The Dynamics of Retail Oligopoly

Arie Beresteanu[1] Paul B. Ellickson[2]

[1]Department of Economics
Duke University

[2]Department of Economics
Duke University

May 2007

Motivation: Retail Landscape

- Retail industries are major part of U.S. economy
- They are increasingly dominated by "big box" chains
  - Efficient & low cost, but concentrated...
- Retailers present several challenges for empirical work
  - Sell a vast array of differentiated products
  - Operate multiple stores in multiple locations in multiple markets
  - Evolve incrementally with population growth

Application: Supermarkets

- We focus on supermarkets
  - Sell a reasonably well-defined basket of goods
  - Mostly regional in scope
  - Arguably not so spatially differentiated
  - Compete in "natural oligopolies"
- Supermarket industry has always been dominated by "big box" chains
  - Constant tension between "big/far" and "small/close"
  - Facing entry by "bigger box" chains: supercenters

A Dynamic Model of Retail

- Propose a dynamic structural model of retail competition in which
  1. firms are chains with multiple stores
  2. market structure & chain size evolves over time
  3. firms are one of two "types"
  4. firms compete in "store density"
- We've constructed an 11 year panel of
  - characteristics & market shares of all the major chains
  - prices for a small subset
- We then
  1. estimate a dynamic model of supermarket competition
  2. evaluate policies aimed at eliminating Supercenters or increasing their costs

A Dynamic Model of Retail

- Basic idea: Propose Ericson/Pakes (EP) style dynamic oligopoly model that includes
  - Differentiated products (SM chains in MSAs)
  - Simultaneous entry & exit
  - Continuous & incremental investment/de-investment
  - Firm specific cost/profit shocks
  - Population growth
- Estimate using recently developed "two-step" techniques
  - Traditional methods (e.g. NFXP algorithm) infeasible

Model Setup

- **Chain** level competition in MSAs
- **Discrete** time with an **infinite** horizon
- M geographic markets ($m = 1, .., M$), each with N_m firms
- Two **types** of players
  - Conventional supermarkets (SM)
  - Supercenters (SC)
- Two **potential entrants** in each period (one of each type)

State Space

- Each chain is characterized by three state variables
  1. Number of stores per capita (may change over time)
  2. Type (fixed over time)
  3. Perceived quality (fixed over time)
- State in period t is $s_t \in S$.
- Firms choose entry, exit & investment actions, $a_t \in A$
- Given s_t, firm i's expected future profits are

$$E\left[\sum_{\tau=t}^{T} \beta_r^{\tau-t} \pi_i\left(a_\tau, s_\tau, \nu_{i\tau}\right) \mid s_t\right]$$

Markov Perfect Equilibrium

- Focus on pure strategy MPE & assume uniqueness (in data)
- Given β_r & σ, value function of firm i is

$$V_i\left(s|\sigma\right)=E_\nu\left[\pi_i\left(\sigma\left(s,\nu\right),s,\nu_i\right)+\beta_r\int V_i\left(s'|\sigma\right)dP\left(s'|\sigma\left(s,\nu\right),s\right)|s\right]$$

- Strategy profile σ is an MPE if

$$V_i\left(s|\sigma\right)\geq V_i\left(s|\sigma_i',\sigma_{-i}\right) \tag{1}$$

for any σ_i' and all s, i

- These inequalities (1) are the basis of estimation

Two-Step Estimation Strategy

- Estimation strategy follows Bajari, Benkard and Levin (07)
- The model is estimated in two steps
- First step
  - Estimate demand and cost parameters governing per-period payoffs
  - Estimate policy functions governing the transition between states
- Second step
  - Recover the (dynamic) parameters of the cost function using the first step estimates and the MPE condition (1) above

Data: Summary Statistics

558 firms, 11 years, an average of just over 5 firms in 276 MSAs.

	Format	
	Supercenter	Supermarket
Store Size	65.9 (26.08)	36.4 (14.98)
Checkouts	29.8 (6.73)	10.2 (3.95)
Stores per Market	3.15 (4.49)	11.1 (24.1)
Market Share	15.4 (11.4)	17.5 (13.8)
Basket Price	81.75 (6.28)	95.46 (9.88)
Firms per MSA	.70 (.64)	4.38 (1.42)

Store size is in 1000s of square feet.

- **Entry Rate:** .049 **Exit Rate:** .040 (Firms last about 25 years)
- **Store Opening Rate:** .038 **Store Closure Rate:** .026 (Stores last about 39 years)

Step 1: Product Market Competition

- Goal: Treating supermarket firms as differentiated products, estimate a discrete choice demand system & recover per-period payoffs
- Firm characteristics $x_{jt} = (d_{jt}, type_j)$ are store density & firm type
- Estimate demand parameters using "Berry logit" (IV)

$$\ln(\frac{\mathcal{S}_{jt}}{\mathcal{S}_{0t}}) = x_{jt}\beta - \alpha p_{jt} + \xi_j + \Delta\xi_{jt} \tag{2}$$

- Outside good: total sales in other retail food & beverage stores
- Back out mc and π, use to construct per period payoffs

Results from Demand Estimation

	Constant	Stores/Pop	SuperC	Price
	.906 (.107)	4.99 (.057)	.250 (.038)	$-.041$ (.001)
R-squared	0.43			
First Stage F-statistic	34.7			
Number of Observations	15371			
Number of Firms	1896			
Estimated Gross Margin	.306 (.054)			

Standard Errors in parentheses.

- All coefficients are significant, with **expected signs**
- All firms price on **elastic** portion of demand curve
- Predicted margins in line with industry estimates
- Basic welfare calculation: eliminating Supercenters reduces household CS by $174 per year

Step 1 (Part 2): Policy Function Estimation

- Purpose: Estimate policy functions that govern state transitions
- Intuition: Describe what firms actually do at each state
    - Estimate entry & exit policies with probits
    - Estimate investment policies with ordered probits
- Parameter estimates are intuitive & sensible

Policy Function Estimates

	Exit Probit	Entry Probit	Entrants Investment	Incumbents Investment
Dependent Variable	$P(exit \mid X)$	$P(entry \mid X)$	$Store'_j$	$Store'_j$
Own Store Density (d_j)	-2.81 (.234)			$-.633$ (.081)
Rival Store Density $(\bar{d}_{-j})$	.795 (.367)	.456 (.552)	$-.393$ (1.12)	-1.46 (.182)
Supercenters (N^{SC})	.073 (.037)	$-.227$ (.055)	.142 (.110)	$-.081$ (.020)
Supermarkets (N^{SM})	.071 (.018)	.057 (.026)	$-.082$ (.054)	$-.060$ (.009)
Own Quality (ξ_j)	$-.254$ (.037)			.177 (.019)
Rival's Quality $(\bar{\xi}_{-j})$	.089 (.061)	$-.068$ (.084)	$-.330$ (.170)	$-.359$ (.031)
Population Growth	-8.97 (2.12)	-14.82 (3.07)	12.45 (6.41)	13.5 (1.06)
Constant	7.26 (2.15)	13.77 (3.09)		
Pseudo R^2	.072	.026	.015	.017
Log Likelihood	-2190.3	-1174.7	-509.6	-12798.5
Observations	12250	2811	432	11328

Standard errors in parentheses.

Policy Function Estimates

	Exit Probit	Entry Probit	Entrants Investment	Incumbents Investment
Dependent Variable	$P(exit \mid X)$	$P(entry \mid X)$	$Store'_j$	$Store'_j$
Own Store Density (d_j)	-2.45 (3.45)			-3.92 (.986)
Rival Store Density ($\bar{d}_{-j}$)	1.96 (1.67)	$-.294$ (.700)	-2.08 (2.17)	-1.73 (.592)
Supercenters (N^{SC})	.792 (.175)	$-.947$ (.091)	.192 (.262)	$-.720$ (.082)
Supermarkets (N^{SM})	$-.018$ (.091)	$-.071$ (.036)	$-.002$ (.099)	$-.113$ (.032)
Own Quality (ξ_j)	$-.073$ (.244)			$-.483$ (.088)
Rival's Quality ($\bar{\xi}_{-j}$)	.521 (.319)	$-.604$ (.113)	$-.008$ (.336)	$-.346$ (.111)
Population Growth	5.38 (9.44)	3.23 (3.64)	32.3 (9.13)	21.6 (3.40)
Constant	-9.02 (9.73)	-3.95 (3.67)		
Pseudo R^2	.131	.117	.071	.190
Log Likelihood	-106.6	-615.7	-108.4	-1251.8
Observations	1770	2760	192	1534

Standard errors in parentheses.

Policy Function Estimates

- Exit
  - Firms less likely to exit if high store density or high quality, more likely to exit if they have more or higher quality rivals
- Entry
  - Regular supermarkets more likely to enter markets with fewer SCs but more SMs, less likely in growing markets
  - Supercenters less likely to enter markets with more and higher quality firms
- Investment
  - Entrants invest more in growing markets, less with more/better rivals
  - Incumbents invest more in growing markets, less with more/better rivals

Step 2: Recover Investment Costs & Exit Values

Basic Idea

- Use forward simulation to estimate value functions (as functions of investment parameters) for paths of s_t implied by step 1 policy functions
- Find parameter vector that makes observed policies optimal (given structure of MPE)

Step 2: Simulation

- Assuming profits linear in parameters θ, re-write MPE condition

$$V\left(s|\sigma_i,\sigma_{-i};\theta\right) \geq V\left(s|\sigma_i',\sigma_{-i};\theta\right)$$

  as

$$W\left(s;\sigma_i,\sigma_{-i}\right)\cdot\theta \geq W\left(s;\sigma_i',\sigma_{-i}\right)\cdot\theta$$

- Simulate $W\left(\cdot\right)$ for many parallel paths
- Find the θ that minimizes the profitable deviations

$$g(x,\theta) = \left[W\left(s;\sigma_i',\sigma_{-i}\right) - W\left(s;\sigma_i,\sigma_{-i}\right)\right]\cdot\theta$$

  using a MD estimator (computed via MCMC)
- Compute entry costs using a separate procedure

Step 2: Simulations

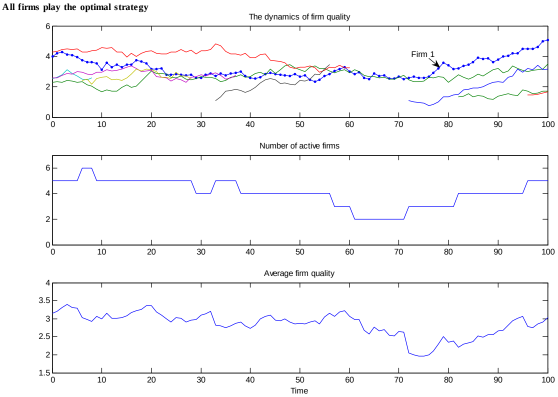

Figure 1: Simulation where all firms follow σ

Step 2: Simulations

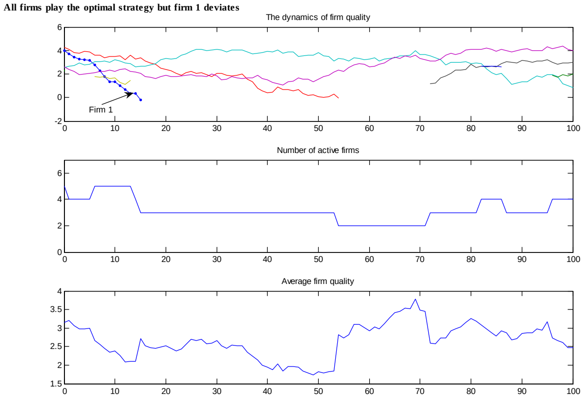

Figure 2: Simulation where firm 1 deviates

Cost Parameters

Table 4: Investment costs and exit values

	Supermarkets	Supercenters
Exit Value (EXIT)	58.03	91.78
MC of Positive Investment (ϕ_0)	-87.83	-190.14
MC^2 of Positive Investment (ϕ_1)	4.70	1.10
MC of Negative Investment (γ_0)	73.68	124.77
MC^2 of Negative Investment (γ_1)	-16.51	

Future Tasks

- Estimation
  - Finalize investment parameters and estimate distribution of entry costs
- Simulation/Policy Experiments
  - Use PM algorithm to solve for equilibria with & without supercenters
  - Compare welfare under both regimes

Conclusions

- We provide a simple model of dynamic oligopoly that incorporates many important features of retail competition
    - Firms are differentiated & operate many stores
    - Firms make optimal entry, exit, and investment decisions, conditioning on the actions of their rivals
    - Markets grow over time
- We estimate this model using data from the supermarket industry
- Initial parameter estimates seem reasonable
- There is still much work to do on the estimations and simulations