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Leveraging Monopoly Power by Limiting Compatibility: Theory and Evidence from the Computer Market

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Introduction

- ⇨ Leveraging Theory: When will monopolist extend market power into a complementary market through reducing compatibility?
  - Software interoperability
  - Common issue in network industries, e.g. telecommunications
- ⇨ Policy issue: Microsoft cases in US and EU – biggest ever EU monopoly abuse fine (500m euros)
- ⇨ Econometrics: Can we determine whether these incentives are large enough to empirically matter (big challenge)?
- ⇨ Is there a problem? The Chicago school critique

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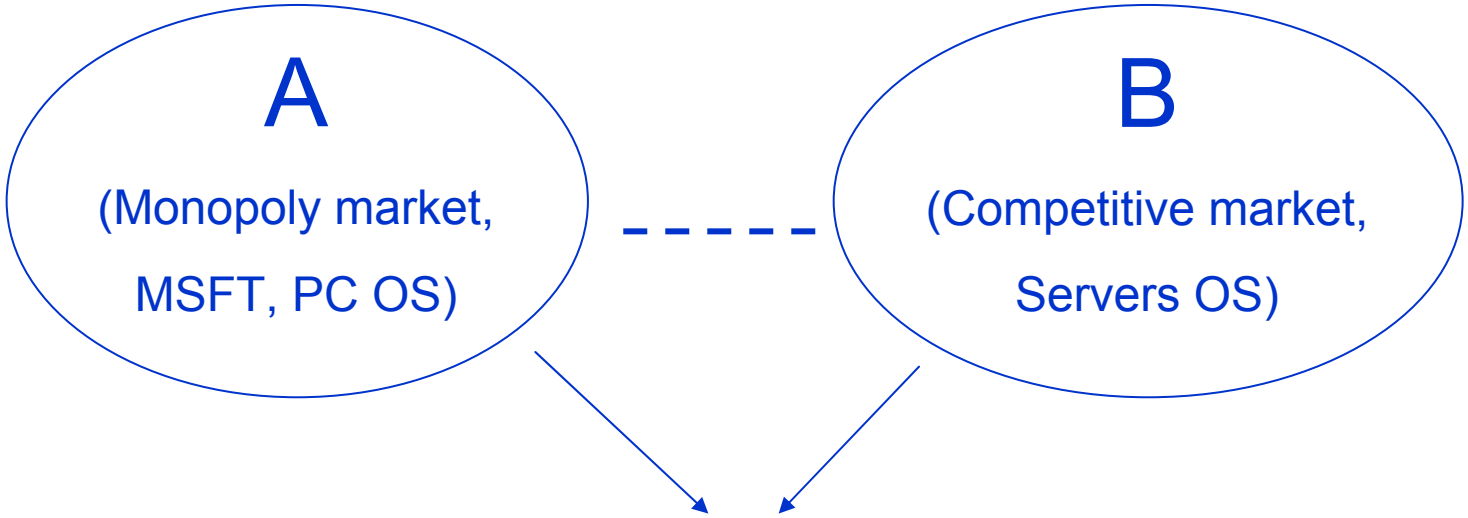
Basic Idea

Analyse the incentives for foreclosure in complementary markets

(workgroup server operating systems)



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Degrading Interoperability in Microsoft's case

"What we're trying to do is use our server control to do new protocols and lock out Sun and Oracle specifically……..the symmetry that we have between the client operating system and the server operating system is a huge advantage for us"

Bill Gates (1997)

- Useful for establishing some intent
- But is this just cheap talk?

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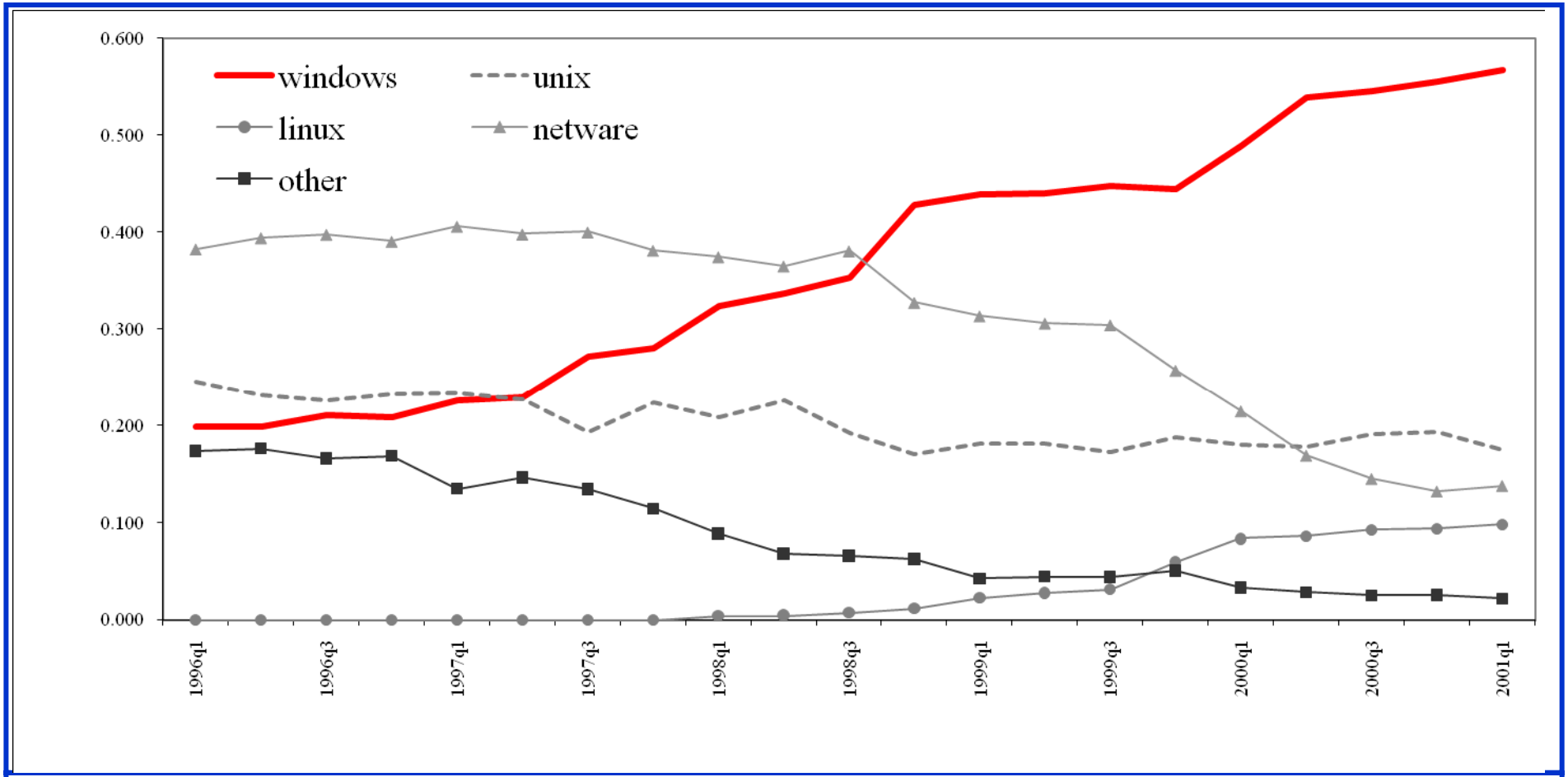
Is Microsoft's rising Server market share partly due to this?



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This paper

Aim: analyse theoretically and empirically the incentives of a monopolist to leverage a complementary market by degrading interoperability.

- Step 1: Simple model with basic mechanism
- Step 2: General model of differentiated products with heterogeneous consumers
- Step 3: Econometric framework to analyse complementary differentiated products markets and evidence on short run incentives

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Why do we care?

1. First attempt to combine theory and empirical evidence in foreclosure, an important area of public policy and research
2. Demonstrating leverage incentives essential for PC and server OS markets' evolution and competition (EU vs. Microsoft)
3. Results are critical for other complementary markets (complementary software, PDA's, Data-enabled mobile phones, Web-based applications)
4. Empirical framework relevant for estimating demand in differentiated oligopolistic markets for complementary products using aggregate data (BLP for complements)

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Step 1: Simple model

- Assume a monopolist (e.g. PC OS) facing two customer segments with different elasticities – large businesses are less price sensitive than small businesses.
- Assume that large businesses are also more likely to buy a complementary product (e.g. server OS), than small firms
- If the monopolist can perfectly price discriminate in the monopoly market, then no incentives to leverage (also Whinston, 1990, prop. 3)
- BUT if not (e.g. due to arbitrage), then the monopolist can restore price discrimination by leveraging the complementary market and shifting market share to his own server OS (exclude arbitrary better rival)

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Step 2: General Model

- Simple model has no product differentiation (and therefore no loss of PC sales from rivals' quality degradation)
- General Model: Each buyer decides on a workgroup (a server and *w* PCs), PC only or nothing
- We allow *w* to be heterogeneous in the population
- Also consumer heterogeneity on price and other product characteristics valuations

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Step 2 – cont.

Conditional indirect utility for consumer *i* purchasing a *jk* system

$$u_{ijk} = w[x_j\beta_i + A_k y_k \gamma_i - \lambda_i [p_j + \frac{p_k}{w}] + \xi_j + \xi_k + \eta_{ijk}]$$

PC characteristics

Server characteristics

PC price

Server price

Unobserved brand specific effects

Idiosyncratic customer taste

A_k captures server OS interoperability with Windows OS. For Microsoft servers $\alpha=1$ (perfect interoperability), whereas $\alpha \leq 1$ for non-Microsoft server OS (reduced interoperability)

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Profits for PC OS monopolist, *M*

Price of PC and OS bundle

Price of server and OS bundle

$$\Pi = (\omega - c)q(\mathrm{p_j}, \mathrm{p_k}, a) + (\omega_M - c_M)q_M(\mathrm{p_j}, \mathrm{p_k}, a)$$

MSFT PC OS margin

Quantity of PC OS sold

MSFT server OS margin

Quantity of server OS sold

Incentives to degrade interoperability (differentiate Π w.r.t. α) come from a trade-off between higher profits earned from shifting share to servers and lower profits on PCs as demand falls

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There exist incentives for foreclosure if:

Differentiate monopolist's profits w.r.t. interoperability parameter, α

$$(\omega - c)\frac{dq(\mathrm{p_j}, \mathrm{p_k}, a)}{da} \mid \omega, \omega_M + (\omega_M - c_M)\frac{dq_M(\mathrm{p_j}, \mathrm{p_k}, a)}{da} \mid \omega, \omega_M < 0$$

$$\underbrace{\frac{\omega_M - c_M}{\omega - c}}_{\text{"Relative Margin Effect"}} > \underbrace{-\frac{\frac{dq(\mathrm{p_j}, \mathrm{p_k}, a)}{da} \mid \omega, \omega_M}{\frac{dq_M(\mathrm{p_j}, \mathrm{p_k}, a)}{da} \mid \omega, \omega_M}}_{\text{"Relative Output Effect"}}$$

"Relative Margin Effect"
Server OS vs. PC OS

"Relative Output Effect"
Effect on demand of interoperability on PCs relative to servers

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Intuition

- Incentives to degrade interoperability always come from a trade off: higher profits earned from shifting share to servers, but lower profits on PCs as demand falls
- Incentives greater:
  - the larger server margins are greater than PC margins (NB – positive server margin a necessary condition, not One Monopoly Profit)
  - Fall in PC demand smaller than shift in server demand
- The right hand side (relative output effect) goes to zero as Microsoft's server share approaches one
- Digression – if MSFT could perfectly control interoperability then condition an equality. This is unlikely because of (a) timing, (b) rival response, (c) anti-trust threat

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Step 3: Econometric Framework

- "Relative Margin": need to estimate demand elasticities for PCs and servers
- Formulate econometric model for estimating demand in differentiated oligopolistic markets for complementary products (extending Berry, Levinsohn and Pakes, 1995, for complements)
- "Relative Output": different ways depending on the empirical formulation of interoperability

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Allowing random coef and complementarity

$$u_{ijk} = \delta_j + \mu_{ij} + \delta_k + \mu_{ik} + \varepsilon_{ijk}$$

Utility of *jk* bundle

$$\delta_j = x_j\beta - \lambda p_j + \xi_j$$

$$\delta_k = A_k y_k \gamma - \lambda p_k + \xi_k$$

Brand means

$$\mu_{ij} = \sum_h \sigma_h^{PC} x_{jh} \nu_{ih}^{PC} + \sigma_p^{PC} p_j \nu_{ip}^{PC}$$

$$\mu_{ik} = \sum_h \sigma_h^{S} y_{kh} \nu_{ih}^{S} + \sigma_p^{S} p_k \nu_{ip}^{S}$$

Random coefficients

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BLP with complements

- Consumers choose bundle that yields the highest utility
- To take this model to the aggregate data, we assume that the error term is “logit” i.i.d. over bundles, consumers and time
- Note: following the theory, we built in complementarity by allowing server purchases only in conjunction with PCs
- Also estimate two alternative models:
  - “strong” complementarity: bundle or nothing
  - “free” complementarity: allow data to determine complementarity/substitutability (Gentzkow, 2007; Song & Chintagunta, 2006)

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Interoperability and Output effect

Basic approach – follows theory:

$$\delta_k = y_k\gamma_1 + \gamma_2 M + \gamma_3 (M * y_k) - \lambda p_k + \xi_k$$

Are server hardware characteristics less valuable if used with a non-Microsoft server?

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Data

- IDC PC Tracker (Pakes 2003), IDC Server Tracker (Ivaldi and Lorinscz, 2004)
- Quarterly data on transaction prices and quantities from 1996Q1-2001Q1 for the US
- Only basic characteristics in IDC. Hand-matched others from various trade publications (e.g. *Datasources*) and magazines (e.g. Computer weekly)
- Unit of observation:
  - PC: Vendor-Brand-Form factor (laptop/desktop); 3,305 obs
  - Server: Vendor-Brand-Operating System; 2,967 obs

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Estimation Algorithm

- Given starting values for non-linear parameters and initial draws calculate brand market shares
- Contraction mapping to numerically compute mean valuations s.t. calculated mkt shares equal the observed mkt shares
- Due to complementarity, we compute each product category's mean valuation conditional on the other category's mean valuation
- Given δ, calculate ξ and form the GMM
- Minimize: $$\hat{\theta} = \arg\min_{\theta} \hat{\xi}(\theta)' Z A^{-1} Z' \hat{\xi}(\theta)$$

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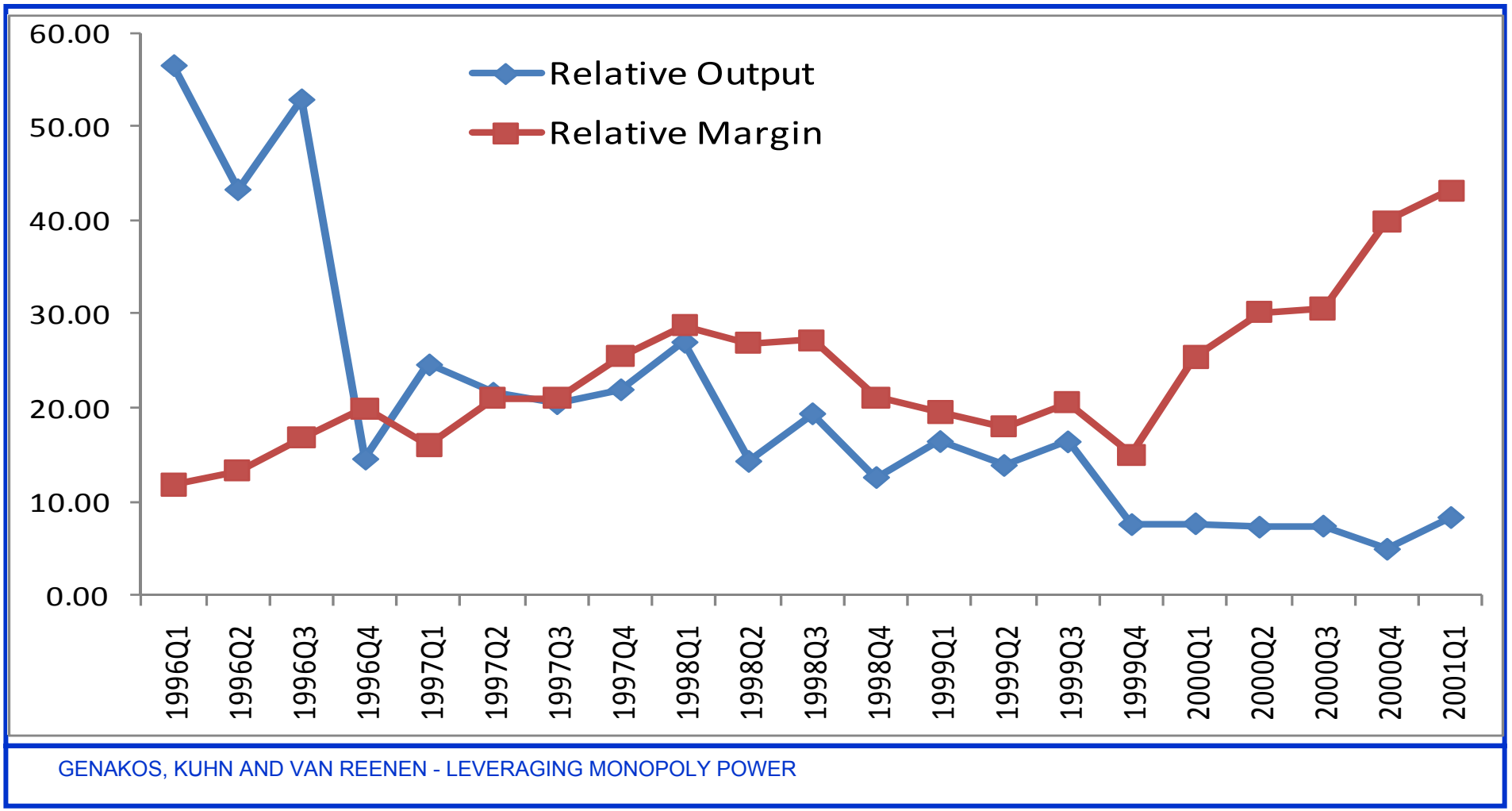
Foreclosure Incentives



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Foreclosure Incentives

- ✓ Server margins higher than PC margins, as expected
- ✓ Positive value of relative output effect indicates that interoperability reduction has a cost to Microsoft

1. Beginning of our sample, relative output higher than relative margin = no incentives to reduce interoperability
2. The two effects follow opposite directions. By 2001, relative margin clearly dominates relative output.
3. Key point when the two lines diverge is around the beginning of 2000 when Microsoft releases new PC OC (Windows 2000)

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Foreclosure Incentives

- Pattern of foreclosure incentives ROBUST to:
  - ✓ Sample of consumers (initial draws)
  - ✓ Different assumption on potential market size
  - ✓ Number of instrumental variables
  - ✓ Number of random coefficients
- Is it model driven? Alternative models:
  - "strong" complementarity: bundle or nothing
  - "free" complementarity: estimate positive and significant indicating that PC and servers are complements

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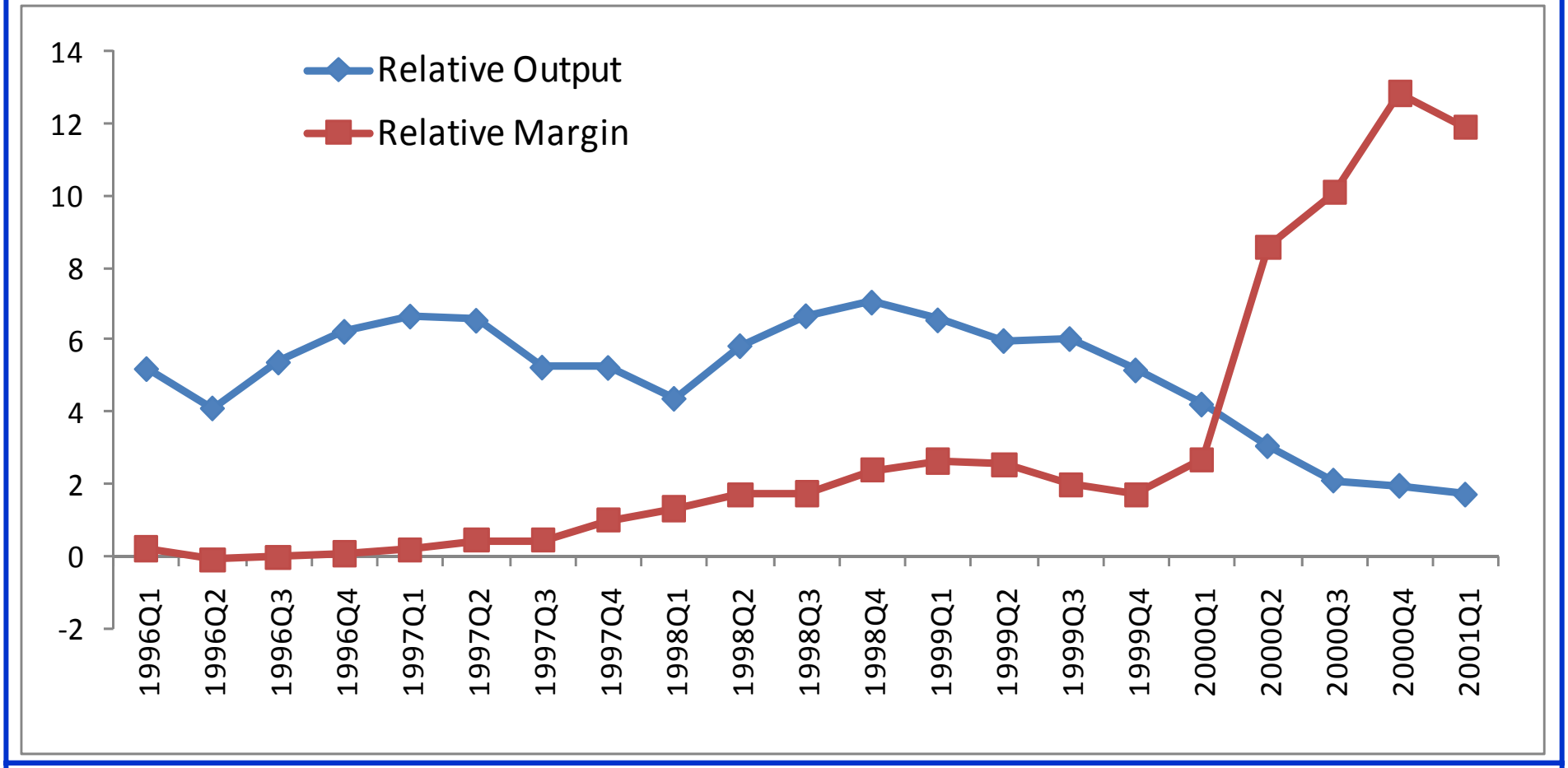
Foreclosure Incentives ("strong" complementarity)



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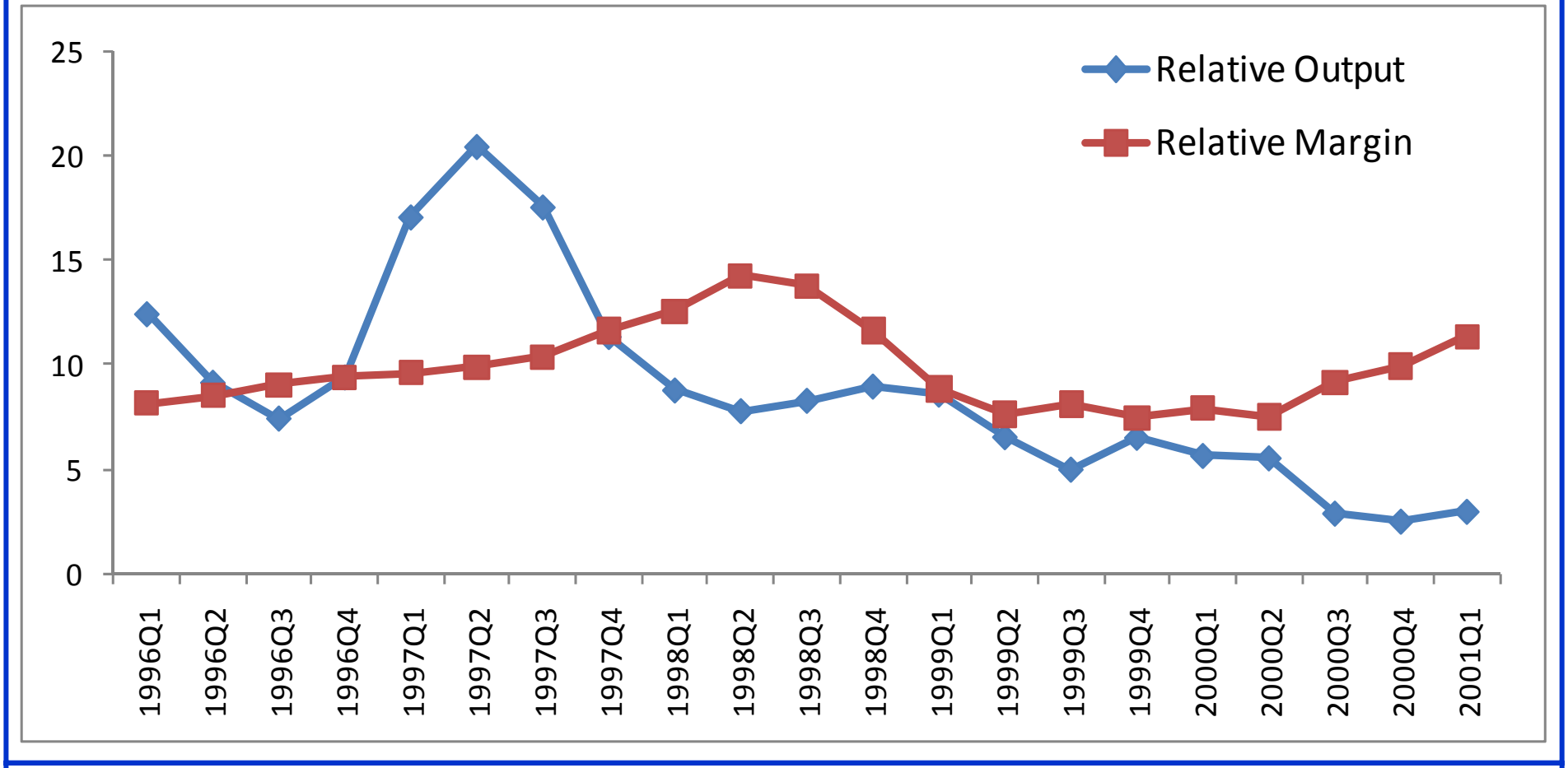
Foreclosure Incentives ("free" complementarity)



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Conclusions

- ✓ We model the incentives of a monopolist to leverage a complementary market because of inability to extract all monopoly rents in primary market through price discrimination
- ✓ We derive explicit conditions for the incentives to hold that are amendable to empirical testing
- ✓ We test these predictions in the context of Microsoft's alleged incentives to leverage market power from the PC to the server OS market in the late nineties
- ✓ We find (robust) evidence that these incentives exist and that they have grown stronger over time

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BACK-UP

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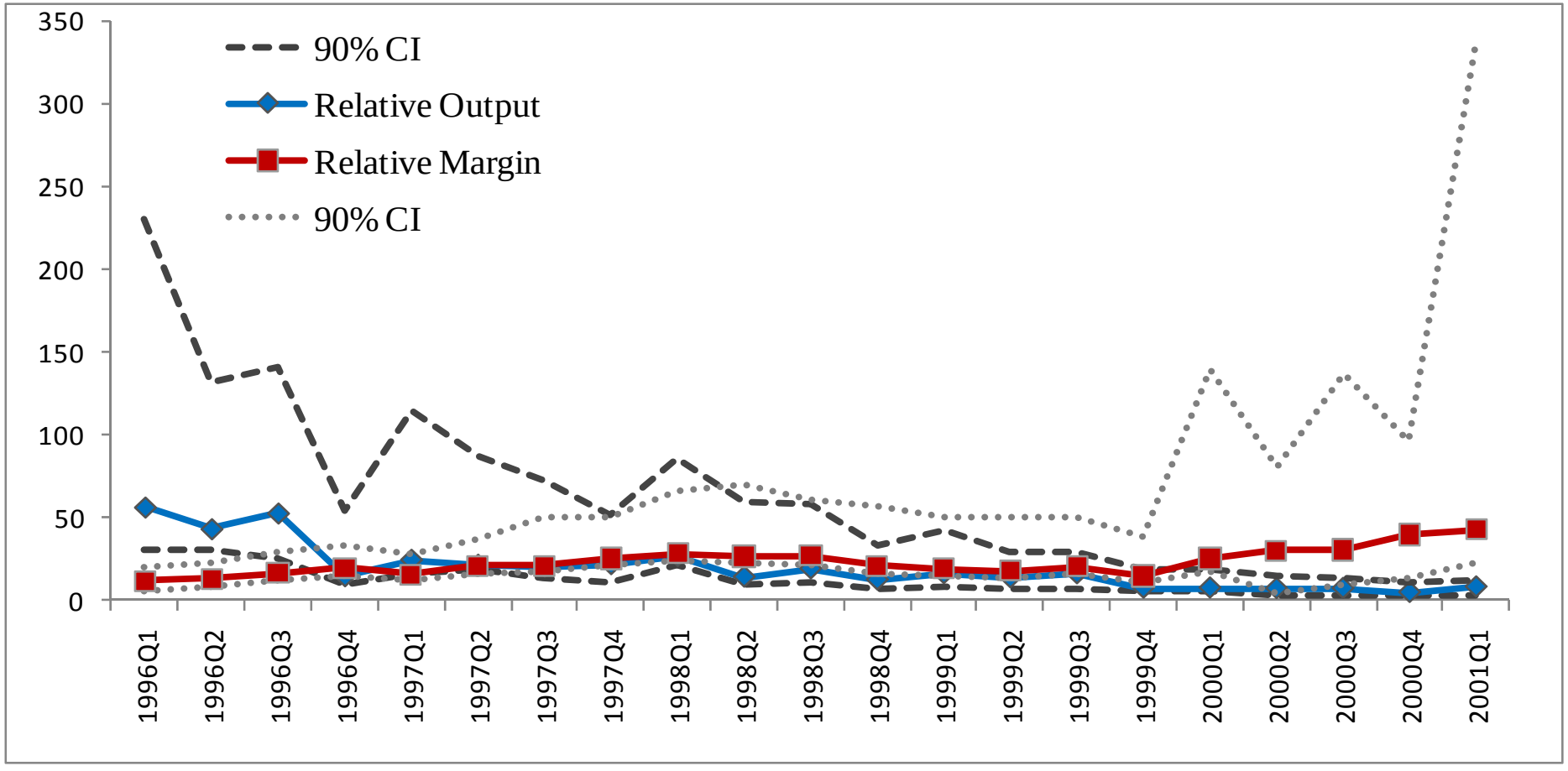
Foreclosure Incentives (bootstrap s.e.)



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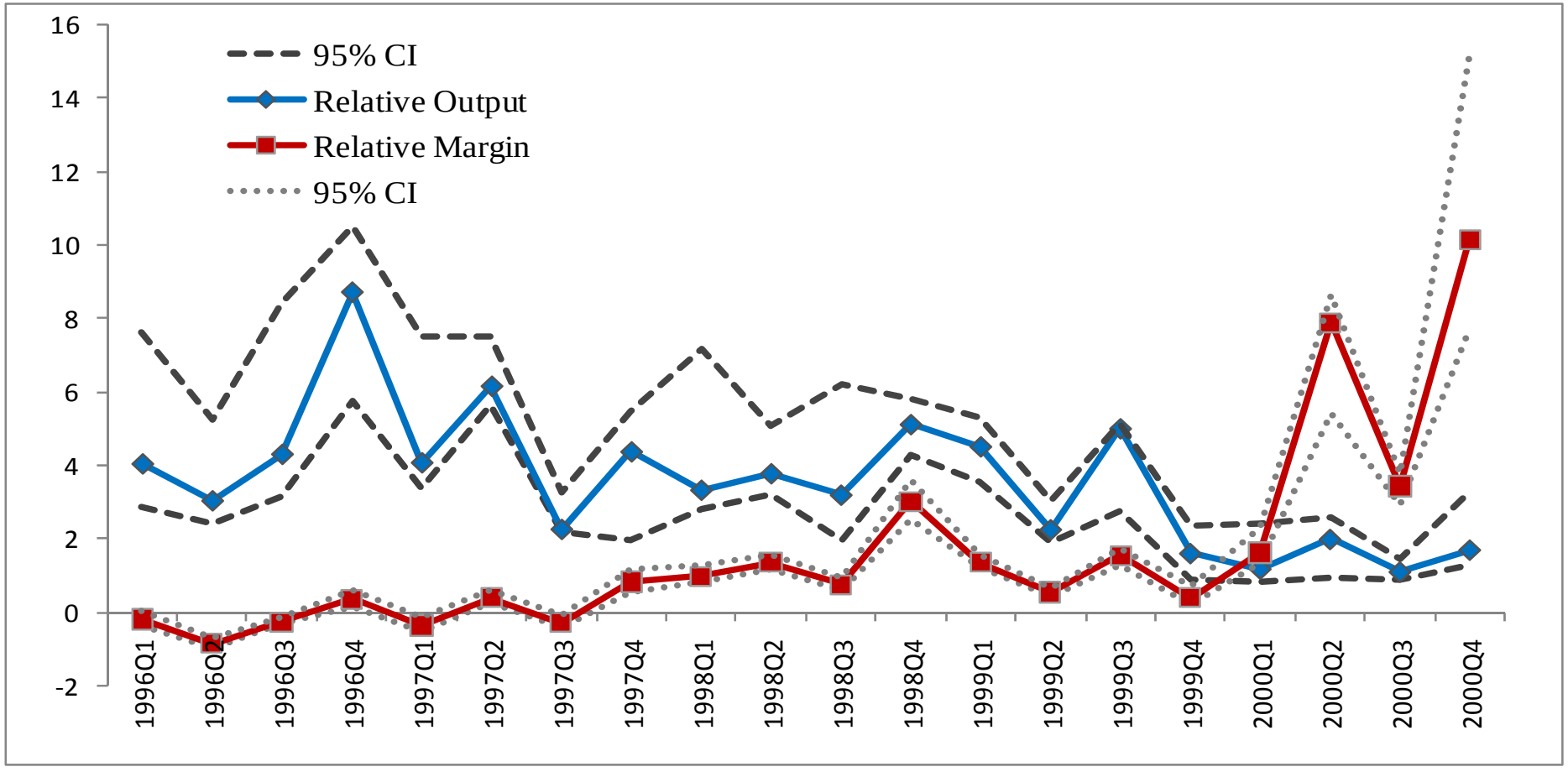
Foreclosure Incentives ("strong" complementarity)



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Other F.O.C. for monopolist

Differentiate monopolist's profits w.r.t. server OS price, ω_Ω, and PC OS price, ω_{OS}

$$q+(\omega-c)\frac{\partial q}{\partial \omega}+(\omega_M-c_M)\frac{\partial q_M}{\partial \omega}=0 \qquad q_M+(\omega-c)\frac{\partial q}{\partial \omega_M}+(\omega_M-c_M)\frac{\partial q_M}{\partial \omega_M}=0$$

Semi-elasticity

$$\varepsilon_M^L=\frac{1}{q_L}\frac{\partial q_L}{\partial \omega_M}$$

$$\omega-c=\frac{\frac{q_M}{q}\varepsilon_\omega^M-\varepsilon_{\omega_M}^M}{\varepsilon_\omega\varepsilon_{\omega_M}^M-\varepsilon_{\omega_M}\varepsilon_\omega^M} \qquad \omega_M-c_M=\frac{\frac{q}{q_M}\varepsilon_{\omega_M}-\varepsilon_\omega}{\varepsilon_\omega\,\varepsilon_{\omega_M}^M-\varepsilon_{\omega_M}\varepsilon_\omega^M}$$

PC OS margin

Server OS price

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Relative mark-up of server OS vs. PC OS

$$\frac{\omega_M - c_M}{\omega - c} = \frac{\frac{q}{q_M}\varepsilon_{\omega_M} - \varepsilon_{\omega}}{\frac{q_\Omega}{q}\varepsilon^M_{\omega} - \varepsilon^M_{\omega_M}}$$

PC own elasticity

Server own elasticity

Relative mark-up is higher if server demand less elastic than PC demand

Aggregate elasticities, ε, are derived from integration over the type specific elasticities denoted, $\varepsilon(\alpha,\beta,\lambda,w)$

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The link between price discrimination and foreclosure

- Consider the server margin, $\omega_\Omega - c_\Omega$,
- Under the logit assumptions we can write this as

Elasticity for a particular type (α,β,γ,w)

$$\frac{q}{q_M}\varepsilon_{\omega_M} - \varepsilon_\omega = \int \left[\frac{q(\theta)}{q} - \frac{q_M(\theta)}{q_M} \right] [\bar{\varepsilon}_\omega - \varepsilon_\omega(\theta)]$$

Mean own price elasticity

-- No heterogeneity implies $\omega_M - c_M = 0$, no price discrimination
-- No price discrimination and one monopoly profit theory holds
-- We need correlation between customer types (e.g. small firms) with higher elasticity and higher probability of buying PCs (relative to servers).

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Econometric issues

- Instruments
  - "Other prices". Use Canadian prices (Hausman, Leonard and Zona, 1994)
  - "Other characteristics" (BLP)
  - Group other characteristics by vendor, its rivals, by form factor (Bresnahan et al, 1997)
  - Factor input prices for servers only
- Supply side – don't impose a particular form of competition (e.g. Bertrand Nash). Preferable as we don't know nature of competition

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Estimated Aggregate Elasticities

Mean	Whole Market (1)	Home Segment (2)	Small Business Segment (3)	Large Business Segment (4)
IV Logit	4.95	7.94	5.93	3.17
Random Coefficients	3.94	4.70	4.17	2.62

- ✓ Considerable heterogeneity in preferences across segments.
- ✓ Confirms intuition that large firms are less price sensitive than smaller firms (who are less price sensitive than home users)

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"Free" complementarity model

$$u_{ijk} = \delta_j + \mu_{ij} + \delta_k + \mu_{ik} + \Gamma(d^{PC} d^{S}) + \varepsilon_{ijk}$$

Utility of *jk* bundle

$$\delta_j = x_j \beta - \lambda p_j + \xi_j$$

$$\delta_k = A_k y_k \gamma - \lambda p_k + \xi_k$$

Brand means

$$\mu_{ij} = \sum_h \sigma_h^{PC} x_{jh} \nu_{ih}^{PC} + \sigma_p^{PC} p_j \nu_{ip}^{PC}$$

$$\mu_{ik} = \sum_h \sigma_h^{S} y_{kh} \nu_{ih}^{S} + \sigma_p^{S} p_k \nu_{ip}^{S}$$

Random coefficients

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"Free" complementarity model

- A bundle includes one and only one alternative from each product category: $\eta_{ijk} = \Gamma(d^{PC}, d^{S}) + \varepsilon_{ijk}$; d^{PC}=1 if buy any PC, 0 otherwise; d^{S} =1 if buy any server, 0 otherwise
- $\Gamma(.)$ is complementary ($\Gamma>0$) /substitution ($\Gamma<0$) function following Gentzkow (2007), Song and Chintagunta (2006)
- Given our aggregate data, we focus on: (i) marginal purchase probability in each product category and (ii) the brand choice probability conditional on purchasing the category.

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Demand cont.

$$\Pr(y_{PC} = 1) = \frac{W_1 W_2 e^{\gamma} + 1}{W_1 W_2 e^{\gamma} + W_1 + W_2 + 1}$$

Marginal Pr of buying a PC

$$\Pr(y_{PCj} = 1 / y_{PC} = 1) = \frac{\exp(V_{PCj})}{\sum_{l=1}^{J_{PC}} \exp(V_{PCl})}$$

Conditional Pr of buying PC j

$$s_{PCj} = \Pr(y_{PCj} = 1) = \Pr(y_{PC} = 1) \times \Pr(y_{PCj} = 1 / y_{PC} = 1)$$

where

Unconditional Pr of buying PC j

$$W_1 = \sum_{l=1}^{J_{PC}} \exp(V_{PCl}) \text{ and } V_{PCj} = \delta_j + \eta_{ij}$$