Introduction to Industrial Organization

Entry and Market Structure

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Introduction

- In Industrial Organization, economists care about market structure and how it affects market competition.
- Some general questions:
  - For the antitrust institute: how many firms does it take to sustain "competition" in the market?
  - For incumbents: can strategic investments in R&D, advertising and capacity deter entry and reduce competition?
  - For entrants: how many firms can fit in a market?
- Before 1970 and early 1970s, theoretical and empirical work examined how variables, such as firm profits, and prices differed between concentrated and unconcentrated markets, which assumed that market structure was exogenous.

Introduction

- In the 1970s and 1980s, IO models started to understand how strategic behavior might affect market structure.
- For instance, a two-stage game:
  - potential entrants decide whether to enter or not
  - entering firms compete in prices or quantities.
- Because of the increased availability of manufacturing census and firm-level data, many studies started to focus on patterns in firm turnover and industry structure.
- Today's lecture is to introduce some structural econometric models related to entry, exit, and market structure.

Outline

- Introduction to structural models
- Entry games with homogeneous firms
  - Bresnahan and Reiss (1991, JPE)
- Firm heterogeneity: two-by-two entry game
  - Mazzeo (2002, RAND) (complete information game)
- Spatial differentiation for entry
  - Seim (2006, RAND) (incomplete information game)

- Reference: Berry and Reiss (2007), "Empirical Models of Entry and Market Structure", *Handbook of Industrial Organization, Volume 3*.

Introduction to Structural Models

Structural Models

- Why do we need a structural model?
  - It allows us to estimate some unobserved variables.
- Example: to understand why a market is concentrated?
  - We have to distinguish between fixed costs and variable dcosts.
  - However, there is usually no data for costs.
  - We can use some observable information, such as prices, quantities, and number of firms in a market to draw inferences about demand, fixed costs, and variable costs.
  - Of course, we need some modeling assumptions.
- Second example: potential entrants
  - Ideally, we need to know who is a potential entrant.
  - However, we only can observe who entered.

Structural Models

- Third example: entry decision v.s. product differentiation
  - The entry decision might be combined with other decision of product differentiation.
  - In the reduced form model, we need to deal with the endogeneity problem of entries.
  - In the structural model, we can develop a theoretical model and use some techniques to estimate the parameters in the model.

Entry Games with Homogeneous Firms

Simple Structural Model

- We start from a simple homogeneous firm model, and the goal is is to develop it as an empirical model.
- Data:
  - T cross-sectional independent markets
  - the number of firms, $N_1^*, N_2^*, ..., N_T^*$, in each market
  - x_i: market i demand and cost variables, such as population
  - the observed data can be summarized as $\{N_i^*, x_i\}_{i=1}^T$.
  - Note: we don't observe prices and quantities in the market
- Model settings:
  - Two-period oligopoly model:
    1. M homogeneous potential entrants decide whether to enter or not.
    2. N firms in the market decide how much to produce.

Simple Structural Model

- Assumptions
  - Firms have complete information about each other's profits.
  - Fixed costs F are not observed by econometrician, but observed by firms.
  - Fixed costs are independently distributed across markets according to the distribution $\Phi(F|x;\omega)$. e.g. normal distribution.
- Given N_i entrants in market i, each entrant earns

$$\pi(N_i) = V(N_i, x_i, \theta) - F_i,$$

where

  - $V(.)$ represents a firm's variable profits (functional form?)
  - F_i is a fixed cost
  - θ: demand, cost and competition parameters

Zero Profit Conditions

- Based on the observed number of firms, N^*, the zero profit conditions can be written as:

$$V(N^*, x; \theta) - F \geq 0$$
$$V(N^* + 1, x; \theta) - F < 0.$$

- Combine these two inequalities, an upper and lower bound on F is given:

$$V(N^*, x; \theta) \geq F > V(N^* + 1, x; \theta).$$

- Based on the distribution of F, the probability of observing N^* firms:

$$\begin{aligned} &\text{Prob}(V(N^*, x; \theta) \geq F|x) - \text{Prob}(V(N^* + 1, x; \theta) > F|x) \\ =&\Phi(V(N^*, x; \theta)|x; \omega) - \Phi(V(N^* + 1, x; \theta)|x; \omega). \end{aligned}$$

Likelihood Function

- Likelihood function for market i:

$$L(\theta, \omega; N_i^*, x_i) = \Phi(V(N_i^*, x_i; \theta)|x_i; \omega) - \Phi(V(N_i^* + 1, x_i; \theta)|x_i; \omega).$$

- Log-likelihood function:

$$l(\theta, \omega) = \sum_{i=1}^{T} \log \left\{ \Phi(V(N_i^*, x_i; \theta)|x_i; \omega) - \Phi(V(N_i^* + 1, x_i; \theta)|x_i; \omega) \right\}.$$

- In practice, it can be equivalent to "ordered probit model".
- Because we have iid assumption across markets, it is better to apply in cross-section data for different markets.

Relating V to the Strength of Competition

- How to specify the variable profit function $V(N, x, \theta)$, and the fixed cost function $F(x, \omega)$?
- Two approaches:
  - Pick a parameterization of $V(.)$, ex: $V(N, x, \theta) = \theta_1(1/N) + \theta_2 x$.
  - Based on a structural model with specific assumptions about function forms and the post-entry game.
- Structural model assumptions:
  - Each potential entrant j has the variable cost function $C_j(q_j)$.
  - Demand in market i has the form $Q_i = S_i q(P_i)$, where S is market size, and $q(.)$ represents the demand function of a representative consumer.
  - Cournot (quantity-based) competition for all the entrants.

Example

- Demand function: $Q(P) = S(\alpha - \beta P)$.
- Inverse demand function: $P(Q) = (1/\beta)(\alpha - Q/S)$.
- Cost function: $F + C(q) = F + cq - dq^2$.
- Profit maximization problem for a firm:

$$\max_q P(Q)q - (F + cq - dq^2)$$

- First-order condition:

$$P(Q) + \frac{\partial P(Q)}{\partial Q}\frac{\partial Q}{\partial q}q - c + 2dq = 0,$$

where

$$\frac{\partial P(Q)}{\partial Q} = -\frac{1}{\beta S}, \quad \text{and} \quad \frac{\partial Q}{\partial q} = 1.$$

Example

- Based on the symmetric assumption, $Q = N^* q$, first-order condition:

$$\frac{1}{\beta}\left(\alpha - \frac{N^* q}{S}\right) + \left(-\frac{1}{\beta S}\right) q - c + 2dq = 0.$$

- Therefore, the optimal quantity for each firm:

$$q^* = \frac{\alpha S - c\beta S}{N^* + 1 - 2dS\beta}.$$

- Market equilibrium quantity:

$$Q^* = N^* q^* = N^* \left[\frac{\alpha S - c\beta S}{N^* + 1 - 2dS\beta}\right].$$

Example

- Market equilibrium price:

$$P^* = \frac{1}{\beta}\left(\alpha - \frac{Q^*}{S}\right) = \frac{1}{\beta}\left(\alpha - N^*\left[\frac{\alpha - c\beta}{N^* + 1 - 2dS\beta}\right]\right)$$
$$\equiv a - N^*\left[\frac{a-c}{N^* + 1 - 2dS/b}\right],$$

where $a = \alpha/\beta$, and $b = 1/\beta$.

- Profit for each firm in market i:

$$\pi_i(N_i^*, S_i) = V(N_i^*, S_i, \theta) - F_i = \theta_1^2 S_i \frac{(1 + \theta_2 S_i)}{(N_i^* + 1 + 2\theta_2 S_i)^2} - F_i,$$

where $\theta_1 = (a-c)/\sqrt{b}$, and $\theta_2 = d/b$.

Bresnahan and Reiss (1991, JPE)

- They use cross-sectional data on number of firms in 202 distinct geographic markets to estimate entry thresholds for five retail and professional service industries.
- The idea of a demand entry threshold: S_N, a measure of the market size required to support a given number of firms, N.
- For instance, we need 1000 consumers to support an monopoly market. Then this entry threshold S_1 is 1000.
- From the previous example, if $d = 0$ ($\theta_2 = 0$), then zero profit condition:

$$\theta_1^2 S \frac{1}{(N+1)^2} - F = 0 \quad \Rightarrow \quad S = \frac{F(N+1)^2}{\theta_1^2} \equiv S_N.$$

Isolated Markets

- They focus on the isolated markets: 202 markets.
- Population distribution:

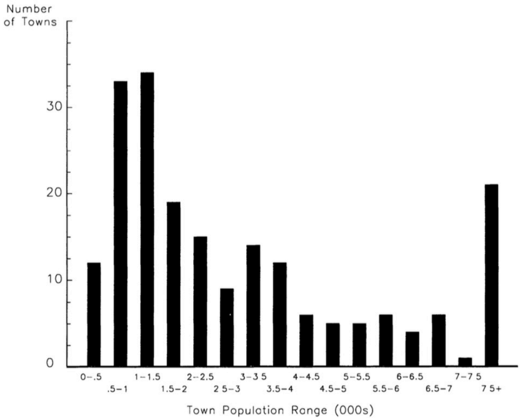


FIG. 2.—Number of towns by town population

Industries

- They focus on five industries: doctors, dentists, druggists, plumbers, and tire dealers.
- Number of firms in each industry:

TABLE 2

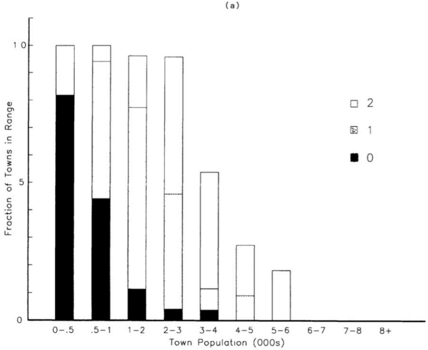
MARKET COUNTS BY INDUSTRY AND NUMBER OF INCUMBENTS

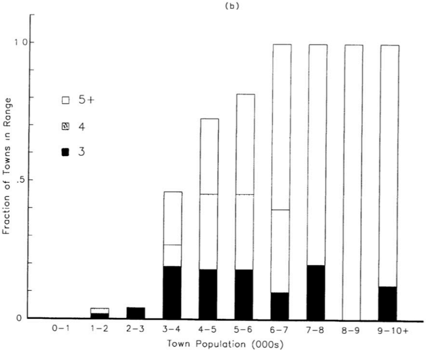
	Number of Firms							
Industry	$N = 0$	$N = 1$	$N = 2$	$N = 3$	$N = 4$	$N = 5$	$N = 6$	$N \geq 7$
Druggists	28	62	68	23	8	6	3	4
Doctors	37	61	36	16	11	7	6	28
Dentists	32	67	39	15	12	12	4	21
Plumbers	71	47	26	21	10	4	6	17
Tire dealers	45	39	39	24	13	15	6	21
Barbers	95	66	23	9	3	6	0	0
Opticians	173	19	5	1	4	0	0	0
Beauticians	10	26	19	24	26	19	11	67
Optometrists	68	85	36	7	3	3	0	0
Electricians	60	54	32	17	10	5	7	17
Veterinarians	53	80	41	21	5	0	1	1
Movie theaters	90	72	25	10	5	0	0	0
Automobile dealers	38	44	54	35	25	2	1	3
Heating contractors	117	40	19	8	4	8	3	3
Cooling contractors	153	30	13	5	1	0	0	0
Farm equipment dealers	90	39	23	19	17	9	1	4

SOURCE.—Authors' tabulations from American Business Lists, Inc.

Dentists

- Relationship between the current town population and the number of practicing dentists.





Function Form Assumption in Bresnahan and Reiss (1991)

- Variable profit function:

$$V(N_i^*, S_i, \alpha, \lambda, \beta) = S_i(Y;\lambda)\left(\alpha_1 + \sum_{k=2}^{M} \alpha_k D_k + x_i\beta\right),$$

where D_k are dummies equal to 1 if at least k firms have entered.

- Market size:

$$S_i(Y;\lambda) = \text{town population} + \lambda_1 \text{nearby population} + \ldots$$

- Fixed cost:

$$F = \gamma_1 + \sum_{k=2}^{M} \gamma_k D_k + W_i \gamma_{M+1},$$

- They use an ordered Probit model to estimate the coefficients, and calculate the entry thresholds based on estimated coefficients.

How to Calculate the Entry Thresholds S_N?

- Assume you have the estimates $\hat{\alpha}$, $\hat{\beta}$, $\hat{\gamma}$, and $\hat{\lambda}$, how can you calculate the entry thresholds $\hat{S}_N$?
- Answer:
  - By zero profits conditions:

$$S_i(Y;\lambda)\left(\alpha_1+\sum_{k=2}^{M}\alpha_k D_k + x_i\beta\right)-\left(\gamma_1+\sum_{k=2}^{M}\gamma_k D_k + W_i\gamma_{M+1}\right)=0$$

$$\Rightarrow S_N = \frac{\gamma_1+\sum_{k=2}^{M}\gamma_k D_k + W_i\gamma_{M+1}}{\alpha_1+\sum_{k=2}^{M}\alpha_k D_k + x_i\beta}$$

  - Based on $\hat{\alpha}$, $\hat{\beta}$, $\hat{\gamma}$, and mean characteristics $\bar{W}$, and $\bar{x}$:

$$\hat{S}_N = \frac{\hat{\gamma}_1+\sum_{k=2}^{M}\hat{\gamma}_k D_k + \bar{W}\hat{\gamma}_{M+1}}{\hat{\alpha}_1+\sum_{k=2}^{M}\hat{\alpha}_k D_k + \bar{x}\hat{\beta}}.$$

Estimated Thresholds

- For instance, a monopoly tire dealer or druggist requires about 500 people in town to set up business.
- Per-firm threshold: $s_N = \frac{S_N^*}{N}$. Entry threshold ratio: s_{N+1}/s_N.

TABLE 5

A. Entry Threshold Estimates

Profession	Entry Thresholds (000's)					Per Firm Entry Threshold Ratios			
	S_1	S_2	S_3	S_4	S_5	s_2/s_1	s_3/s_2	s_4/s_3	s_5/s_4
Doctors	.88	3.49	5.78	7.72	9.14	1.98	1.10	1.00	.95
Dentists	.71	2.54	4.18	5.43	6.41	1.78	.79	.97	.94
Druggists	.53	2.12	5.04	7.67	9.39	1.99	1.58	1.14	.98
Plumbers	1.43	3.02	4.53	6.20	7.47	1.06	1.00	1.02	.96
Tire dealers	.49	1.78	3.41	4.74	6.10	1.81	1.28	1.04	1.03

B. Likelihood Ratio Tests for Threshold Proportionality

Profession	Test for $s_4 = s_5$	Test for $s_3 = s_4 = s_5$	Test for $s_2 = s_3 = s_4 = s_5$	Test for $s_1 = s_2 = s_3 = s_4 = s_5$
Doctors	1.12 (1)	6.20 (3)	8.33 (4)	45.06* (6)
Dentists	1.59 (1)	12.30* (2)	19.13* (4)	36.67* (5)
Druggists	.43 (2)	7.13 (4)	65.28* (6)	113.92* (8)
Plumbers	1.99 (2)	4.01 (4)	12.07 (6)	15.62* (7)
Tire dealers	3.59 (2)	4.24 (3)	14.52* (5)	20.89* (7)

Note.—Estimates are based on the coefficient estimates in table 4. Numbers in parentheses in pt. B are degrees of freedom.
* Significant at the 5 percent level.

Estimated Thresholds

- These ratios decline with N; however, the decline stops abruptly at $N = 3$ and s_3 approximately equals s_4 and s_5.

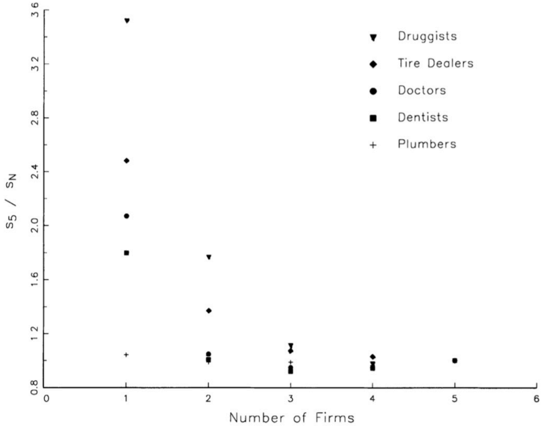


FIG. 4.—Industry ratios of s_5 to s_N by N

Main Results in Bresnahan and Reiss (1991)

- Competitive conduct changes quickly as market size and the number of incumbents increase.
- In markets with five or fewer incumbents, almost all variation in competitive conduct occurs with the entry of the second and third firms.
- Once a market has between three and five firms, the next entrant has little effect on competitive conduct.

Firm Heterogeneity: Two-by-Two Entry Game

Firm Heterogeneity

- Firm heterogeneity:
  - fixed and variable costs
  - product attributes and distribution
  - different locations
- How does the heterogeneity of entrants affect estimation?
- It may include observed and unobserved differences.
- So far, most of the empirical models assume that differences among firms are given.
- We begin with the simplest form of heterogeneity, heterogeneity in unobserved fixed costs.
- This heterogeneity is known to the firms but not the researcher.

Simple Model with Unobserved Heterogeneity

- Consider a one-play, two-by-two entry game.
- Two potential entrants, firm 1 and firm 2. $(j = 1, 2)$
- Each of them has two potential strategies (D_j), "enter" $(D_j = 1)$, and "do not enter" $(D_j = 0)$.
- They make the decisions simultaneously.
- Suppose firms 1 and 2 have perfect information about each other.
- Profits for firms 1 and 2, $\pi_1(D_1, D_2)$, and $\pi_2(D_1, D_2)$, depend on the other firm's strategy.
- We would like to derive equilibrium conditions linking the firms observed actions to inequalities on their profits.

Equilibrium Conditions

- Assume that π_j^M and π_j^D denote the profits firm j earns as a monopolist and duopolist, respectively.
- Market structure outcomes:

Market outcome	N	Conditions on profits
No firms	0	$\pi_1^M < 0$, $\pi_2^M < 0$
Firm 1 monopoly	1	$\pi_1^M > 0$, $\pi_2^D < 0$
Firm 2 monopoly	1	$\pi_2^M > 0$, $\pi_1^D < 0$
Duopoly	2	$\pi_1^D > 0$, $\pi_2^D > 0$

- Researcher would like to use observations on (D_1, D_2) to recover information about π_j^M and π_j^D.

Equilibrium outcomes

- Two possible equilibrium outcomes:
  - One pure-strategy Nash equilibrium
  - Two pure-strategy Nash equilibria (central region): one where firm 1 is a monopolist and the other one where firm 2 is a monopolist.

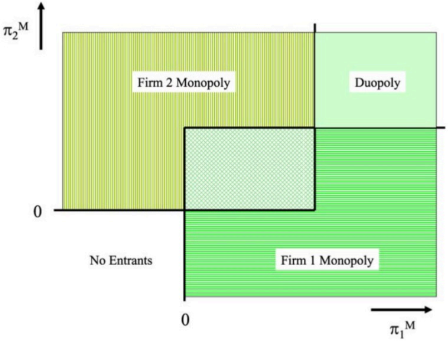


Figure 29.1. Monopoly and duopoly entry thresholds.

Specification on Profits

- We have to specify how firms profits differ in observable and unobservable ways:

$$\pi_j = \begin{cases} 0 & \text{if } D_j = 0, \\ \bar{\pi}_j^M(x, z_j) + \epsilon_j & \text{if } D_j = 1 \text{ and } D_k = 0, \\ \bar{\pi}_j^D(x, z_j) + \epsilon_j & \text{if } D_j = 1 \text{ and } D_k = 1. \end{cases}$$

- $\bar{\pi}$ represent observable profits, the functions of market characteristics x, and firm-specific variables z_j.
- ϵ_j represent profits that are known to the firms but not to the researcher.

Specification on Profits

- Notes for unobserved terms ϵ_j:
  - This additive specification presumes that competitor k's action only affects competitor j's profits through observed profit.
  - One rationale for it is that the error term ϵ_j represents firm j's unobservable fixed costs, and competitor k is unable to raise or lower the rivals fixed costs by being in or out of the market.
- We can rewrite the equilibrium condition as

Market outcome	N	Conditions on profits
No firms	0	$\epsilon_1 < -\bar{\pi}_1^M$, $\epsilon_2 < -\bar{\pi}_2^M$
Firm 1 monopoly	1	$\epsilon_1 > -\bar{\pi}_1^M$, $\epsilon_2 < -\bar{\pi}_2^D$
Firm 2 monopoly	1	$\epsilon_2 < -\bar{\pi}_2^M$, $\epsilon_1 < -\bar{\pi}_1^D$
Duopoly	2	$\epsilon_1 > -\bar{\pi}_1^D$, $\epsilon_2 > -\bar{\pi}_2^D$

Solutions to Multiplicity of Equilibria

- Four potential ways to solve that:
  1. To model the probabilities of aggregated outcomes that are robust to the multiplicity of equilibria.
  2. To place additional conditions on the model that guarantee an unique equilibrium.
  3. To include in the estimation additional parameters that can select among multiple equilibria.
  4. To accept that some models with multiple equilibria are not exactly identified, and yet to note that they nevertheless do generate useful restrictions on economic quantities.

Additional Conditions on Timing

- The assumption of sequential entry with predetermined orders can guarantee an unique equilibrium.
- Suppose that we know or assume that firm 1 (exogenously) moves first, and then firm 1 can preempt the entry of firm 2 in the central area.

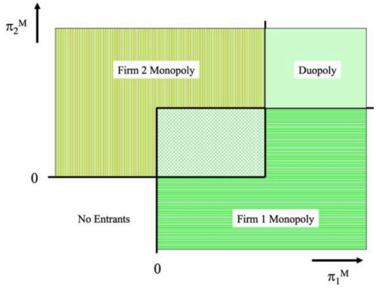


Figure 29.1. Monopoly and duopoly entry thresholds.

Equilibrium Conditions

- Market structure outcomes and equilibrium conditions:

Market outcome	N	Conditions on profits
No firms	0	$\pi_1^M < 0,\ \pi_2^M < 0$
Firm 1 monopoly	1	$\pi_1^M > 0,\ \pi_2^D < 0$
Firm 2 monopoly	1	$\pi_2^M > 0,\ \pi_1^M < 0$
	1	$\pi_2^D > 0,\ \pi_1^D < 0 < \pi_1^M$
Duopoly	2	$\pi_1^D > 0,\ \pi_2^D > 0$

Estimation

- Since the equilibrium is unique, we can calculate the probability of each outcome (D_1, D_2).
- The likelihood function:

$$L = \prod_{m=1}^{M} \text{Prob}[(D_1, D_2)_m^O],$$

where $(D_1, D_2)_m^O$ is the observed configuration of firms in market m - its probability is a function of the solution concept, the parameters, and the data for market m.

Mazzeo (2002)

- Research question: What drives the product-type decisions of firms in oligopoly market?
- He focuses on motel markets located along U.S. interstate highway.
- This paper endogenizes the product choices for firms in the equilibrium entry models.

Model Settings

- Two-stage game:
  - Investment stage: firms decide whether to enter or not and choose to offer low-quality or high-quality services (product-type decisions)
  - Competition stage: payoff are determined.
- In the investment stage, two distinct assumptions:
  1. A Stackelberg game: firms make decisions about entry and product type sequentially.
  2. Two substages:
     2.1 Firms choose whether to enter or not.
     2.2 Product types are selected simultaneously.

Equilibrium Conditions

- An observed pair (L, H) has the following inequalities:

$$\pi_L(L-1, H) > 0$$

$$\pi_H(L, H-1) > 0$$

$$\pi_L(L, H) < 0$$

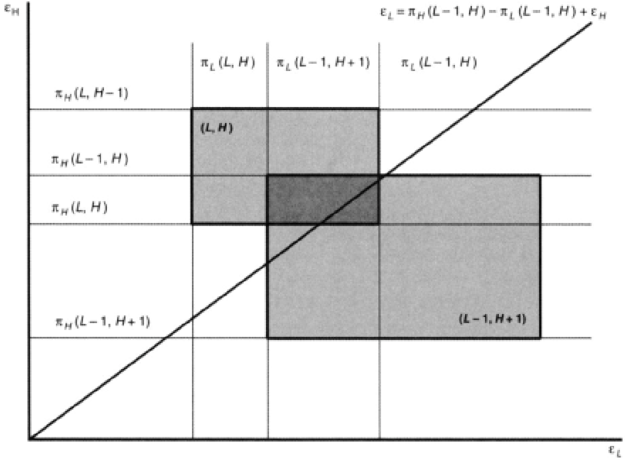
$$\pi_H(L, H) < 0$$

$$\pi_L(L-1, H) > \pi_H(L-1, H)$$

$$\pi_H(L, H-1) > \pi_L(L, H-1)$$

Equilibrium Conditions

FIGURE 1
PARTITIONING FOR EQUILIBRIUM OUTCOMES



Results I

- If there are no competing firms, operating a high-quality motel is on average more profitable than operating a low-quality motel. ($C_H = 2.5252$, and $C_L = 1.6254$)
- If *PLACEPOP*$= 1/10$ and without competitors, the payoffs to operating a low-quality motel are on average higher than those to operating a high-quality motel.
  - $\pi_L = 1.6254 + (-2.303) * (0.2711) = 1.001$
  - $\pi_H = 2.5252 + (-2.303) * (0.6768) = 0.9668$

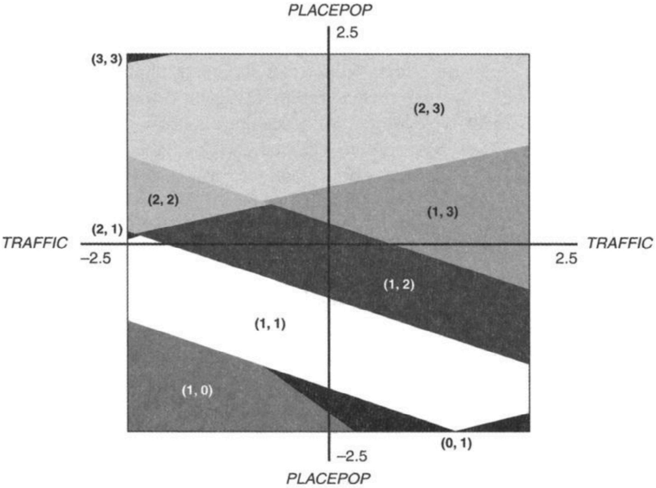
Results II

- For low-quality firms, the first low-type competitor ($\theta_{LL1} = -1.7744$) has more than twice the (negative) effect on payoffs as the first high-type competitor ($\theta_{L0H1} = -.8552$).
- For high-quality firms, the effect of the first competitor is 65% greater if it is also a high type ($\theta_{HH1} = -2.0270$ versus $\theta_{H0L1} = -1.2261$).
- Therefore, the effect of the first same-type competitor is significantly greater than that of the first different-type competitor in both cases.

Results III

- Differentiation is a profitable product choice strategy for firms.
- For instance, consider a firm choosing whether to operate a low- or high-quality motel when there is one high-type competition.
  - $\pi_L = 1.6254 + (-0.8552) = 0.7702.$
  - $\pi_H = 2.5252 + (-2.0270) = 0.4982.$
- The parameters also show the incremental effects of additional competing firms. These effects are smaller than the impact of the first competing firm.

Predictions (Two-Substage Version)



Homework 9

- Recall the data in the simple structural model: $\{N_i^*, x_i\}_{i=1}^T$
  - Pick up an industry, and define several markets in this industry.
  - Count the number of firms, N_i^*, in the markets. Can you observe any difference across the markets?
  - What kinds of the factors, x_i, are important to affect the number of firms in the markets?
  - If you have the data, plot the figure to see the correlation. (optional)
  - Do you also find any important strategies accompanied with the entry?
- (optional) If you have the data, $\{N_i^*, x_i\}_{i=1}^T$, you can estimate the simple structural model by assuming a linear form in $V(.)$.