Structural Econometrics in Industrial Organization: Demand

Marc Rysman

Boston University

February 13, 2009

What is a structural model?

Definition 1

A structural model estimates the parameters in a theoretical model.

Definition 2

A structural model estimates the parameters in the objection function of agents.

Consider a theoretical model with 2 equilibria, where equ. 1 is selected with prob. θ. Estimating θ is structural under Def. 1 but not Def. 2.

Why estimate a structural model

- Construct counterfactuals
- Provides a disciplined method for handling complex situations
- But usually requires many assumptions
- and can be numerically demanding.

Why do we estimate demand?

- Learn price elasticities
- Learn elasticities to other product characteristics
- Learn value of new goods
    - construct price indices

Why estimate with aggregate data?

- Disaggregate data
  - Observe actual prices, outside options
  - Account for interaction of household and product characteristics explicitly
  - Panel data allows for rich models of learning, stockpiling, switching, etc.
- Aggregate data
  - Often all that is available
  - Necessary for accurate market share data, which is important for oligopoly analysis

Standard Approach

Or at least, standard at one time

Let indirect utility over J products be:

$$ln(V) = \sum_{j=1}^{J} \beta_j \ln(P_j) + \sum_{j=1}^{J} \sum_{k=1}^{J} \frac{\beta_{jk}}{2} \ln(P_j) \ln(P_k)$$

Roy's Identity: $\partial \ln(V) / \partial \ln(P_j) = X_j \Rightarrow$

$$X_j = \beta_j + \beta_{jj} \ln(P_j) + \sum_{k \neq j}^{J} \frac{1}{2} \beta_{jk} \ln(P_k)$$

- Read elasticities right off of regression

Problems

1. Problems with many products
   - $J \times J + 1$ parameters
2. Doesn't handle entry and exit well
   - What does it mean to drop a product?
     $p = \infty$? $p =$choke value?
3. Doesn't look like a discrete choice model

Discrete Choice Model

Can solve all 3

- Think of goods as a collection of characteristics.
  - We can project lots of goods onto a space of only a few chars.
- Model: Utility to *i* from product *j* is:

$$u_{ij} = u_j + \epsilon_{ij}$$

- Consumer picks *j* s.t. $u_{ij} \geq u_{ik} \forall k$
- u_j is a function of observable variables. In disaggregate data, it could vary by *i*.

Logit model

- Assume $\epsilon_{ij} \sim$ Extreme Value
- CDF for Extreme Value distribution with mean α and variance $\pi^2\mu^2/6$ is:

$$F(\epsilon) = e^{-e^{-\left(\frac{\epsilon-\alpha}{\mu}+\gamma\right)}}$$

  where γ is euler's constant.
- Has bell shape with fat tails
- Logit magic: probability that *i* picks *j*:

$$P_j = \frac{e^{u_j/\mu}}{\sum_k e^{u_k/\mu}}$$

- Proof: Chapter 2, Anderson, De Palma and Thisse

Welfare

More logit magic!

- Indirect utility to i is $V + \epsilon_i'$ where:

$$V = \mu \ln \left(\sum_{j=1}^{J} e^{u_j/\mu} \right)$$

  and ϵ_i' is distributed EV with variance parameter μ
- Note similarity to CES utility function:

$$e^V = \sum_{j=1}^{J} \left((e^{u_1})^{1/\mu} + (e^{u_1})^{1/\mu} + \dots \right)^{\mu}$$

- Entry and exit handled naturally.

Application to aggregate data

- Let utility to consumer i from product j be:

$$u_{ij} = \underbrace{x_j\beta - \alpha p_j + \xi_j}_{\delta_j} + \epsilon_{ij}$$

- Assume our population contains a continuum of consumers with $\epsilon_{ij} \sim \mathtt{EV}$.
- Market shares:

$$s_j = \frac{\exp(\delta_j)}{1 + \sum_{k=1}^{J} \exp(\delta_j)}$$

Berry (RAND, 1994)

$$s_j = \frac{\exp(\delta_j)}{1 + \sum_{k=1}^{J} \exp(\delta_j)} \qquad s_0 = \frac{1}{1 + \sum_{k=1}^{J} \exp(\delta_j)}$$

$$\Rightarrow \frac{s_j}{s_0} = \delta_j$$

$$\Rightarrow \ln(s_j) - \ln(s_0) = x_j\beta - \alpha p_j + \xi_j$$

- Estimate via OLS, linear IV
- Note that there is a general principal at work – inverting market shares to get mean utilities.

What's not to like about Logit?

Relative market shares do not depend on characteristics or presence of other goods

Independence of Irrelevant Alternatives (IIA)

$$\frac{s_j}{s_k} = \frac{e^{u_j}}{e^{u_k}}$$

$$\frac{\partial s_j}{\partial p_k} = -s_j s_k \beta_p$$

Random Coefficient model

$$u_{ij} = x_j\beta_i - \alpha_i p_j + \xi_j + \epsilon_{ij}$$

$$u_{ij} = \underbrace{x_j\beta - \alpha p_j + \xi_j}_{\delta_j} + \underbrace{\sum_{l=1}^{L} \sigma_l x_{jl}\nu_{il}}_{\mu(x_j,\sigma,\nu_i)} + \epsilon_{ij}$$

- Dimensionality of x_j is L.
- $\nu_i \sim \mathbb{N}(0, 1)$.

Market shares

$$s_{ij} = \frac{\exp\left(\delta_j + \mu(x_j, \sigma, \nu_i)\right)}{1 = \sum_{k=1}^{J} \exp\left(\delta_k + \mu(x_k, \sigma, \nu_i)\right)}$$

$$s_j = \int s_{ij}\left(\overrightarrow{\delta}, \mu_i\right) f(\nu_i) d\nu_i$$

With logit:

- s_j had a closed form solution as function of $\overrightarrow{\delta}$
- AND the function could be inverted.

Solutions

1. Numerically integrate:
   - Draw *ns* values of ν_i
   - Compute:

$$s_j = \frac{1}{ns} \sum_{i=1}^{ns} \frac{\exp\left(\delta_j + \mu(x_j, \sigma, \nu_i)\right)}{1 + \sum_{k=1}^{J} \exp\left(\delta_k + \mu(x_k, \sigma, \nu_i)\right)}$$

2. Invert via a fixed point equation:

$$\delta_j' = \delta_j + \underbrace{\ln(s_j)}_{data} - \underbrace{\ln(\hat{s}_j(\overrightarrow{\delta}, \sigma))}_{model}$$

Full Algorithm

1. Draw a set of ν_i
2. Pick parameters β, α, σ
3. Guess $\overrightarrow{\delta}$
4. Compute $\delta' = \delta + \ln(s_j) - \ln(\hat{s}_j(\overrightarrow{\delta}, \sigma))$
5. If $d(\overrightarrow{\delta}', \overrightarrow{\delta}) > \texttt{cutoff}$, go to 3.
6. Compute $\xi_j = \delta_j - x_j\beta + \alpha p_j$
7. Compute $m = z'\xi$ and $\texttt{obj} = m'wm$
8. Find β,α,σ that minimizes `obj`, go to 2.

Instruments

- Cost shifters don't provide enough variation across products.
- but remember: $P = MC + \mathtt{Mark} - \mathtt{up}$
- Use instruments that shift the mark-up.
- Measures of competition in product space.
- Requires assumption that characteristics are exogenous – Controversial!

Supply Side

- Older research used accounting data to measure cost but the modern view is that accounting data is unreliable.
- Instead, we estimate marginal cost.
- We can use the demand system and an assumption about equilibrium play (i.e. Bertrand Nash) to compute marginal revenue and assume it is equal to marginal cost.
- Firm f that sells all products $j \in \mathfrak{F}_f$ solves:

$$\max_{p_j, j \in \mathfrak{F}_f} \sum_{j \in \mathfrak{F}_f} (p_j - mc_j) M s_j(\overrightarrow{p})$$

$$\Rightarrow s_j + \sum_{k \in \mathfrak{F}_f} (p_k - mc_k) \frac{\partial s_k}{\partial p_j} = 0$$

Estimate marginal cost

- In matrix notation:

$$\begin{aligned} \overrightarrow{s} + \Delta(\overrightarrow{p} - \overrightarrow{mc}) &= 0 \\ \overrightarrow{p} + \Delta^{-1}\overrightarrow{s} &= \overrightarrow{mc} \\ \ln\left(\overrightarrow{p} + \Delta^{-1}\overrightarrow{s}\right) &= w\gamma + \omega \end{aligned}$$

- Now moments are:

$$m = \begin{bmatrix} z'\xi & z'\omega \end{bmatrix}$$

- Some papers add moment from dissagregate data sets at this stage, for instance, the average income conditional on purchase (Petrin, JPE, 2002).

Application: Berry, Levinsohn, Pakes (AER, 1999)

- What is the impact of Japanese voluntary export restraints?
- Japanese auto manufacturers obtained increasing markets shares in the US throughout the 1970’s.
- US firms ask for protection and Reagan “asked” Japan to institute “voluntary export restraints."

Sales and VER limits

TABLE 1—U.S. AUTOMOBILE IMPORTS FROM JAPAN

Year	International Trade Commission data U.S. imports from Japan including Puerto Rico	VER limit	Difference (Imports-VER)
1981	1,833,313	1,832,500[a]	813
1982	1,831,198	1,832,500	−1,302
1983	1,851,694	1,832,500	19,194
1984	2,031,250	2,016,000[b]	15,250
1985	2,605,407	2,506,000[c]	99,407
1986	2,518,707	2,506,000	12,707
1987	2,377,383	2,506,000	−128,617
1988	2,115,304	2,506,000	−390,696
1989	2,015,920	2,506,000	−490,080
1990	1,911,828	2,506,000	−594,172

Sources: The ITC figures are for “VER years” which ran

Hedonic regression

TABLE 4—A FIRST PASS AT EXAMINING THE EFFECT OF THE VER ON AUTOMOBILE PRICES
AN ORDINARY LEAST-SQUARES HEDONIC REGRESSION
[DEPENDENT VARIABLE IS LN(PRICE)]

Variable	Parameter estimater	Standard error
Constant	2.248	0.044
ln(HP/Weight)	0.593	0.027
ln(Space)	1.038	0.056
ln(MP$)	−0.312	0.035
Air	0.479	0.015
Trend	0.021	0.004
Japan	2.358	2.945
Euro	2.357	0.436
jtrend	−0.006	0.018
etrend	−0.018	0.005
ln(e-rate)	−0.272	0.091
Lag[ln(e-rate)]	0.258	0.089
ln(e-rate)*Japan	0.295	0.300
ln(e-rate)*Euro	0.374	0.070
VER80	−0.199	0.078
VER81	−0.155	0.083
VER82	−0.156	0.114
VER83	−0.099	0.121
VER84	−0.148	0.135
VER85	−0.149	0.151
VER86	−0.120	0.115
VER87	−0.122	0.118
VER88	−0.191	0.129
VER89	−0.257	0.137
VER90	−0.280	0.150
DOM80	−0.056	0.037
DOM81	0.018	0.039
DOM82	0.112	0.041
DOM83	0.130	0.043
DOM84	0.109	0.048
DOM85	0.076	0.050
DOM86	0.216	0.057
DOM87	0.171	0.060
DOM88	0.164	0.065
DOM89	0.111	0.069
DOM90	0.063	0.073

Note: The regression had 2,217 observations and an R^2 of 0.815.

Model

- Treat VER as a type of cost, constraining firms to set $MR > MC$.

$$\Rightarrow s_j + \sum_{k \in \mathfrak{F}_f} (p_k - mc_k - \lambda_t \mathrm{VER}_t) \frac{\partial s_k}{\partial p_j} = 0$$

- Intuition: Do J firms set prices at a point where MR is relatively higher than US firms?

Main results

Table 5—Estimated Parameters of the Demand and Pricing Equations: Base Case Specification 1971–1990 Data, 2,217 Observations

	Variable	Parameter estimate	Standard error
Demand-side parameters			
Means ($\bar{\beta}$'s)	Constant	−5.901	0.712
	HP/Weight	2.946	0.486
	Size	3.430	0.342
	Air	0.934	0.199
	MP$	0.202	0.084
Standard deviations (σ_β's)	Constant	1.112	1.171
	HP/Weight	0.167	4.652
	Size	1.392	0.707
	Air	0.377	0.886
	MP$	0.416	0.132
Term on price (α)			
	($-p/y$)	44.794	4.541
Cost-side parameters			
	Constant	0.035	0.310
	ln(HP/Weight)	0.604	0.063
	ln(Size)	1.291	0.106
	Air	0.484	0.043
	Trend	0.018	0.004
	Japan	3.255	0.667
	Japan*trend	−0.036	0.008
	Euro	3.205	0.525
	Euro*trend	−0.032	0.006
	lag[ln(e-rate)]	0.026	0.024
	ln(wage)	0.356	0.079
VER dummies			
	VER81	−0.085	0.187
	VER82	−0.022	0.228
	VER83	0.001	0.248
	VER84	0.403	0.245
	VER85	0.361	0.303
	VER86	0.675	0.307
	VER87	1.558	0.353
	VER88	1.490	0.379
	VER89	1.277	0.458
	VER90	1.063	0.469

Simulations

- VER causes J prices to climb substantially, US prices only a bit.
  - Price sensitive consumers are the ones that switch.
- VER causes J profits to go up.
  - VER implements the collusive outcome
- CS down 13 mil, profits up 10mil, total loss 3 mil
  - But standard error is 7.5mil.
  - Should use a tariff?