Benkard—"A Dynamic Analysis of the Market for Wide-Bodied Commercial Aircraft"

- Background about industry
- A word about strategic trade literature

Model

- $t = \{1, 2, ...\}$

- Three state variables for firm j

—$E_{j,t}$ experince

—μ_j type (small, medium, large)

—$\xi_{j,t}$ quality

- Aggregate state M_t aggregate demand

- s state of industry (includes state of individual firms)

- 2 stages in a period

—Stage 1: Exit decision $\chi_j \in \{0, 1\}$, scrap value ϕ_j,

—Stage 2: Production and Entry (but entry is mechanical so ignore here)

- Markov perfect equilibrium

$$
\begin{aligned}
v(j, s, M) &= \max_{\chi_j, q_j} \chi_j \phi_j + (1 - \chi_j)\pi_j(s, q, M) \\
&\quad + \beta \sum_{s', M'} v(s', M') P(s', M' | s, M, q, \chi)
\end{aligned}
$$

- Restricts attention to symmetric MPE

—Has bite in this context

Technology

$$\ln L_{lt} = \ln A + \theta \ln E_t + \gamma \ln S_t + \varepsilon_{lt}$$

- l unit (plane
- L_{lt} is labor input
- A constant
- E_t experience
- S_t line-speed

- Learning by doing with forgetting

$$E_{t+1} = \delta E_t + q_t$$

- $\hat{\delta} = .61$, $\hat{\theta} = -.63$. Double experience, cost falls 36 percent.

Discretize

$$E_t \in \{1, 10, 20, 40, 70, 110, 165\}$$

Stochastic. Let E^*_{t+1} be future experience according to formula. Then

$$E_{t+1} = \begin{array}{c} E_u \text{ with prob} \frac{E^*_{t+1} - E_d}{E_u - E_d} \\ E_d \text{ with prob } 1 - \frac{E^*_{t+1} - E_d}{E_u - E_d} \end{array}$$

Demand—Background

- Start with simple logit demand

$$u_{ij} = X_j\beta + \xi_j - \alpha p_j + \varepsilon_{ij}$$

- Consumer picks choice $j^* = \arg\max_j u_{ij}$

- Define

$$\delta_j = X_j\beta + \xi_j - \alpha p_j$$

- Assume ε_{ij} is extreme value distribution ("double exponential" "Gumbel" $F(\varepsilon) = e^{-e^{-\varepsilon}}$). Then

$$s_j = \frac{e^{\delta_j}}{\sum_{k=0}^{J} e^{\delta_k}}$$

Equilibrium in the Pricing Subgame

- Have demands $s_j(p_1, ...p_J\ )$
- Firms compete in prices in Bertrand fashion. Profit is
$$\pi(p_j, p_{-j}) = \left(p_j - c_j\right) s_j(p_1, ...p_J\ )$$
FONC
$$s_j(p) + \left(p_j - c_j\right) \frac{\partial s_j(p)}{p_j} = 0,\ j = 1, ...J$$
- Caplin-Nalebuff (1991). Prove there exists a unique equilibrium.
- Straightforward to calculate on the computer.

Two Issues: (1) Unobservable Quality

$$u_{ij} = X_j\beta + \xi_j - \alpha p_j + \varepsilon_{ij}$$

- Solve for $\delta_j(s)$

$$\ln s_j - \ln s_0 = \delta_j - \delta_0$$

  Normalize things for the outside good to 0 so $\delta_0 = 0$. Done

- Assume large number of purchase decisions so no sampling variance.

—appeal to law of large numbers

—so s_j and hence δ_j is observable. It is data.

$$\delta_j = X_j\beta - \alpha p_j + \xi_j$$

- Suppose ξ_j term is not observable. (Berry, Rand 1994)

- Suppose use OLS to estimate β and α

- Suppose $E[\xi' p] \neq 0$. Then $\hat{\alpha}_{OLS}$ is biased.

(2) Second Issue: Substitution Patterns

$$
\begin{aligned}
s_j &= \frac{e^{\delta_j}}{\sum_{k=0}^{J} e^{\delta_k}} \\
\delta_j &= X_j \beta_j - \alpha p_j + \xi_j
\end{aligned}
$$

- Suppose have two cases, $p_2^\circ < p_2'$, *ceteris paribus*. Let s_j° and s_j' be the associated shares. Suppose $s_0^\circ = s_1^\circ$. then $\delta_0^\circ = \delta_1^\circ$. But then $\delta_0' = \delta_1'$, so $s_0' = s_1'$. Thus

$$\frac{\partial s_0}{\partial p_2} = \frac{\partial s_1}{\partial p_2} > 0$$

Independence of Irrelevant Alternatives. The ratio of the choice probabilities of any two alternatives is entirely unaffected by the systematic utilities of any other alternatives.

Nested Logit

- Simplest nest

—In addition to the draw ε_{ij} for each individual i and product $j \in \{0, 1, ..., J\}$

—Draw ζ_0, ζ_1 such that

$$\begin{aligned} u_{i0} &= \delta_0 + \zeta_0 + (1 - \sigma)\,\varepsilon_{i0} \\ u_{ij} &= \delta_j + \zeta_1 + (1 - \sigma)\,\varepsilon_{ij} \end{aligned}$$

- ε_{ij} is i.i.d. extreme value.

- ζ has a distribution that depends upon σ, $0 \leq \sigma < 1$. Make it the unique distribution such that if ε is extreme value than $\zeta + (1-\sigma)\varepsilon$ is also extreme value. Get the following formulas:

$$s_{j/purchase}(\delta, \sigma) = \frac{\exp\left(\frac{\delta_j}{1-\sigma}\right)}{\sum_{k=1}^{J} \exp\left(\frac{\delta_k}{1-\sigma}\right)}$$

$$s_{purchase} = \frac{\left(\sum_{k=1}^{J} \exp\left(\frac{\delta_k}{1-\sigma}\right)\right)^{1-\sigma}}{1 + \left(\sum_{k=1}^{J} \exp\left(\frac{\delta_k}{1-\sigma}\right)\right)^{1-\sigma}}$$

Back to Benkard Paper

- Demand for stock of planes (here taking note of durable nature of planes)

—relevant price is rental rate $p_{j,t}$

- Doesn't observe $p_{j,t}$ so assumes is proportional to the sale price $P_{j,t}$

—An ugly assumption. tries to justify by noting that

(i) Things that would tend to make changes in the sale price that wouldn't affect the rental rate (interest, depreciation, changes in new price), may not be big

(ii) “Across price variation in rental prices is driven much more by variation in the levels of new prices than it si by variation in expected price changes.”

Nesting of Products

- New wide-bodies in a nest (the inside good)
- New narrow body and all used are the outside good.
- There is an aspect of this modeling that is incoherent. What is it?
- Look at demand estimates

Game Plan

- Simulate the model economy given these parameters
- Compare output of the model economy with data
- Compare welfare under Markov perfect equilibrium with pure monopoly and social planner
- Examine inpact of policies limiting market share.

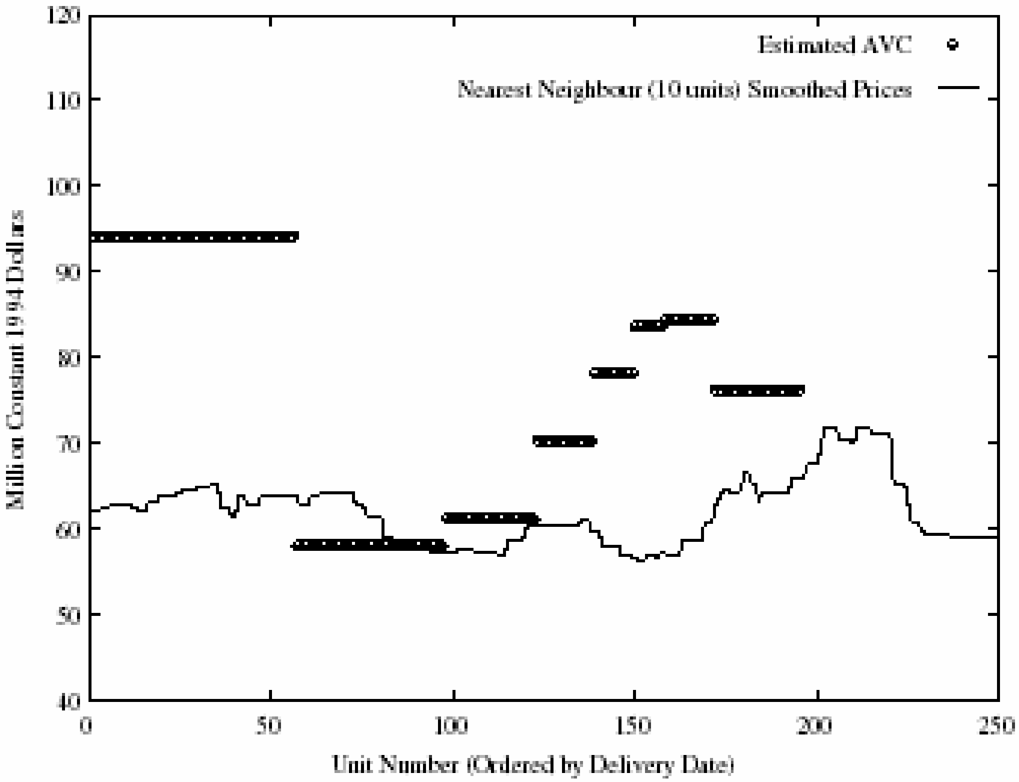


FIGURE 1

Lockheed L-1011: price vs. AVC 1972–1985

TABLE 1

Cost parameters

Parameter	Explanation	Value
A	Labour cost intercept	7·73 (0·01)
γ	Returns to scale	0·11 (0·17)
δ	Depreciation of experience	0·613 (0·023)
θ	Learning parameter	−0·63 (0·03)
	(Implied learning rate)	36%
W	Wage rate	\$20/h
FC	Fixed costs	\$200 million/year
TCF	Total variable cost/labour cost	6·0
TCC	Total variable cost intercept	36·2
	Cost/plane-size ratio	1·0
x_1^l, x_1^h	Type 1: entry cost distribution	\$2·5–\$3·5 billion
x_2^l, x_2^h	Type 2: entry cost distribution	\$3·3–\$4·6 billion
x_3^l, x_3^h	Type 3: entry cost distribution	\$4·4–\$6·2 billion

TABLE 2

Demand function estimates

Variable	Estimate	S.E.	Robust S.E.'s
Constant	−4.81	0.16	0.15
Seats/100	1.10	0.21	0.23
Freighter	2.45	0.24	0.26
No. of engines	−0.30	0.53	0.46
Price/100	−2.40	0.21	0.30
Last year dummy	−0.90	0.37	0.38
Trend	0.25	0.43	0.58
λ	0.77	0.18	0.18

Specification includes model dummies.

TABLE 3

Demand and other parameters

Parameter	Explanation	Value
λ	Group corr. parameter	0·77 (0·18)
α	Price coefficient	-0.024 (0·002)
μ	Discrete plane types (small, medium, large)	$[-2.6, -2.2, -1.6]$
$P(\mu^e)$	Entry type distribution (small, medium, large)	$\begin{pmatrix} 0.50 & 0.38 & 0.12 \end{pmatrix}$
ξ	Discrete plane qualities	$[-0.90, -0.40, 0.11, 0.61]$
$\Delta\xi$	Transition matrix for quality	$\begin{pmatrix} 1.00 & 0.04 & 0.033 & 0.000 \\ 0.00 & 0.44 & 0.233 & 0.200 \\ 0.00 & 0.48 & 0.667 & 0.800 \\ 0.00 & 0.04 & 0.067 & 0.000 \end{pmatrix}$
M	Discrete market sizes	$(10{,}339 \quad 10{,}929 \quad 11{,}519)$
ΔM	Transition matrix for market size	$\begin{pmatrix} 0.895 & 0.143 & 0.000 \\ 0.105 & 0.786 & 0.200 \\ 0.000 & 0.071 & 0.800 \end{pmatrix}$
β	Firm's discount factor	0·925
(Φ^l, Φ^h)	Range of scrap values	(\$300m, \$700m)

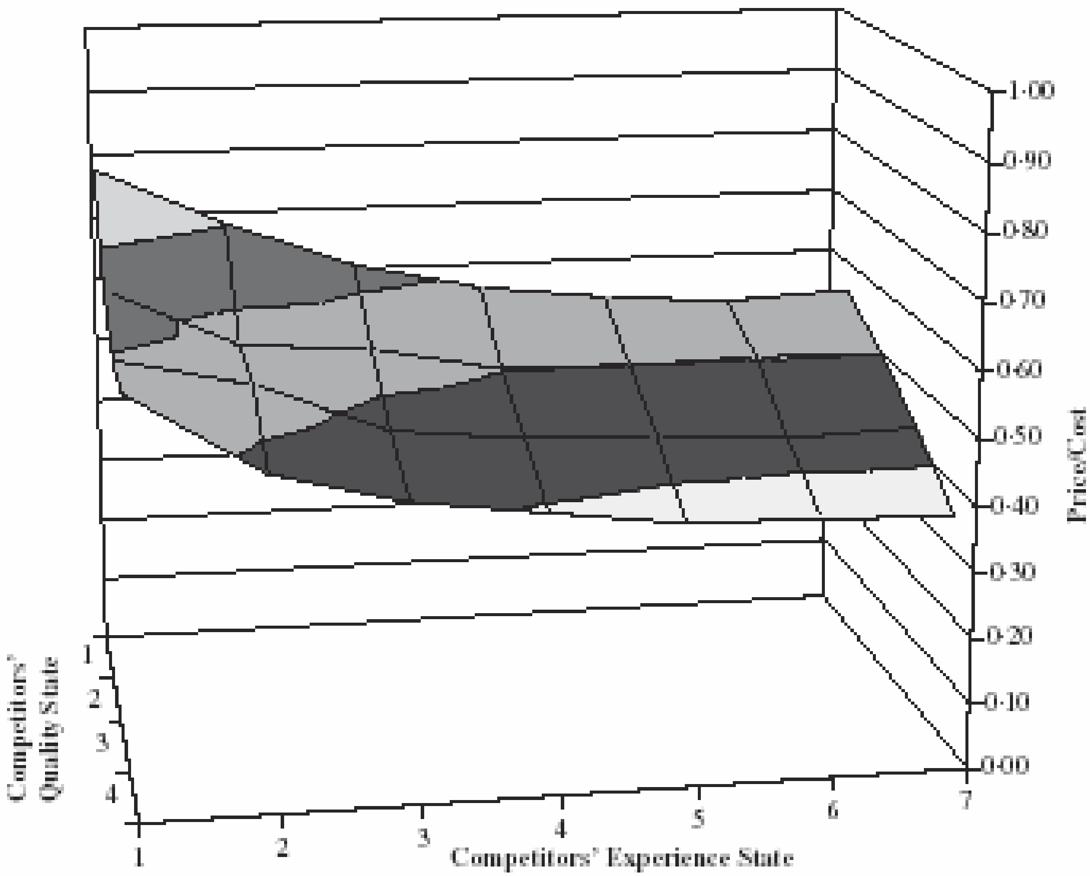
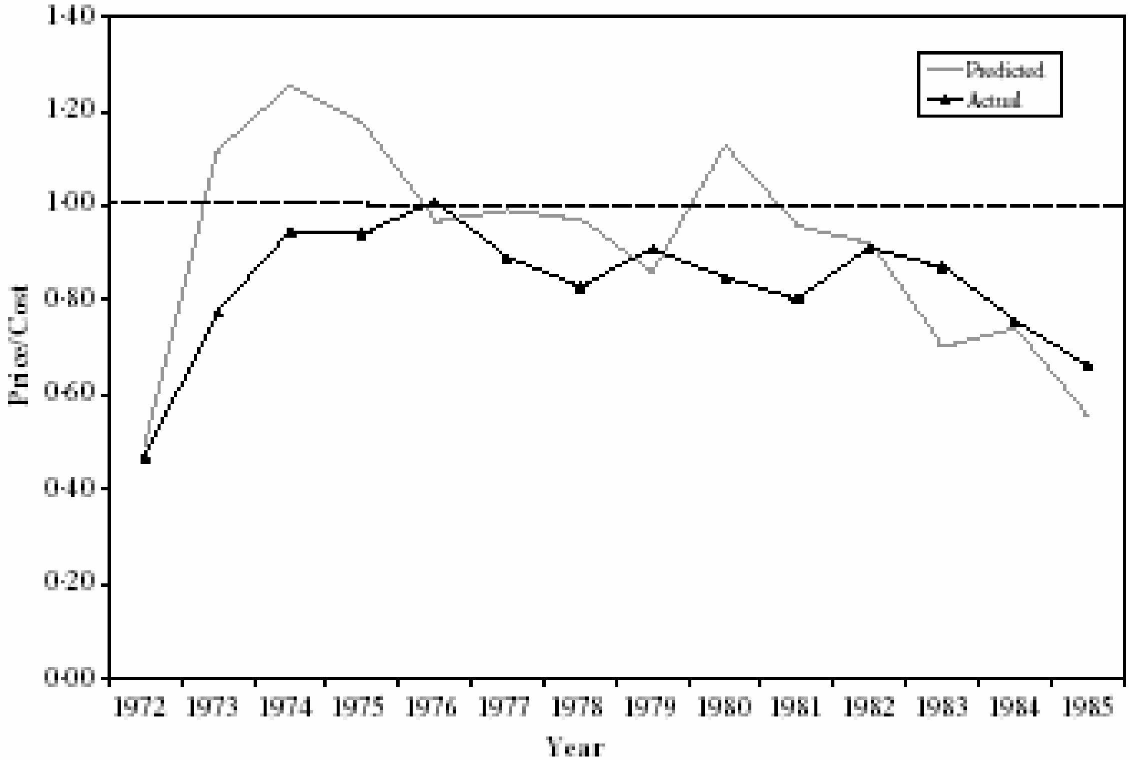


FIGURE 3

Introductory P/MC ratios for a small aircraft entrant with three equal rivals


Predicted
Actual
1·40
1·20
1·00
0·80
0·60
0·40
0·20
0·00
Price/Cost
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
Year

Welfare Comparisons

- Compare

—MPE

—multi-product monopolist

—social planner

- Social planner raises total surplus by “just 10%.”

- Monopolist provides much lower welfare

- All three cases get sufficient learning

- Welfare gains come from standard Hotelling triangles (social planner has 40% higher output)

- Social planner has fewer models (‘excess entry)

TABLE 7

Statistics from 10,000 industry simulations under alternative policies

Maximum concentration:	100%	60%	51%
Concentration ratios:	(Invariant distribution)		
1-Firm/plane	0.396	0.392	0.385
S.D.	0.102	0.094	0.081
2-Firm/plane	0.692	0.690	0.688
S.D.	0.109	0.107	0.103
Consumer surplus:			
Mean	135,373	134,917	133,895
S.D.	7040	7268	7488
Producer surplus:			
Mean	42,335	42,306	42,320
S.D.	3769	3776	3785
Total surplus:			
Mean	177,708	177,223	176,215
S.D.	10,441	10,645	10,832