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. **Estimating CV parameters without data on MCs**
2. **Application: Genesove & Mullin**
3. **Conjectural variations with product differentiation**

1. Estimating CV parameters without data on MCs

Estimating CV parameters without data on MCs

- So far, we have considered the estimation of CV parameters when the researcher knows both demand and firms' marginal costs.
- We now consider the case where the **researcher knows the demand, but it does not know firms' marginal costs**.
- Identification of CVs requires also de identification of MCs.
- Under some conditions, we can **jointly identify CVs and MCs** using the marginal conditions of optimality and the demand.

Data

- Researcher observes data:

$$\text{Data} = \left\{ P_t, \ q_{it}, X_t^D, X_t^{MC} : \ i = 1, ...N_t; \ t = 1, ..., T \right\}$$

- X_t^D are variables affecting consumer demand, e.g., average income, population.
- X_t^{MC} are variables affecting marginal costs, e.g., some input prices.

Model: Demand and MCs

- Consider the linear (inverse) demand equation:

$$P_t = \alpha_0 + \alpha_1 \; X_t^D - \alpha_2 \; Q_t + \varepsilon_t^D$$

with $\alpha_2 \geq 0$, and ε_t^D is unobservable to the researcher.

- Consider the marginal cost function:

$$MC_{it} = \beta_0 + \beta_1 \; X_t^{MC} + \beta_2 \; q_{it} + \varepsilon_{it}^{MC}$$

with $\beta_2 \geq 0$, and ε_{it}^{MC} is unobservable to the researcher.

Model: Profit maximization

- Profit maximization implies $MR_{it} = MC_{it}$, or equivalently:

$$P_t + \frac{dP_t}{dQ_t}\left[1 + CV_{it}\right]\ q_{it} = MC_{it}$$

- In the model above, $\dfrac{dP_t}{dQ_t} = -\alpha_2$. Therefore,

$$P_t - \alpha_2\left[1 + CV_{it}\right]\ q_{it} = \beta_0 + \beta_1\ X_t^{MC} + \beta_2\ q_{it} + \varepsilon_{it}^{MC}$$

- Or equivalently,

$$P_t = \beta_0 + \beta_1\ X_t^{MC} + \left[\beta_2 + \alpha_2(1 + CV_{it})\right]\ q_{it} + \varepsilon_{it}^{MC}$$

- This equation describes the marginal condition for profit maximization. We assume now that $CV_{it} = CV$ for every observation i, t in the data.

Complete structural model

- The structural equations of the model are:

$$\text{Demand:} \quad P_t = \alpha_0 + \alpha_1 \; X_t^D - \alpha_2 \; Q_t + \varepsilon_t^D$$

$$\text{F.O.C.:} \quad P_t = \beta_0 + \beta_1 \; X_t^{MC} + [\beta_2 + \alpha_2(1 + CV)] \; q_{it} + \varepsilon_{it}^{MC}$$

- Using this model and data, **can we identify (estimate consistently, without asymptotic bias) the CV parameter?**
- First, we will see that NO. In this model we cannot separately identify CV and MC.
- Second, we will see that a simple modification of this model implies separate identification of CV and MC.

Identification of demand parameters

$$\text{Demand:} \quad P_t = \alpha_0 + \alpha_1 \; X_t^D - \alpha_2 \; Q_t + \varepsilon_t^D$$

- Endogeneity problem: in equilibrium, $cov(Q_t, \varepsilon_t^D) \neq 0$.
- The model implies a valid instrument to estimate demand.
- In equilibrium, Q_t depends on X_t^{MC}. Note that X_t^{MC} does not enter in demand. If X_t^{MC} is not correlated with ε_t^D, then X_t^{MC} satisfies all the conditions for being a valid instrument.
- Parameters α_0, α_1, and α_2 are identified using this IV estimator.

Identification of CV and MCs

$$\text{F.O.C.:} \quad P_t = \beta_0 + \beta_1 \, X_t^{MC} + [\beta_2 + \alpha_2(1 + CV)] \, q_{it} + \varepsilon_{it}^{MC}$$

- Endogeneity problem: in equilibrium, $cov(q_{it}, \varepsilon_{it}^{MC}) \neq 0$.
- The model implies a valid instrument to estimate demand.
- In equilibrium, q_{it} depends on X_t^D. Note that X_t^D does not enter enter in the F.O.C. If X_t^D is not correlated with ε_{it}^{MC}, then X_t^D satisfies all the conditions for being a valid instrument.
- Parameters β_0, β_1, and $\gamma \equiv \beta_2 + \alpha_2(1 + CV)$ are identified using this IV estimator.

The identification problem

$$\text{F.O.C.:} \quad P_t = \beta_0 + \beta_1 \; X_t^{MC} + \gamma \; q_{it} + \varepsilon_{it}^{MC}$$

- Note that we can identify the parameter γ, where $\gamma \equiv \beta_2 + \alpha_2(1 + CV)$, and the slope of inverse demand function, α_2.
- However, knowledge of γ and α_2 is not sufficient to identify separately CV and the slope of the MC, β_2.
- Suppose that $\gamma = 1$ and $\alpha_2 = 0.4$, such that we have the constraint:

$$1 = \beta_2 + 0.4 \; (1 + CV)$$

- This equation is satisfied by any of the following:
  [Perfect competition] $CV = -1$ and $\beta_2 = 1.0$
  [Cournot] $CV = 0$ and $\beta_2 = 0.6$
  [Cartel, with $N = 3$] $CV = N - 1 = 2$ and $\beta_2 = 0.2$

The identification problem [2]

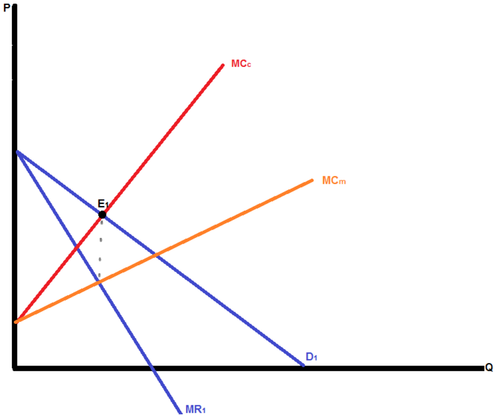
- The IV estimator identifies the MC by using the instrument X_t^D that shifts the demand.

- When we make an assumption about the form of competition, shifts in the demand curve are able to trace out the marginal cost curve, i.e., to identify the MC parameters.

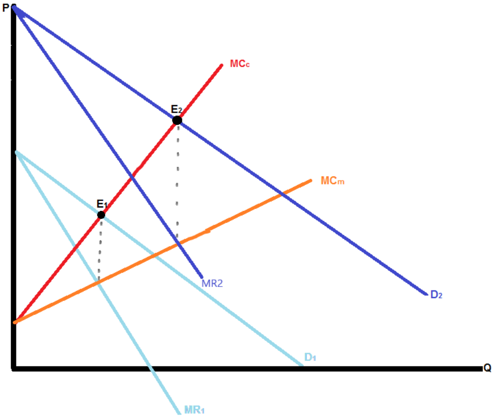
- However, without specifying the form of competition, shifts in the demand alone are not sufficient to separately identify MC and CV.

- Let $\widehat{q}_{it}(X_t^D)$ be the part of q_{it} explained X_t^D. When X_t^D varies, we see a positive correlation between P_t and $\widehat{q}_{it}(X_t^D)$. But the magnitude of this correlation can be explained by the combination of:
  - either zero/negative CV and positive and large β_2;
  - or positive CV and small or zero β_2.

The identification problem [3]



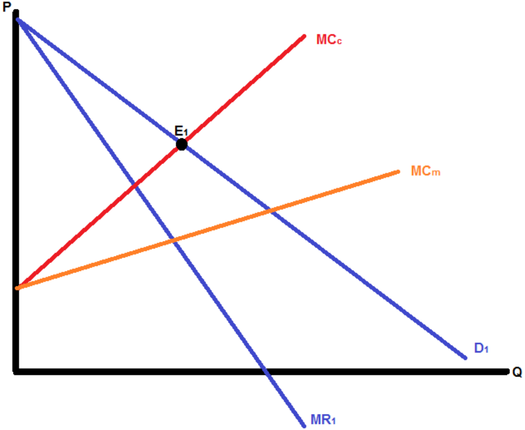
The identification problem [4]



Solving the identification problem

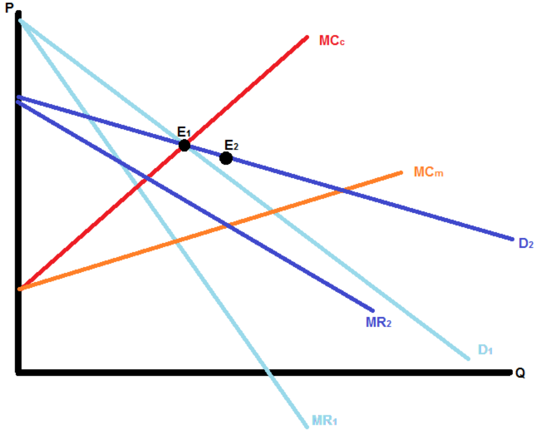
- Solving the identification problem involves generalizing demand so that changes in exogenous variables do **more than just parallel shift** the demand curve and MR.
- In particular, we need to allow for additional exogenous variables that are capable of **rotating** the demand curve as well.
- "Demand Rotators" are exogenous variables affecting the slope of the demand curve:

Solving the identification problem [2]



- Note that E_1 could be an equilibrium either for a perfectly competitive industry with cost MC_c or for a monopolist with cost MC_m.
- There is no observable distinction between the hypotheses of competition and

Solving the identification problem [3]



- Now, rotate the demand curve to D_2, with MR_2
- Competitive equilibrium stays at E_1. But monopoly equilibrium moves to E_2

Solving the identification problem [4]

- Consider now the following demand equation:

$$P_t = \alpha_0 + \alpha_1 \ X_t^D - \alpha_2 \ Q_t - \alpha_3 \ \left[R_t \ Q_t \right] + \varepsilon_t^D$$

- R_t is an observable variable that affects the slope of the demand, i.e., the price of a substitute or complement product.
- Key condition: $\alpha_3 \neq 0$.
- That is, when R_t varies, there should be rotation (i.e., change in the slope of the demand curve).

Solving the identification problem [5]

- Given this demand model, we have that:

$$\frac{dP_t}{dQ_t} = -\alpha_2 - \alpha_3 \; R_t$$

- And the F.O.C. for profit maximization

$$P_t + \frac{dP_t}{dQ_t} \left[1 + CV \right] \; q_{it} = MC_{it}$$

become:

$$P_t + \left(-\alpha_2 - \alpha_3 \; R_t \right) \; \left[1 + CV \right] \; q_{it} = MC_{it}$$

or equivalently:

$$P_t = MC_{it} + \left(\alpha_2 + \alpha_3 \; R_t \right) \; \left[1 + CV \right] \; q_{it}$$

Solving the identification problem [6]

- Combining this F.O.C. with the MC function, $MC_{it} = \beta_0 + \beta_1 X_t^{MC} + \beta_2 \ q_{it} + \varepsilon_{it}^{MC}$, we have:

$$P_t = \beta_0 + \beta_1 X_t^{MC} + \beta_2 \ q_{it} + (\alpha_2 + \alpha_3 \ R_t) \ \ [1 + CV] \ \ q_{it} + \varepsilon_{it}^{MC}$$

- That we can represent using the following regression model:

$$P_t = \beta_0 + \beta_1 X_t^{MC} + \gamma_1 \ q_{it} + \gamma_2 \ \ (R_t \ q_{it}) + \varepsilon_{it}^{MC}$$

with $\gamma_1 \equiv \beta_2 + \alpha_2 \ [1 + CV]$ and $\gamma_2 \equiv \alpha_3 \ [1 + CV]$.

Solving the identification problem [7]

- The structural equations of the model are:

$$\text{Demand:} \quad P_t = \alpha_0 + \alpha_1 \; X_t^D - \alpha_2 \; Q_t - \alpha_3 \; [R_t \; Q_t] + \varepsilon_t^D$$

$$\text{F.O.C.:} \quad P_t = \beta_0 + \beta_1 \; X_t^{MC} + \gamma_1 \; q_{it} + \gamma_2 \; (R_t \; q_{it}) + \varepsilon_{it}^{MC}$$

- Using this model and data, **we can identify separately CV and MC parameters.**

Identification of demand parameters

$$\text{Demand:} \quad P_t = \quad \alpha_0 + \alpha_1 \; X_t^D - \alpha_2 \; Q_t - \alpha_3 \; [R_t \; Q_t] + \varepsilon_t^D$$

- Endogeneity problem: in equilibrium, $cov(Q_t, \varepsilon_t^D) \neq 0$.
- The model implies a valid instrument to estimate demand.
- In equilibrium, Q_t depends on X_t^{MC}. Note that X_t^{MC} does not enter in demand. If X_t^{MC} is not correlated with ε_t^D, then X_t^{MC} satisfies all the conditions for being a valid instrument.
- Parameters α_0, α_1, α_2, and α_3 are identified using this IV estimator.

Identification of CV and MCs

$$\text{F.O.C.:} \quad P_t = \beta_0 + \beta_1 \; X_t^{MC} + \gamma_1 \; q_{it} + \gamma_2 \; (R_t \; q_{it}) + \varepsilon_{it}^{MC}$$

- Endogeneity problem: in equilibrium, $cov(q_{it}, \varepsilon_{it}^{MC}) \neq 0$.
- The model implies a valid instrument to estimate demand.
- In equilibrium, q_{it} depends on X_t^D. Note that X_t^D does not enter enter in the F.O.C. If X_t^D is not correlated with ε_{it}^{MC}, then X_t^D satisfies all the conditions for being a valid instrument.
- Parameters β_0, β_1, γ_1, and γ_2 are identified.

Identification of CV and MCs [2]

$$\text{F.O.C.:} \quad P_t = \beta_0 + \beta_1 \, X_t^{MC} + \gamma_1 \, q_{it} + \gamma_2 \, (R_t \; q_{it}) + \varepsilon_{it}^{MC}$$

- Note that:

$$\gamma_1 = \beta_2 + \alpha_2 \left[1 + CV\right]$$

$$\gamma_2 = \alpha_3 \left[1 + CV\right]$$

- It is clear that given γ_2 and α_3, we identify CV.
- And given γ_1, α_2, and CV we identify β_2.

Identification of CV and MCs [3]

$$\text{F.O.C.:} \quad P_t = \beta_0 + \beta_1 \, X_t^{MC} + \gamma_1 \, q_{it} + \gamma_2 \, (R_t \, q_{it}) + \varepsilon_{it}^{MC}$$

- with

$$\gamma_2 = \alpha_3 \, [1 + CV]$$

- The identification of CV is very intuitive: $1 + CV = \gamma_2 / \alpha_3$. It measures the ratio between the sensitivity of P_t with respect to $(R_t \, q_{it})$ in the F.O.C. and the sensitivity of P_t with respect to $(R_t \, Q_t)$ in the demand.

- Example: $\alpha_3 = 0.5$ and $N = 3$.
  [Perfect competition] $CV = -1$ such that $\gamma_2 / \alpha_3 = 0$
  [Cournot] $CV = 0$ such that $\gamma_2 / \alpha_3 = 1/0.5 = 2$
  [Cartel, with $N = 3$] $CV = N - 1 = 2$ such that $\gamma_2 / \alpha_3 = 2/0.5 = 4$

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.

$$Q_t = \beta_t \ (\alpha_t - P_t)$$

- GM consider the following specification for α_t and β_t:

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

- α_L and β_L are the intercept and the slope of the demand during the "Low Season" (when $S_t = 0$).
- And α_H and β_H 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	5.81	(1.90)
α_H	7.90	(1.57)
β_L	2.30	(0.48)
β_H	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 $\varepsilon_L = 2.24$ and $\varepsilon_H = 1.04$, 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

- Given this estimated demand and the MCs, they obtain the following estimate of the CV parameter $\theta \equiv \dfrac{CV}{N}$.

Estimate of CV Parameter	Estimate (s.e.)
$\theta \equiv \dfrac{CV}{N}$	0.10 (0.02)

- Therefore, we can reject the null hypothesis of Cournot competition in favor of some form of collusion.
- Next week, we will see how it is possible to identify CVs even when the researcher does not have data on marginal costs, and needs to estimate marginal costs together with CVs.

Genesove and Mullin (1998) - Costs and Conduct

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

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

- The $MR = MC$ condition yields:

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

where

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

Genesove and Mullin (1998) - Costs and Conduct

- GMs estimates of the Supply parameters.

	Estimate	Direct Measure
CV/N	0.038 (0.024)	0.100
β_0	0.466 (0.285)	0.260
β_1	1.052 (0.085)	1.075

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

- Based on the estimates of CV/N, the *predicted values* for the Lerner index in the low and in the high season are:

$$LI = 1.7\% \qquad LI = 3.6\%$$

3. Conjectural variations with product differentiation

CVs with product differentiation

- See Problem set #2