

ECO 310: Empirical Industrial Organization

Lecture 8: Models of Competition in Prices or Quantities: Introduction

Victor Aguirregabiria (University of Toronto)

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Outline on today's lecture

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1. Introduction

Introduction

- Firms' decisions of how much to produce (or sell) and the price to charge are fundamental determinants of firms' profits.
- These decisions are main sources of strategic interactions between firms.
- In the market for an homogeneous good, the price depends on the total quantity produced by all the firms in the industry.
- With differentiated products, demand for a firm's product depends on the prices of products sold by other firms in the industry.
- These **strategic interactions** have first order importance to understand competition and outcomes in most industries.
- For this reason, models of competition where firms choose prices or quantities are at the core of Industrial Organization.

Equilibrium model of competition

- The answer to many economy questions require not only the estimation of demand and cost functions but also the explicit specification of an equilibrium model of competition.
- For instance, suppose that we are interested in measuring the effects of:
 - a merger
 - a sales tax
 - firms' collusion
 - the entry of a new firm or product in the market
 - ...
- Answering these questions requires the explicit specification of a model of competition.

Empirical models of Price or Quantity competition

- We can distinguish three general classes of applications of empirical models of competition in prices or quantities.
- [1] Estimation of firms' marginal costs.
- [2] Identification of the "form of competition".
- [3] Joint identification of marginal costs and "form of competition"

Estimation of firms' marginal costs

- In many empirical applications, the researcher has information on firms' prices and quantities sold, but **information on firms' costs is not always available**.
- In this context, empirical models of competition in prices or quantities may provide an approach to obtain estimates of firms' marginal costs, and of the structure of these costs.
- Given an assumption about competition (e.g., Cournot, Bertrand, Stackelberg, Collusion), the model predicts that for every firm i , $MR_i = MC_i$, where the concept of MR_i depends on the assumption of the model of competition.
- Based on an estimation of demand, we can construct estimates of firms' MR . Then, the equilibrium conditions of the model imply and estimate of MCs .

Identification of the "Nature of competition"

- Suppose that the researcher has data to estimate separately the demand function and firms' marginal costs (e.g., from the production function and firms' input prices).
- Given an assumption about the form or nature of competition in this industry (e.g., Perfect competition, Cournot, Collusion), the researcher can use the demand to obtain firms' marginal revenues, MR_i , and check if they are equal to the observed marginal costs, MC_i .
- That is, the researcher can test if a particular form of competition is consistent with the data.
- In this way, the researcher can find the form of competition that is more consistent the data, **e.g., identify if there is evidence of firms' collusion.**

Joint identification of MCs and Nature of competition

- Suppose that the researcher does not have data on firms' MCs (or estimates of these MCs from production function).
- We will see that, under some conditions, it is still possible to use the estimated demand and equilibrium conditions **to jointly identify firms' marginal costs and the form of competition in the market.**
- This is the purpose of the **conjectural variation approach.**

Main References

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2.1. Estimating marginal costs given a form of competition: Perfect competition

Estimating MCs: Perfect competition

- We first illustrate this approach in the context of a **perfectly competitive industry for an homogeneous product**.
- The research has data on the market price and on firms' output for T periods of time (or geographic markets):

$$\text{Dataset} = \{p_t, q_{it} : \text{for } i = 1, 2, \dots, N_t \text{ \& } t = 1, 2, \dots, T\}$$

where N_t is the number of firms active at period t .

- The variable profit of firm i is:

$$\Pi_{it} = p_t q_{it} - C_i(q_{it})$$

- Under perfect competition, the marginal revenue of any firm i is the market price, p_t . Profit maximization implies:

$$p_t = MC_i(q_{it}) \quad \text{for every firm } i$$

where $MC_{it} \equiv C'_i(q_{it})$.

Estimating MCs: Perfect competition [2]

- Suppose that:

$$MC_i(q_{it}) = q_{it}^{\theta} \exp\{\varepsilon_{it}^{MC}\}$$

where θ is a technological parameter and ε_{it}^{MC} is an unobservable that captures the cost efficiency of a firm.

- (i) Constant Returns to Scale (CRS), i.e., constant marginal cost or $\theta = 0$;
- (ii) Decreasing Returns to Scale (DRS), i.e., increasing marginal cost or $\theta > 0$;
- (iii) Increasing Returns to Scale (IRS), i.e., decreasing marginal cost or $\theta < 0$.
- Using the equilibrium condition, we can estimate θ and the cost efficiency ε_{it}^{MC} of every firm i .

Estimating MCs: Perfect competition [3]

- The equilibrium condition $p_t = MC_i(q_{it})$ implies the following regression model in logarithms:

$$\ln(p_t) = \theta \ln(q_{it}) + \varepsilon_{it}^{MC}$$

- Using data on prices and quantities, we can estimate the slope parameter θ in this regression equation.
- Given an estimate of θ , we can estimate ε_{it}^{MC} as a residual from this regression, i.e., $\varepsilon_{it}^{MC} = \ln(p_t) - \theta \ln(q_{it})$.
- Therefore, we can estimate the marginal cost function of each firm, $MC_i(q_{it}) = q_{it}^{\theta} \exp\{\varepsilon_{it}^{MC}\}$.

Estimating MCs: Perfect competition [4]

$$\ln(p_t) = \theta \ln(q_{it}) + \varepsilon_{it}^{MC}$$

- Estimation of this equation by OLS suffers of an **Endogeneity problem**.
- The equilibrium condition implies that the less efficient firms (with larger value of ε_{it}^{MC}) have a lower level of output.
- Therefore, the regressor $\ln(q_{it})$ is negatively correlated with the error term ε_{it}^{MC} .
- This negative correlation between the regressor and the error term implies that the OLS estimator provides a downward biased estimate of the true θ , e.g., the OLS estimate can show IRS (i.e., $\theta < 0$) when the true technology has DRS (i.e., $\theta > 0$).

Estimating MCs: Perfect competition [5]

- This **Endogeneity problem** does not disappear if we consider the model in market means:

$$\ln(p_t) = \theta \overline{\ln q_t} + \bar{\varepsilon}_t^{MC}$$

where $\overline{\ln q_t}$ and $\bar{\varepsilon}_t^{MC}$ represents the means values of the variables $\ln(q_{it})$ and ε_{it}^{MC} over all the firms active at period t .

- We still have that $\overline{\ln q_t}$ and $\bar{\varepsilon}_t^{MC}$ are negatively correlated:
 - in time periods with larger aggregate cost shocks $\bar{\varepsilon}_t^{MC}$ there is lower average log-output $\overline{\ln q_t}$.

Estimating MCs: Perfect competition [6]

$$\ln(p_t) = \theta \overline{\ln q_t} + \bar{\varepsilon}_t^{MC}$$

- We can deal with this endogeneity problem by using **instrumental variables**.
- Suppose that X_t^D is a vector of observable variables that affect demand. These variables should be correlated with $\overline{\ln q_t}$ because demand shocks affect firms' output decisions.
- Under the assumption that these observable demand variables X_t^D are not correlated with $\bar{\varepsilon}_t^{MC}$, we can use these variables as instruments for $\overline{\ln q_t}$ for the consistent estimation of θ .

2.2. Estimating marginal costs given a form of competition: Cournot competition

Estimating MCs: Cournot competition

- We still have an homogeneous product industry and a researcher with data on quantities and prices over T periods of time: $\{p_t, q_{it}\}$ for $i = 1, 2, \dots, N_t$ and $t = 1, 2, \dots, T$.
- But now, the researcher assumes that the market is not perfectly competitive and that firms compete a la Nash-Cournot.
- The variable profit of firm i is $\Pi_{it} = p_t q_{it} - C_i(q_{it})$.
- The demand can be represented using the inverse demand function,

$$p_t = P(Q_t, X_t^D)$$

where $Q_t \equiv \sum_{i=1}^N q_{it}$ is the market total output, and X_t^D is a vector of exogenous market characteristic that affect demand.

Estimating MCs: Cournot competition [2]

- Each firm chooses its own output q_{it} to maximize profit.
- Since profit is equal to revenue minus cost, profit maximization implies the condition of **marginal revenue equal to marginal cost**.
- The marginal revenue function is:

$$\begin{aligned} MR_{it} &= \frac{d(p_t q_{it})}{dq_{it}} = p_t + \frac{dp_t}{dq_{it}} q_{it} \\ &= p_t + P'_Q(Q_t, X_t^D) \left[1 + \frac{dQ_{(-i)t}}{dq_{it}} \right] q_{it} \end{aligned}$$

where:

$P'_Q(Q_t, X_t^D)$ is the derivative of the inverse demand function with respect to total output;

$Q_{(-i)t}$ is the aggregate output of firms other than i .

Estimating MCs: Cournot competition [3]

$$MR_{it} = p_t + P'_Q(Q_t, X_t^D) \left[1 + \frac{dQ_{(-i)t}}{dq_{it}} \right] q_{it}$$

- $\frac{dQ_{(-i)t}}{dq_{it}}$ represents the **belief** or **conjecture** that firm i has about how other firms will respond by changing their output when this firm changes marginally its own output.
- Under the assumption of Nash-Cournot competition, this *belief* or *conjecture is zero*:

$$\text{Nash} - \text{Cournot} \Leftrightarrow \frac{dQ_{(-i)t}}{dq_{it}} = 0$$

- Firm i takes as fixed the quantity produced by the rest of the firms, $Q_{(-i)t}$, and chooses his own output q_{it} to maximize his profit.

Estimating MCs: Cournot competition [4]

- Therefore, the first order condition of optimality under Nash-Cournot competition is:

$$MR_{it} = p_t + P'_Q(Q_t, X_t^D) q_{it} = MC_i(q_{it})$$

- Since $P'_Q(Q_t, X_t^D) < 0$ (downward sloping demand curve), it is clear that $MR_{it} < p_t$.
- Therefore, if the marginal cost $MC_i(q_{it})$ is a non-decreasing function, we have that the optimal amount of output q_{it} under Cournot is smaller than under perfect competition.
- Oligopoly competition reduces output and consequently increases price.

Estimating MCs: Cournot competition [5]

- Consider the same specification of the cost function as before, with $MC_i(q_{it}) = q_{it}^{\theta} \exp\{\varepsilon_{it}^{MC}\}$.
- Suppose that the demand function has been estimated in a first step, such that there is a consistent estimate of the demand function.
- The researcher can construct consistent estimates of marginal revenues $MR_{it} = p_t + P'_Q(Q_t, X_t^D) q_{it}$ for every firm i .

Then, the econometric model can be described in terms of the following linear regression model in logarithms:

$$\ln(MR_{it}) = \theta \ln(q_{it}) + \varepsilon_{it}^{MC}$$

Estimating MCs: Cournot competition [6]

$$\ln(MR_{it}) = \theta \ln(q_{it}) + \varepsilon_{it}^{MC}$$

- OLS estimation of this regression function suffers of the same endogeneity problem as in the perfect competition case.
- To deal with this endogeneity problem, we can use instrumental variables.
- As in the case of perfect competition, we can use observable variables that affect demand but not costs, X_t^D , as instruments.
- In the case of Cournot competition we can have additional types of instruments.

Estimating MCs: Cournot competition [7]

- Suppose that the researcher observes also some exogenous characteristics of firms that affect the marginal cost.
- For instance, suppose that there is information at the firm level on the firm's wage rate, or its capital stock, or its installed capacity.
- Let us represent these variables using the vector Z_{it} .

Therefore, the marginal cost function is now $MC_i(q_{it}) = q_{it}^{\theta} \exp\{Z_{it}\gamma + \varepsilon_{it}^{MC}\}$, where γ is a vector of parameters. The marginal condition of optimality, in logarithms, becomes:

$$\ln(MR_{it}) = \theta \ln(q_{it}) + Z_{it} \gamma + \varepsilon_{it}^{MC}$$

Estimating MCs: Cournot competition [8]

$$\ln(MR_{it}) = \theta \ln(q_{it}) + Z_{it} \gamma + \varepsilon_{it}^{MC}$$

- Note that the characteristics Z_{jt} of firms j other than i have an effect on the equilibrium amount of output of a firm i .
- The smaller Z_{jt} the more cost efficient firm j , the larger its output, the smaller price p_t and the marginal revenue MR_{it} , and the smaller q_{it} for any firm i other than j .
- Under the assumption that the vector of firm characteristics in Z are exogenous, i.e., $E(Z_{jt} \varepsilon_{it}^{MC}) = 0$ for any (i, j) , we can use the characteristics Z_{jt} of other firms as instrumental variables.

Estimating MCs: Cournot competition [9]

- For instance, we can use $\sum_{j \neq i} Z_{jt}$ as an instrumental variables, and estimate θ and γ using the moment conditions:

$$E \left(\begin{bmatrix} Z_{it} \\ \sum_{j \neq i} Z_{jt} \end{bmatrix} [\ln(MR_{it}) - \theta \ln(q_{it}) - Z_{it} \gamma] \right) = \mathbf{0}$$

- Or equivalently, using a 2SLS estimator.

2.3. Estimating marginal costs given a form of competition: Bertrand with diff. product

Estimating MCs: Bertrand with diff. prod.

- Consider the industry of a differentiated product.
- The researcher has data on prices, quantities, and product characteristics for the J products in the industry, where J is large: $\{p_i, q_i, X_i\}$ for $i = 1, 2, \dots, J$.
- For the moment, we consider that each product is produced by only one firm and each firm produces only one product.
- The profit of firm i is $\Pi_i = p_i q_i - C_i(q_i)$.

Estimating MCs: Bertrand with diff. prod. [2]

- The demand system comes from a discrete choice model of demand:

$$q_i = H s_i = H \sigma_i(\mathbf{p}, \mathbf{X})$$

- H is the number of consumers in the market, s_i is the market share of product, i.e., $s_i \equiv q_i/H$.
- $\sigma_i(\mathbf{p}, \mathbf{X})$ is the market share function in the demand model, and \mathbf{p} and \mathbf{X} are the vectors of prices and characteristics.
- For instance, under a logit demand system we have that,

$$\sigma_i(\mathbf{p}, \mathbf{X}) = \frac{\exp\{-\alpha p_i + X_i \beta\}}{1 + \sum_{j=1}^J \exp\{-\alpha p_j + X_j \beta\}}$$

Estimating MCs: Bertrand with diff. prod. [3]

- Under Bertrand competition, each firm chooses its price p_i to maximize its profit.
- The marginal condition of optimality implies that $\frac{d\Pi_i}{dp_i} = 0$, or equivalently, $\frac{d(p_i q_i)}{dp_i} = \frac{dC_i(q_i)}{dp_i}$.
- Note that profit Π_i depends on price p_i both directly and indirectly through q_i . Then we have that

$$\frac{d(p_i q_i)}{dp_i} = q_i + p_i \frac{dq_i}{dp_i}$$

And

$$\frac{dC_i(q_i)}{dp_i} = MC_i(q_i) \frac{dq_i}{dp_i}$$

Estimating MCs: Bertrand with diff. prod. [4]

- Combining these equations, $\frac{d(p_i q_i)}{dp_i} = \frac{dC_i(q_i)}{dp_i}$, we have:

$$MR_i = p_i + \frac{q_i}{dq_i/dp_i} = MC_i(q_i)$$

- And taking into account that $q_i = H s_i = H \sigma_i(\mathbf{p}, \mathbf{X})$:

$$MR_i = p_i + \frac{s_i}{d\sigma_i/dp_i} = MC_i(q_i)$$

- The term $\frac{s_i}{d\sigma_i/dp_i}$ is negative. Therefore, $\frac{-s_i}{d\sigma_i/dp_i}$ is the price-cost margin $p_i - MC_i(q_i)$ in equilibrium.
- For instance, for the Logit demand system, we have that $d\sigma_i/dp_i = -\alpha s_i(1 - s_i)$, such that:

$$p_i - \frac{1}{\alpha(1 - s_i)} = MC_i(q_i)$$

Estimating MCs: Bertrand with diff. prod. [5]

- In general, we have that the marginal revenue,

$$MR_i = p_i + \frac{s_i}{d\sigma_i/dp_i}$$

only depends on p_i , s_i , and the demand function $\sigma_i(\mathbf{p}, \mathbf{X})$.

- After estimating the demand function, the researcher knows (or has estimates) of the marginal revenues MR_i for every firm/product in the market.

Estimating MCs: Bertrand with diff. prod. [6]

- Suppose that the marginal cost function is $MC_i(q_{it}) = q_{it}^{\theta} \exp\{X_{it} \gamma + \varepsilon_{it}^{MC}\}$.
- The marginal cost of producing a product depends on the characteristics of this product.
- Suppose that the demand function has been estimated in a first step, such that there is a consistent estimate of the demand function.
- Then, the econometric model is:

$$\ln(MR_{it}) = \theta \ln(q_{it}) + X_{it} \gamma + \varepsilon_{it}^{MC}$$

Estimating MCs: Bertrand with diff. prod. [7]

$$\ln(MR_{it}) = \theta \ln(q_{it}) + X_{it} \gamma + \varepsilon_{it}^{MC}$$

- OLS estimation of this regression function suffers of the same endogeneity problem as in the PC or Cournot.
- To deal with this endogeneity problem, we can use instrumental variables.
- We can use the characteristics of products other than i , $X_{jt} \ j \neq i$, as instruments.

$$E \left(\begin{bmatrix} X_{it} \\ \sum_{j \neq i} X_{jt} \end{bmatrix} [\ln(MR_{it}) - \theta \ln(q_{it}) - X_{it} \gamma] \right) = \mathbf{0}$$