# 1 Sutton: Entry and Equilibrium Market Structure

Main question: how do markets become concentrated? How to interpret the "stylized fact" that advertising is higher in concentrated industries?

Compare the role of sunk costs in different market structures.

1. Perfect competition, with exogenous (and symmetric) sunk costs and free entry. Familiar characteristics of competitive equilibrium: production at minimum efficient scale, (p, q) at min AC.
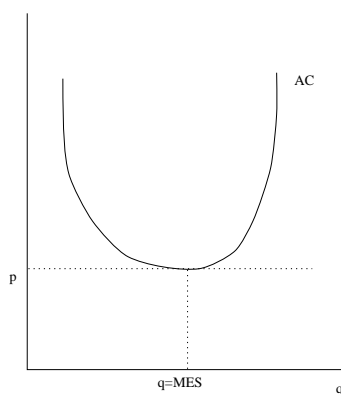

Effect of increasing market size: as $M \to \infty$, #firms $\to \infty$.
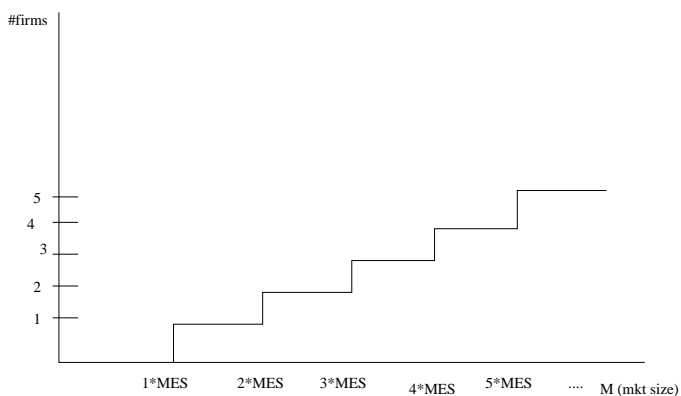
Sutton: when would this relationship not hold?

2. Try imperfect competition, but still exogenous sunk costs and free entry.

Generally, consider two stage game: (1) firms decide whether to enter (and pay fixed costs A); (2) firms play noncooperative oligopolistic game (Sutton considers symmetric Cournot). Note: in general, results are probably sensitive to game played second period (i.e., if homogeneous products Bertrand, then you immediately get perfect competition result).
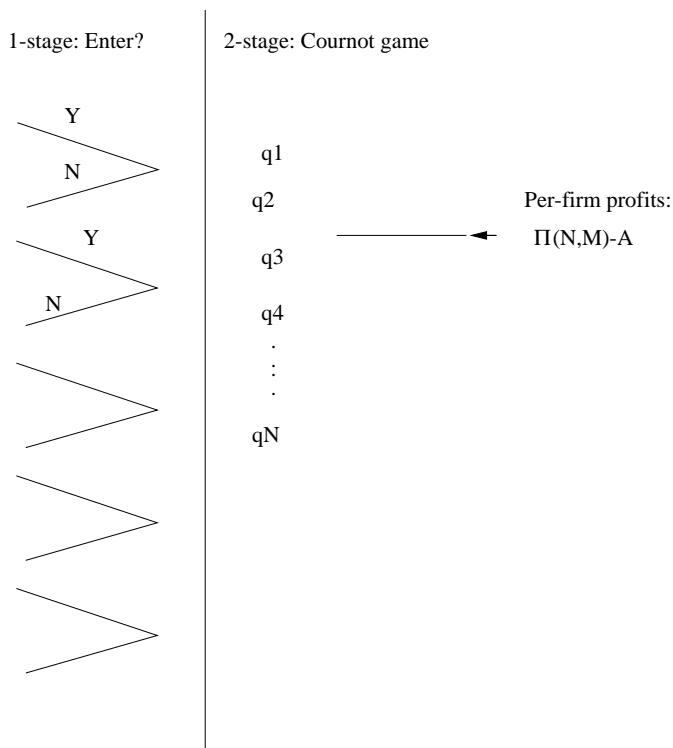

Suppose N firms enter, and market size is M. Each firm's profits is $\Pi(N, M)$. Free entry determine N:

$$N^*(M, A) : \Pi(N, M) > A, \Pi(N+1, M) < A.$$

Usual (regularity?) conditions: For a given M, $\Pi(N, M)$ decreasing in N. For a given N, $\Pi(N, M)$ increasing in M. (True for Cournot?)

Limiting behavior: as $M \to \infty$, $N^* \to \infty$, but "entry thresholds" may not be equally spaced, as in perfect competition case. Like Bresnahan/Reiss, size of thresholds may be rising in M (which we would expect if more firms makes market more competitive). This is the framework basically considered by BR.
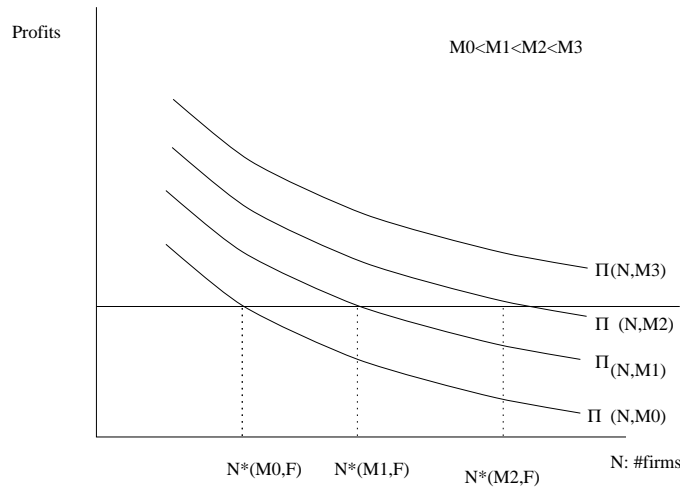
3. So you still don't get concentration in the limit. Now Sutton considers **endogenous sunk costs**, endogenous in the sense that scale of costs varies depending on N: $A(N)$.

Three-stage game: (1) entry; (2) advertising; (3) Cournot

Free entry:

$$N^*(M) : \Pi(N, M) > A(N), \Pi(N+1, M) < A(N+1).$$

$N^*(M)$ may not be monotonic increasing in M, could even be decreasing (i.e., when industry "jumps" from no-advertising to positive advertising).
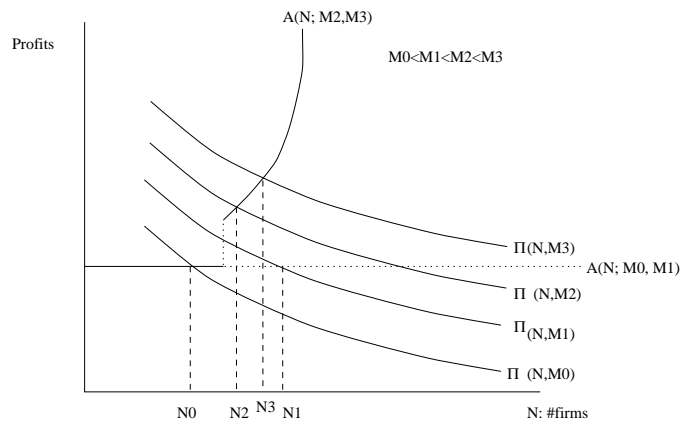
Possibility that as $M \to \infty$, $N^* < \infty$: Sutton's "nonconvergence" result. There is a lower bound on concentration.

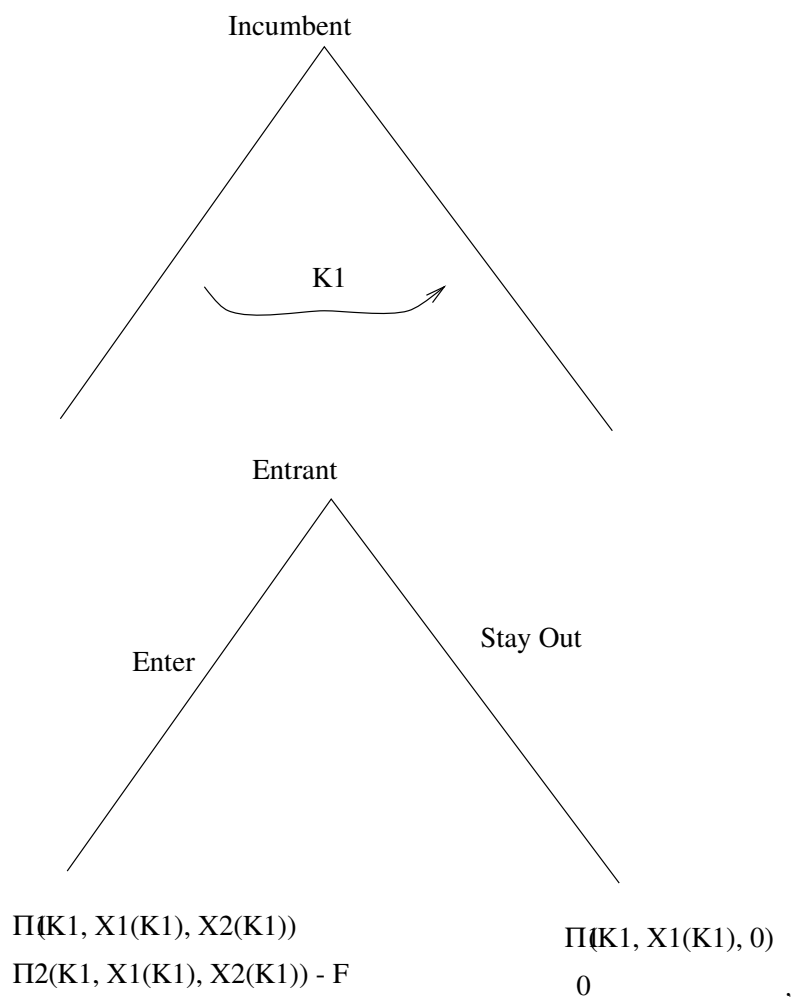Is advertising a "barrier to entry", as either exogenous or endogenous sunk cost? If BTE is defined as something *asymmetric* (i.e., which later entrants need to pay but not incumbents), then endogenous sunk costs are *not* a BTE, since they are equally borne by all firms. (But no dynamics in Sutton's model: no distinction between incumbent and entrant, etc.) Entry deterrence literature explicitly focuses on this distinction, and possible first-mover advantages.

2 Strategic Models of Entry

2.1 Entry deterrence

Incumbent

K1

Entrant

Enter

Stay Out

$\Pi(K1, X1(K1), X2(K1))$

$\Pi2(K1, X1(K1), X2(K1))$ - F

$\Pi(K1, X1(K1), 0)$

0 ,

Solve backwards. Entrant will not enter if $K_1 : \Pi^2(\cdots) < F \iff K_1 \in \mathcal{K}_D$.

Define:

$$K_1^D \equiv argmax_{K_1 \in \mathcal{K}_D} \Pi^1(K_1, x_1^*(K_1), 0)$$
$$K_1^E \equiv argmax_{K_1 \notin \mathcal{K}_D} \Pi^1(K_1, x_1^*(K_1), X_2^*(K_1))$$

Incumbent accommodates if

$$\Pi^1(K_1^E, x_1^*(K_1^E), X_2^*(K_1^E)) \geq \Pi^1(K_1^D, x_1^*(K_1^D), 0).$$

Two important distinguishing features of post-entry game.

Strategic complements/substitutes SC: upward-sloping reaction (or best-response) functions
SS: downward-sloping ....

SC: increase in firm 1's strategic variable (i.e., X_1) increases the marginal return to firm 2 from increasing its strategic variable (i.e., X_2). SS: opposite.

Mathematically, focus on sign $\left(\frac{\partial x_2^*}{\partial x_1} \right)$ (Fudenberg-Tirole) or, equivalently, sign $\left(\frac{\partial^2 \Pi^2}{\partial x_1 \partial x_2} \right)$ (Bulow-Geanakoplos-Klemperer).

SC if sign is positive, SS if sign is negative.

BGK's definition perhaps more intuitive: SC means that increase in X_1 increases the marginal profitability to firm 2 from increasing x_2.

Toughness/Softness Define: If

$$\frac{d\Pi^2}{dK_1} > 0, \text{investment makes incumbent "soft"}$$
$$\frac{d\Pi^2}{dK_1} < 0, \text{investment makes incumbent "tough"}.$$

How does optimal entry deterrence/accommodation strategy distort incumbent's investment (K_1) decisions?

2.2 Optimal Entry deterrence strategies:

If you decide to deter entry (i.e., $\Pi^1(K^E) < \Pi^1(K^D)$), your priority is to make firm 2's entry unprofitable, i.e., choose K_1 s.t. $\Pi^2(K_1, x_1^*(K_1), x_2^*(K_1))=0$. How this should be done

is determined by

$$\frac{d\Pi^2}{dK_1} = \underbrace{\Pi_1^2}_{\text{Direct effect}} + \underbrace{\Pi_2^2 * \frac{dx_1}{dK_1} + \Pi_3^2 * \frac{dx_2^*}{dK_1}}_{\text{strategic effect}} . \tag{1}$$

Clearly, if $\frac{d\Pi^2}{dK_1} < 0$, then "overinvest" to deter entry, and if $\frac{d\Pi^2}{dK_1} > 0$, then "underinvest".[1] In other words, using definitions above, overinvest if investment makes incumbent tough, and underinvest if investment makes incumbent soft.

Ignore direct effect (assume $=0$). By envelope theorem, $\Pi_3^2=0$, so ignore second term of strategic effect. Therefore toughness or softness depends on $\frac{dx_1^*}{dK_1}$ (eg. this is > 0 if increasing K_1 shifts out incumbents reaction function $x_1^*(x_2; K_1)$), as well as how this outward shift in x_1 affects firm 2's profits (thru Π_2^2).

Note: whether post-entry game is SS or SC does not affect optimal entry deterrence strategy.

Tough: Overinvest in K_1 in order to keep firm 2 out (Innovation: invest in cost reducing technology to keep entrant out; Dixit capacity expansion model; Schmalensee brand proliferation/pre-emption model). **Top Dog**.
Soft: Underinvest in K_1 in order to keep firm 2 out (advertising with spillovers which benefit entrant?). **Lean and Hungry Look**.

2.3   Optimal Entry accommodation strategies

For entry accommodation (i.e., $\Pi^1(K^E) > \Pi^1(K^D)$), incumbent is just worried about improving his post-entry profits, i.e., choose K_1 to maximize $\Pi^1(K_1, x_1^*(K_1), x_2^*(K_1))$.

How this should be done is determined by

$$\frac{d\Pi^1}{dK_1} = \underbrace{\Pi_1^1}_{\text{Direct effect}} + \underbrace{\Pi_2^1 * \frac{dx_1}{dK_1} + \Pi_3^1 * \frac{dx_2^*}{dK_1}}_{\text{strategic effect}} .$$

Question: how to relate sign of $\frac{d\Pi^2}{dK_1}$ to concept of SS/SC and toughness/softness?

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[1]Over- and under-invest relative to "open-loop" (cf. Tirole, footnote 44, pg. 326) case where firm 2's choice of x_2 is not a function of K_1 (essentially, take away incumbent's first-mover advantage). In other words, $\frac{dx^2}{dK_1} = 0$, so that $K_1 = \text{argmax}_K \Pi^1(K_1, x_1(K_1), x_2)$.

Ignore direct effect (assume =0). By envelope theorem, $\Pi_2^1=0$, so ignore first term of strategic effect. Therefore over/under-investment decision depends just on second term of strategic effect. Next make some simplifications:

- Assume sign $\left(\Pi_2^2\right)$ = sign $\left(\Pi_3^1\right)$; true for Cournot (both negative) and Bertrand (both positive).

- Note that

$$\frac{dx_2^*}{dK_1} = \frac{dx_2^*}{dx_1}\frac{dx_1^*}{dK_1}$$

- ...so that one can sign the strategic effect

$$\text{sign}\left(\Pi_3^1\frac{dx_1^*}{dK_1}\right)$$

$$= \text{sign}\left(\Pi_2^2\frac{dx_2^*}{dK_1}\right) * \text{sign}\left(\frac{dx_2^*}{dx_1}\right) \qquad \text{by sign}(\Pi_3^1) = \text{sign}(\Pi_2^2)$$

$$= \text{sign}\left(\text{equation 1}\right) * \text{sign}\left(\frac{dx_2^*}{dx_1}\right) \quad \text{by 1st/3rd terms of equation (1)=0} \qquad (2)$$

$$= \text{sign}\left(\text{soft?}\right) * \text{sign}\left(\text{SC?}\right) \qquad \begin{array}{l} \text{Total>0: overinvest} \\ \text{Total<0: underinvest.} \end{array} \qquad (3)$$

In other words, whether you over/under-invest depends on *both* whether investment makes incumbent tough (first term of (2)) or post-entry game is SS/SC (second term of (2)). Four cases:

Tough/SS: Here strategic effect > 0, and you overinvest ("top dog"). Examples: Dixit capacity expansion model with entry (i.e., identical to Stackelberg result).
Tough/SC: Here strategic effect < 0, and you underinvest ("puppy dog"). Examples: Maximal product differentiation in Hotelling 2-firm model.
Soft/SS: Here strategic effect < 0, so underinvest ("lean and hungry look").
Soft/SC: Here strategic effect > 0, so overinvest ("fat cat"). Example: Endogenous switching costs; overinvest in (say) frequent-flyer programs to soften price competition.

2.4   Empirical implications

Data on markets with and without entry. Can "interpret" markets with just one firm as those in which an incumbent has "chosen" to deter entry, and those where there are two firms

as those where incumbent has chosen to accommodate entry. Investment strategies (i.e., advertising, degree of product differentiation, brand proliferation) should differ markedly in the two market settings, assuming that post-entry game is Bertrand (SC). Examples:

1. Advertising in post-patent drug markets. If advertising makes you "tough", then you should see more advertising in markets without generics (top dog vs. puppy dog). If advertising creates spillovers for generic rival, then you should see less advertising in markets without generics. Note difference between "nonstrategic" stories: they would argue that you see more advertising when there are more firms because you just want to differentiate yourself.

2. Airport presence/degree of "hubness" in specific city-pair markets. Airport presence makes incumbent tough, so that incumbent should have *less* airport presence (eg. flight frequency) in city-pairs with competitors.

3. Amenities at gas stations?

3   Empirical work

Bresnahan and Reiss (1991): "Entry and Competition in Concentrated Markets"

Empirical model of entry when one does not observe "strategic" variables: prices, costs, advertising, etc. Only observe market characteristics, and number of firms (not even firms' market shares). So implicit assume: all firms have the same market shares in equilibrium.

In the background: Sutton(-like) model of symmetric firms, and free entry. No dynamics (assume period-by-period static equilibrium).

Behavioral model   Solve it backwards. Assuming N firms, derives each firm's profits.

Demand in market m

$$Q_m = d(Z_m, p) * S(Y_m)$$

where "$d(Z_m, p)$ represents the demand function of a representative consumer, $S(Y)$ denotes the number of consumers, and Y and Z denote demographic variables affecting market demand." This demand specification has "constant returns to scale": double S, you double Q. Inverse demand curve $P(Q, Z, Y)$.

Implicitly (??), assume Cournot competition (just like Sutton). Each firm solves:

$$\max_{q_i} P(q_i, q_{-i}, Z_m, Y_m) * q_i - F_N - C(q_i).$$

Interpret F_N are "endogenous sunk costs" (depend on N)?

In symmetric equilibrium: $q_i = q_j = q^*$, $\forall\ i, j$. By plugging in equilibrium quantities, symmetric N-firm Cournot profits are

$$\Pi_{N,m} = \left[P(q^*, q^*, Z_m, Y_m) - \frac{C(q^*)}{q^*} \right] * q^* - F_N$$

$$= [P_N - AVC(q^*) - b_N] * d(Z_m, P_N)\frac{S}{N} - F_N - B_N$$

where $q^* = d(Z_m, P_N)\frac{S}{N}$ (so each firm produces the same amount), and b_N and B_N allow AVC and fixed costs, respectively, to depend on the number of firms.

Now go back to first stage. Number of firms in market m, N_m^*, is determined by free entry conditions: $\Pi_{N_m^*, m} > 0$, but $\Pi_{N_m^*+1, m} < 0$.

Alternatively, for each N, breakeven condition $\Pi_{N,m} = 0$ defines the per-firm entry threshold s_N (i.e., market demand level at which N firms would enter):

$$s_N = \frac{S_N}{N} = \frac{F_N + B_N}{(P_N - AVC_N - b_N)\, d_N}.$$

The ratio of successive entry thresholds is also important:

$$\frac{s_{N+1}}{s_N} = \frac{F_{N+1} + B_{N+1}}{F_N + B_N} \frac{(P_N - AVC_N - b_N)\, d_N}{(P_{N+1} - AVC_{N+1} - b_{N+1})\, d_{N+1}}.$$

If market is competitive, then this ratio should $\to 1$ (i.e., new firms enter as market size increases by a multiple of the MES). This is not true, for example, with endogenous sunk costs (there the ratio $\to \infty$)??

Point of analysis is to estimate these entry thresholds. But do not observe prices, cost components, etc: how to do it?

Empirical implementation   Specify reduced-form profit function (since prices and costs are not observed):

$$\Pi_{N,m} = S\left(Y_m, \lambda\right) * V_N\left(Z_m, W_m, \alpha, \beta\right) - F_N(W_m, \gamma) + \epsilon_m$$

$$\equiv \bar{\Pi}_{nM} + \epsilon_m.$$

Data: observe N_m.

$$Prob(N_m) = Prob(\Pi_{N_m,m} > 0, \Pi_{N_m+1,m} < 0)$$
$$= Prob(\bar{\Pi}_{N_m,m} + \epsilon_m > 0, \bar{\Pi}_{N_m+1,m} + \epsilon_m < 0)$$
$$= Prob(\epsilon_m > -\bar{\Pi}_{N_m,m}, \epsilon_m < -\bar{\Pi}_{N_m+1,m})$$
$$= Prob(\bar{\Pi}_{N_m+1,m} < \epsilon_m < \bar{\Pi}_{N_m,m}).$$

Likelihood function depends on assumptions about ϵ_i. B/R assume $\epsilon \sim N(0, \sigma^2)$, *i.i.d.* across markets m, so that

$$Prob(N_m) = \begin{cases} \Phi(\bar{\Pi}_{N_m,m}) - \Phi(\bar{\Pi}_{N_m+1,m}) & N_m > 1 \\ 1 - \Phi(\bar{\Pi}_{2,m}) & N_m = 1. \end{cases}$$

This is an "ordered probit" model.

Problem: parametric restrictions real important. Without regressors (homogeneous markets), "cut points" chosen to match actual proportions in the data.

Example: in the data, ten markets with $N = 1$, 10 with $N = 2$, ten with $N = 3$, and 10 with $N \geq 4$. For any distribution function F, will find cutpoints $\bar{\Pi}_2 \geq \bar{\Pi}_3 \geq \bar{\Pi}_4$ so that $F(\bar{\Pi}_2) = 3/4$, $F(\bar{\Pi}_2) - F(\bar{\Pi}_3) = 1/4$, etc.

Specification details

- Market size $S(Y_m, \Lambda)$: Y_m includes size characteristics for market m (population, nearby population, growth, commuters)

- Reduced-form per-capita N-firm profits: $V_N = \alpha_1 + X'\beta - \sum_{n=2}^{N} \alpha_n$

  - X are economic variables, includes demand (Z) and cost (W) shifters

  - α_n: allow number of firms to affect intercept of profits, restrict that each one ≥ 0 (more firms $\rightarrow$ lower per-capita profits)

- N-firm fixed costs $F_N = \gamma_1 + \gamma_L w_L + \sum_{n=2}^{N} \gamma_n$. γ_n's allow number of firms to affect magnitude of fixed costs (capture entry deterrence, endogenous sunk costs?)

BR analysis leaves open the question of *why* the number of firms affects entry thresholds. Mazzeo (2002) considers this question, focusing on the possibility that firms avoid the "toughness of price competition" via *product differentiation*. He considers a BR-type model

in which firms have two strategic variables: (i) whether or not to enter, and (ii) what type of product to produce. He studies motel markets: geographically isolated markets with clear quality differentiation (2-star, 3-star, etc.) amongst competitors.

Berry (1992): "Estimation of a Model of Entry in the Airline Industry"

Allow for firm (indexed by k) heterogeneity in fixed costs:

$$\Pi_{m,k,N} = \underbrace{v_m(N)}_{\text{common component}} - \underbrace{\phi_{m,k}}_{\text{firm } k \text{ component}}$$

$$= \underbrace{X_m\beta - \delta \log N + \rho u_{m0}}_{v_m(N)} + \underbrace{Z_k\alpha + \sqrt{1-\rho^2}u_{mk}}_{-\phi_{m,k}}$$

where common component is like $\bar{\Pi}_{m,N}$ in B/R.

The composite error term for firm k is $\epsilon_{m,k} \equiv \rho u_{m0} + \sqrt{1-\rho^2}u_{mk}$, where ρ essentially measures correlation between the errors terms of the firms in a given market. Therefore, Berry assumes that

$$\begin{pmatrix} \epsilon_{m,1} \\ \epsilon_{m,2} \\ \vdots \\ \epsilon_{m,K_m} \end{pmatrix} \sim N \left(\mathbf{0}, \begin{bmatrix} 1 & \rho & \cdots & \rho \\ \rho & 1 & \cdots & \rho \\ \vdots & \cdots & \ddots & \vdots \\ \rho & \rho & \cdots & 1 \end{bmatrix} \right). \tag{4}$$

In what follows, I go over a slightly simplified version of Berry's model.

Similar free-entry multi-stage theoretical model (as in B/R) underlying empirics, but now there are K_m error terms (rather than 1, as in B/R) for each market, corresponding to the fixed-cost errors for the K_m potential entrants in market m:

$$Prob(n_m = N|Z_m) = Prob\left(\epsilon_{m,1}, \ldots, \epsilon_{m,K_m} : \sum_{k=1}^{K_m} \mathbf{1}(v_m(N;Z_m) > \phi_{m,k}) = N \right)$$

$$= \underbrace{\int \cdots \int}_{K_m \text{ times}} \mathbf{1}\left(\sum_{k=1}^{K_m} \mathbf{1}(v_m(N;Z_m) > \phi_{m,k}) = N \right) dF(u_{m0}, u_{m1}, \ldots, u_{mK_m}; \theta)$$

$$\tag{5}$$

where θ is a parameter vector. It is understood that the $v(\cdot)$'s and $\phi(\cdot)$'s in the equation depend on the errors ϵ.

Estimation   Likelihood function as defined in equation (5) features multivariate integral which is difficult to compute.

Estimate by nonlinear least squares instead: match data (on number of market participants N_m) to predicted mean $E_{\phi_{m,1},\dots,\phi_{m,K_m}}(n_m|Z_m;\theta)$.

$$\hat{\theta} = argmin_\theta \frac{1}{M} \sum_m (N_m - E_{\epsilon_{m,1},\dots,\epsilon_{m,K_m}}(n_m|Z_m;\theta))^2$$

where

$$E_{\epsilon_{m,1},\dots,\epsilon_{m,K_m}}(n_m|Z_m;\theta) =$$
$$\int \cdots \int n_m^*(\epsilon_{m,1},\dots,\epsilon_{m,K_m})dF(\epsilon_{m,1},\dots,\epsilon_{m,K_m};\theta). \tag{6}$$

Since multivariate integration difficult to handle analytically, use simulation methods to compute this integral. The resulting estimation method is **Simulated Nonlinear Least Squares (SNLS):**

$$E_{\epsilon_{m,1},\dots,\epsilon_{m,K_m}}(n_m|Z_m;\theta) \approx$$
$$\frac{1}{S}\sum_s n_m^{*,s}(\epsilon_{m,1}^s,\dots,\epsilon_{m,K_m}^s;\theta)$$

where $n_m^{*,s}(\epsilon^s;\theta)$ is the equilibrium number of firms n_m for a draw of $\epsilon^s \equiv (\epsilon_{m,1},\dots,\epsilon_{m,K_m})'$. This is calculated as:

$$n_m^{*,s}(\epsilon^s) \equiv \max_{0 \le n \le K_m} \left\{ n : \sum_{k=1}^{K_m} \mathbf{1}\left(v_m(n) > \phi_{m,n}|\epsilon^s;\theta\right) \ge n \right\}. \tag{7}$$

The s superscript denotes simulated draws from the multivariate normal distribution .

To reiterate, in order to simulate $E_{\epsilon_{m,1},\dots,\epsilon_{m,K_m}}(n_m|Z_m;\theta)$, we following these three steps:

1. For $s = 1,\dots,S$, draw ϵ^s according to the multivariate normal distribution (4).

2. For each draw ϵ^s, calculate $n^{*,s}(\epsilon^s)$ according to equation (7). (This is not easy!)

3. Approximate $E_{\epsilon_{m,1},\dots,\epsilon_{m,K_m}}(n_m|Z_m;\theta)$ by the average $\frac{1}{S}\sum_{s=1}^S n^{*,s}(\epsilon^s)$. Consistency and asymptotic (in S) properties of simulated quantity follows from *i.i.d.* LLN and CLT.

How could you use data on prices? Look at predatory models? Look at limit pricing models?

Generally, in models with asymmetric firms, where entry is just dictated by free-entry conditions, uniqueness of equilbrium is not guaranteed. A given realization of the firm-specific error vector $\epsilon_1, \ldots, \epsilon_{K_m}$ ($\bar{N}$ is the number of potential entrants) may support multiple values of N as equilibria, in the sense of

$$\sum_{k=1}^{K_m} \mathbf{1}(v_m(N; Z_m) > \phi_{m,k}) = N$$

for multiple values of $N \in \{1, \ldots, K_m\}$.

- Berry overcomes this by his assumption about the order of entry: firms with the highest profitability get to move first. (See discussion on pg. 904.)

- Seim (2002) considers a differentiated-product entry model in which firms choose both (i) whether to enter and (ii) their location. She overcomes the multiple equilibrium problem by introducing incomplete information to the entry model. To see why this helps, consider a setting where ϵ_i represents firm i's private information about its profits (which are unobserved by other firms). Firm i's entry and location decisions are functions only of its ϵ_i.

  In any symmetric equilibrium of a simulataneous entry game, firms' strategies are common knowledge, so that each firm has identical perceptions about the location choices and entry decisions each of its rivals. The equilibrium strategies must then satisfy a set of K_m best-response conditions. Uniqueness of equilibrium then boils down to the uniqueness of solutions to the system of best-response equations, pointwise in $\epsilon_1, \ldots, \epsilon_{K_m}$. Once the strategies are established, one can easily simulate the number of firms and location configurations of each entering firm for any realization of the private errors $\epsilon_1, \ldots, \epsilon_{K_m}$.

- More recent entry literature confronts multiple equilibrium problem head-on, and focuses on estimation methods when there are multiple equilibria. (See next handout.)

References

BERRY, S. (1992): "Estimation of a model of entry in the airline industry," *Econometrica*, 60(4), 889–917.

BRESNAHAN, T., AND P. REISS (1991): "Entry and competition in concentrated markets,"
Journal of Political Economy, 99, 977–1009.

MAZZEO, M. (2002): "Product Differentiation and Market Structure: An Empirical Model
of the Hotel Industry," *RAND Journal of Economics*, 33, 221–242.

SEIM, K. (2002): "An Empirical Model of Firms' Entry and Endogenous Product-Type
Choices," Manuscript, Stanford Business School.