 1) .... much more erratic that figure 2

Equation to be estimated:

$\text{margin}_t = \alpha_1 \text{ volume}_t + \alpha_2$(expectation volume change)$+\alpha_3$ exp(terminal price change)+controls$+\varepsilon_t$

controls=city fixed effects
time effects
past retail prices
past terminal prices

- Absent the incentives from collusive possibilities, then

Retail price t$=\alpha_1 \text{volume}_t$+city effects+distributed lag of past retail and terminal prices

that is $\alpha_2 = \alpha_3 = 0$,

- The Haltwinger-Harrington collusive theory implies $\alpha_2 > 0$ and $\alpha_3 < 0$

AR, city by city:

- Predict Nvolume t = function of past Nvolume+ month dummies+ function of time

much of what they get is seasonal. Fit is between .8 and .95

- predict terminal t =function of month dummies+ past terminal prices and past crude prices

fit is less good than above, between .3 and .6 .

Conclusion: volume varies in a much more predictable way (seasonal) than terminal (input) prices - authors say that terminal prices follow crude prices which approximately follow a random walk.

Endogeneity (Problems)

volume t is on the RHS $\text{p}_t - \text{terminal}_t = \alpha_4 \text{vol}_t + ... + \varepsilon_t$

but volume is a function of price itself (any unobservable determinant of price is in the residual and therefore also affect quantity (volume)).

$\text{volume}_t = f(price_t) + v$

If model for volume is given by ln (q_t) =z$\beta + \eta \ln p + v$

If ε and v are orthogonal, η is identified

$\underbrace{\ln(q) - \widehat{\eta} \ln p}$

use this as instrument for current volume

Is this a valid instrument???

- the part of qt that is not explained by price.

Estimation of VAR model (problems)

There is a lot of econometric structure here-are the exclusion restrictions credible?

Table 3:

-Both estimated coefficients associated with the expectation variables are of right sign

$\hat{\alpha}_2 > 0$ and $\hat{\alpha}_3 < 0$ and significant.

- average margin is 10.6 cents. The effect of one standard deviation change in expNvolume on the margin, evaluated at the mean is of about .26 cents (small - possibly because so many retailers of gasoline).

Two remarks: (1) what about repeated purchase/inventory behavior?

(2) Is the paper looking at the right place-where would we expect to see collusion ? at retail or wholesale?

3 Green and Porter (1984)

-interest : games where price/quantity choices made by opponents are not directly observable.

-question (dating back to Stigler (1960s)) :How to detect normal shocks in demand from deviations from rivals?

-each firm knows its own play but not its rival's play$\Longrightarrow$asymmetric information

$\rightarrow$*with no uncertainty of demand*, price choices/quantity choices are perfectly observable.

-higher prices were sustained with grim punishments

-punishment periods were actually **never occurring** on the equilibrium path

$\rightarrow$*With uncertainty* $\Longrightarrow$cartel will punish sometimes by mistake (unavoidable)

why a mistake? -when go to punishment period but then notice all that p was high for all firms the only thing that happened was a bad demand shock!

Green and Porter actually consider a quantity game, while here we'll consider a price game similar to the game we have been seeing so far - for comparison purposes.

3.1 Model:

Homogeneous good market, constant marginal cost c, two firms, 1 and 2

Demand

with probability α, low demand state

with probability 1-α, high demand state

realizations of demand (again) iid over time

Profits

$\alpha - - - - \pi_1 = \pi_2 = 0$

1-$\alpha - - -$ if $p_2 < p_1 = p^m$, $\pi_1 = 0$ and $\pi_2 = \pi^m - \alpha$

if $p_2 = p_1 = p^m, \pi_1 = \pi_2 = \pi^m/2$

so when a firm earns $\pi = 0$, does not know if demand was low or its rival played a low p and demand high.

-repeated game, T$= \infty$

3.2 When are the following strategies a Nash Equilibrium?

-Both $p_1 = p_2 = p^m$ until one firm i earns $\pi_i = 0$

-The occurrence of $\pi = 0$ triggers a punishment phase

-During the punishment phase $p_1 = p_2 = c$ during T periods

-At T+1 they revert to the collusive phase

Question: Are the trigger strategies NE?

* During punishment period: YES. Given $p_i = c$ for T periods, firm j has no incentive to play anything else

*During the collusive phase:

Denote V^- be value in punishment phase, V^+ be value in collusive phase .

If this strategy is played at the beginning of each phase.

*Prices are set before knowing the realization of the demand shock.

so $V^+ = (1-\alpha)(\underbrace{\pi^m/2 + \delta V^+}_{\text{if high demand}}) + \alpha \underbrace{(0 + \delta V^-)}_{\text{if low demand}}$ (1)

and $V^- = \underbrace{(0 + \delta \cdot 0 + ... + \delta^{T-1} \cdot 0)}_{\text{T punishment periods}} + \underbrace{\delta^T V^+}_{\text{Again cooperative periods}}$ (2)

substitute (2) in (1) gives

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

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

* **For the strategy to be a NE** we need to satisfy the incentive constraint, that is, that a firm will want to play collusively, and not want to deviate

$\Longrightarrow$Incentive constraint to collude/not deviate:

$\underbrace{\alpha 0 + (1-\alpha)\pi^m/2 + \delta[(1-\alpha)V^+ + \alpha V^-]}_{\pi(\text{not deviate})} > \underbrace{(1-\alpha)\pi^m + \delta V^-}_{\pi(\text{deviate})}$ punishment

$\Longleftrightarrow \delta(V^+ - V^-) > \pi^m/2$

$\Longleftrightarrow V^+ > \pi^m/[2\delta(1-\delta^T)]$ (B)

So

–To deter price-cutting behavior we need V^+ to be sufficiently larger than V^- ($V^- = \delta^T V^+$)$\Longrightarrow$requires a large T

–On the other hand , if incentive constraint satisfied, then increasing V^- the better off is firm, V^- will be increased when T decreased.

$\Longrightarrow$ so we can think of the "optimal punishment" in terms of time T:

choose T to Max V^+ subject to the Incentive Compatibility (IC) constraint / choose minimum T s.t. IC satisfied.

substitute (A) in (B) to sustain collusion:

$$\frac{(1-\alpha)}{(1-\alpha\delta^{T+1}-(1-\alpha)\delta)} > \frac{1}{\delta(1-\delta^{T})}$$

4 Comparing Green & Porter (1984) and Rotenberg & Saloner (1986)

- In G&P what causes a price war (punishment) are low demand periods
- In R&S it was during high demand periods that there were more incentives to deviate
- In G&P there will be price wars
- In R&S there are no price wars

Porter (1983) : are there price wars? (will not address the causes)
in equilibrium firms should not cheat, price wars are only due to demand shocks

Ellison (1994, optional) causes of price wars - not required for this class.

Before we look at Porter's paper, lets talk about Identification and Testing different Theories, today in IO and how empirical studies in IO have evolved (for your background information).

Please read Porter (1983) for next lecture.

5 *Porter (1983) JEC:*

Question:

He observes p,Q shifts over time. Are they due to exogenous shifts in cost (supply) or demand equations or are these price wars?

Method:

–Uses a *Conduct Parameter* Approach$\Longrightarrow$Identification Issues

Demand Q=$\alpha_0 + \alpha_1 p + \alpha_2 y + \varepsilon$

marginal cost: mc=$\beta_0 + \beta_1 Q + \beta_2 w + \eta$

Assumption of supply relation (from FOC profit max):

p=$\theta(-Q/\alpha_1) + \beta_0 + \beta_1 Q + \beta_2 w + \eta$

if $\theta = 0, p = mc \Longrightarrow$perfect competition

$\theta = 1, mr = p + Q/\alpha_1 = mc \Longrightarrow$monopoly model

$\theta = 1/N \Longrightarrow$ Cournot model with N players

We have, in this way, nested into one model the several conducts.

Can we identify θ?

we observe $\{Q_t, P_t\}_{t=1}^{T}$,system of simultaneous equations:

w identifies $\alpha_0, \alpha_1, \alpha_2$

y identifies β_0, β_2, and $(\beta_1 - \theta/\alpha_1) = \gamma$

so one cannot distinguish β_1 from θ! So in this set-up, θ is *not* identified.

5.1 Identifying Sources

-$\beta_1 = 0$: assume constant mc (see previous figures on identification with constant mc)

-Use direct measures of mc

-Rotation of demand curve (Bresnahan,1982)

-Assume $\theta = \{\theta^c, \theta^p\}$ as in Porter' estimate lnp=$\beta_0 + \beta_1 \ln Q + \beta_2 st + \beta_3 It + \eta$ where It=1 if collusive state, 0 otherwise

5.2 Back to the paper:

Question: We observe (p,Q) shifts over time. Are they due to (exogenous) shifts in costs/supply or demand equations or are these price wars?

Data See figure!

- The Joint Executive Committee(JEC), a cartel of (mostly grain) rail shipment,

that operated out of Chicago to the East, during 1880-86 before Sherman Act(1890).

$\Longrightarrow$Could publicly acknowledge being a cartel.

- Principal function of JEC was information gathering and dissemination to the member every week.
- Market allocations through market share allocation.
- Demand was variable , so the cartel used a variant of a trigger price strategy to maintain collusion: If p$<\overline{p}$,

q=$q^{cournot}$ for T periods.

5.3 Theoretical Predications

1.Price wars occur as part of equilibrium

2.there is something that sets price wars, that triggers them.

3. In equilibrium, firms should not cheat - price wars are only due to demand shocks.

5.4 Model

5.4.1 Demand (constant elasticity)

$\ln Q_t = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 L_t + \omega_t$

$L_t = 1$ if Lakes open, 0 otherwise.

Note: When L=1, this is a negative demand shock because Lakes were an alternative mean of transportation.

5.4.2 Supply

N (asymmetric) firms, homogenous products with costs

$c_i(q_{it}) = \alpha_i + q_{it}^{\delta} + F_i$, i=1,...,N

profit maximizing pricing $\forall i$ yields

$p_t = (mark-up) + mc_i(q_{it})$, i=1,...., N

$p_t = -\theta_{it}/\alpha_1 + mc_i(q_{it})$, i=1,...,N (B)

Let $\theta_t = \sum_{i=1}^{N} \theta_{it} \underbrace{\frac{q_{it}}{Q_t}}_{\text{s}_{it} = \text{share firm i period t}}$

$$\sum_{i=1}^{N} s_{it} \; \text{P}_t(1 + \theta_{it}/\alpha_i) = \sum_{i=1}^{N} s_{it}.mc_i(q_{it})$$

$$\text{P}_t(1 + \theta_t/\alpha_i) = \sum_{i=1}^{N} s_{it}.mc_i(q_{it})$$

$$= \underbrace{\delta(\sum \alpha_i^{1/1-\delta})^{1-\delta}}_{D} Q_t^{\delta-1}$$

Taking logs:

$$\text{lnP}_t = -\log(1 + \theta_t/\alpha_1) + \log D + (\delta - 1)\log Q_t$$

Note: If θ_t unrestricted$\Longrightarrow$ not identified, cannot estimate θ_t.

For example:
If $\theta_t = \theta$ (constant) $\Longrightarrow \theta$ is identified$\Longrightarrow \widehat{\theta}$

Let $\theta_t = \{\theta^c, \theta^p\}$,, take two values, where
θ^c indicates the value under collusion, and
θ^p indicates the value under punishment.
- From a railway review newspaper there was "repeated" if cartel was having a price war (credible?)
-
Let $\text{I}_t = 1$ if collusive state, 0 if otherwise.

The the supply equation to be estimated is:
$\text{lnP}_t = \beta_0 + \beta_1 \ln Q_t + \beta_2 S_t + \beta_3 I_t + u_t$

5.5 Results - see Table 3:

Equations are in logs. β_3 is the dummy for collusion,
and given estimated alpha1 we get that estimated theta $\hat{\theta} = .336$.
In collusive state p is 40% higher than in punishment phase

Price wars occur, Figure 1, see GR (price) PO and PN.
Punishment period corresponds to price wars but they vary in duration and magnitude.

Comments:
-Paper shows that price wars exists not *why* they start (Ellison, if interested).
-Exists missing data=lake(ship) price
-i.i.d. demand$\Longrightarrow$Ellison(if interested).