Entry Models I

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Outline

Outline

Welcome to IO II

- This is the final course in the PhD Industrial Organization sequence
  - Goal: prepare you to write a thesis in empirical IO
  - Pre-requisite: Conlon's empirical IO course at Stern
  - Experience coding structural econometric models is assumed
- Logistics
  - Lecture is Monday 10:30am-12:30pm, Room 624
  - Office Hours: by appointment
- Introductions...

Overview of Course

- This course has two objectives
  1. Finish training in core empirical IO topics and methods
  2. Show how to apply these tools elsewhere
- Core IO topics: market structure and firm conduct
  - Entry
  - Moment Inequality Models
  - Dynamic Games
  - Auctions
- Applications of IO methods to (traditionally) non-IO topics
  - Centralized matching markets
  - Selection markets (health insurance, credit)
  - Time permitting: search, transportation
  - Many others, e.g. education, energy, etc

Course Requirements

- Reading
  - Essential that you read assigned papers carefully
  - 1 paper in great detail (*** on syllabus)
  - 1-2 papers more quickly (* on syllabus)
  - 1 page write-up on (***) paper, due 10am EST prior to lecture
    - **Brief** summary in your own words
    - Comment, evaluation, research idea
- 2 Problem Sets
  - The best way to learn structural estimation is to do it!
  - Encouraged to work in groups of 2-3. Submit joint code+write-up
  - These are very long; start when assigned
  - Must be reproducible: I will run your code start-to-finish
- 2 Referee Reports
  - Evaluate recent empirical IO papers
  - I will provide guidelines

Outline

Market Structure is Endogenous

- Many empirical papers take market structure as given
  - e.g. BLP instruments are competitors' product characteristics
- What determines market structure in the first place? "Structure" means
  - The number of firms in the market
  - The scale of production (firm sizes)
  - Types, varieties, and qualities of products offered
- Determines the answers to many IO/policy questions
  - Antitrust: how many firms are needed to sustain competition?
    - Can the threat of entry discipline monopoly?
    - Can firms deter entry through R&D, advertising, price wars?
  - When is there "too much" or "too little" entry?
  - Costs and benefits of (de-)regulation (pollution, privatization)

Past Approaches to Entry Models

- 1950s-1970s: Look at correlation between profits, R&D, prices in concentrated vs unconcentrated markets
  - Assumes market structure exogenous
- 1970s-1980s: theory of how strategic interactions determine market structure. Workhorse model of a two-stage game
  1. Firms decide whether to operate
  2. Entrants compete

  Focus on full-information, pure-strategy Nash equilibra
- Predictions depended heavily on modeling assumptions (many of which are not directly observable)
  - Size of fixed entry costs
  - Sensitivity of firm profits to entry and exit of competitors
  - Number of potential entrants, expectations about post-entry payoffs
- 1990s-2000s: empirical progress on endogenous market structure
  - Facilitated by econometric and computational advances

Empirical Analysis of Entry Models

- Next two lectures focus on number and identities of entrants
    - Later: endogenous product choice, entry deterrence
- Static view: "long-run" equilibrium using cross-sectional data
    - Key idea: entry decisions reveal expectations about profitability
    - Discrete choice models familiar from demand analysis
        - But payoffs depend on competitors' entry decisions
- Raises several conceptual and empirical challenges
    - Simultaneity of market structure and firm profitability
    - Multiple equilibria
    - High-dimensional state/strategy space
- This lecture covers early advances
    - Competitive effects: Bresnahan & Reiss '91
    - Firm heterogeneity: Berry '92

Outline

1. Industrial Organization II
2. Entry: Overview
3. Bresnahan & Reiss, 1991
   - Model
   - Empirical Application
4. Berry 1992

Overview

Example of "early modern" empirical IO

- Question: what are the competitive effects of entry?
  - Do incumbents' profits fall as additional firms enter, or is the *threat* of entry enough to discipline market power?
- Empirical challenges:
  - Lack of data on variable profits, entry costs
  - Need data on many "comparable" markets
- Empirical Strategy: relationship between number of firms and market size reveals effect of competition on profits
  - Idea: variable profits for last entrant must justify fixed costs
  - Approach requires limited firm-specific heterogeneity
  - Only need data on markets, # entrants
- Analyze local markets for professional services
  - Arguably homogeneous firms: e.g. dentists, plumbers
  - Cross-section of geographically isolated markets

Outline

Simplified Argument

- Firms have fixed costs F, variable profits $\pi(N, S)$
  - N - # firms in market
  - S - market size (population)

  N firms enter if $\pi(N, S) \geq F$ and $\pi(N + 1, S) < F$

- Data on (N, S) for many markets differing only in size
  - Observe entry thresholds $S_1, S_2, ..., S_N, ...$ at which $\pi(N, S_N) = F$
  - $[0, S_1)$: no firms enter; $[S_N, S_{N+1})$: N firms enter

- Entry thresholds evenly spaced: small competitive effects
  - $(S_1, S_2, S_3, ...) = (500, 1000, 1500)$: 500 residents support a firm
  - Variable profits *per customer* – hence markups – constant

- Entry thresholds not evenly spaced: large competitive effects
  - $(S_1, S_2, S_3, ...) = (500, 1500, 3000)$
  - 500 for 1 firm; 750/firm for 2; 1000/firm for 3
  - Profit per customer: 2/3 monopoly; 1/2 monopoly

Model of Entry

- Demand: Q = d(**Z**,P)S(**Y**)
  - $d(\mathbf{Z}, P)$ – "representative consumer"
  - $S(\mathbf{Y})$ – number of consumers

If S doubles, market demand doubles at any fixed price

- Costs
  - F(**W**) – fixed costs
  - AVC(q,**W**) – average variable costs. Assumed "U-shaped"

- Game structure
  1. Firms make entry decisions. If enter, pay F
  2. N entrants compete in product market: (Q_N, P_N)

- Payoffs: entrants split customers evenly. With N entrants:

$$\Pi_N(S) = \underbrace{[P_N - AVC(q_N, \mathbf{W})]d(\mathbf{Z}, P_N)\frac{S}{N}}_{\text{variable profits}} - F$$

Entry Thresholds

- There is a threshold S_N for which $\Pi_N(S_N) = 0$:

$$s_N \equiv \frac{S_N}{N} = \frac{F}{[P_N - AVC(q_N, \mathbf{W})]d(\mathbf{Z}, P_N)}$$

- If s_N rises with N, variable profits (per customer) fall with N
    - Compare s_N to competitive benchmark $s_\infty \equiv \lim_{N\to\infty} s_N$
    - $\frac{s_\infty}{s_N} > 1$ indicates higher variable profits rel. to perfect competition
        - Note: reveals *changes* in competition, not level
    - $\frac{s_{N+1}}{s_N}$ reveals competitive effect of (N+1)-th entrant
    - Key advantage: does not directly depend on P_N, Q_N, AVC

- Requires limited firm- and market-specific heterogeneity:
    - Marginal entrant could have higher fixed/variable costs. More general:

$$\frac{s_N}{s_M} = \frac{V_M}{V_N}\frac{F_N}{F_M}$$

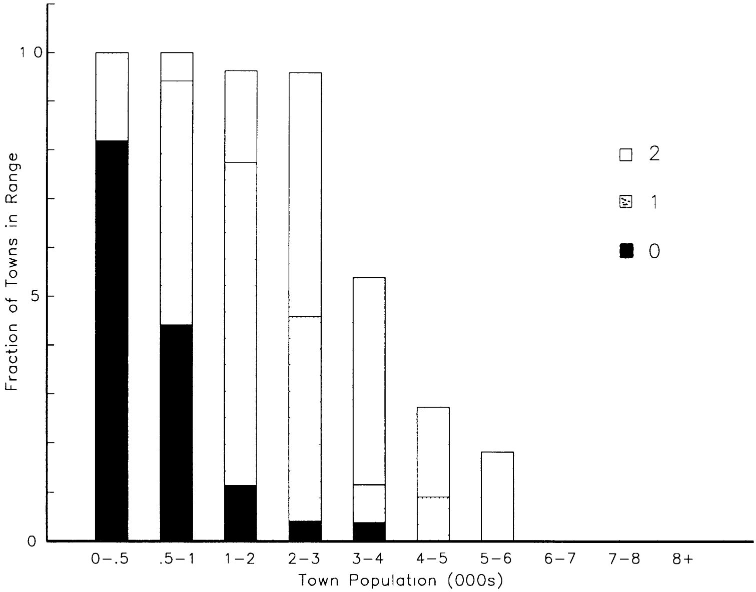
- How is $\frac{s_N}{s_1}$ affected by rising fixed costs (F_N)? Product differentiation? Price discrimination?

Outline

Data

- Empirical strategy requires data on market size (S($\mathbf{Y}$)) and number of firms (N)
- Cross-section of 202 geographically isolated markets
  - Population centers of small U.S. counties
    - Assumption: d($\mathbf{Z}$,P) constant across markets; only S($\mathbf{Y}$) varies
  - Geographically separated from other towns, cities
    - Assumption: can identify all relevant competitors (testable)
- Occupations providing narrowly defined product/service
  - Doctors, dentists, druggists, plumbers, tire dealers
  - Chosen due to sufficient variation in N across markets
  - Manual data collection: phone books, trade info
  - Assumption: homogeneous fixed costs across markets

Entry Thresholds: Dentists



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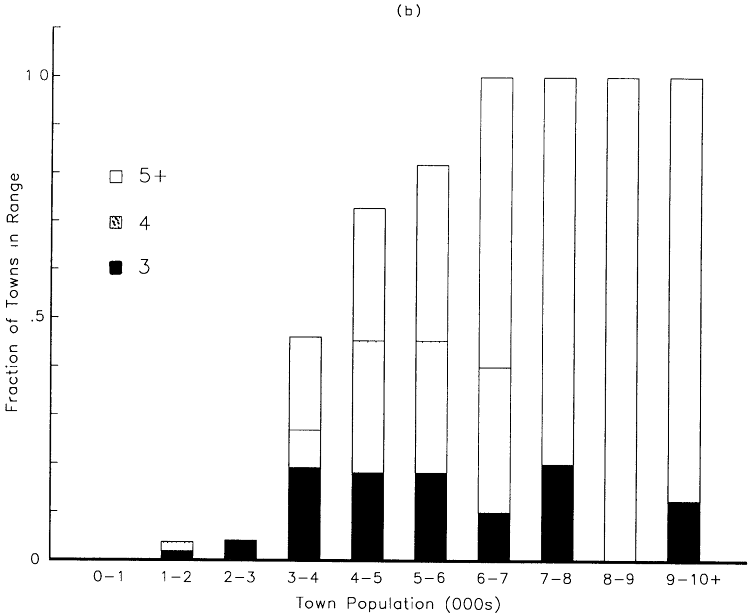


Estimator

- N imperfectly predicted by town population
    - Introduce market-level observed and unobserved heterogeneity:

$$\Pi_N = S(\mathbf{Y}, \lambda) V_N(\mathbf{Z}, \mathbf{W}, \alpha, \beta) - F_N(\mathbf{W}, \gamma) + \epsilon$$

    - In principle, S should enter V_N through q, P. Similar entry threshold estimates when allowed
    - ϵ market-specific, not firm-specific
    - $\epsilon \sim N(0,1) \longrightarrow$ ordered probit for N
- Likelihood function defined by $\bar{\Pi}_N \equiv \Pi_N - \epsilon$:
    - N=0: $Pr(\Pi_1 < 0) = 1 - \Phi(\bar{\Pi}_1)$
    - N=1,2,3,4: $Pr(\Pi_n \geq 0, \Pi_{n+1} < 0) = \Phi(\bar{\Pi}_n) - \Phi(\bar{\Pi}_{n+1})$
    - N≥5: $Pr(\Pi_5 > 0) = \Phi(\bar{\Pi}_5)$

Parameterization

- Market size: $S(\mathbf{Y}, \lambda) = \mathbf{Y}\lambda$
  - Town pop., nearby pop., (+) growth, (-) growth, commuters
  - Normalization wrt town pop.
- Variable profits: $V_N = \alpha_1 + \mathbf{X}\beta - \sum_{n=2}^{N} \alpha_n$
  - $\mathbf{X} = [\mathbf{Z},\mathbf{W}]$: income, demographics from county-level census
  - Robustness: non-linear V_1, α_n vary across markets, S($\mathbf{Y}$) enters V_N
- Fixed costs: $F_N = \gamma_1 + \gamma_L W_L + \sum_{n=2}^{N} \gamma_n$
  - W_L: price of agricultural land
  - Excludes other vars from F_N to distinguish (α_n, γ_n)
  - Limited ability to interpret γ_n

Estimation

- Implementation challenges
  - Demand and cost parameter estimates statistically insignificant
    - "...each specification has too many parameters"
    - Evidence for homogeneity, or measurement/sample size issue?
  - Impose constraints $\alpha_N \geq 0$, $\gamma_N \geq 0$ in estimation
  - Challenges distinguishing α's and γ's
- Present entry thresholds evaluated at mean characteristics:

$$S_N = \frac{\hat{\gamma}_1 + \hat{\gamma}_L \bar{W}_L + \sum_{n=2}^{N} \hat{\gamma}_n}{\hat{\alpha}_1 + \bar{X}\hat{\beta} + \sum_{n=2}^{N} \hat{\alpha}_n}$$

Competitive Effects of Entry

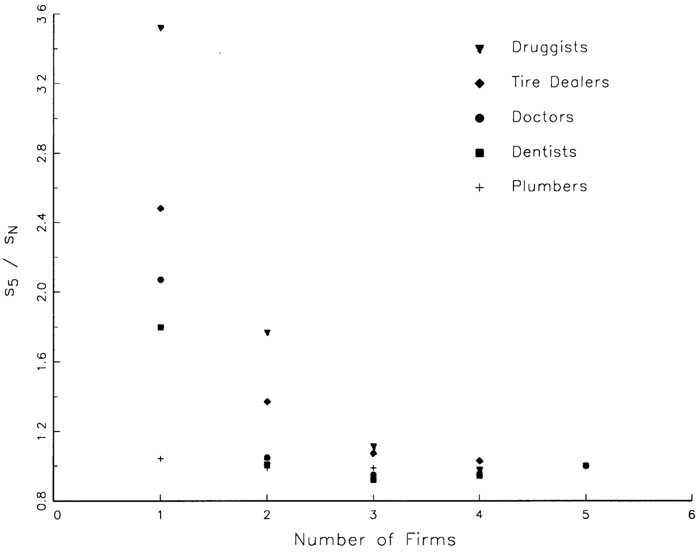


FIG. 4.—Industry ratios of s_5 to s_N by N

Statistical Tests

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)

- Interesting economic conclusions from noisy estimates
    - Competitive effects large for second and third entrant, smaller after

Interpretation of Results

- Authors argue they are estimating changes in variable profits
  - Argue against product differentiation, fixed and variable costs
    - Mostly on a priori grounds
    - Careful sample selection was intended to support this claim
  - Cannot rule out offsetting changes in margins and costs as additional firms enter
- Many robustness checks/tests
  - Tests for differences in fixed costs
  - Market definition – focus on very isolated markets
  - Sensitivity to predictors of variable profits
  - Validation with tire price data
    - Prices consistently above (competitive) urban markets
- What drives differences across industries?
  - Would need additional data to distinguish cost- and demand-side explanations

Outline

Motivation: Adding Firm Heterogeneity

- The 1970s-90s saw deregulation of several U.S. industries
  - Airlines were a major example. Also energy, finance, telecoms
- Civil Aeronautics Board regulated air travel as a public utility
  - Prohibited entry (and exit), high prices set by statue
- How do changes in entry costs affect airline competition?
  - Depends crucially on firm heterogeneity, existing route networks
- Incumbent advantage is a central feature
  - Route *networks*, hub and spoke systems
    - Possible source of product differentiation
  - Airport presence: incumbent airlines may be able to deter entry
- Firm heterogeneity raises new challenges
  - Large number of possible market states
  - Heterogeneity raises possibility of multiple equilibria

Outline

Overview of Approach

- Ideal model of airline networks would have several features
  - Profits depend on airline's own networks, and competitors'
    - State space would include all possible network configurations
  - Explicit model of operating costs, demand, pricing
  - Forward-looking entry and investment decisions
- Berry simplifies in several dimensions:
  - Initial network structure taken as fixed
  - Firms make independent entry decisions across routes
  - Reduced-form model of post-entry profits
  - Static decisions
- Adapt discrete choice methods to learn about profitability from entry decisions
  - Allows for observed and unobserved firm-level heterogeneity
  - Key difference: strategic interactions among firms

Model Setup

Two-stage game in each market (city pair)

- Notation
  - i - market
  - $k \in 1, \ldots, K_i$ - potential entrant in market i
- Game structure
  1. Entry decisions: $s \in \{0,1\}^{K_i}$
  2. Entrants earn profits $\pi_{ik}(s)$
- Pure-strategy Nash equilibrium s^* requires $\forall k = 1, \ldots, K_i$
  - $s_k^* \pi_{ik}(s^*) \geq 0$ (if entered)
  - $(1 - s_k^*)\pi_{ik}(s^{*+k}) \leq 0$ (if didn't enter)
- Existence of PSNE not guaranteed without more structure

Specification of Firm Profits

- The following structure is placed on profits

$$\pi_{ik}(s) = v_i(N(s)) + \phi_{ik}$$

  with $v_i(.)$ strictly decreasing.
  - Does not distinguish fixed costs and variable profits

- Embeds several assumptions
  - Only number of competitors, not identities, affects profits
  - All firms equally sensitive to competition
  - Firms' profitability ranking independent of market structure

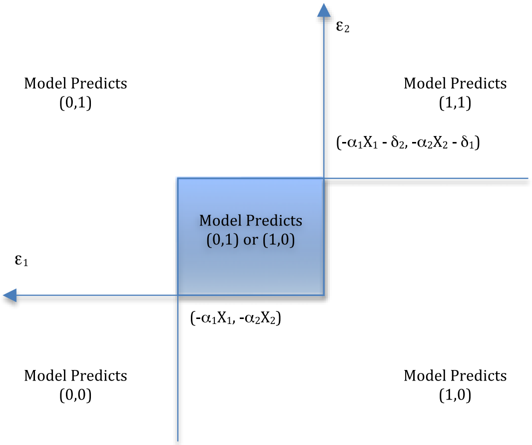
- Yields unique equilibrium in the *number* N^* of entering firms

$$N_i^* = \max_{0 \leq n \leq K_i} \{n : v_i(n) + \phi_{in} \geq 0\}$$

  Identities of entering firms may not be unique

Outline

Computational Challenge



- From Ciliberto & Tamer '09
- Multiple equilibria for same N^* $\longrightarrow$ complex integration region for MLE

Simulation Estimator

- Estimation based on prediction error for N_i:

$$\nu_{i0}(N_i^*, W_i, \theta) = N_i^* - E[N^* \mid W_i, \theta]$$

- Key idea: unbiased estimate of $E[N^* \mid W_i, \theta]$ via simulation:
  - Set of random draws $\hat{u}_i$ in each market $\longrightarrow \hat{N}(W_i, \theta, \hat{u}_i)$ st

$$E_{\hat{u}}[\hat{N}(W_i, \theta, \hat{u}_i)] = E[N^* \mid W_i, \theta]$$

- New estimating equation with draws $\hat{u}_i = (\hat{u}_i^1, ..., \hat{u}_i^T)$:

$$N_i^* = \hat{N}(W_i, \theta, \hat{u}_i) + \hat{\nu}_{i0}$$

$$\hat{N}(W_i, \theta, \hat{u}_i) = \frac{1}{T} \sum_{t=1}^{T} \hat{n}(W_i, \theta, \hat{u}_i^t)$$

  Since $\hat{N}$ is an unbiased estimator of $\bar{N}$, $E[\hat{\nu}_{i0} \mid W_i, \theta_0] = 0$

- In practice, Berry also uses moments based on identities of entering firms
  - Additional assumptions on order of entry $\longrightarrow$ unique PSNE

Econometric Specification

- Competitive effects: $v_i(N) = X_i\beta - \delta \ln(N) + \rho u_{i0}$
  - Could estimate a more general $h(N, \delta)$ specification
  - Microfounded with Cournot competition with constant MC
- Firm heterogeneity: $\phi_{ik} = Z_{ik}\alpha + \sqrt{1-\rho^2}\, u_{ik}$
- Profits are

$$\pi_{ik}(N) = \underbrace{X_i\beta - \delta \ln(N) + Z_{ik}\alpha}_{r_{ik}(N)} + \underbrace{\rho u_{i0} + \sqrt{1-\rho^2}\, u_{ik}}_{\epsilon_{ik}}$$

  - $u_{i0} \overset{iid}{\sim} N(0,1)$, $u_{ik} \overset{iid}{\sim} N(0,1)$
  - ρ^2: within-market correlation of ϵ_{ik} across firms
    - What are the empirical implications of $\rho = 1$? $\rho = 0$? $\delta = 0$?

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$$Z_{ik}\alpha - Z_{ij}\alpha > \delta(\ln(N^*) - \ln(N^* + 1))$$

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    - Variation in *potential* entrants key to identifying δ

Outline

Data and Sample

- *Origin and Destination Survey of Air Passenger Traffic*
  - 10% random sample of issued U.S. airline passenger tickets
  - Aggregates by airline: counts of travelers by (origin,destination)
  - Microdata contains price information, which are ignored
- Sample:
  - Routes connecting 50 largest U.S. cities (1225 city pairs)
  - Two periods: Q1 and Q3, 1980
    - Long enough to plan and execute entry
    - Short enough to abstract from long-run dynamics
    - Initial airport presence in Q1 used to predict Q3 entry
  - Market definition: an (origin,destination) city pair, non-stop or not
    - Airlines make binary decision to serve a route
    - Entry decisions independent across routes
    - Must serve at least 90 (sampled) passengers in a quarter

Fact 1: Simultaneous Entry and Exit in a Market

TABLE I

THE JOINT FREQUENCY DISTRIBUTION OF ENTRY AND EXIT, IN PERCENT OF TOTAL MARKETS SERVED

		Number of Exits, as % of Total Markets in the Sample: 0	1	2	3 +	Total
Number of Entrants (as %)	0	68.50	10.01	1.07	0.00	79.57
	1	15.09	2.63	0.41	0.00	18.13
	2	1.96	0.25	0.00	0.00	2.05
	3 +	0.16	0.08	0.00	0.00	0.24
	Total	85.56	12.96	1.48	0.00	100.00

- Entry and exit positively correlated in a market

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- Entry and exit positively correlated in a market
- Consistent with firm-level heterogeneity

Fact 2: Simultaneous Entry and Exit by an Airline

TABLE II

NUMBER AND PERCENTAGE OF MARKETS ENTERED AND EXITED IN THE LARGE CITY SAMPLE, BY AIRLINE

	Airline	# of Markets Served	# of Markets Entered	# of Markets Exited	% of Markets Entered	% of Markets Exited
1	Delta	281	43	28	15.3	10.0
2	Eastern	257	33	36	12.8	14.0
3	United	231	36	10	15.6	4.3
4	American	207	22	12	10.6	5.8
5	USAir	201	20	17	10.0	8.5
6	TWA	174	22	23	12.6	13.2
7	Braniff	112	10	20	8.9	17.9
8	Northwest	75	6	7	8.0	9.3
9	Republic	69	9	6	13.0	8.7

- Airlines not systematically expanding/contracting

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- Airlines not systematically expanding/contracting
  - Consistent with firm-market-specific heterogeneity

Fact 3: Entry into Cities Already Served

TABLE III

NUMBER OF POTENTIAL ENTRANTS, BY NUMBER OF CITIES SERVED WITHIN A CITY PAIR, WITH NUMBER AND PERCENTAGE ENTERING

Number of Cities Served	Total # of Potential Entrants	# Entering	% Entering
0	47600	4	0.01%
1	12650	45	0.36
2	3590	232	6.46

- Entering firms already serve at least one city in pair
- Motivates definition of potential entrants
- What about market size?

Correlates of # Firms in Market

TABLE IV

REGRESSION RESULTS FOR NUMBER OF FIRMS

Var	Est Parm (Std. Error)	Mean Value of Var. (Std. Dev.)
N		1.629
		(1.393)
Const	−0.727	—
	(0.097)	
Pop	2.729	0.558
	(0.255)	(0.114)
Dist	−1.591	1.149
	(0.827)	(0.093)
Dist^2	0.337	0.022
	(1.850)	(0.039)
Tourist	0.134	0.116
	(0.089)	(0.320)
City $N2$	0.338	4.574
	(0.011)	(2.684)
City $N+$	0.084	10.377
	(0.009)	(3.656)

R-squared is: 0.612

Maximum Likelihood Estimates

MAXIMUM LIKELIHOOD RESULTS[a]

Variable	No Heterogeneity	Only Observed Heterogeneity	No Correlation
Constant	1.00	−0.973	−1.54
	(0.056)	(0.485)	(0.815)
Population	4.33	4.16	4.32
	(0.102)	(0.180)	(0.059)
Dist	−0.184	−0.841	−0.903
	(0.034)	(0.070)	(0.112)
City2	—	1.68	1.43
		(0.479)	(0.524)
City share	—	1.20	−2.94
		(0.118)	(0.070)
δ	1.81	1.66	0.252
	(0.050)	(0.470)	(1.92)
−2 log-likelihood:	3715	3619	1732

[a]Observations are 1219 markets. Standard errors are in parentheses.

- Zero-probability events occur frequently for $\rho = 1$
- Wacky results for No Correlation ($\rho = 0$)

Implementation of MSM Estimator

- Two assumptions on order of entry
  1. Most profitable firm moves first
  2. Firms ordered by incumbency, then profitability
- Is assuming an order of entry necessary?
  - In principle, could base estimation on N^* alone
  - Berry adds moments of whether leading firms enter
- Moments based on conditional mean-zero prediction error in
  - Number of firms in the market
  - Probability of entry for each of four firms with highest "City Share"

Simulation-Based Estimates

SIMULATION ESTIMATES[a]

Variable	Most Profitable Move First	Incumbents Move First
Constant	−5.32	−3.20
	(0.354)	(0.258)
Population	1.36	5.28
	(0.239)	(0.343)
Dist	1.72	−1.45
	(0.265)	(0.401)
City2	4.89	5.91
	(0.295)	(0.149)
City Share	4.73	5.41
	(0.449)	(0.206)
δ	0.527	4.90
	(0.119)	(0.206)
ρ	0.802	0.050
	(0.105)	(0.048)
Value of the objective fn:	33.3	26.2

- Order-of-entry assumption matters
- What might explain these differences?
- How might one decide which specification is preferable?

Prediction and Policy

Predictions from the Models
Actual Mean Number of Firms: 1.629

		Predicted Mean Number of Firms		
		Probit	No Heterogeneity (Ordered Probit)	Full Model
1.	Actual exog. data	1.326	1.887	1.699
2.	.5 Mil. popl. increase	10.78	2.308	1.809
3.	500 extra miles dist.	0.6710	1.770	1.406
4.	All entrants "Well-Qual"	2.724	—	2.045
5.	All firms "Well-Qual"	6.334	—	2.080
6.	10% incr. in City Shr	2.178	—	1.697
		% Correctly Predicted Entrants		
7.		90.29	—	92.75
		Mean Squared Error in the Prediction of N:		
8.		1.257	2.072	1.299

Parting Remarks

- Early advances dealt with
  - Simultaneity of market structure and profitability
  - Firm-level heterogeneity
- Limitations of these early papers include
  - Multiple equilibria $\rightarrow$ parametric assumptions, equilibrium selection
  - Lack of data on (P,Q), costs $\rightarrow$ reduced-form models of profits
    - Limited ability to perform counterfactuals
    - Efficiency, profits, consumer surplus
  - Cross-sectional analysis
- Where we're going next:
  - Can we move away from equilibrium selection (next week)?
  - Welfare analysis and endogenous product characteristics
    - Structural model of post-entry profits: Berry & Waldfogel '99
    - Firm differentiation: Mazzeo '03, Seim '06, Wollman '18
  - What determined the initial market state? (dynamics)

Next Time

- Ciliberto & Tamer, ECMA 2009 (***)
- Tamer, ReStud 2003 (*)
- Chernozhukov, Hong, & Tamer, ECMA 2007 (*)