Advertising in the US Personal Computer Industry

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Outline of Talk

- Introduction and Motivation
- Overview of Data and Related Literature
- Model and Estimation Technique
- Results and Conclusion

“He who has a product to sell
And goes and whispers in a well
Is not so apt to get the dollars
As one who climbs up a tree and hollers.”

– Author Unknown
Introduction

・PC industry is highly concentrated
  - top 5 firms account for over 60% of dollar sales

・Rapidly changing product line
  - over 200 new products introduced by top 15 firms every year

・High revenues and advertising expenditures
  - in 1998 over 36 million PCs sold
  - over $62 billion in sales
  - $2 billion in advertising

(source: Gartner Inc and Leading National Advertisers)
Introduction

- Model of demand in markets characterized by rapid change
  - consumers may not know all products when making purchase decision

- Advertising influences set of products from which consumers choose to purchase
  - probability consumer knows a product is a function of advertising and consumer attributes

- Multi-product firms choose prices and advertising expenditures across media to maximize profits
Data

• Ideally would have individual-level purchase and advertising exposure data

• Combine data from three primary sources
  
  (1) Gartner Inc.’s Dataquest
      – product-level sales, prices, and other product characteristics
  
  (2) Leading National Advertisers (LNA)
      – national advertising expenditures across media
  
  (3) Simmons Market Research
      – consumer-level PC purchases across manufacturers, consumer characteristics, and media exposure information

• Incorporate consumer heterogeneity with respect to choice sets, tastes, and advertising exposure
Product-Level Data

- Quarterly price and quantity of PCs sold between 1996 and 1998
  - manufacturer, brand, CPU type, CPU speed, form factor
  - Compaq Armada 3xxx Pentium 150/166 MHz laptop

- Home sector which comprises 30% of all sales

- Restrict attention to top 10 firms plus 5 others
  - account for over 85% sales to home market

- Treating model/quarter as observation total sample size is 2112
  - represent 723 distinct models
  - on average each firm offered a particular model for 3 quarters
  - “modal” PC: desktop pentium average speed 220 MHz
Advertising Data

- Quarterly data on advertising expenditures across media
  - newspaper, magazine, television, radio

- Growth in ad expenditures
  - average annual rate 13 % from 1995 to 1999

- Includes some expenditures for non-home sectors

- Variation in ad across firms
  - 50 % by IBM

- Group advertising
  - 1996 Compaq campaign for Presario brand PCs
  - need measure of advertising by product that includes group advertising
Group Advertising

- $ad_H$ are total advertising expenditures for group $H$

\[
\overline{ad_H} \equiv \frac{ad_H}{|H|}
\]

- “Effective” product-level ad expenditures are sum of observed product-specific advertising and weighted average of group expenditures

\[
ad_j = \sum_{H \in G_j} \gamma \overline{ad_H} + \pi \overline{ad_H}^2
\]

where the weights $\gamma$ and $\pi$ are estimated

- First quarter of 1998 there were 18 group advertisements for Apple computers
  - various computers, Powerbook, Mac Power PC G3 Portable
Consumer-Level Data

- Simmons survey of about 20,000 households annually (1996, 1997)
  - Demographic characteristics
    age, household size, income, gender, race, education, marital status...
  - PC ownership information
    whether purchased PC in last year
    PC manufacturer (only top 10 plus 5 others listed separately)
  - Media habits
    ranked according to how often viewed TV, read paper, etc.
- CPS survey for 1998
  define distribution of consumer characteristics for macro-moments
Related Literature

- Discrete choice models of product differentiation
  - Berry, Levinsohn, and Pakes, 1995

- Combining aggregated and micro-level data in estimation
  - Petrin, 2002 and Berry, Levinsohn, and Pakes 1998

- Structural econometric models of advertising
  - Erdem and Keane, 1996; Ackerberg, 2002; Anand and Shachar, 2001
  - Shum, 1997

- Theoretical models of informative advertising
  - Grossman and Shapiro, 1984
Utility and Demand

- indirect utility consumer $i$ receives from product $j$ (suppress time subscript)

\[ u_{ij} = \alpha \ln(y_i - p_j) + x'_j \beta_i + \xi_j + \epsilon_{ij} \]

\[ \beta_i = \beta + \Pi D_i + \Sigma \nu_i, \quad \nu_i \sim N(0, I_k) \]

\[ u_{i0} = \alpha \ln(y_i) + \xi_0 + \epsilon_{i0} \]

- under full information about all the products for sale, the market share of product $j$ is

\[ s_j = \int y_i^{\alpha} \exp(\delta_j + \mu_{ij}) \left[ \frac{1}{y_i^{\alpha} + \sum_r \exp(\delta_r + \mu_{ir})} \right] dF_{y,D}(y, D) dF_{\nu}(\nu) \]

with mean utility: \[ \delta_j = x'_j \beta + \xi_j \]

and a mean-zero deviation: \[ \mu_{ij} = \alpha \ln(y_i - p_j) + x'_j (\Pi D_i + \nu_i) \]
Utility and Demand

Assumption that consumers are aware of all products may not hold

- let $\phi_j$ denote probability consumer $i$ is informed about product $j$
- conditional market share for product 3 is

$$
\phi_3(1 - \phi_1)(1 - \phi_2)\frac{\exp(\delta_3 + \mu_3)}{y^\alpha + \exp(\delta_3 + \mu_3)}
$$

$$
+ \phi_3 \phi_1 (1 - \phi_2)\frac{\exp(\delta_3 + \mu_3)}{y^\alpha + \sum_{k = \{1,3\}} \exp(\delta_k + \mu_k)}
$$

$$
+ \phi_3 (1 - \phi_1) \phi_2 \frac{\exp(\delta_3 + \mu_3)}{y^\alpha + \sum_{k = \{2,3\}} \exp(\delta_k + \mu_k)}
$$

$$
+ \phi_3 \phi_1 \phi_2 \frac{\exp(\delta_3 + \mu_3)}{y^\alpha + \sum_{k = \{1,2,3\}} \exp(\delta_k + \mu_k)}
$$
The probability consumer $i$ is informed about product $j$

$$\phi_{ij} = \frac{\exp(\tau_{ij})}{1 + \exp(\tau_{ij})}$$

$$\tau_{ij} = \tilde{D}'_i \lambda + a'_j (\varphi + \rho a + \Psi \tilde{x} + \Upsilon D_i^s + \kappa_i) \quad \ln \kappa_i \sim N(0, I_m)$$

- $a_{mj}$ number of advertisements in medium $m$
- $D_{id}^s$ are observed consumer characteristics from Simmons data
- $\Upsilon_{md}$ captures how advertising media’s effectiveness varies by observed consumer characteristics
- $\kappa_{im}$ are unobserved consumer heterogeneity
The market share for product \( j \), \( s_j(p, a) \), is given by

\[
\int \sum_{S' \in C_j} \prod_{i \in S'} \phi_{il} \prod_{k \notin S'} (1 - \phi_{ik}) \frac{\exp(\delta_j + \mu_{ij})}{y_i^\alpha + \sum_{r \in S'} \exp(\delta_r + \mu_{ir})} dF(y, D) dF(\nu) dF(\kappa)
\]

- where \( \phi_{ij} \) is the probability consumer \( i \) is informed about product \( j \)
- and the sum is over the different choice sets that include product \( j \)
Firm Behavior

• Non-cooperate oligopolistic competition

• Profits of firm $f$

$$\sum_{j \in J_f} (p_j - mc_j) M s_j (p, a) + \sum_{j \in J_f} \Pi^{n h}_j (p^{n h}, a) - \sum_{m} mc_{j m}^{a d} (\sum_{j \in J_f} a_{j m}) - C_f$$

• Marginal costs

$$\ln (mc_j) = w'_j \eta + \omega_j$$

$$\ln (mc_{j m}^{a d}) = w_{j m}^{a d} \psi + v_j \quad v_j \sim N(0, I_m)$$
Firm Behavior

• Any product sold in the home market sector, must have prices that satisfy

\[ s_j(p, a) + \sum_{r \in J_f} (p_r - mc_r) \frac{\partial s_r(p, a)}{\partial p_j} = 0 \]

• In vector form, the \( J \) first-order conditions are

\[ s - \Delta(p - mc) = 0 \]

• And advertising medium choices \( a_{jm} \) that satisfy

\[ M \sum_{r \in J_f} (p_r - mc_r) \frac{\partial s_r(p, a)}{\partial a_{jm}} + m r_{jm}^{nh}(p^{nh}, a) = m c_{jm}^{ad} \]
Estimation

Estimation is in two parts:

- Use consumer-level data on media exposure to estimate media-specific parameters
- Estimate remainder of the parameters simultaneously using generalized method of moments
- Construct composite error term arising from four sets of moments
  1. one from demand side
  2. arises from firm’s optimal pricing choices
  3. arises from the firm’s optimal advertising choices
  4. arises from individual level (firm specific) purchase probabilities
Individual Media Exposure

- Simmons survey reports only quintile to which consumer belongs

- Let $Y_{im}$ be the amount of exposure $i$ has to medium $m$ where
  
  $$Y_{im} = D_{i}'\gamma_m + \varepsilon_{im}$$

- Consumer $i$ belongs to the $q$th quintile if $c_{qm} < Y_{im} < c_{(q-1)m}$

- $Z_{iqm}$ is equal to one if $i$’s level of exposure falls in quintile $q$

  $$\Pr(Z_{iqm} = 1) = \Phi \left( c_{(q-1)m} - D_{i}'\gamma_m \right) - \Phi \left( c_{qm} - D_{i}'\gamma_m \right)$$

- The ordered-response likelihood function for medium $m$ is

  $$\mathcal{L}_m = \prod_{i}^{N} \prod_{q}^{5} \left[ \Phi \left( c_{(q-1)m} - D_{i}'\gamma_m \right) - \Phi \left( c_{qm} - D_{i}'\gamma_m \right) \right]^{Z_{iqm}}$$
Macro-Moments (BLP)

(1) Demand side moment

Restrict the model predictions for product \( j \)'s market share to match the observed market shares

\[ S_t^{obs} - s_t(\delta, \theta) = 0 \]

then solve for the demand side unobservable

\[ \xi_{jt} = \delta_{jt}(S, \theta) - x'_j \beta \]

(2) Pricing moment

Rearranging price FOC's yields

\[ mc = p - \Delta^{-1}s \]

combined with marginal costs yields cost side unobservable

\[ \omega = \ln(p - \Delta^{-1}s) - w' \eta \]
(3) Ad Moments

• Some firms choose not to advertise some products in some media

• let $a^*_{jm}$ denote the latent variable, we observe

$$a_{jm} = \begin{cases} 
    a^*_{jm} & \text{if } \frac{\partial \Pi_j}{\partial a_{jm}} |_{a_{jm}=a^*_{jm}} = 0 \\
    0 & \text{if } \frac{\partial \Pi_j}{\partial a_{jm}} |_{a_{jm}=0} < 0
\end{cases}$$

• The errors from the ad FOCs cannot be used to construct moment conditions since they depend on latent variables

• Use method proposed by Gourieroux, Monfort, Renault, and Trognon (GMRT)

• Replace the errors by their best prediction conditional on the observable variables and use these residuals in constructing moments

• Let $T(\delta, \theta, \eta_{ad})$ be the vector formed by stacking the residuals over media and over products
Ad Moments Detail

• The latent variable $a_{jm}^*$ is the implicit solution to

\[
\ln h_{jm}(a_{jm}) - w_{jm}^d \psi = v_{jm}
\]

where $h_j$ is the marginal revenue associated with ad medium $m$

• The errors $v_{jm}$ depend on the latent variable

• Use best prediction of the errors conditional on the observed level of advertising

\[
\tilde{v}_{jm}(\hat{\Theta}) = E[v_{jm}(\hat{\Theta}) | a_{jm}]
\]

where $\Theta$ are the associated parameters and $\hat{\Theta}$ the maximum likelihood estimator
Ad Moments Detail

- Construct a tobit likelihood function from ad marginal costs and FOCs

\[ \mathcal{L} = \prod_{j:a_{jm}>0} \frac{1}{\sigma_v} \phi \left( \frac{\ln h_j - w_{jm}' \psi}{\sigma_v} \right) \prod_{j:a_{jm}\leq0} 1 - \Phi \left( \frac{\ln h_j - w_{jm}' \psi}{\sigma_v} \right) \]

- Then the generalized residual is

\[ \tilde{\upsilon}_{jm} = \tilde{h}_{jm} 1(a_{jm}>0) - \frac{\phi(\tilde{h}_{jm})}{1-\Phi(h_{jm})} 1(a_{jm}=0) \]

- The moments express an orthogonality between the generalized residuals and the instruments

- The \( \Theta \) that solves

\[ \frac{1}{J} \sum_j \frac{\partial \tilde{h}_{jm}}{\partial \Theta} \tilde{\upsilon}_{jm} = 0 \]

is the MOM estimator, where \( \frac{\partial \tilde{h}_{jm}}{\partial \Theta} \) are the appropriate instruments
Micro-Moments

The micro-moments are constructed from individual (firm-level) purchase data from the Simmons survey.

- Let $B_i$ be a vector of firm choices for individual $i$.
- $b_i$ is a realization of $B_i$ where $b_{if} = 1$ if PC produced by firm $f$ was chosen.
- Define the residual for individual $i$ as the difference between the vector of observed choices in the data and the model prediction given $(\delta, \theta)$:

$$G_i(\delta, \theta) = b_i - E_{\nu, \kappa}E[B_i \mid D_i^s, \delta, \theta]$$

- For example, the element of $E_{\nu, \kappa}E[B_i \mid D_i^s, \delta, \theta]$ corresponding to firm 2 is

$$\sum_{j \in J_2} \int \sum_{S' \in C_j} \prod_{l \in S'} \phi_{ilt} \prod_{k \notin S'} (1 - \phi_{ikt}) \exp\{\delta_{jt} + \mu_{ijt}\} \frac{\exp\{\delta_{rt} + \mu_{irt}\}}{y_{it}^{\alpha} + \sum_{r \in S'} \exp\{\delta_{rt} + \mu_{irt}\}} dF_\nu(\nu) dF_\kappa(\kappa)$$
Estimation

- Use GMM estimation to find the parameters that minimize the objective function

$$\Lambda'Z\Lambda^{-1}Z'\Lambda$$

where $\Lambda$ is an appropriate weighting matrix and $Z$ are instruments orthogonal to the composite error term

- Specifically, the sample moments are

$$Z'\Lambda = \begin{bmatrix}
\frac{1}{J} \sum_{j=1}^{J} Z_{\xi,j}\xi_j(\delta, \beta) \\
\frac{1}{J} \sum_{j=1}^{J} Z_{\omega,j}\omega_j(\delta, \theta, \eta) \\
\frac{1}{J} \sum_{j=1}^{m*J} Z_{ad,j}\mathcal{T}_j(\delta, \theta, \eta_{AD}) \\
\frac{1}{N} \sum_{i=1}^{N} Z_{micro,i}\mathcal{G}_i(\delta, \theta)
\end{bmatrix}$$
Instruments

- Optimal instruments weight disturbances according to their sensitivity to changes in parameters
  - for any disturbance-parameter pair these are the expected value of the derivative of the disturbance with respect to the parameters
  - must be uncorrelated with the disturbances

- Firms consider unobserved characteristics when setting price and ad
  - Correct for the endogeneity of prices and advertising
  - similar to BLP (1999)
  - form approximations that are functions of exogenous data by evaluating the derivatives at the expected value of the unobservables
Simulation

- No closed form solution for market shares
  - distribution of consumer attributes is an empirical one
  - do not observe which of the possible $2^J$ choice sets the consumer faces

General outline of simulator:

- sample $n_s$ draws from a set of “individuals”
  - each individual consists of $(v_{i1}, \ldots, v_{ik})$ taste parameters; demographic characteristics, $(y_i, D_{i1}, \ldots, D_{id})$; and unobserved ad effectiveness draws $(\kappa_{i1}, \ldots, \kappa_{im})$

- construct a choice set for each individual
  - for each individual, draw $J$ uniform random variables
  - compute probability each consumer is informed about each product, $\phi_{ij}$
  - compare vector of $\phi_i$’s with her uniform draws
Simulation

- compute choice probabilities
- construct an importance sampler
  - use initial choice set weight to smooth simulated choice probabilities
  - initial choice set weight is product over all $\phi$'s for products in choice set multiplied by product over all $(1 - \phi)$ for products not in the choice set
- simulated market share is average over individuals of smoothed choice probabilities
Results

- importance of product differentiation
- influence of advertising
- strategic information provision
Results: differentiation and substitution patterns

<table>
<thead>
<tr>
<th>Variable</th>
<th>Means</th>
<th>Standard Deviation</th>
<th>Interactions with Demographic Variables</th>
</tr>
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<td></td>
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<td>constant</td>
<td>-12.2812 **</td>
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<tr>
<td>ln(income-price)</td>
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<td>apple</td>
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<td>dell</td>
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<td>ibm</td>
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<td>packard bell</td>
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</table>

Notes: ** indicates significant at the 5% level; * significant at the 10% level.
Results: advertising

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Firm Interactions with Advertising Expenditures</th>
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<td><strong>advertising coefficients</strong></td>
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<td>(group advertising)^2</td>
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<td>(tv advertising)^2</td>
<td>-0.0346 **</td>
<td>micron 0.7384</td>
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</tbody>
</table>

Notes: ** indicates significant at the 5% level; * significant at the 10% level.
Results: group advertising

• A firm that sells 2 products has decide whether to advertise these in a group or individually

• Assume optimal advertising choices dictate they spend $10 million on advertising in this particular quarter

\[ ad_1 = ad_2 = \gamma ad + \pi ad^2 = 0.87 \times 5 + 0.092 \times (5)^2 = 6.6 \]

the return to group advertising per product is 6.6 million higher return to group advertising than to individual advertising

• In contrast if have only $2 million to spend return to group advertising is 0.96 million, which is lower than return to individual advertising
## Results: advertising

<table>
<thead>
<tr>
<th>Variable</th>
<th>Magazine</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Newspaper</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Television</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Radio</th>
<th>Coefficient</th>
<th>Std. Error</th>
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<td>0.1988 ** (0.0242)</td>
<td>0.0173 (0.0236)</td>
<td>-0.0301 (0.0241)</td>
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<tr>
<td>mature</td>
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<td>0.5284 ** (0.0243)</td>
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<td>0.1869 ** (0.0184)</td>
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<td>hh size</td>
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<td>high</td>
<td>0.1565 ** (0.0294)</td>
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<td>male wh</td>
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<tr>
<td>edu hs</td>
<td>-0.1219 ** (0.0254)</td>
<td>-0.3354 ** (0.0251)</td>
<td>0.2682 ** (0.0256)</td>
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<td>edu ad</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>edu sp</td>
<td>-0.0302 ** (0.0034)</td>
<td>-0.0660 ** (0.0035)</td>
<td>0.0315 ** (0.0033)</td>
<td>-0.0134 ** (0.0034)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Log Likelihood

|        | -31983 | -31087 | -31052 | -28597 |

Notes: Estimates include time dummies. ** indicates significant at the 5% level; * significant at the 10% level.
Results: advertising

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Firm Interactions with Advertising Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>advertising coefficients</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>group advertising</td>
<td>0.8706 **</td>
<td></td>
</tr>
<tr>
<td>(group advertising)²</td>
<td>0.0918 **</td>
<td></td>
</tr>
<tr>
<td><strong>information technology coefficients</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>-1.5700 **</td>
<td>acer 0.5824</td>
</tr>
<tr>
<td>high school graduate</td>
<td>0.5504 **</td>
<td>apple 0.3644 *</td>
</tr>
<tr>
<td>income &lt; $60,000</td>
<td>0.4818 **</td>
<td>compaq 0.6244 **</td>
</tr>
<tr>
<td>income &gt; $100,000</td>
<td>0.4512</td>
<td>dell 0.5827 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>gateway 0.9046 **</td>
</tr>
<tr>
<td>np and mag advertising</td>
<td>1.0317</td>
<td>hp 0.8049</td>
</tr>
<tr>
<td>tv advertising</td>
<td>1.0626 **</td>
<td>ibm 0.6215 **</td>
</tr>
<tr>
<td>(np and mag advertising)²</td>
<td>-0.0212 *</td>
<td>micron 0.7384</td>
</tr>
<tr>
<td>(tv advertising)²</td>
<td>-0.0346 **</td>
<td>packard bell 0.6550 **</td>
</tr>
</tbody>
</table>

Notes: ** indicates significant at the 5% level; * significant at the 10% level.
Results: advertising

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>non-home sector demand</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>2.4053 *</td>
<td>(1.2869)</td>
</tr>
<tr>
<td>non-home sector price</td>
<td>1.0350 **</td>
<td>(0.0749)</td>
</tr>
<tr>
<td>cpu speed</td>
<td>0.0198 **</td>
<td>(0.0028)</td>
</tr>
<tr>
<td>non-pc sales</td>
<td>5.2707 *</td>
<td>(2.8202)</td>
</tr>
<tr>
<td><strong>In marginal cost of production</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>10.0230 **</td>
<td>(0.1784)</td>
</tr>
<tr>
<td>ln(cpu speed)</td>
<td>0.4932 **</td>
<td>(0.0062)</td>
</tr>
<tr>
<td>pentium</td>
<td>-0.3978 **</td>
<td>(0.0926)</td>
</tr>
<tr>
<td>laptop</td>
<td>1.3054 **</td>
<td>(0.2691)</td>
</tr>
<tr>
<td>quarterly trend</td>
<td>-0.1320 **</td>
<td>(0.0214)</td>
</tr>
<tr>
<td><strong>In marginal cost of advertising</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>7.0356 **</td>
<td>(1.9230)</td>
</tr>
<tr>
<td>price of advertising</td>
<td>1.0004 **</td>
<td>(0.0002)</td>
</tr>
</tbody>
</table>

Notes: ** indicates significant at the 5% level; * significant at the 10% level.
Results: advertising

<table>
<thead>
<tr>
<th></th>
<th>Average Price</th>
<th>Ad to Sales Ratio</th>
<th>Median Percentage Markup over marginal costs</th>
<th>Median Percentage Markup including ad costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Industry</strong></td>
<td>$2,239</td>
<td>3.34%</td>
<td>19%</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Top 6 firm</strong></td>
<td>$2,172</td>
<td>8.66%</td>
<td>22%</td>
<td>12%</td>
</tr>
<tr>
<td>Apple</td>
<td>$1,859</td>
<td>4.90%</td>
<td>19%</td>
<td>10%</td>
</tr>
<tr>
<td>Compaq</td>
<td>$2,070</td>
<td>2.56%</td>
<td>24%</td>
<td>16%</td>
</tr>
<tr>
<td>Gateway</td>
<td>$2,767</td>
<td>5.99%</td>
<td>12%</td>
<td>9%</td>
</tr>
<tr>
<td>Hewlett Packard</td>
<td>$2,203</td>
<td>10.28%</td>
<td>17%</td>
<td>11%</td>
</tr>
<tr>
<td>IBM</td>
<td>$2,565</td>
<td>19.55%</td>
<td>17%</td>
<td>10%</td>
</tr>
<tr>
<td>Packard Bell</td>
<td>$2,075</td>
<td>19.55%</td>
<td>18%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Note: Ad to sales ratios are from LNA and include ad and sales across all sectors. Percentage markups are the median \((p-mc)/p\) across all products. The last column is percentage total markups per unit after including advertising. These are determined from estimated markups and estimated effective product advertising in the home sector.
## Results: information

<table>
<thead>
<tr>
<th></th>
<th>Estimated Median Percentage Markup</th>
<th>Estimated Change in Markups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Under Partial Information</td>
<td>Under Full Information</td>
</tr>
<tr>
<td><strong>Total industry</strong></td>
<td>19%</td>
<td>5%</td>
</tr>
<tr>
<td><strong>Apple</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iMac</td>
<td>22.2%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Power Mac</td>
<td>13.7%</td>
<td>2.0%</td>
</tr>
<tr>
<td>PowerBook Duo*</td>
<td>15.9%</td>
<td>2.0%</td>
</tr>
<tr>
<td><strong>Compaq</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Armada*</td>
<td>42.3%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Presario</td>
<td>18.1%</td>
<td>2.6%</td>
</tr>
<tr>
<td>Presario*</td>
<td>15.3%</td>
<td>2.0%</td>
</tr>
<tr>
<td>ProLinea</td>
<td>23.4%</td>
<td>7.0%</td>
</tr>
<tr>
<td><strong>Gateway</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gateway Desk Series</td>
<td>12.9%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Gateway Portable Series</td>
<td>8.1%</td>
<td>1.5%</td>
</tr>
<tr>
<td><strong>HP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OmniBook*</td>
<td>15.7%</td>
<td>8.4%</td>
</tr>
<tr>
<td>Pavilion</td>
<td>21.8%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Vectra</td>
<td>15.3%</td>
<td>6.8%</td>
</tr>
<tr>
<td><strong>IBM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aptiva</td>
<td>16.0%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Thinkpad*</td>
<td>11.9%</td>
<td>2.0%</td>
</tr>
<tr>
<td>IBM PC</td>
<td>23.2%</td>
<td>2.3%</td>
</tr>
<tr>
<td><strong>Packard Bell</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEC Versa*</td>
<td>11.1%</td>
<td>1.6%</td>
</tr>
<tr>
<td>NEC Desk Series</td>
<td>17.7%</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

Notes: Percentage markups are defined as (price - marginal cost)/price. Full information is the traditional model in which consumers know all products; under partial information the choice set is estimated. * indicates that computers are laptops.
Results: information

<table>
<thead>
<tr>
<th></th>
<th>Apple</th>
<th>Compaq</th>
<th>Gateway</th>
<th>HP</th>
<th>IBM</th>
<th>Packard Bell</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>under partial information</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>-10.1720</td>
<td>0.0576</td>
<td>0.0199</td>
<td>0.0249</td>
<td>0.0178</td>
<td>0.0241</td>
</tr>
<tr>
<td>Compaq</td>
<td>0.0404</td>
<td>-6.6810</td>
<td>0.0416</td>
<td>0.0516</td>
<td>0.0370</td>
<td>0.0499</td>
</tr>
<tr>
<td>Gateway</td>
<td>0.0396</td>
<td>0.1184</td>
<td>-10.1177</td>
<td>0.0511</td>
<td>0.0366</td>
<td>0.0494</td>
</tr>
<tr>
<td>Hewlett-Packard</td>
<td>0.0434</td>
<td>0.1288</td>
<td>0.0447</td>
<td>-6.2509</td>
<td>0.0399</td>
<td>0.0538</td>
</tr>
<tr>
<td>IBM</td>
<td>0.0296</td>
<td>0.0870</td>
<td>0.0304</td>
<td>0.0377</td>
<td>-7.5830</td>
<td>0.0364</td>
</tr>
<tr>
<td>Packard Bell</td>
<td>0.0312</td>
<td>0.2808</td>
<td>0.0543</td>
<td>0.0676</td>
<td>0.0484</td>
<td>-7.4831</td>
</tr>
<tr>
<td><strong>under full information (blp benchmark)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>-29.2337</td>
<td>0.1901</td>
<td>0.0448</td>
<td>0.1036</td>
<td>0.0726</td>
<td>0.0735</td>
</tr>
<tr>
<td>Compaq</td>
<td>0.0188</td>
<td>-34.1364</td>
<td>0.0237</td>
<td>0.0548</td>
<td>0.0384</td>
<td>0.0389</td>
</tr>
<tr>
<td>Gateway</td>
<td>0.0378</td>
<td>0.2024</td>
<td>-34.6917</td>
<td>0.1103</td>
<td>0.0773</td>
<td>0.0782</td>
</tr>
<tr>
<td>Hewlett-Packard</td>
<td>0.0032</td>
<td>0.0171</td>
<td>0.0040</td>
<td>-37.9312</td>
<td>0.0066</td>
<td>0.0067</td>
</tr>
<tr>
<td>IBM</td>
<td>0.1014</td>
<td>0.5431</td>
<td>0.1277</td>
<td>0.2963</td>
<td>-32.5824</td>
<td>0.2102</td>
</tr>
<tr>
<td>Packard Bell</td>
<td>0.0707</td>
<td>0.3793</td>
<td>0.0895</td>
<td>0.2066</td>
<td>0.1446</td>
<td>-35.8697</td>
</tr>
</tbody>
</table>

Notes: Cell entries $i,j$ where $i$,indexes row and $j$ column, give the percentage change in market share of brand $I$, with a one percentage change in the price of $j$. Each entry represents median elasticities over all products for first quarter of 1998.
Conclusions

The results suggest that

- firms benefit from partial information on part of consumers
  - consumers know only some of the products for sale
  - high industry markups explained in part by partial information
  - estimated median markups over marginal costs are 19%
  - if consumers had full information median markups would be one-fourth the magnitude

- assuming full information may result in incorrect conclusions regarding the nature of competition
  - estimates of product-specific demand curves that are biased towards being too elastic
Conclusions

- the top five firms have higher than average markups and engage in higher than average advertising
  - firms are using advertising to target high income individuals

- products are priced on the elastic portion of demand consistent with oligopolistic conduct

- there are economies of scope in group advertising

- word-of-mouth or experience plays a role in informing consumers
“In the end life is all about advertising”

Freddie Heineken (1923-2002)
Simulation Details

- For a given value of parameters, calculate $\phi_{ij}(\theta)$

$$
\phi_{ij}(\theta) = \frac{\exp(\tau_{ij})}{1 + \exp(\tau_{ij})}
$$

$$
\tau_{ij} = \tilde{D}_i' \lambda + a'_j (\varphi + \rho a_j + \Psi \tilde{x}_j + \Upsilon D_i^s + \kappa_i)
$$

- Given $\phi_{ij}(\theta)$ and uniform draws, $u_{ij}$, construct a Bernoulli vector, $b_i(\theta)$ where the $j$th element is determined according to

$$
b_{ij} = \begin{cases} 
1 & \text{if } \phi_{ij}(\theta) > u_{ij} \\
0 & \text{if } \phi_{ij}(\theta) \leq u_{ij}
\end{cases}
$$

This defines the choice set $S'$
Simulation Details

- Define $b^0_i$ as the Bernoulli vector generated from the initial choice of parameters
- Calculate choice probability

$$P_{ij}(\theta) = \frac{\exp\{\delta_j + \mu_{ij}\}}{y_i^\alpha + \sum_{k:b^0_{i,k}=1} \exp\{\delta_k + \mu_{ik}\}}$$
Simulation Details

• Calculate

\[ s_{ij}(\theta) = \prod_{l \in S'} \phi_{il} \prod_{k \notin S'} (1 - \phi_{ik}) \frac{P_{ij}(\theta)}{\phi_{i}^0(\theta_0)} \]

where \( \phi_{i}^0(\theta_0) \) is the value of \( \prod_{l \in S'} \phi_{il} \prod_{k \notin S'} (1 - \phi_{ik}) \) using initial value of the parameters and the initial choice set \( S' \)

• Calculate the simulator for the market share

\[ \hat{s}_j = \frac{1}{ns} \sum_i s_{ij} \]