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. **Application (Homogeneous product): Genesove & Mullin**
2. **Conjectural variations with product differentiation**

1. 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.

- **Purpose of this paper**

  [1] Estimating the Form of Competition using CV approach.

  [2] Testing the validity of this approach by estimating CV with and without data on MCs, and checking if the results are different.

- **Why this industry & period?**

  High-quality estimates of marginal costs because:

  [1] Production technology of Refined Sugar was quite simple.

  [2] Investigation of the industry by the US anti-trust authority. Multiple expert reports with very good estimates of marginal costs.

Refined Sugar Industry: U.S. 1890-1914

- **Homogeneous product industry**. Sold in barrels wout brand names.
- **Very similar MCs for all firms**. Differences in market shares are because differences in firms' capacities.
- **Highly concentrated industry**. Leader, **American Sugar Refining Company (ASRC) (later Domino Sugar)** $>65\%$ market share.
- **Refining sugar plants** (around 20)

  - Located in East Coast (NYC, Boston) close to ocean.

  - Buy raw sugar in national & international markets, transform it into refined sugar, and sell it to grocers.
- **New York refined sugar market**. Centralized market where refining firms sell to grocers and intermediaries. One price.

Production technology (Production Function)

- Raw sugar is 96% sucrose and 4% water. Refined sugar is 100% sucrose (at least 99.7%).
- **Process of transforming raw sugar into refined sugar**:

  Melting (with hot water) –> Filtering/Decoulorization (with natural charcoal) –> Evaporation\Crystalization\Drying.
- Industry experts reported that the **production technology was fixed coefficients** (Leontief).

$$q^{refined} = \min \{\lambda_{raw} \; q^{raw}, \lambda_{labor} \; Labor, \lambda_{water} \; Water, ...\}$$

- Like a **cooking recipe**: to product 1 kg of refined sugar, we need: $\dfrac{1}{\lambda_{raw}}$ kg of raw sugar, $\dfrac{1}{\lambda_{labor}}$ hours of labor, $\dfrac{1}{\lambda_{water}}$ liters of water, ...

Production technology & Marginal Costs

- "Cooking recipe" technology implies that the **Marginal Cost = Per unit Cost**, and it has the following form:

$$MC = \frac{1}{\lambda_{raw}} P^{raw} + \frac{1}{\lambda_{labor}} P^{labor} + \frac{1}{\lambda_{water}} P^{water} + ...$$

  P^{raw} = price raw sugar (\$/lb); P^{labor} = price labor (\$/hour); etc.

- Industry experts agree that MC in dollars per pound of sugar was:

$$MC = 1.075 \; P^{raw} + 0.26$$

- Producing 1 lb of refined sugar, requires 1.075 lb of raw sugar.

- The contribution of the other inputs is $0.26 per lb.

- Industry experts also report that inputs prices other than P^{raw} were stable over this period.

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.

Speficification of Demand Function

- GM estimate four different demand models. Main results are consistent for the four models. I concentrate on linear demand.

$$Q_t = \beta_t^D \left(\alpha_t^D - P_t \right) \qquad \text{or} \qquad P_t = \alpha_t^D - \frac{1}{\beta_t^D} Q_t$$

- GM consider the following specification for α_t and β_t:

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

- α_L^D & $\frac{1}{\beta_L^D}$ = intercept & slope demand in "Low season" $S_t = 0$
- α_H^D & $\frac{1}{\beta_H^D}$ = intercept & slope demand in "High season" $S_t = 1$

Estimation of Demand Parameters

- The regression model for demand is:

$$P_t = \pi_0 + \pi_1 \ S_t + \pi_2 \ Q_t + \pi_3 \ S_t Q_t + \varepsilon_t^D$$

with $\pi_0 = \alpha_L^D$, $\pi_1 = \alpha_H^D - \alpha_L^D$, $\pi_2 = \frac{1}{\beta_L^D}$, $\pi_3 = \frac{1}{\beta_H^D} - \frac{1}{\beta_L^D}$.

- Q_t is endogenous: potentially correlated with ε_t^D. Instrumental variables estimation.

- P_t^{raw} might be a valid IV. GM are argue that it is not a plausible instrument because US demand had a significant impact on international prices: $Cov(\varepsilon_t^D, P_t^{raw}) > 0$.

- GM use production of cane sugar in Cuba. Almost all production was exported to US, and variation was due to weather shocks.

Estimation of Demand Parameters [2]

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

- High season: demand shifts upwards and becomes less elastic.
- The estimated price elasticities of demand in Low and the High season are $\eta_L = 2.24$ and $\eta_H = 1.04$, respectively.
- Any model of oligopoly competition where firms have some market power predicts that price cost margin increases in high season due to lower price sensitivity of demand.

Estimation 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.

Estimation of CV Parameter using Data on MCs

- Models of competition with homogeneous product and homogeneous marginal costs imply the first order condition:

$$P_t + P_t'(Q_t)\ [1 + CV_t]\ \frac{Q_t}{N_t} = MC_t$$

- Given that $P_t'(Q_t) = \dfrac{-1}{\beta_L^D}(1 - S_t) + \dfrac{-1}{\beta_H^D}\ S_t$, and $MC_t = 1.075$ $P_t^{raw} + 0.26$, we have that:

$$P_t - \left[\frac{1}{\beta_L^D}(1 - S_t) + \frac{1}{\beta_H^D} S_t\right]\ [1 + CV_t]\ \frac{Q_t}{N_t} = 1.075\ P_t^{raw} + 0.26$$

- We can obtain CV_t from this expression.
- Thes estimates imply that $\dfrac{CV_t}{N_t}$ is very stable over time, equal to 0.100, and not significantly greater than 0.
- This is interpreted as evidence consistent with Cournot competition.

Estimation of CV Parameter without Data on MCs

- GM specify a constant-cost MC 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:

$$P_t = \beta_0^{MC} + \beta_1^{MC} \; P_t^{RAW} + \gamma_1 \; \frac{Q_t}{N_t} + \gamma_2 \; \left(S_t \; \frac{Q_t}{N_t} \right) + \varepsilon_{it}^{MC}$$

where

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

Estimation Results

	Estimate without MC data	Estimate without MC data
CV/N	0.038 (0.114)	0.100 (0.076)
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 consistent with Cournot competition.

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 $\frac{ds_i}{dp_i}$ 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 $\dfrac{ds_1}{dp_1}$ and partial derivatives, $\dfrac{\partial s_1}{dp_1}$ and $\dfrac{\partial s_1}{dp_2}$. The partial derivative $\dfrac{\partial s_1}{dp_1}$ fixes p_2 as a constant, and the partial derivative $\dfrac{\partial s_1}{dp_2}$ 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:

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

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

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

- Or:

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

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:

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

- This is identified under mild conditions.