Industrial Economics (EC3313) 2006/07

Johan Lagerlöf, February 28, 2007 [updated version]

Lectures 13 & 14: Empirical tests of oligopoly (C&W, parts of Chapters 8 & 12)

Today's Agenda

- The Conduct Parameter
- Two ways of thinking about the conduct parameter
  - Conjectural Variations
  - The Competition Parameter
- Identifying the conduct parameter
  - The Bresnahan-Lau approach
- Some empirical results

The Conduct Parameter

- So far in the course:
  - A number of theories about oligopolistic behavior.
- Different models imply different degrees of market power and competition.
  - Bertrand with homogeneous goods [⇒ marginal cost pricing]
  - Cournot with homogeneous or heterogeneous goods [⇒ some market power — how much depending on the number of firms and on the degree of product differentiation — but full collusion not possible]
  - Infinitely repeated Cournot (or Bertrand) game [⇒ full collusion if firms are sufficiently patient.]

- Question: Which model is right, given some market environment?
- As a first step towards answering this, we can summarize all the models that we have studied in a single equation, the so-called **supply relationship**:

$$D(Q) + \lambda D'(Q) q_i - C'(q_i) = 0, \qquad (1)$$

  where
  - $D(Q)$ $(= p)$ is the indirect demand function,
  - $C(q_i)$ is a firm's cost function,
  - $Q = \sum_{i=1}^{n} q_j$ is total output in the industry,
  - q_i is Firm i's output
  - and λ is the so-called **conduct parameter**.
- Different values of the conduct parameter yield the outcome of different oligopoly models, and our objective will be to estimate the value of the conduct parameter empirically.

- In particular we have:
  - $\lambda = 0$ corresponds to price taking behavior, as this yields p=MC.
  - $\lambda = 1$ corresponds to Cournot behavior, as this yields the FOC for a Cournot oligopolist.
  - $\lambda = n$ corresponds to collusive behavior, as this yields a condition that defines the optimal cartel output.
    - ∗ To see this, note that under symmetry we have $nq_i = Q$, and the FOC

$$D(Q) + D'(Q) Q - C'(q_i) = 0$$

      defines Firm i's optimal cartel output.
- More generally, larger values of λ yield a higher price-MC margin, and λ can therefore be thought of as a measure of market power.

- We can also understand the role of λ by relating it to the Lerner index, which we recall is defined as

$$LI = \frac{p - MC}{p}.$$

- Rewriting the supply relationship (1) (imposing symmetry) yields

$$LI = -\frac{\lambda D'(Q)\,q}{D(Q)} = -\frac{\lambda Q D'(Q)}{nD(Q)} = \frac{\lambda}{n\varepsilon},$$

where

$$\varepsilon \equiv -\frac{dQ}{dp}\frac{p}{Q}.$$

- Interpretation:
  - The LI is a measure of market power that runs from 0 to 1.
  - Its value in this model is increasing in the conduct parameter λ (which is consistent with the results above).

Two ways of thinking about the conduct parameter

- Before investigating how we can estimate the conduct parameter, we will here study two different (but, as it turns out, equivalent) interpretations of this parameter.

- In particular the first interpretation, the conjectural variations approach, is an often used tool in industrial economics and is therefore worthwhile knowing about in its own right, not only as a way of thinking about the conduct parameter.

Conjectural Variations

- Not proper game theory, but useful for empirical studies.

- Firms produce and sell a homogeneous good, they choose quantities, the indirect demand function is given by $D(Q)$, and a firm's cost function is given by $C(q_i)$.

- **Key assumption**:
  - Each Firm i believes (forms a conjecture) that if it changes its output, the rival, Firm j, will *react* to some extent by changing its own output:

$$\frac{dq_j}{dq_i} = v_{ij} \qquad \text{for all } j \neq i.$$

- The parameters v_{ij} are called **conjectural variations parameters**.

- Note: The choices are made simultaneously and the firms interact only once, so expecting a response from your rival doesn't make sense (this is why it's not proper game theory). Ignore this (think of it as a reduced form of a richer model).

- Consider Firm i's maximization problem:

$$\max_{q_i \geq 0} D(Q)\,q_i - C(q_i).$$

- Now take the FOC — exactly as before except that we now must take the reactions (the v_{ij}s) into account:

$$D(Q) + D'(Q)\left[1 + \sum_{j \neq i} \frac{dq_j}{dq_i}\right] q_i - C'(q_i) = 0$$

or

$$D(Q) + D'(Q)\left[1 + \sum_{j \neq i} v_{ij}\right] q_i - C'(q_i) = 0$$

or, assuming symmetry,

$$D(Q) + [1 + (n-1)\,v]\,D'(Q)\,q_i - C'(q_i) = 0.$$

- We see that

$$1 + (n-1)\,v = \lambda, \qquad (2)$$

where λ is the conduct parameter defined above.

- Note that:
  - $v = -1/(n-1)$ corresponds to price taking behavior, as this yields p=MC.
  - $v = 0$ corresponds to Cournot behavior, as this yields the FOC for a Cournot oligopolist.
  - $v = 1$ corresponds to collusive behavior, as this yields a condition that defines the optimal cartel output.
- Conclusion: the conjectural variation story, with firms being able to react to each other's choices, is one way of thinking about the conduct parameter.
  - The exact relationship between the conduct parameter and the conjectural variation parameter is given by (2).

The "Competition Parameter"

- This is another way of thinking about the conduct parameter.
  - It is conceptually different from the conjectural variation approach.
  - However, it turns out that with symmetric firms this approach and the conjectural variation approach are formally equivalent (in a problem set you will see that this is not true in an asymmetric model).
- **Key assumption:**
  - Each firm is assumed to maximize a weighted sum of its own profits and the rivals' joint profits, where the weight for the latter is the parameter μ:

$$D(Q)\,q_i - C(q_i) + \mu\left[\sum_{j\neq i} D(Q)\,q_j - C(q_j)\right]$$

  - The weight μ is a fixed parameter, which we will call the "**competition parameter**" (in the literature it has been called the "coefficient of cooperation" and the "coefficient of effective sympathy").
  - Even though I call it a "weight", it's not necessarily the case that $0 \leq \mu \leq 1$.
- One can show that:
  - $\mu = -1/(n-1)$ corresponds to price taking behavior, as this yields p=MC.
  - $\mu = 0$ corresponds to Cournot behavior, as this yields the FOC for a Cournot oligopolist.
  - $\mu = 1$ corresponds to collusive behavior, as this yields a condition that defines the optimal cartel output.
- That is, at least for these three cases, $\mu = v$, and the role of the "competition parameter" μ is exactly the same as that of the conjectural variation parameter v.

- Conclusion: the "competition parameter" story, with firms maximizing some weighted sum of their own profits and the rivals' profits, is another way of thinking about the conduct parameter.
  - Formally, with symmetric firms this approach is equivalent to the conjectural variations approach (even though this is not obvious a priori).
  - Therefore, the exact relationship between the "competition parameter" and the conjectural variation parameter is again given by (2).

Identifying the conduct parameter

The Problem

- We want to learn about the degree of competition in some market, and our measure of competition is the conduct parameter, λ.
- Only a limited amount of data are available:
  - The market price, p.
  - Total industry output, Q.
  - Consumer income or some other variable that shifts the demand curve, Z.
  - Price of a production factor (like the wage level or the price of energy or material), W.
  - The number of firms in the market, n.
- Each variable is observed in many consecutive periods (maybe yearly data).
- We have *no* data on the firms' costs or on firm specific outputs.
- The question: Can we identify and estimate the conduct parameter λ?

The Bresnahan-Lau approach

- The methodology explained below was introduced by Bresnahan (1982) and Lau (1982).
  - Here we will assume a linear demand function and quadratic cost function. However, one can use a similar methodology with, for a example, a demand function that is not linear.

- Thus, assume a linear inverse demand function and a quadratic cost function:

$$D(Q) = \delta_0 + \delta_1 Q + \delta_2 Z + \delta_3 QZ,$$

$$C(q_i) = \tau_{0i} + \tau_{1i} q_i + (\tau_2/2) q_i^2 + \tau_3 q_i W + \tau_4 W + \tau_5 W^2.$$

- Given these assumptions, we have

$$D'(Q) q_i = (\delta_1 + \delta_3 Z) q_i, \quad (3)$$

$$C'(q_i) \equiv MC_i = \tau_{1i} + \tau_2 q_i + \tau_3 W. \quad (4)$$

- Recall the supply relationship (allowing for firm specific cost functions and therefore asymmetries across firms in terms of output):

$$D(Q) + \lambda D'(Q) q_i - C_i'(q_i) = 0 \Leftrightarrow$$

$$p = MC_i - \lambda_i D'(Q) q_i. \quad (5)$$

- Plugging (3) and (4) into (5):

$$p = \tau_{1i} + \tau_2 q_i + \tau_3 W - \lambda (\delta_1 + \delta_3 Z) q_i.$$

This holds for all firms i — adding them up yields

$$np = \sum_{i=1}^{n} \tau_{1i} + \tau_2 Q + n\tau_3 W - \lambda (\delta_1 + \delta_3 Z) Q$$

or

$$\begin{aligned} p &= \frac{1}{n}\sum_{i=1}^{n} \tau_{1i} + \frac{\tau_2}{n} Q + \tau_3 W - \frac{\lambda\delta_1}{n} Q - \frac{\lambda\delta_3}{n} ZQ \\ &= \frac{1}{n}\sum_{i=1}^{n} \tau_{1i} + \frac{\tau_2 - \lambda\delta_1}{n} Q + \tau_3 W - \frac{\lambda\delta_3}{n} ZQ. \end{aligned}$$

- The relationship thus has the following form:

$$p = \alpha_0 + \alpha_1 Q + \alpha_2 QZ + \alpha_3 W, \quad (6)$$

where

$$\alpha_0 = \tau_1 = \frac{1}{n}\sum_{i=1}^{n} \tau_{1i}, \quad (7)$$

$$\alpha_1 = \frac{\tau_2 - \lambda\delta_1}{n}, \quad (8)$$

$$\alpha_2 = -\frac{\lambda\delta_3}{n}, \quad (9)$$

$$\alpha_3 = \tau_3. \quad (10)$$

- We can estimate the supply relationship in (6) jointly with the demand function

$$p = \delta_0 + \delta_1 Q + \delta_2 Z + \delta_3 QZ$$

(adding an error term to each equation).

  - Practical problem: The RHS variable Q is endogenous.

  - Solution: Use Q from a previous period as an instrument.

- Estimating the two equations gives us estimates of the δs and the αs.

- That is, we can identify all the demand parameters, i.e., all the δs.

  - The other parameters — the conduct parameter and the parameters in the cost function — are not, however, automatically identified.

- By studying the supply relationship (6) we see that we can recover λ if $\delta_3 \neq 0$. For then it follows from (9) that we can write λ as

$$\lambda = -\frac{\alpha_2 n}{\delta_3},$$

and we know n by assumption and we have estimates of δ_3 and α_2.

- Once we know λ, we can infer τ_2 from (8):

$$\alpha_1 = \frac{\tau_2 - \lambda\delta_1}{n} = \frac{\tau_2 - \left(-\frac{\alpha_2 n}{\delta_3}\right)\delta_1}{n} \Rightarrow \tau_2 = \left(\alpha_1 - \frac{\alpha_2}{\delta_3}\delta_1\right)n,$$

where we know n and we have estimates of δ_1, δ_3, α_1 and α_2.

- Finally, (10) gives us an estimate of τ_3, and (7) gives us an estimate of $\tau_1 \equiv \frac{1}{n}\sum_{i=1}^{n}\tau_{1i}$ (but not the individual τ_{1i}s).

- Nor can we identify or estimate the cost function parameters that don't show up in the MC functions, τ_{0i}, τ_4 and τ_5.

- Conclusion:

  - We can recover the conduct parameter λ (as well as many other parameters) if $\delta_3 \neq 0$.

  - If $\delta_3 = 0$, then (8) is the only equation that involves λ. However, this equation also contains τ_2, which doesn't show up in any other equation. Therefore, we cannot separate λ from τ_2 — these two parameters are not identified.

- The economic interpretation of $\delta_3 \neq 0$:

  - The slope of demand function is a function of a shift variable (and we have data on this variable).

- Graphical analysis:

  - Figure 1: shift only in the demand *intercept*.

    * Low intercept: Perfect competition and monopoly both give rise to equilibrium E_1.

    * High intercept: Perfect competition and monopoly both give rise to equilibrium E_2.

    * Conclusion: If we observe only p, Q and demand, we *cannot* infer whether we have perfect competition or monopoly.

  - Figure 2: shift in the *slope* of demand.

    * Perfect competition gives rise to the equilibrium E_1 for both demand functions.

    * Monopoly gives rise to equilibrium E_1 with a steep demand but E_3 with a flat demand.

    * Conclusion: Even if we observe only p, Q and demand, we *can* infer whether we have perfect competition or monopoly, as the two different market structures give rise to different behaviors (in terms of things we can observe).

Some Empirical Results

Brander and Zhang (1990) [C&W pp. 273-274]

- Assuming a duopoly we can rewrite the Lerner index with conjectural variations as follows:
$$\frac{p - MC_1}{p} = \frac{\lambda}{n\varepsilon} = \frac{s_1(v_1 + 1)}{\varepsilon},$$
where s_1 is Firm 1's market share and ε is the demand elasticity.

- Solve for v_1:
$$v_1 = \frac{(p - MC_1)\,\varepsilon}{s_1 p} - 1. \qquad (11)$$

- Of course, we can derive a similar expression for v_2.

- Recall the relationship between the conjectural variation parameter v_i and the conduct parameter λ_i:
$$\lambda_i = 1 + v_i.$$

- If we have estimates of price, marginal cost, demand elasticity, and market share, we can plug these into the formula (11).

- Brander and Zhang (1990) did this for American Airlines and United Airlines (33 duopoly routes out of Chicago):

	American	United
Point estimate of v_i	0.06	0.12
95% conf. interval	(-0.17, 0.30)	(-0.14, 0.38)

- Strong support for the Cournot behavior.

- See also Table 12.4 in C&W (page 447).

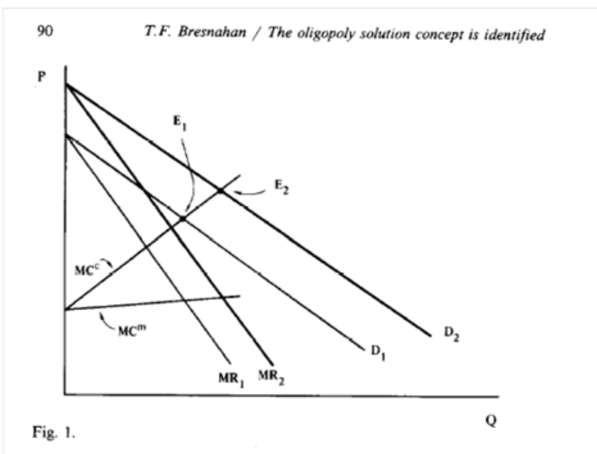

Figure 1:

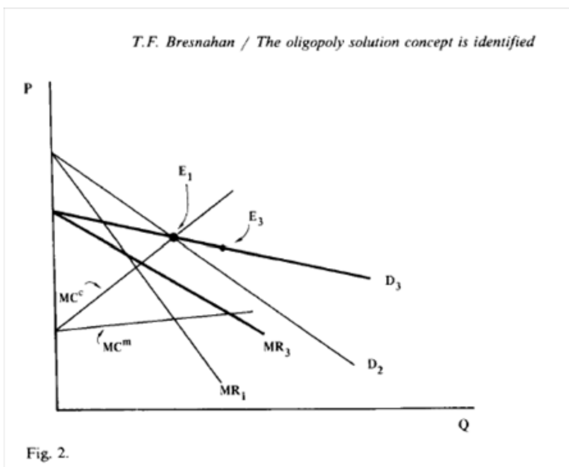

Figure 2: