Agenda

- course overview
- brief Introduction to IO
- static models of competition in homogenous good markets
  - cournot model
  - bertrand competition
- illustrating the "New Empirical IO" approach

Introductions

- Name?
- Which Program? What year?
- What do you know about IO?
- What is your current interested field? in which field do you plan to write your thesis?

Course Description and Prerequisites

- graduate level introduction to IO
  - cover a range of topics, industries and techiques
  - start doing independent research in the field
- prerequisites
  - advanced microeconomics and econometrics
  - coding skills in Stata and Matlab
  - (not required) research experience in some industries

Topics (Tentative)

1. static models of competition: homogeneous good market
2. product differentiation
3. price dispersion and consumer search
4. advertising
5. static models of entry and exit
6. vertical contracts and integration
7. antitrust policy
8. other topics (TBD)

Assignments

- attendance and readings: 10%
- problem sets: 30%
- one assigned paper: 40%
  - in-class presentation: 30%
  - referee report: 10%
- term paper (research proposal + preliminary results): 20%

IO Overview: Einav and Levin (2010)

- what is IO?
  - structure of industries in the economy
  - behaviour of firms and individuals in these industries
  - depart from perfect competition: finite number of firms
- a brief history (since 1970s)
  - theoretical: game theory revolution (Tirole 1988)
  - empirical: cross-industry regression to "New Empirical IO" (Bresnahan 1989)

Einav and Levin (2010) (Cont.)

- cross-industry regression: "structure-conduct-performance", e.g.,

$$\text{profit} = \beta_0 + \beta_1 \times \text{concentration} + \text{other stuff} + \varepsilon$$

  - often $\beta_1 > 0$: more concentrated industries are more profitable
  - so what? is this causal? not really, because hard to find *exogeneous* variation to shift concentration
  - what are the policy prescriptions? reduce concentration to lower price?
- "New Empirical IO": the current state of the field
  - focus on a single industry/market
  - knowledge on institutional details: hypothesis testing/structural modelling/conterfactual analysis
  - advantages: clarity of economic theory + convincing empirical measurement/econometric identification

1 Homogeneous Products: Theory

Oligopoly Pricing in Homogenenous Products Markets

- main question: how are prices and output determined when there are a small number of firms producing a homogenous (identical) product?
- monopoly models: agent optimizes against a fixed environment
- oligopoly models: agent has to consider what actions its competitors will take (i.e., beliefs) and how they may react to its actions (i.e., dynamics)
- focus initially on static models: they will give us some insights into more complicated dynamic models

Cournot Model

- normal form representation
  - player: $i = 1, 2, ..., N$
  - strategy for firm i: $q_i \in [0, \infty)$
  - payoff: $\pi(q_i, q_{-i}) = P\left(\sum_i q_i\right) q_i - C(q_i)$
- interpretation: two firms decide simultaneously what quantity to produce and supply to the market, price adjusts so as to clear the market
- examples: commodity markets (e.g., spring water, sugar)

Solution Concept: Nash Equilibrium

- each firm chooses output optimally given other firms' output choices
- formally, a Nash equilibrium is a profile $\{q_1^*, ..., q_N^*\}$ such that

$$\pi\left(q_i^*, q_{-i}^*\right) \geq \pi\left(q_i, q_{-i}^*\right) \;\; \forall q_i \in [0, \infty) \;\; i = 1, ..., N$$

- interpretation: each firm is behaving optimally given its conjecture about its rival's choice of quantity and, in equilibrium, their conjectures are correct
- problem: not very useful, typically not the case in reality

Alternative Formulation: Best-Reply Response

- let $R_i(q_{-i})$ denote firm i's best replies to its rivals' output choices, then a Nash equilibrium is a profile $\{q_1^*, ..., q_N^*\}$ such that
$$q_i^* \in R_i\left(q_{-i}^*\right) \text{ for } i = 1, ..., N$$

- in other words, the Nash equilibrium is a fixed point of the mapping $\mathbf{R}$, where $\mathbf{R}$ is the Cartesian product of R_i

- existence reduces to checking that $\mathbf{R}$ meets conditions of some fixed point theorem, this also provides algorithm for finding Nash equilibria

Symmetric Case with Linear Demand

- demand: $P(Q) = a - bQ,\ Q = q_1 + ... + q_N$
- supply: $C(q_i) = cq_i,\ i = 1, ..., N$

- firm i's optimization problem: choose q_i to maximize
$$\pi(q_i, q_{-i}) = \left[a - b\left(q_i + \sum_{j \neq i} q_j\right) - c\right] q_i$$

- taking first-order condition, the best reply is
$$R(q_{-i}) \equiv q_i = \frac{a - c - b\left(\sum_{j \neq i} q_j\right)}{2b},\ i = 1, ..., N$$

- solve the N equations for N unknown
$$q_i^* = \frac{a - c}{b(N+1)}$$

Asymmetric Case

- 2 firms with marginal costs $c_1 < c_2$

- best reply functions
$$R(q_j) \equiv q_i = \frac{a - c_i - bq_j}{2b}$$

- solution (equilibrium)
$$q_i^* = \frac{a - 2c_i + c_j}{3b}$$
  - interpretation: the more efficient (lower cost) firm produces more output

Markups

- evaluated at the equilibrium, the FOC can be written as

$$\frac{P(Q^*) - c_i}{P(Q^*)} = \frac{s_i^*}{\eta^*}$$

  where $s_i^* = \frac{q_i^*}{Q^*}$ is firm i's market share and η^* is the the elasticity of market demand

- firms have market power (price is above marginal cost)
- the more elastic is demand, the lower are the markups
- firms with lower marginal costs have higher market shares
- more firms $\Rightarrow$ smaller shares $\Rightarrow$ lower markups
- solution lies between competition and monopoly
- structural equation: right-hand side is observable $\Rightarrow$ can infer markups

Bertrand Model

- price competition: simultaneously choose prices
  - firms' products are perfect substitutes: consumers buy from firm offering the lowest price
- players: two firms indexed by $i = 1, 2$
- stragety of firm i: $p_i \in [0, \infty)$
- payoffs

$$\pi_i(p_i, p_j) = \begin{cases} p_i D(p_i) - C(D(p_i)) & \text{if } p_i < p_j \\ \frac{1}{2}[p_i D(p_i) - C(D(p_i))] & \text{if } p_i = p_j \\ 0 & \text{if } p_i > p_j \end{cases}$$

Solution

- Nash Equilibrium: a pair of prices $\{p_1^*, p_2^*\}$ such that

$$\pi_i\left(p_i^*, p_j^*\right) \geq \pi_i\left(p_i, p_j^*\right) \;\; \forall p_i \in [0, \infty) \;\; i = 1, 2$$

  - payoff functions are discontinuous, best-reply functions are not well-defined

- unique NE: $p_1^* = p_2^* = c$
  - can $p_1 > p_2 > c$ be an equilibrium?
  - can $p_1 = p_2 > c$ be an equilibrium?
  - no, because it is profitable to undercut rival

Bertrand Paradox

- one is monopoly, two is perfect competition?
  - puzzle: firms do not typically sell at marginal costs in markets with few sellers
- price competition seems more natural than quantity competition but yields predictions that contradict reality
  - unlimited capacity: in reality firms may not have the capacity to serve the whole market
  - homogeneous good: in reality it's rare for two firms' products to be perfect substitutes
  - static competition: in reality firms play pricing games against each other repeatedly
  - perfect information: in reality consumers may have to engage in costly search to determine which firm has the lowest price
- relaxing any one of these assumptions yields a richer model with more realistic predictions

An Example: Kreps and Scheinkman (1983)

- two-stage game: firms simultaneously choose capacity and then simultaneously choose prices knowing capacity choices
- main conclusion: capacity-constrained Bertrand price competition can yield the Cournot outcome (capacity/quantity and price)
- interpretation: Cournot game is a reduced form of the two-stage game

2 Estimating Markups in Homogeneous Products Market

Structural Model

- a structural econometric model is a stochastic economic model of behavior of economic agents
- the structural model generates a conditional distribution of endogenous variables given exogenous variables of the interaction: this conditional distribution is known as the reduced form model
- the data only has something to say about the reduced form parameters
  - statistical analysis yields consistent estimates of reduced form parameters
- identification: is the mapping from reduced form parameters to structural parameters one-to-one?
  - typically involve exclusion and inclusion restrictions

Example: Supply and Demand in Competitive Market

- aggregate supply: $P_t = MC_t = \alpha_1 + \gamma_1 Y_t^S + \beta_1 w_t + \varepsilon_{1t}$
- aggregate demand: $Y_t^D = \alpha_2 + \gamma_2 P_t + \beta_2 x_t + \varepsilon_{2t}$
- equilibrium: $Y_t^D = Y_t^S = Y$
- Y_t^S is output supplied by representative firm in market t, Y_t^D is output demanded by consumers in market t, w_t and ε_{1t} are the observed and unobserved factors shifting marginal costs, x_t and ε_{2t} are the observed and unobserved factors shifting demand, $E\left(\varepsilon_{1t}, \varepsilon_{2t}\right) = \Sigma$
- the three equations represents the structural model: the structural parameters are $(\alpha, \gamma, \beta, \Sigma)$; the endogenous variables are $\left(Y_t^D, Y_t^S, P_t\right)$; the exogenous variables are (x_t, w_t)

Reduced-Form

- reduced-form equations

$$P_t = \pi_{10} + \pi_{11} x_t + \pi_{12} w_t + u_{1t}$$

$$Y_t = \pi_{10} + \pi_{11} x_t + \pi_{12} w_t + u_{1t}$$

- conditions necessary for OLS estimation of the structural model are $E(\varepsilon_1|w, Y) = E(\varepsilon_2|x, P) = 0$, unlikely to hold since P and Y depend upon the disturbances through market-clearing

Estimation and Identification

- could estimate by 2SLS: regress P on x and w and substitute the predicted value of P into the demand equation, i.e., use w as instrument for P, it is correlated with P but uncorrelated with unobserved demand shock
  - similarly, use x as instrument for Y in the supply equation.
- could also estimate the reduced form by OLS since the necessary conditions $E(u_1|x, w) = E(u_2|x, w) = 0$ are satisfied
  - the exclusion of x from supply and w from demand are sufficient for identification: recover structural parameters $(\alpha, \gamma, \beta, \Sigma)$ from reduced form parameters

Remarks

- reduced form establishes correlation, not causation
  - suppose true structural model is $X = \gamma Z + \beta W + \varepsilon_1$ and $Y = \delta Z + \varepsilon_1$, then X and Y are correlated but X does not cause Y or vice versa, a.k.a. confounding problem
- causality is determined by economic theory, which specifies which variables are endogenous and which variables are exogenous

Remarks (Cont.)

- the reduced form model depends upon the economic environment (e.g., monopolist's response depends upon whether or not it is regulated).
  - it can answer questions like: what is the impact on prices and quantity of a $\$\Delta$ rise in income? in general, any prediction about the impact of an exogeneous variable on an endogeneous variable can be examined using reduced-form analysis
- the structural model is invariant to underlying economic environment
  - it is used to answer questions about primitives like elasticity of demand and marginal costs, perform welfare analysis, and conduct counterfactuals (e.g., what happens to equilibrium prices and output if firms merge)

Cournot Model

- (inverse) demand function: $P_t = \alpha_0 + \alpha_1 x_t - \gamma Y_t + \varepsilon_t$
- firm i's supply is determined by the FOC (Nash equilibirium)

$$P(Y) + y_i \frac{\partial p}{\partial Y} - mc_i(y_i) = 0$$

- assume $mc_i(y_i) = \beta w_i + \delta_i y_i + \eta_i$ and the FOC evaluated at equlibirium becomes

$$P_t = \beta w_{it} + (\gamma + \delta_i) y_{it} + \eta_{it} \; i = 1, ..., N$$

  - N supply equations, demand equation, and (equilibrium) identity $Y = y_1 + \ldots + y_N$
  - could estimate using data on prices and firm outputs under the assumption that $E(\varepsilon|x, w) = E(\eta|x, w) = 0$
  - could estimate reduced form by OLS or ML, alternatively, use GMM

GMM

- first write

$$\eta_{it}(\theta) = P_t - \beta w_{it} - (\gamma + \delta_i) y_{it}$$

  where $\theta = (\beta, \delta_i, \gamma)$
- find a sufficiently rich vector valued function $f(x, w)$ and form the sample moments conditions

$$G_T(\theta) = \frac{1}{NT} \sum_{i,t} \eta_{it}(\theta) f(x_t, w_{i,t})$$

- search for the value of θ that makes $\|G_T(\theta)\|$ as close to zero as possible
- demand and firm cost shifters are good instruments
- could also jointly estimate demand and supply equations by stacking moments together

Identification

- in general, the FOC does not identify the slope of either marginal cost or demand function: yields estimates of $\gamma + \delta_i$
  - FOC cannot distinguish between price-taking behavior or Cournot competitors
- need to combine demand and supply equations, estimate γ using the demand equation
- could also achieve identification by assuming that marginal costs are constant
  - in this case, the FOC becomes $\eta_{it}(\theta) = P_t - \beta w_{it} - \gamma y_{it} - \delta_i$
- if demand shifters affect slope as well as intercept, we can test for market power
  - for example, suppose $P_t = \alpha_0 + \alpha_1 x_t - \gamma Y_t - \alpha_2 x_t Y_t + \varepsilon_t$, then FOC of Cournot model is $\eta_{it}(\theta) = P_t - \beta w_{it} - (\gamma + \delta_i + \alpha_2 x_t) y_{it}$
  - in the perfectly competitive model, the FOC is $\eta_{it}(\theta) = P_t - \beta w_{it} - \delta_i y_{it}$, therefore, if demand shifters affect supply equations, this is evidence of market power

Conduct Parameter

- in Nash equilibrium, firms choose quantities taking rival quantities as fixed
  - change in aggregate output with respect to change in own output is 1
- empirical economists frequently write down the FOC of a firm as follows

$$P(Y) + y_i \frac{\partial P(Y)}{\partial Y} \frac{\partial Y}{\partial y_i} - mc_i(y_i) = 0$$

  and treat the second partial as a parameter φ_i, which is interpreted as firm i's conjecture about the market response to changes in its output

- usually assume that conjectures are common: $\varphi = 1$ is Cournot, $\varphi = 0$ is Bertrand, $\varphi = 1/s_i$ is perfect collusion (i.e., monopoly)
  - supply function equilibria: firms report marginal cost curves to auctioneer who chooses price to clear the market and allocates output efficiently (Hendricks and McAfee, 2000)

Identification

- empirically, the conduct parameter introduces a degree of flexibility into the price-markup equation
  - the parameter value is interpreted as measuring the competitiveness of the market
- however, conduct parameter is identified only if demand shifters affect slope of demand, in which case, FOC becomes

$$\eta_{it}(\theta) = P_t - \beta w_{it} - (\gamma\varphi + \varphi\alpha_2 x_t + \delta_i) y_{it}$$

- estimates of demand equation yields values for γ and α_2, dividing the coefficient on the cross-product term $x_t y_{it}$ yields an estimate of φ, which in turn means that δ_i is identified
  - alternatively, could assume marginal cost is constant, but all of this relies heavily on functional form
- prefered method: direct compare marginal cost and price and see what model can explain the difference (though not always possible due to availability of data)

3 Case Study: Genesove and Mullin(1998)

Genesove and Mullin (1998)

- illustrate the NEIO approach
- goals:
  - estimate markups in the U.S. East Coast cane sugar refining industry, 1890-1941
  - compare estimates against direct measures of markups, does the econometric methodology work?

Industry Background

- geographic market is sugar refining on East Coast of United States
- American Sugar Refining Co. had 95% of industry capacity in 1892
- entry eroded ASRC's capacity share between 1892 and 1900, precipitating a price war that ended in consolidation, cartel from 1900-11
- fringe suppliers: domestic and European beet sugar producers; not much of a threat for most of the sample period

Cost Structure

- technology: raw sugar is transformed into refined sugar

$$MC = c_0 + kP_{\text{raw}}$$

  - c_0 is variable cost: \$0.26 for producing 100 lb of refined sugar
  - k is conversion ratio: 1.041 (1 lb of raw sugar = .96 lb of refined sugar)
- excess capacity for entire sample period
- entry costs are substantial
  - mostly plant and machinery cost which are sunk: no resale value
  - land costs were not sunk

Demand

- simple linear demand model
$$Q(P) = \beta(\alpha - P) + \epsilon$$
  - P: quarterly price of 100 lbs. of refined sugar
  - β: measure of size of market
  - α: maximum willingness to pay
  - ϵ: unobserved demand shock

- sugar is an input into fruit canning which occurs in the third quarter: demand parameters can differ in high season from other quarters (basically two demand curves)

$$Q(P) = \begin{cases} \beta_H(\alpha_H - P) + \epsilon & \text{high season} \\ \beta_L(\alpha_L - P) + \epsilon & \text{low season} \end{cases}$$

Endogeneity

- OLS gives biased estimates of β since P is endogenous: high demand shocks will raise price

- need to find a variable that is correlated with P but not with demand shock (known as an instrument)

- usually use input prices that shift supply: helps determine P but typically independent of demand shocks
  - intuition: changes in quantity demanded due to shifts in marginal cost curve identifies slope of the demand function

Instrument

- the "natural" instrument is P_{raw}, but
  - P_{raw} is probably not exogenous because US consumption is 25% of world market: likely to be correlated with US demand shocks

- Cuban imports as an instrument: a proxy for Cuban production
  - Cuban raw sugar was inframarginal source of supply to U.S. and represents a substantial share of total U.S. imports of raw sugar: variation in Cuban imports affects price of raw sugar and hence price of refined sugar
  - but variation in Cuban imports is due to supply factors such as weather: independent of U.S. demand shocks

TABLE 3 Demand for Refined Sugar, Separately by Season

		(1) Quadratic ($\gamma = 2$)		(2) Linear ($\gamma = 1$)		(3) Log-Linear ($\alpha = 0$)		(4) Exponential ($\gamma,\alpha \to \infty$)
Low season [N = 73]								
Refined Price	α_L	7.72 (.86)	β_L	−2.30 (.48)	γ_L	−2.03 (.48)	$\left(\frac{\gamma}{\alpha}\right)_L$	−.53 (.12)
Intercept		−1.20 (.47)	$\beta\alpha_L$	13.37 (1.90)		4.19 (.65)		3.52 (.48)
High season [N = 24]								
Refined Price	α_H	11.88 (2.03)	β_H	−1.36 (.36)	γ_H	−1.10 (.28)	$\left(\frac{\gamma}{\alpha}\right)_H$	−.26 (.07)
Intercept		−2.48 (.54)	$\beta\alpha_H$	10.74 (1.57)		3.17 (.40)		2.70 (.29)
$\chi^2_{(2)}$ test		6.90		28.18		29.17		25.96

Notes: Standard errors are in parentheses. They are heteroskedasticity-robust and corrected for serial correlation with four lags, by the method of Newey and West (1987). *Refined Price* is instrumented by the log of *Cuban Imports*. The reported $\chi^2_{(2)}$ statistic is for the joint test of equality of the coefficients on price and the intercept across seasons.

Demand Estimates

- demand is larger and less elastic in high season

Pricing Rule

- basic markup equation

$$\frac{P - MC}{P} = \frac{\theta}{\eta(P)}$$

  - LHS is known as the Lerner index
  - θ is "the average collusiveness of conduct" (Bresnahan 1989)
  - special cases: $\theta = 1$ if monopoly; $\theta = 0$ if competitive; $\theta = s_i$ if Cournot

- in this case, $\eta(P) = P/(\alpha - P)$, so

$$P = \frac{\theta\alpha + c_0 + kP_{\text{raw}}}{1 + \theta}$$

Estimation

- suppose P_{raw} is exogenous, we could run this regression

$$P = \beta_0 + \beta_1 \times 1\,(\text{high season}) + \beta_2 \times P_{\text{raw}}$$

  - then use $(\beta_0, \beta_1, \beta_2)$ and (α_L, α_H) to recover (θ, c_0, k)

- P_{raw} is endogenous and but we can use the moment condition restriction

$$E\left[\{P(1+\theta) - \theta\alpha - c_0 - kP_{\text{raw}}\}\, Z\right] = 0$$

  - instruments: $Z =$ (constant, 1(high season), log($CubanImports$))

TABLE 7 **NLIV Estimates of Pricing Rule Parameters**

	Linear		Direct Measure
	(1)	(2)	(3)
$\hat{\theta}$	.038 (.024)	.037 (.024)	.10
$\hat{c}_o$	.466 (.285)	.39 (.061)	.26
$\hat{k}$	1.052 (.085)		1.075

Results

- market is a lot more competitive than monopoly or even Cournot (with nine firms or fewer firms)
- the NEIO approach performs reasonably well although variable cost is overestimated (imposing the value of k improves the precision)

Summary of NEIO Approach

- firms' price-cost margins are not taken to be observables: marginal cost is inferred from firm behavior (i.e., FOC)
- individual industries have important idiosyncracies: firm's conduct is likely to vary across industries based on these unobserved industry-specific factors so little can be learned from cross-sectional studies of industries
- the behavioral equations by which firms set prices and quantities are estimated and the structural parameters identified