ECO 310: Empirical Industrial Organization

Lecture 10: Models of Competition in Prices or Quantities: Conjectural Variations [2]

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Outline on today's lecture

1. **Conjectural variations with product differentiation**

2. **Application (Homogeneous product): Genesove & Mullin**

2. Conjectural variations with product differentiation

CVs with product differentiation

- I present this approach in a simplified model with 2 firms with 1 product each. It is straightforward to extend this approach to N multiproduct firms (see Nevo (Econ Letters, 1998).

- Consider an industry with a differentiated product. Two firms: 1 and 2. Each firm produces and sells only one product.

- Profit of firm i is:
$$\Pi_i = p_i \; q_i - C_i(q_i)$$

- Demand has a Logit structure:
$$q_1 = H \; s_1 = \frac{\exp\left\{\beta \; x_1 - \alpha \; p_1\right\}}{1 + \exp\left\{\beta \; x_1 - \alpha \; p_1\right\} + \exp\left\{\beta \; x_2 - \alpha \; p_2\right\}}$$

Profit maximization

- Each firm i chooses its own price p_i to maximize its profit. The F.O.C of optimality for firm 1 is:

$$\frac{d\Pi_i}{dp_i} = 0 \Rightarrow q_i + p_i \frac{dq_i}{dp_i} - MC_i \, \frac{dq_i}{dp_i} = 0$$

- That we can write as:

$$p_i - MC_i = \frac{-s_i}{\frac{ds_i}{dp_i}}$$

- Now, we examine the term $\dfrac{ds_i}{dp_i}$ and how it depends on the Nature of Competition of Conjectural Variation (CV).

Conjectural Variation

- Remember:

$$s_1 = \frac{\exp\{\beta\ x_1 - \alpha\ p_1\}}{1 + \exp\{\beta\ x_1 - \alpha\ p_1\} + \exp\{\beta\ x_2 - \alpha\ p_2\}}$$

- Now, we have that s_1 depends on p_1 through two different channels:

$$\begin{cases} \text{Direct effect of } p_1 \text{ on } s_1 \\ \\ \text{Indirect effect: } p_1 \longrightarrow p_2 \longrightarrow s_1 \end{cases} \tag{1}$$

- Here we need to distinguish between total derivative $\frac{ds_1}{dp_1}$ and partial derivatives, $\frac{\partial s_1}{dp_1}$ and $\frac{\partial s_1}{dp_2}$. The partial derivative $\frac{\partial s_1}{dp_1}$ fixes p_2 as a constant, and the partial derivative $\frac{\partial s_1}{dp_2}$ fixes p_1 as a constant.

Conjectural Variation [2]

- We have:

$$ds_1 = \frac{\partial s_1}{\partial p_1}\ dp_1 + \frac{\partial s_1}{\partial p_2}\ \frac{dp_2}{dp_1}\ dp_1$$

- Or:

$$\frac{ds_1}{dp_1} = \frac{\partial s_1}{\partial p_1} + \frac{\partial s_1}{\partial p_2}\ \frac{dp_2}{dp_1}$$

- The term $\frac{dp_2}{dp_1}$ represents the **Belief or Conjecture** of firm 1 about the response of firm 2.

- We denote it as CV_1 (**Firm 1's Conjectural Variation**)

Conjectural Variation [3]

- For the standard Logit demand model: $\dfrac{\partial s_1}{\partial p_1} = -\alpha\ s_1(1 - s_1)$ and $\dfrac{\partial s_1}{\partial p_2} = \alpha\ s_1\ s_2$, such that:

$$\begin{aligned}
\frac{ds_1}{dp_1} &= \frac{\partial s_1}{\partial p_1} + \frac{\partial s_2}{\partial p_1}\ CV_1 \\
&= -\alpha s_1(1 - s_1) + \alpha\ s_1\ s_2\ CV_1 \\
&= -\alpha\ s_1\ \left(1 - s_1 - s_2\ CV_1\right)
\end{aligned}$$

- And plugging this into the F.O.C:

$$p_1 - MC_1 = \frac{-s_1}{-\alpha\ s_1\ \left(1 - s_1 - s_2\ CV_1\right)}$$

- Or:

$$p_1 - MC_1 = \frac{1}{\alpha\left(1 - s_1 - s_2\ CV_1\right)}$$

Different Conjectures - Forms of Competition

- Nash-Bertrand **competition:** $CV_1 = 0$, such that:

$$p_1 - MC_1 = \frac{1}{\alpha \left(1 - s_1\right)}$$

- **Collusion between Firms 1 & 2:** $CV_1 = 1$, such that:

$$p_1 - MC_1 = \frac{1}{\alpha \left(1 - s_1 - s_2\right)}$$

- This expression corresponds to the F.O.C. of when firms 1 & 2 choose their prices as if they were a single firm maximizing their joint profits.

Extension to N firms

- With $N > 2$ firms, the $CV_{i \to j}$ represent firm i's conjecture about the response of firm j: $\dfrac{dp_j}{dp_i}$.

- Then, for the logit model we have that the F.O.C. of profit maximization for firm i becomes:

$$p_i - MC_i = \frac{1}{\alpha \left(1 - s_i - \sum_{j \neq i} s_j \ CV_{i \to j} \right)}$$

Identification of Collusion

- $$p_i - MC_i = \frac{1}{\alpha \left(1 - s_i - \sum_{j \neq i} s_j \ CV_{i \to j} \right)}$$

- As in the homogeneous product case, we need to distinguish two cases: MC's known or unknown to the researcher.

- Empirical papers focus on the identification of collusion:

$$\begin{cases} CV_{i \to j} \text{ is either } 0 \text{ or } 1 \\ CV_{i \to j} = CV_{j \to i} \end{cases}$$

- This is identified under mild conditions.

2. Empirical application: Genesove & Mullin

An Application: US sugar industry 1890-1914

- Genesove and Mullin (GM) study competition in the US sugar industry during the period 1890-1914.

- Why this period? High quality information on the value of marginal costs because:

  (1) the production technology of refined sugar during this period was very simple;

  (2) there was an important investigation of the industry by the US anti-trust authority. As a result of that investigation, there are multiple reports from expert witnesses that provide estimates about the structure and magnitude of production costs in this industry.

The industry

- Homogeneous product industry.
- Highly concentrated during 1890-1914. The industry leader, American Sugar Refining Company (ASRC), had more than 65% of the market share during most of these years.
- Refined sugar companies buy "raw sugar" from suppliers in national or international markets, transformed it into refined sugar, and sell it to grocers.
- **Production technology.**
  - Raw sugar is 96% sucrose and 4% water. Refined sugar is 100% sucrose. Process of transforming raw sugar into refined sugar is called "melting".
  - Industry experts reported that the industry is a "fixed coefficient" production technology

Production technology: Costs

- "Fixed coefficient" production technology

$$q^{refined} = \lambda \ q^{raw}$$

where $q^{refined}$ is refined sugar output, q^{raw} is the input of raw sugar, and $\lambda \in (0, 1)$ is a technological parameter.

- **Marginal cost function.** Given this production technology, the marginal cost function is:

$$MC = c_0 + \frac{1}{\lambda} \ P^{raw}$$

- P^{raw} is the price of the input raw sugar (in dollars per pound).
- c_0 is a component of the marginal cost that depends on labor and energy.

Production technology: Costs [2]

$$MC = c_0 + \frac{1}{\lambda}\ P^{raw}$$

- Industry experts unanimously report that the value of the parameter λ was close to 0.93, and c_0 was around \$0.26 per pound.
- Therefore, the marginal cost at period (quarter) t, in dollars per pound of sugar, was:

$$MC_t = 0.26 + 1.075\ P_t^{raw}$$

Data

- Quarterly US data for the period 1890-1914.
- The dataset contains 97 quarterly observations on industry output, price, price of raw sugar, imports of raw sugar, and a seasonal dummy.

$$\text{Data} = \{\ Q_t,\ P_t,\ P_t^{raw},\ IMP_t,\ S_t : t = 1, 2, ..., 97\}$$

- IMP_t represents the imports of raw sugar from Cuba.
- And S_t is a dummy variable for the Summer season: $S_t = 1$ is observation t is a Summer quarter, and $S_t = 0$ otherwise.
- The summer was a high demand season for sugar because most the production of canned fruits was concentrated during that season, and the canned fruit industry accounted for an important fraction of the demand of sugar.

Estimates of demand parameters

- GM estimate four different models of demand. The main results are consistent for the four models. Here I concentrate on the linear demand.

$$Q_t = \beta_t^D \left(\alpha_t^D - P_t \right)$$

- GM consider the following specification for α_t and β_t:

$$\begin{aligned} \alpha_t^D &= \alpha_L^D \, (1 - S_t) + \alpha_H^D \, S_t + e_t^D \\ \beta_t^D &= \beta_L^D \, (1 - S_t) + \beta_H^D \, S_t \end{aligned}$$

- α_L^D and β_L^D are the intercept and the slope of the demand during the "Low Season" (when $S_t = 0$).

- And α_H^D and β_H^D are the intercept and the slope of the demand during the "High Season" (when $S_t = 1$).

Estimates of demand parameters [2]

Demand Estimates		
Parameter	Estimate	Standard Error
α_L^D	5.81	(1.90)
α_H^D	7.90	(1.57)
β_L^D	2.30	(0.48)
β_H^D	1.36	(0.36)

- According to these estimates, in the high season the demand shifts upwards but it also becomes more inelastic.
- The estimated price elasticities of demand in the low and the high season are $\eta_L = 2.24$ and $\eta_H = 1.04$, respectively.
- According to this, any model of oligopoly competition where firms have some market power predicts that the price cost margin should increase during the price season due to the lower price sensitivity of

Estimates of demand parameters [3]

- Importantly, the seasonality in the demand of sugar introduces a "rotator" in the demand curve.
- The slope of the demand curve is steeper in the high season than in the low season.

Estimates of CVs

- GM specify a constant-cost Marginal Cost function for US sugar producers

$$MC_t = \beta_0^{MC} + \beta_1^{MC} \ P_t^{RAW} + \beta_2^{MC} \ q_t + \varepsilon_t^{MC}$$

- The $MR = MC$ condition yields:

$$P_t = \beta_0^{MC} + \beta_1^{MC} \ P_t^{RAW} + \gamma_1 \ q_t + \gamma_2 \ (S_t \ q_t) + \varepsilon_{it}^{MC}$$

where

$$\begin{aligned} \gamma_1 &= \beta_2^{MC} + \frac{1}{\beta_L^D} [1 + CV] \\ \gamma_2 &= \left(\frac{1}{\beta_H^D} - \frac{1}{\beta_L^D} \right) [1 + CV] \end{aligned}$$

Estimation Results

	Estimate	Direct Measure
CV/N	0.038 (0.014)	0.100
β_0^{MC}	0.466 (0.285)	0.260
β_1^{MC}	1.052 (0.085)	1.075

- Estimated cost parameters not too far from their "direct measures" which seems to validate CV approach.
- Evidence of collusion