Assessing an Efficiency Defense: The Case of Intel's Marketing Campaign

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Motivation

- Antitrust authorities typically establish exclusivity/anticompetitive cases by considering pricing
- This paper focuses on non-price anticompetitive behavior arising from advertising/marketing campaigns
- Propose a general framework for analyzing marketing predation
- Use the framework to determine if Intel's cooperative marketing campaign was predatory
- Unlike predatory pricing, no clear short-run benefit of the short-term profit sacrifice
  - can be even more harmful if effect is long lasting (i.e., by establishing goodwill)
  - may become an endogenous entry barrier

Test of Advertising Predation (TAP)

- Develop Test of Advertising Predation (TAP)
  - Based on the presumption that if a marketing campaign is not predatory, marketing expenses should be efficient.
  - Should be sufficient increased product demand to justify costs
  - Focuses on detecting short-term profit sacrifice
- With flavor of the Areeda-Turner test of predatory pricing
  - Compute marginal revenue from the marketing behavior (MMR) and then compare this to its (observed) marginal cost.
- Based on a structural approach (demand estimation)
  - Allows us to disentangle the potential positive impact of a marketing program from the anticompetitive predatory effect

Implementing TAP

1. Estimate demand as a function of marketing variables.
   - Demand specification chosen depends on, e.g. the data available, how marketing variables are thought to impact demand, as well as the nature of the relevant market
2. Use the demand estimates to compute MR of marketing (MMR)
3. Compare it to the observed marketing costs (MMC)
   - Marginal cost often unavailable. Then use AVC as a proxy
4. If MMR>MMC, TAP result if "positive", meaing that the marketing behavior is predatory.
   - The observed MMC above the 95% CI for the estimated MMR suggestive that there was "excessive" expenditure on the marketing.

- Why not modeling a firm's profit function? Requires a specific assumption on how marketing is done and more data

Issues to consider when using TAP

- TAP is a test of short-term profit sacrifice: need to make case for long-term profit recoupment
  - Dominant position of the predator
  - Information asymmetries
  - High entry barriers
  - Potential for advertising to establish a barrier to entry
- Efficiency rationals for short-term profit sacrifice such as:
  - Dynamic efficiencies
    - e.g. learning-by-doing, promotional purpose, or network externality
    - not as likely driving factors for a dominant firm with large market share, long history of production
  - Brand-loyalty-building effect

Issues to consider when using TAP

How do we address brand-loyalty-building effect?

- Anticompetitive period vs. normal period
  - While the incentive to build goodwill is constant across all periods, anticompetitive motive prevails in certain periods of time
- Anticompetitive firms vs. innocent firms
- Possible empirical examination
  - Include lagged marketing variables in the demand specification
  - Determine how many future periods of MMR would need to be considered by firm to rationalize the current period MMC

Why apply TAP to Intel?

- **Intel Inside** launched in 1991
  - Intel contributes percentage of the purchase price of processors to a pool for PC firms to use to market Intel-based computers
  - PC firms can receive a rebate of marketing expenditures if ads include Intel logo
  - End of the 1990s, over 2,700 PC firms and spent more than 7 billion

- Allegedly anticompetitive use
  - Intel dominant accouting for 80% worldwide CPU sales, AMD the only rival with 18% market share
  - "conditional rebates" (1.5 billion in 2002) during 2002-2005 that severely restricts PC firms' use of AMD chips
  - coincides with the introduction of Athlon and Opteron (in 1999 and 2003, respectively)
  - found guilty of anticompetitive use the marketing program 2002-2005 in many jurisdictions

Intel's Anticompetitive Conduct with Dell

- Consider specifically Intel's marketing subsidy to Dell during the 2002-2005 period
- Rebates given on the condition of not using any AMD chips

  "the original basis for the [Intel marketing] fund is ... Dell's loyalty to Intel" meaning "no AMD processors." - 2002 Dell document

  "The key talking point [for Intel] is: 'Gee, if you're going to reduce our bottom line [rebate] as AMD gets weaker, what incentive do we have to help AMD get weaker'?" - April 2004 Dell internal email

- Detailed data on Intel's rebate amount from antitrust documents

Rebate Amounts Paid by Intel to Dell

		Meet the Competition Program (MCP)				
Quarter	Rebate Rate on CPU purchases (1)	Percentage Rebate Payment (2)	Lump Sum Payment (3)	Total MCP Payments (4)	Dell's Operating Income (5)	MCP % of Operating Income (6)
2002Q1	6%	$61m	-	$61m	$590m	10%
2002Q2	6%	$57m	$3m	$60m	$677m	9%
2002Q3	6%	$59m	$12m	$71m	$758m	9%
2002Q4	6.3%	$77m	$7m	$84m	$819m	10%
2003Q1	6.3%	$91m	$8m	$99m	$811m	12%
2003Q2	6.3%	$106m	$6m	$112m	$840m	13%
2003Q3	6.3%	$105m	$40m	$145m	$912m	16%
2003Q4	7%	$118m	$82m	$200m	$981m	20%
2004Q1	8.7%	$137m	$70m	$207m	$966m	21%
2004Q2	12% + var.	$210m	-	$210m	$1,006m	21%
2004Q3	12% + var.	$250m	-	$250m	$1,095m	23%
2004Q4	12% + var.	$293m	$75m	$368m	$1,187m	31%
2005Q1	12% + var.	$307m	$81m	$388m	$1,174m	33%
2005Q2	12% + var.	$313m	$119m	$432m	$1,173m	37%
2005Q3	12% + var.	$339m	-	$339m	$754m	45%
2005Q4	12% + var.	$423m	$60m	$483m	$1,246m	39%
2006Q1	12% + var.	$405m	$318m	$723m	$949m	76%

Source: p.14 MCP table from "Securities and Exchange Commission vs. Dell", U.S. District Court of Columbia Summary Statement

Implementing TAP - Intel Case Application

- Compute MR that would accrue to Intel from the marketing campaign and then compare this to the (observed) marginal cost of the marketing campaign. To do this, we

1. estimate a model of demand for for PC-CPUs that is a function of PC-CPU characteristics, demographics, marketing variables
2. infer CPU demand from PC demand
3. compute MMR of Intel's marketing campaign and compare to (observed) measures of MMC (proxied by AVC computed in 4 different ways)

Data Sources

- PC/CPU sales and attributes (from Gartner Group)
- Intel CPU price and cost estimates (from In-Stat)
- Advertising (from Kantar Media Group)
- (Annual) consumer survey on PC purchase (from Forrester Research)
- Time period: 2002:Q1 - 2005:Q4

Step 1: PC Demand

- Indirect utility from purchasing j by consumer i in market t:

$$u_{ijt} = \delta_{jt} + \mu_{ijt} + \epsilon_{ijt}$$

where

$$\begin{aligned} \delta_{jt} &= x'_{jt}\beta + \gamma a^{\text{pc}}_{jt} + \lambda a^{\text{cpu}}_{jt} + \xi_{jt}; \\ \mu_{ijt} &= \alpha \ln(y_{it} - p_{jt}) + a'_{jt}\varpi \; exposure_{it}; \\ u_{i0t} &= \alpha \ln(y_{it}) + \xi_{0t} + \epsilon_{i0t} \end{aligned}$$

  - y: income, p: price of PC model
  - x: non-price attributes (platform, Intel, speed, CPU benchmark, age variables, PC firm)
  - ad^{pc}: PC firm advertising, ad^{cpu}: CPU vendor advertising (at firm and brand level)
  - exposure: num. hours of media exposure in an average week
  - ϵ_{ijt} idiosyncratic logit error
  - $j = 0$ is the outside option (i.e. buying PCs with non-Intel/AMD cpu)

Step 2: Inferred CPU Demand

- (Conditional) probability that consumer i purchases product j

$$s_{ijt} = \frac{\exp\{\delta_{jt} + \mu_{ijt}\}}{{y_{it}}^{\alpha} + \sum_r \exp\{\delta_{rt} + \mu_{irt}\}}$$

- (Given a PC is equipped with one CPU) market share for PC firm f of cpu type c

$$\begin{aligned} s_{fct} &= \sum_{j \in \mathcal{J}_c \cap \mathcal{J}_f} \int \frac{\exp\{\delta_{jt} + \mu_{ijt}\}}{{y_{it}}^{\alpha} + \sum_r \exp\{\delta_{rt} + \mu_{irt}\}} dG_D(D) \\ &= \sum_{j \in \mathcal{J}_c \cap \mathcal{J}_f} s_{jt}(p, a) \end{aligned}$$

  - $\mathcal{J}_f$: set of firm fś products;
  - $\mathcal{J}_c$: set of PCs with CPU type c
  - $D = \{y, exposure\}$

Step 3: MMR estimate

- Total marketing revenue (TMR) of Intel from subsidizing firm f

$$TMR_f = \sum_{c \in \mathcal{J}_{intel}} \sum_{f} (p_c^{CPU} - mc_c) \mathcal{M} s_{fc}(p, a)$$

  - $\mathcal{J}_{intel}$: set of PCs with Intel chip; $\mathcal{M}$ is a market size;
  - p_c^{CPU} : price of CPU c; mc_c : marginal production cost of CPU c;
  - $s_{fc}(p, a)$: market share of firm f's products with CPU c

- Intel's marginal revenue from giving marketing subsidy to firm f

$$MMR_f = \mathcal{M} \sum_{\substack{j,r \in \mathcal{J}_f \\ c \in \mathcal{J}_{intel}}} (p_c^{CPU} - mc_c) \frac{\partial s_j(p, a)}{\partial a_r^{pc}} \varpi_r \quad \text{where} \quad \sum_{\substack{r \in \mathcal{J}_f \\ c \in \mathcal{J}_{intel}}} \varpi_r = 1$$

- Need assumption on how the marketing subsidy will be allocated among PCs with Intel chip (ϖ_r)
  - We consider 2 cases: (1) proportional to market share, (2) equal allocation

Step 4: Proxies for MMC

- Same vein as Areeda-Turner test: use AVC as proxy for MC
- AVC of marketing campaign is

$$MMC_f = \frac{\text{total marketing subsidy paid by Intel to PC firm } f \ (TC)}{\text{total advertising by PC firm } f \text{ for PCs with Intel chip } (Q)}$$

  - while Q is given by data,

- Use four measures of TC :

TC1 total payment of Intel to Dell as given in case files

TC2 **TC1***Percentage of Revenue from PC sales across all segments sold by Dell

TC3 6% rebate; no lump sum payment (as in normal periods)

TC4 3% rebate; no lump sum payment (as stated on Intel website)

Limitations of Using AVC as a Proxy for MC

Is AVC a good measure of MC?

- Need to distinguish variable cost from fixed cost - not much of an issue in advertising
- Ignore advertising spill-over across different segments (education, business), server market - Both MMC and MMR likely to be underestimated
- Assume PC firms' responsiveness to Intel's marketing program is constant

PC/CPU Demand (Berry Logit)

	Variables	(1)	(2)	(3)	(4)	(5)	(6)
		Dependent Variable: ln(Market Share) - ln(Share of Outside Goods)					
Price		-0.286***	-1.047*	-0.515***	-0.337***	-1.765***	-2.228***
		(0.0855)	(0.609)	(0.0671)	(0.0647)	(0.541)	(0.643)
PC Characteristics	Laptop	-0.178**	0.146			0.410*	0.497*
		(0.0711)	(0.266)			(0.236)	(0.292)
	Older PC	0.906***	0.858***			0.655***	0.582***
		(0.122)	(0.128)			(0.114)	(0.145)
	PC Age	0.126***	0.138***			0.0940***	0.0904***
		(0.0222)	(0.0241)			(0.0215)	(0.0238)
CPU Characteristics	Intel	-0.510***	-0.233	-0.0104	-0.000200	0.502	-2.060
		(0.103)	(0.244)	(0.231)	(0.221)	(0.319)	(1.308)
	ln(Benchmark)	0.371**	0.851**	0.575***	0.415***	1.315***	1.362***
		(0.155)	(0.414)	(0.128)	(0.120)	(0.371)	(0.434)
	ln(Speed)	1.594***	1.731***	1.381***	1.108***	1.625***	1.724***
		(0.106)	(0.149)	(0.0883)	(0.0847)	(0.135)	(0.166)
	Older CPU	-0.0906	-0.0641	0.487***	0.494***	0.237**	0.192
		(0.113)	(0.116)	(0.0922)	(0.0832)	(0.107)	(0.129)
	CPU Age	0.00524	-0.0101	0.0994***	0.0960***	0.0360*	0.0226
		(0.0174)	(0.0206)	(0.0135)	(0.0131)	(0.0186)	(0.0229)
Advertising	CPU ad			-0.0259	0.0945	-0.139	4.186***
				(0.187)	(0.174)	(0.193)	(1.360)
	CPU ad squared			-0.00803	-0.0370	0.0167	-0.868***
				(0.0306)	(0.0278)	(0.0321)	(0.253)
	PC ad			2.352***		2.363***	3.496***
				(0.0830)		(0.0862)	(0.302)
	PC ad squared			-0.294***		-0.304***	-0.581***
				(0.0216)		(0.0223)	(0.133)
Included Controls							
	IV for Price		Included			Included	Included
	IV for Advertising						Included
	PC Advertising				Included		
	PC Advertising Squared				Included		
	PC Firm Fixed Effects	Included	Included	Included	Included	Included	Included
Observations		5,327	5,327	5,327	5,327	5,327	5,327
R-squared		0.498	0.491	0.597	0.649	0.575	0.470
Median (Own) Price Elasticity		-0.336	-1.231	-0.605	-0.396	-2.075	-2.619

Notes:Standard errors are in parenthesis. *** indicates significant at 1%; ** at 5% and * at 10%. All regressions include time dummies.

PC/CPU Demand (Random Coefficient)

Variables		(1)	(2)	(3)
Price		25.2698***	25.0832***	25.9999***
		(6.5513)	(6.8557)	(7.8098)
Advertising	CPU ad	3.9723***	4.827**	3.9657***
		(1.322)	(1.9045)	(1.4147)
	CPU ad squared	-0.8275***	-0.8948***	-0.8256***
		(0.2466)	(0.2574)	(0.2577)
	PC ad	3.4768***	1.8457*	3.4783***
		(0.2939)	(0.9447)	(0.3051)
	PC ad squared	-0.594***	-0.5422***	-0.5921***
		(0.1314)	(0.1329)	(0.1327)
Interactions	CPUad with Exposure	-	-2.3768	-
			(2.4979)	
	PCad with Exposure	-	5.6917***	-
			(2.117)	
	ln(Speed) with age			-0.0086
				(0.2892)
	ln(Speed) with married			0.0996
				(14.3185)
	ln(Speed) with kids			0.0998
				(13.5293)
	ln(Speed) with inc_high			0.0999
				(8.1763)
	ln(Speed) with inc_low			0.0997
				(5.0587)
Included Controls				
	IV for Price	Included	Included	Included
	IV for Advertising	Included	Included	Included
	PC Firm Fixed Effects	Included	Included	Included
Observations		5,327	5,327	5,327
R-squared				
Median (Own) Price Elasticity			-4.233	

Notes:Standard errors are in parenthesis. *** indicates significant at 1%; ** at 5% and * at 10%. All regressions include time dummies.

PC/CPU Demand (Random Coefficient) - continued

	Variables	(1)	(2)	(3)
PC Characteristics	Laptop	0.2944	0.3816	0.3152
		(0.2839)	(0.2954)	(0.357)
	Older PC	0.6671***	0.7199***	0.6655***
		(0.139)	(0.1451)	(0.1551)
	PC Age	0.0871***	0.0944***	0.0878***
		(0.024)	(0.0253)	(0.0285)
CPU Characteristics	Intel	-2.0702	-2.2444*	-2.0546
		(1.2755)	(1.3256)	(1.3808)
	ln(Benchmark)	1.1066***	1.0779**	1.1345**
		(0.4281)	(0.4753)	(0.5226)
	ln(Speed)	1.6322***	1.7341***	1.906
		(0.1596)	(0.1688)	(31.1688)
	Older CPU	0.1776	0.1655	0.1817
		(0.1274)	(0.1376)	(0.1558)
	CPU Age	0.0359*	0.0371*	0.0355
		(0.0212)	(0.0218)	(0.0244)
Included Controls				
	IV for Price	Included	Included	Included
	IV for Advertising	Included	Included	Included
	PC Firm Fixed Effects	Included	Included	Included
Observations		5,327	5,327	5,327
R-squared				
Median (Own) Price Elasticity			-4.233	

Notes:Standard errors are in parenthesis. *** indicates significant at 1%; ** at 5% and * at 10%. All regressions include time dummies.

TAP Results (Berry logit) - market-share-weighted average

Time	Computed Marginal Revenue Est.	95% conf. Interval		Observed Marginal Cost (1)	(2)	(3)	(4)	TAP Result Positive in	# Years (1)	# Years (4)
2002Q1	1.11	(0.93	1.29)	34.54	31.12	3.33	1.66	all	7.8	0.4
2002Q2	0.66	(0.55	0.77)	45.62	40.70	3.73	1.87	all	17.4	0.7
2002Q3	0.90	(0.75	1.04)	53.31	48.05	5.90	2.95	all	14.9	0.8
2002Q4	1.58	(1.32	1.85)	91.86	82.59	13.02	6.51	all	14.5	1.0
								all		
2003Q1	1.94	(1.61	2.26)	352.14	315.44	44.78	22.39	all	45.5	2.9
2003Q2	1.64	(1.36	1.91)	192.68	171.66	17.50	8.75	all	29.4	1.3
2003Q3	2.12	(1.77	2.48)	140.80	126.81	13.61	6.80	all	16.6	0.8
2003Q4	2.05	(1.71	2.38)	93.19	82.75	7.57	3.79	all	11.4	0.5
								all		
2004Q1	2.23	(1.86	2.61)	682.73	607.55	56.66	28.33	all	76.4	3.2
2004Q2	1.32	(1.10	1.55)	345.53	306.09	18.57	9.28	all	65.2	1.8
2004Q3	1.12	(0.94	1.31)	133.28	118.52	7.39	3.69	all	29.7	0.8
2004Q4	1.31	(1.09	1.52)	192.46	171.46	8.55	4.27	all	36.8	0.8
								all		
2005Q1	3.55	(2.95	4.14)	390.02	340.19	15.51	7.75	all	27.5	0.5
2005Q2	2.45	(2.04	2.86)	370.16	323.16	11.29	5.65	all	37.8	0.6
2005Q3	2.58	(2.15	3.01)	348.36	307.69	15.68	7.84	all	33.8	0.8
2005Q4	3.40	(2.83	3.97)	340.69	298.21	13.24	6.62	all	25.04	0.49

Notes: Unit: $ (inflation adjusted - base: 2000)

TAP Results (Berry logit) - ordinary average

	Computed Marginal Revenue			Observed Marginal Cost				TAP Result	# Years	# Years
Time	Est.	95% conf. Interval		(1)	(2)	(3)	(4)	Positive in	(1)	(4)
2002Q1	0.33	(0.28	0.39)	34.54	31.12	3.33	1.66	all	25.9	1.2
2002Q2	0.25	(0.21	0.29)	45.62	40.70	3.73	1.87	all	45.8	1.9
2002Q3	0.28	(0.24	0.33)	53.31	48.05	5.90	2.95	all	47.3	2.6
2002Q4	0.42	(0.35	0.49)	91.86	82.59	13.02	6.51	all	54.2	3.8
								all		
2003Q1	0.43	(0.36	0.50)	352.14	315.44	44.78	22.39	all	203.8	13.0
2003Q2	0.40	(0.34	0.47)	192.68	171.66	17.50	8.75	all	119.4	5.4
2003Q3	0.51	(0.43	0.59)	140.80	126.81	13.61	6.80	all	69.0	3.3
2003Q4	0.56	(0.47	0.65)	93.19	82.75	7.57	3.79	all	41.7	1.7
								all		
2004Q1	0.71	(0.59	0.83)	682.73	607.55	56.66	28.33	all	239.0	9.9
2004Q2	0.46	(0.38	0.54)	345.53	306.09	18.57	9.28	all	186.8	5.0
2004Q3	0.48	(0.40	0.56)	133.28	118.52	7.39	3.69	all	68.8	1.9
2004Q4	0.49	(0.41	0.58)	192.46	171.46	8.55	4.27	all	97.4	2.2
								all		
2005Q1	1.83	(1.52	2.14)	390.02	340.19	15.51	7.75	all	53.3	1.1
2005Q2	1.54	(1.28	1.79)	370.16	323.16	11.29	5.65	all	60.2	0.9
2005Q3	1.49	(1.24	1.74)	348.36	307.69	15.68	7.84	all	58.5	1.3
2005Q4	1.63	(1.36	1.91)	340.69	298.21	13.24	6.62	all	52.13	1.01

Notes: Unit: $ (inflation adjusted - base: 2000)

TAP Results (Berry logit) - HP and Toshiba

PC firm	HP						Toshiba					
	Computed MR			Observed MC		TAP Result	Computed MR			Observed MC		TAP Result
Time	Est.	95% conf. Interval		(3)	(4)	Positive in	Est.	95% conf. Interval		(3)	(4)	Positive in
2002Q1	-0.02	(-0.25	0.22)	0.11	0.05		0.13	(0.11	0.15)	0.14	0.07	
2002Q2	0.87	(0.74	1.00)	0.26	0.13		0.25	(0.21	0.29)	0.09	0.04	
2002Q3	0.99	(0.83	1.15)	0.27	0.13		0.64	(0.54	0.73)	0.16	0.08	
2002Q4	-4.41	(-7.67	-1.14)	0.12	0.06	3,4	0.61	(0.51	0.70)	0.45	0.22	
2003Q1	-0.35	(-1.06	0.36)	0.09	0.05		0.33	(0.28	0.39)	1.37	0.68	3,4
2003Q2	0.11	(-0.29	0.51)	0.11	0.05		0.20	(0.17	0.23)	0.82	0.41	3,4
2003Q3	0.27	(-0.21	0.74)	0.17	0.09		0.29	(0.25	0.34)	1.47	0.74	3,4
2003Q4	0.44	(-0.37	1.25)	0.30	0.15		0.42	(0.35	0.49)	1.45	0.72	3,4
2004Q1	-0.07	(-0.66	0.52)	0.14	0.07		0.33	(0.28	0.39)	0.99	0.50	3,4
2004Q2	0.25	(0.00	0.50)	0.13	0.07		0.34	(0.28	0.40)	0.99	0.50	3,4
2004Q3	0.44	(0.24	0.64)	0.20	0.10		0.41	(0.35	0.47)	0.48	0.24	3
2004Q4	0.29	(0.00	0.58)	0.17	0.09		0.96	(0.81	1.10)	0.29	0.15	
2005Q1	1.97	(0.64	3.31)	0.17	0.08		1.89	(1.59	2.19)	0.35	0.17	
2005Q2	3.90	(3.28	4.52)	0.33	0.17		1.93	(1.62	2.24)	0.42	0.21	
2005Q3	5.40	(4.60	6.19)	0.57	0.29		2.81	(2.34	3.27)	0.72	0.36	
2005Q4	5.02	(4.12	5.91)	0.41	0.21		2.84	(2.39	3.30)	0.49	0.24	

Unit: $ (inflation adjusted - base: 2000)

TAP Results (Berry logit) - Gateway

PC firm	Gateway						
	Computed Marginal Revenue				served Marginal C		TAP Result
Time	Est.	95% conf. Interval			(3)	(4)	Positive in
2002Q1	0.51	(0.33	0.69	)	0.14	0.07	
2002Q2	0.35	(0.25	0.44	)	0.10	0.05	
2002Q3	0.42	(0.34	0.49	)	0.16	0.08	
2002Q4	0.71	(0.60	0.82	)	0.26	0.13	
2003Q1	0.81	(0.69	0.93	)	0.20	0.10	
2003Q2	0.45	(0.38	0.51	)	0.20	0.10	
2003Q3	0.48	(0.41	0.55	)	0.17	0.08	
2003Q4	0.53	(0.45	0.61	)	0.15	0.07	
2004Q1	0.57	(0.49	0.66	)	0.78	0.39	3
2004Q2	0.36	(0.30	0.42	)	0.50	0.25	3
2004Q3	0.47	(0.39	0.54	)	0.37	0.18	
2004Q4	1.03	(0.86	1.20	)	2.66	1.33	3,4
2005Q1	4.12	(3.43	4.81	)	6.37	3.18	3
2005Q2	3.26	(2.72	3.80	)	2.64	1.32	
2005Q3	4.26	(3.55	4.97	)	4.21	2.11	
2005Q4	5.13	(4.30	5.95	)	1.79	0.90	

Unit: $ (inflation adjusted - base: 2000)

Motive and Recoupment

- Motive: In 1999 and 2003, AMD introduced Athlon and Opteron, respectively.
  - Almost unanimous agreement that the AMD chips are better-performing/cheaper than Intel counterparts.
- Successful predation and recoupment:
  - Capital-intensive, Continuous innovation: Deep-pocket theory of predation
  - Rapid change, Introduction of new products: Test-market theory of predation
  - Economies of scale

Efficiency Rationales

- Dynamic efficiencies less of a concern for Intel due to its persistent and dominant position
- Main Concern is brand-loyalty-building effect.
  - Anticompetitive vs. normal period: MC1, MC2 (based on actual payments- driven not only by procompetitive motives but also by predatory motives) vs. MC3, MC4 (serve as benchmark where normal rebate rates assumed)
  - Dell vs. other PC firms: Given that Dell has large market share in PC market and that Intel case was mainly about subsidy to Dell (in the US case), anticompetitive motive weaker for other PC firms
  - The number of periods required to justify the cost is huge.

Identification

- Assume demand unobservables are mean independent of observable product characteristics

$$E\left[\xi_{jt}(\Theta_0) \mid x_t\right] = 0$$

- Market participants know unobservables - endogeneity of prices and advertising
- Variables that shift markups valid as IV for price (BLP 1995) and valid as IV for ads (Sovinsky Goeree 2008)
    - Specifically, we use the characteristics of other products of the same PC firm and those of other PC firms and
    - Technological change affects production cost: a series of the interactions between CPU cohort dummies and time dummies; a series of the interactions between PC cohort dummies and time dummies

Moments

- BLP Macro moments: restrict predicted shares to match observed shares: $s(\xi;\theta) = S$ then solve for unobservable ξ
- Micro moments:
  - B_i vector of CPU firm choices of individual i and b_i is a realization where $b_{ir} = 1$ if a CPU produced by r ={Intel, AMD, or Other} was chosen
  - Residual difference between observed choice vector and prediction

$$\mathcal{B}_i(\delta,\theta) = b_i - E[B_i \mid D_{it}, \delta, \theta].$$

  - Population restriction is is $E[\mathcal{B}_i(\delta,\theta) \mid (x,\xi)] = 0$

BLP estimation technique

- We use GMM to find the parameter values that minimize the objective function, $\Lambda' Z A^{-1} Z' \Lambda$,
  - A is weighting matrix
  - Z_ξ, $Z_\mathcal{B}$ are instruments for each disturbance/residual
- Sample moments are

$$Z'\Lambda = \left[\begin{array}{c} \frac{1}{J}\sum_{j=1}^{J} Z_{\xi,j}\xi_j(\delta,\beta) \\ \frac{1}{N}\sum_{i=1}^{N} Z_{\mathcal{B},i}\mathcal{B}_i(\delta,\theta) \end{array} \right]$$

Assessing an Efficiency Defense:

The Case of Intel's Marketing Campaign

Hwa Ryung Lee, Andras Pechy and Michelle Sovinsky[1]

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Abstract

Antitrust authorities typically try to establish exclusivity and the anticompetitiveness of loyalty rebates through pricing, but do not address the strategic use of advertising and, more generally, marketing campaigns. In this paper we focus on non-price anticompetitive behavior arising from marketing. We propose a Test of Advertising Predation (TAP) that can be used to detect non-price predatory behavior. The TAP test is based on a structural approach and allows us to disentangle the potential positive impact of a marketing program from the anticompetitive predatory effect. We apply the TAP test to the Intel case, but it can be used to guide antitrust authorities in future cases, as it provides a more general framework for testing for the anticompetitive use of marketing campaigns. We use the test to examine whether Intel's choice of processor marketing via PC firms is consistent with predatory behavior, and find evidence that the "Intel Inside" marketing campaign had predatory effects.

JEL Codes: L4, D22, M37

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1 Introduction

Generally, predatory pricing is a price reduction that is profitable only because of the additional market power gained from excluding or otherwise inhibiting the rival from competing. However, the predator may also induce rivals to exit the industry via non-price predation. Predatory investments could be made in excessive capacity, product differentiation, advertising, etc. For example, excessive investments that have the objective and likely effect of weakening or eliminating competitors can be predatory. Indeed in many predatory situations, pricing is only one aspect of anticompetitive behavior.

We present a framework to test if firms are using marketing/advertising campaigns in an anticompetitive fashion. Our "Test of Advertising Predation (TAP)" is based on the presumption that, if a firm's marketing campaign is not predatory, marketing expenses should be efficient (i.e., profit maximizing) and so should result in sufficient increased product demand to justify costs.[2] The TAP test examines if the return on advertising (i.e., how it impacts demand) is high enough to justify marketing expenditures (as these are directed at increasing demand). The test is based on a structural approach that allows us to disentangle the potential positive impact of a marketing program from potential anticompetitive predatory effects. Constructing the TAP test does not require any more "fancy" econometrics than that needed to estimate a model of demand. We use this test to examine if the Intel Inside marketing program, which provided marketing support for firms that sold Intel processors, was used in a predatory fashion (during $2002 - 2005$). TAP results suggest short-term profit sacrifice by Intel over this period, which indicates that the Intel Inside campaign was used for predation.

While there is a vast theoretical literature on predation there are relatively few empirical studies, and these focus exclusively on pricing predation. Related papers in the price predation literature include: Weiman and Levin (1994) who examine predatory behaviour by Southern Bell Telephone Company between 1894 to 1912 when independent phone companies were trying to enter the market. Granitz and Klein (1996) provide evidence that Standard

[2] Our test is related to advertising but as advertising is (a very important) marketing tool, we use the terms marketing and advertising interchangeably, while realizing that marketing can involve more than just advertising (e.g., corporate training).

Oil engaged in predatory behavior by threatening to withhold inputs from railroads that were not in the railroad cartel. Genesove and Mullin (2006) estimate the price-cost margin in the sugar industry. They find that the price-cost margin was negative during price wars and predation was profitable in that it established a reputation as a tough competitor. Ellison and Ellison (2011) examine entry deterrence behavior in the pharmaceutical market prior to patent expiration by focusing on the asymmetry in detailing activities in markets of different size. Similarly, Chen and Tan (2007) focus on whether detailing in the pharmaceutical industry is consistent with predation incentives. Finally, Snider (2009) and Besenko, Doraszelski, and Kryukov (2010) estimate dynamic models of predatory pricing.

Our work contributes to the recent stream of research that uses structural models to study strategic behavior in the market for CPUs and PCs. These include papers by Salgado (2008a), Song (2007, 2010), Gordon (2009), and Goettler and Gordon (2009) who study the upstream CPU market. This literature mostly abstracts from PC manufacturer and PC characteristics when estimating CPU demand, and assumes that final consumers buy CPUs directly. Instead we model consumer's choice of a PC and use it to infer CPU demand. An advantage of our approach is that we can more easily estimate the effect of advertising by a PC firm on demand. Given that the Intel Inside program is the marketing subsidy from Intel to PC firms, this will allow us to estimate the effect of the Intel Inside on demand more directly. As a result our work is related to the literature on estimating demand in the PC industry. Papers in this area include Eizenberg (2011), Sovinsky Goeree (2008), Prince (2008), and Gowrisankaran and Rysman (2007). Finally, we estimate the impact of advertising on PC demand, which is related to work by Sovinsky Goeree (2008) and Salgado (2008b).

This paper is structured as follows. We describe the TAP test and explain how to implement it in section 2. We discuss why the Intel Inside campaign is a useful application of the TAP test and discuss the data we will use to conduct the test in section 3. In section 4, we develop and estimate a model of demand and present the parameter estimates. In section 5, we compute the marginal revenue of the market campaign, and use this to construct the tests presented in section 6. In section 7, we provide robustness tests and model specifications to address limitations of the TAP test. In the final sections we note the policy implications of this test and provide our concluding thoughts.

2 Test of Advertising Predation (TAP)

Predation is not a sensible business strategy if it cannot drive a rival out of a market, discipline a rival not to compete against a predator, or if the predator cannot maintain market power for a sufficient period of time after predation. Predation can be seen as an investment in long-run market power, and, as such we propose that marketing/advertising predation has two components: short-term profit sacrifice and long-term recoupment. We develop a Test of Advertising Predation (TAP) based on the presumption that, if the marketing/advertising campaign is not predatory, marketing expenses should be efficient (i.e., profit maximizing), and, so should result in sufficient increased product demand to justify costs.

The first step to construct TAP is to estimate product demand as a function of marketing variables. The second step is to use the demand estimates to compute firm marginal revenue derived from the marketing campaign. That is, one should compute the marginal revenue of marketing/advertising dollars spent on the marketing campaign (at the firm or product level). Notice that the marginal revenue of the marketing program depends on the parameters of consumer utility (including advertising/marketing variables), price and marginal manufacturing cost. Given data on marketing costs, the final step of TAP is to compare the marginal marketing revenue to the observed marketing costs. When observed marketing marginal costs are above the 95 percent confidence interval for the estimated marketing marginal revenue, we conclude that the marketing program is not consistent with profit maximization and, more specifically, that there was an excessive marketing subsidy. In this case the TAP test result is "positive."

Alternatively, the efficiency of the marketing program could be estimated by explicitly modeling how the marketing program works and estimating the parameters of the profit function. However, such an approach would have some non-trivial complications given that the way marketing programs function differs across firms and due to the fact that joint estimation of demand, supply, and optimal marketing choices would quickly complicate the econometrics. Furthermore, the resulting test would be program specific, and hence not applicable in many situations. A benefit of the TAP efficiency test is that it allows us to circumvent modeling a firm's profit maximization problem (and hence their marketing program) while still allowing for an easy to compute efficiency test.

2.1 Step 1: Estimate Demand

The first part of the test requires the researcher to specify a model of demand as a function of marketing variables. Notice that the demand specification can take any form as long as the marketing variables may have an impact on demand. Some common demand specifications include logit based (e.g., SOURCE) perhaps with different levels of nests (e.g., Goldberg, 1995) or random coefficients (e.g., Berry, Levinsohn, Pakes, 1995; Nevo, YEAR). The benefits and drawbacks of these various specifications are well documented in the empirical IO literature (SOURCE). The demand specification chosen depends on a number of considerations including, the data that are available, the time available to conduct the TAP test, as well as the nature of the market being considered.

In addition to choosing a product demand system, it is important to consider how the marketing variables may impact demand. Some items to consider include the nature of the impact of marketing on demand. For example, is advertising assumed to influence the choice set of consumers (e.g., Sovinsky Goeree, 2008), provide additional utility to the consumed good (e.g., SOURCE), OTHER EXAMPLES from marketing literature.

For the sake of illustration, we assume that only aggregate data are available and specify product specific market shares (this would arise from a random coefficients BLP type demand, for example). Specifically, let $s_j(p, m \mid \Theta)$ represent the predicted market share for product j, as a function of a vector of all product prices (p) and a vector of all product marketing variables (m), where Θ represents the parameters to be estimated. If the market is one with multiproduct firms then firm f would sell the subset of products denoted by $\mathcal{J}_f$.

2.2 Step 2: Compute Marginal Marketing Revenue

The second step uses the demand side estimates to compute firm f's marginal revenue from the marketing campaign. In other words, this step computes the marginal revenue of marketing/advertising dollars spent on the campaign (this can be done at the firm or product level). The marginal revenue of the marketing program depends on the parameters of consumer utility (including marketing, price and marginal manufacturing cost (denoted mc_j).

Suppressing time notation, the total marketing/ad revenue (TMR) of firm f is given by

$$TMR_f = \sum_{j \in \mathcal{J}_f} (p_j - mc_j)\mathcal{M}s_j(p, m),$$

where $\mathcal{J}_f$ is the set of firm f's products; $\mathcal{M}$ is the market size; $s_j(p, m)$ is market share, which depends on product prices in the market (p) and marketing (m). Firm f's marginal revenue from the marketing campaign (MMR) is given by

$$MMR_f = \mathcal{M} \sum_{r,j \in \mathcal{J}_f} (p_j - mc_j)\frac{\partial s_j(p, m)}{\partial m_r},$$

where a multiproduct firm will consider the impact on its complete product line arising from a change in marketing for its product r. One important caveat: to compute the marginal marketing revenue it is necessary to have data on (or an estimate of) the marginal cost of production.

2.3 Step 3: Compare to Marginal Cost of Marketing Campaign

The final step of TAP is to compare the marginal marketing revenue to the observed marketing costs. However, in most situations the researcher will not observe marginal marketing costs. To overcome this data restriction a solution implemented in the predatory pricing literature is to use average variable costs to proxy for marginal costs.[3] In this setting, the researcher does not require a proxy for marginal costs of production, but rather a proxy

[3] There are other proposals for how to calculate marginal costs associated with predatory pricing behavior. For example, Bolton, Brodley and Riordan (2000, 2001) suggest that the relevant cost is not average variable cost but the long run average incremental cost. This is measured by the per unit cost of producing the predatory increment of output where all costs that were incurred (regardless of when they were incurred) are considered. Specifically, it is calculated as the firm's total production cost less what the firm's total cost would have been had it not produced the predatory units divided by the quantity of the product produced. There is no analogy for the advertising predation measure that we could construct without measuring the output produced under the predatory behavior.

for marginal marketing costs. However, the same solution can be applied to use average variable marketing costs as a proxy for marginal marketing costs.

There may be a concern whether the average cost of the marketing program is a proper measure of the marginal cost of the marketing program. This issue arises in the predatory pricing literature as there is a practical difficulty in determining the nature of production cost: whether it is variable or fixed, or whether it is a sunk cost. However, this is less of a concern as it relates to marketing as there are few fixed or sunk components to advertising expenditures. Aside from practical difficulties, average variable cost may not be a good proxy for marginal marketing cost in the presence of returns to scale of the marketing program. The TAP results will reflect the assumption that firms' responsiveness to the marketing program is constant.

2.4 Step 4: Consider TAP Limitations

There are few issues to consider when using the TAP efficiency test. First, TAP is fundamentally a test of profit sacrifice, hence, a case would need to be made that long-term profit recoupment is possible. Second, short-term profit sacrifice can be rationalized by potential dynamic efficiency reasons such as learning-by-doing, promotional purposes, or network externalities. As the TAP test examines if the return on advertising (i.e., how it impacts demand) is high enough to justify marketing expenditures (as these are directed at increasing demand) the model includes only the current, short-term effect of advertising. Hence the potential long-run benefit of the marketing program is not taken into account. Note this is less of a concern when considering firms that have been operating for a while: just as the efficiency reasons for pricing below marginal cost are not usually applicable to an already dominant, incumbent firm with a large customer base, in this setting too an unprofitable advertising/marketing subsidy is not easily justified by efficiency reasons.

A third issue relates to the brand-loyalty-building effect of marketing programs. Advertising is generally believed to build goodwill and this may be a reason to invest in marketing at the expense of short-term profits. Notice that this critique is less important if there is some time element during which the marketing program behavior is being investigated. The reason being that the incentive to build goodwill is constant across all periods but the predatory motive would only be present during certain periods. That is, we can see whether the TAP results are different between potentially anticompetitive periods and competitive periods. Similarly, if an anticompetitive case does not involve all firms in a market so that we have candidate firms and competitive firms, then we can compare the TAP results for candidate firms with those for competitive firms if not all firms in a market are involved in the anticompetitive case. In general cases, one way to examine the dynamic efficiency argument is to include lagged marketing variables in the demand specification. Another way to address this concern is to determine how many future periods of MR would need to be considered by firm to rationalize current period MCs.

3 Application of TAP to "Intel Inside" Campaign

3.1 Background on "Intel Inside" Campaign

Intel has been investigated for predatory (pricing), exclusionary behavior, and the abuse of a dominant position in the market for central processing units (CPU). According to U.S. lawsuits, Intel used narketing loyalty rebates, payments, and threats to persuade computer manufacturers, including Dell and Hewlett-Packard (HP), to limit their use of AMD (Intel's main rival) processors. In their investigations, U.S. antitrust authorities focused on whether the loyalty rebates used by Intel were a predatory device in violation of the Sherman Act. The European Commission (EC) brought similar charges and imposed a 1.06 billion Euro fine on Intel for abuse of a dominant position. South Korean and Japanese antitrust authorities also imposed fines on Intel for breach of antitrust regulations.

In the case of Intel, an important component to the case involved their marketing campaign, "Intel Inside," which provided marketing support for firms that sold Intel CPU chips. Specifically, it is a cooperative advertising program in which Intel contributes a percentage of the purchase price of processors to a pool for PC firms to use to market Intel-based computers. According to the rules of the program PC firms can receive a rebate of their marketing expenditures if they include the Intel logo in their advertising. By the end of the 1990s, Intel had spent more than $7 billion on the marketing campaign (Moon and Darwall, 2005).

Intel was accused of using the marketing program to attempt to prevent computer makers from offering machines with non-Intel computer chips. It became clear through correspondence that Intel was trying to circumvent antitrust laws by using non-price predatory avenues. For example, a 2002 Dell document states that the "original basis for the [Intel marketing] fund is ... Dell's loyalty to Intel." The document explains that this means "no AMD processors."[4] The beginning of the alleged anticompetitive use of the Intel Inside program coincides with the introduction by their main rival AMD's Athlon chip (in 1999). Antitrust documentation shows that Intel issued "conditional rebates" from December 2002 to December 2005, whereby they would give rebates to some PC firms (Dell in particular) under the condition that the PC firm buy exclusively from Intel.[5] Otherwise, Intel would retract the marketing rebate and instead use the market development money to fund competitors. An internal Dell presentation (in 2003) noted that if Dell switched to AMD, Intel's retaliation "could be severe and prolonged with impact to all LOBs [Lines of Business]." Intel allegedly treated HP, Lenovo, and Acer similarly. For example, Intel rebates were conditional on HP buying 95% of its microprocessors for business desktops from Intel. In 2002, an HP executive wrote "PLEASE DO NOT . . . communicate to the regions, your team members or AMD that we are constrained to 5% AMD by pursuing the Intel agreement."

We focus on Intel's marketing subsidy to Dell during the $2002 - 2005$ period to take advantage of antitrust documentation on marketing rebate payments made to Dell. Although the data are not as extensive for other PC firms, we evaluate the TAP test for firms involved the Intel antitrust case (HP and Toshiba) and a firm that was not involved (Gateway).

3.2 Data

We use three main data sources for our analysis: PC and CPU sales are from Gartner Group, advertising data are from Kantar Media Group, and CPU price and cost data are from In-Stat. All data are available from the first quarter of 2002 through the last quarter of 2005.

[4] US District Court for the District of Delaware Complaint. 2009

[5] U.S. District of Court for District of Columbia; SEC (Securities and Exchange Commission) vs. Dell, pp. 10-11 and U.S. District of Court for District of Delaware; State of New York, by Attorney General Andrew M. Cuomo vs. Intel Corporation, p.6.

We discuss each in turn.

Quarterly PC and CPU sales are at the product level, where a product is defined as PC vendor (i.e., Acer), PC vendor brand (i.e., Aspire), platform type (i.e., Notebook), CPU vendor (i.e., Intel), CPU family (i.e., Pentium 4), CPU speed (i.e., 1600/1799 MHz) combination. We focus on the market for US home consumers for two primary reasons. First, businesses make multiple purchases at a time, which would greatly complicate the empirical model, and, second, we don't have access to advertising data for each sector separately.

PC firm	Num.obs	Market share (% shipment)	Quarterly Average Total PC-related advertising (M$)
Acer	428	0.31%	9.45*
Apple	223	4.80%	-
Averatec	37	0.42%	0.00
Dell	1020	32.44%	1.58
emachines	59	3.86%	9.45*
Fujitsu	193	0.30%	3.06
Gateway	487	11.62%	9.45*
HP	1438	29.17%	65.59
IBM/Lenovo	535	0.23%	22.81
Sony	360	2.93%	5.08
Systemax	507	0.36%	0.19
Toshiba	294	3.54%	4.13
Other	1867	10.03%	-
Total	7,448	100%	

Notes: Market share is total firm PC Shipments / total industry PC shipments. *Our measure of advertising includes emachines and Gateway together with Acer so we can't separate the three.

Table 1. Market Shares and Advertising Expenditures by PC Firms

Advertising data consist of PC advertising expenditures.[6] The advertising data are quite detailed, sometimes even at the level of a specific product/model (e.g., Acer Aspire AS5735 Notebook Computer). However, it is difficult to match with the data from Gartner Group because the definition of products/models varies between the two datasets. Kantar Media Group uses a model name, such as Aspire AS5735; whereas, Gartner Group defines

[6] PC firms advertise printers and other computer accessories. We do not include these advertising expenditures.

PC models as a combination of PC vendor, PC brand, platform type, CPU vendor, CPU family, and CPU speed. We match the two data sets based on brand and platform type. Table 1 shows the market share and total PC advertising expenditures by PC firm in the entire sample.

In-Stat provides data on CPU prices and manufacturing costs for selected processors and time periods. We need to match our PC data (where a CPU is in a PC) from Gartner group with CPU prices and manufacturing costs from In-Stat. CPU prices are available by processor core on a quarterly basis.[7] In our PC data, we know the CPU family (that is, the marketing name, e.g., Pentium 4) and speed (frequency) of the CPU. The same processor core is often used to make processors that are marketed under different family names with different sets of features enabled, and the processor core used in a processor changes over time as technology advances. For instance, processor core "Williamette" was used for processors families marketed as Pentium 4 and as Celeron for desktop computers, while in later periods the same CPU families switched to the next-generation processor core "Northwood." We match the data based on platform group (whether desktop or mobile), type (whether mainstream, value, or ultraportable), family/marketing name of a CPU, CPU speed, year, and quarter.[8] We provide the product cross-reference in Table A1[9] in the appendix.

CPU manufacturing cost estimate data are more limited in that the cost estimates are available by CPU processor core for a broader definition as of 2005. For processor core Willamette, we have cost estimates for different years, but not throughout the data period.

[7] CPU prices are available at several different levels of detail. The most detailed information is list prices of specific processors (e.g. Pentium M 1.40GHz). These prices are available for selected processors from July 2004 to July 2005, mostly on a monthly basis. Although it would be ideal to have list prices for all processors for all time periods, these detailed data cover only a subset of our sample.

[8] This process (and a slight generalization of it described below) generates a high match. For example, among Dell PCs, we have 78% match. For the CPUs not matched at first attempt, we drop type, then we have 83% match. When unmatched, the data are matched based on family/marketing name of a CPU, CPU speed, year, and quarter, ignoring platform group. Then we obtain a 96% match. When the data are not matched, we try matching based on platform group, family/marketing name of a CPU, CPU speed, ignoring time, and then we have 99% match. For observations still not matched, we take the averages of prices and cost estimates of CPUs of the same marketing name, year and quarter.

[9] The cross-reference table is constructed based on In-Stat's document and an website specialized in CPU information, www.cpu-world.com.

Intel has constructed fabs and changed the use of existing fabs, which affected cost levels over time. Also, learning-by-doing drives the cost level downward over time and so cost depends on how mature the manufacturing process is. We use two approaches to construct our CPU marginal cost variable. First, we use In-Stat cost estimates matched with PC data using the cross-reference Table A1.[10] Table 2 presents the summary statistics for the price and cost estimates of Intel CPUs in the sample. Recall that the cost estimates are not time-varying for almost all processor cores. As a second approach, instead of using the same cost estimates for all periods, we estimate marginal manufacturing costs for each processor by regressing the available cost estimates on cost shifters such as processor features, the number of fabs used for processors, size of the fabs (square feet), wafer size, and IC process.

	Num.obs	Mean	Std.Dev.	Min	Max
CPU price	1020	146.98	57.14	49	317
CPU marginal cost	1020	36.64	5.77	26	57

Table 2. CPU price and CPU marginal cost of Intel-based Dell PCs

Table 3 shows the percentage of PCs sold by PC firm and CPU vendor as well as the overall market share that the firm contributes toward the CPU manufacturers product over the sample period. As the Table illustrates Dell, IBM/Lenovo, and Toshiba used Intel based CPUs exclusively. Dell's purchases of Intel based CPUs contributed the most (32%) of any PC firm to Intel's market share, with HP following a close second (23%). These contributions to Intel's market share are significantly higher than the next closest PC firm, which is Gateway at 9%.

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[10] As for reliability of the cost estimates, In-Stat document states "Equations to calculate the number of die sites per wafer, yield, and cost per good die are well known throughout the industry. Important physical parameters, such as package type and die size, are generally published by the vendor and are verifiable through destructive analysis. The key areas of uncertainty are in estimating wafer cost, defect density, testing cost, and package cost."

	Intel		AMD		Total
	% PCs	Market share	% PCs	Market share	Num.obs
Acer	89.72%	0.26%	10.28%	0.05%	428
Averatec	40.54%	0.13%	59.46%	0.30%	37
Dell	100.00%	32.44%	0.00%	0.00%	1020
emachines	57.63%	1.75%	42.37%	2.11%	59
Fujitsu	88.82%	0.28%	11.18%	0.01%	170
Gateway	93.84%	8.60%	6.16%	3.23%	487
HP	78.13%	23.03%	21.87%	6.14%	1436
IBM/Lenovo	100.00%	0.23%	0.00%	0.00%	535
Sony	90.40%	2.77%	9.60%	0.14%	354
Systemax	74.16%	0.29%	25.84%	0.07%	507
Toshiba	100.00%	3.54%	0.00%	0.00%	294
Total	88.38%		11.62%		5327

Table 3: Percent and Market Share of PCs by CPU Type

The summary statistics in Table 4 indicate, 88% of the PCs have an Intel CPU, where the average price of a PC is $1,250. Over half of the PCs are mobile as opposed to desk-based. Approximately 19% of the PCs were shipped in the first quarter of the data period, i.e., 2002:Q1 (these are denoted *Older PC*) and about 36% of CPUs where used in these PCs.[11] If the PC is not an *Older PC* then *PC age* indicates a mean of 1.6 quarters since the first shipment of the PC and 2.5 quarters since the first sales record of a CPU. The age variables (*Older PC*, *PC age*, *Older CPU*, and *CPU age*) are intended to capture the quality (how obsolete the production technology is), popularity and consumer awareness of a product (how long it has been on the market). CPU benchmark is a (continuous) quality benchmark that compares the relative speeds of different CPUs (collected by PassMark[12]). CPU manufacturers spent an average 23 million dollars on general firm promotions and chip

[11] If there is a shipment record of a CPU in the first quarter of the data period, we can assume that the CPU has been introduced in that quarter or earlier.

[12] CPU Benchmark results were gathered from users' submissions to the PassMark web site (http://www.cpubenchmark.net/cpu_list.php) as well as from internal testing. PerformanceTest conducts eight different tests and then averages the results to determine the CPU Mark for a system. To ensure that the full CPU power of a PC system is realized, PerformanceTest runs each CPU test on all available CPUs. Specifically, PerformanceTest runs one simultaneous CPU test for every logical CPU (Hyper-threaded); physical CPU core (dual core) or physical CPU package (multiple CPU chips). So hypothetically if you have a PC that has two CPUs, each with dual cores that use hyper-threading then PerformanceTest will run eight simultaneous tests. Since PassMark point is not available for some models, we use a linear interpolation for those missing data, based on CPU model and CPU speed.

advertising while PC firms spend an average 4.4 million dollars for PC brand advertising. For the summary statistics we present the market share weighted measure of PC brand advertising.[13]

Variable	Mean	Min	Max
Price (1000$2000)	1.25	0.38	3.52
Intel CPU	0.88	0	1
Mobile PC	0.57	0	1
CPU benchmark	0.34	0.13	0.9
CPU speed (100mhz)	2.08	0.65	3.8
Older PC	0.19	0	1
PC age	1.6	0	10
Older CPU	0.36	0	1
CPU age	2.52	0	10
Chip ads (10 mil.$2000)	2.39	0.02	4.66
PC brand ads (10 mil.$2000)	0.44	0	6.49
Num. obs.	5327		

Notes: Price (unit: 1000$) and advertising (unit: 10 million $) variables are adjusted to 2000 dollars using Consumer Price Index (CPI) data from the U.S. Department of Labor Bureau of Labor Statistics.

Table 4. Descriptive Statistics

Table 5 presents descriptive statistics for the two main CPU manufacturers: Intel and AMD. As the table indicates, over the data period, average AMD chips used in PCs performed significantly better than average Intel chips (see *CPU benchmark*). On average, we

[13] We construct a brand-platform advertising variable with a market share weight. It is the sum of brand-platform advertising, brand advertising weighted by market share of a platform within the brand, brand combination advertising weighted by market share of brand-platform within the brand combination, platform advertising weighted by market share of brand within the platform, and firm advertising weighted by market share of brand-platform within the firm. Market shares are computed based on shipments. For model j of brand b, platform p, and firm f, we have:

$$
\begin{aligned}
ad_j^{\text{brand}} &= a_{b,p}^{\text{brand,platform}} + \frac{\sum_{i\in\mathcal{J}_{fpb}} s_i}{\sum_{i\in\mathcal{J}_{fp}} s_i} a_{b,f}^{\text{brand}} + \frac{\sum_{i\in\mathcal{J}_{fpb}} s_i}{\sum_{b'\in\mathcal{J}_{fpc}} \sum_{i\in\mathcal{J}_{fpb'}} s_i} a_{c,p}^{\text{brand comb}} \\
&+ \frac{\sum_{i\in\mathcal{J}_{fpb}} s_i}{\sum_{i\in\mathcal{J}_{fp}} s_i} a_{f,p}^{\text{platform}} + \frac{\sum_{i\in\mathcal{J}_{fb}} s_i}{\sum_{i\in\mathcal{J}_{f}} s_i} a_{f}^{\text{firm}}
\end{aligned}
$$

where $\mathcal{J}_*$ denotes the set of models in category $*$, $a_{b,p}^{\text{brand,platform}}$ is brand-platform advertising, $a_{b,f}^{\text{brand}}$ is brand advertising; $a_{c,p}^{\text{brand comb}}$ is brand combination advertisin, $a_{f,p}^{\text{platform}}$ is firm-platform advertising, and a_f^{firm} is firm advertising. This is a similar methodology that is used in the literature for quantity weighted average prices (see for example, Song (2007).

can see that the PC models with Intel chips are priced higher and advertised significantly more at the CPU level. In many cases, the same PC brand has models with AMD chips and models with Intel chips. Thus PC brand ads do not accurately capture the difference between PCs with Intel chips versus those with AMD chips. Although PC brand ads are larger for the brands of PCs with AMD chip on average, it is because some heavily advertised brands have models with AMD and Intel chips.

	Mean Intel	Mean AMD	Difference	t-value
Price (1000$2000)	1.28	0.98	0.30	17.10
Mobile	0.58	0.52	0.06	2.63
CPU benchmark	0.33	0.46	-0.14	-26.01
CPU speed (1000mhz)	2.09	1.93	0.16	5.20
Older PC	0.19	0.21	-0.02	-1.34
PC age	1.65	1.25	0.40	4.74
Older CPU	0.37	0.33	0.04	1.87
CPU age	2.60	1.93	0.67	5.64
Chip ads (10 mil.$2000)	2.65	0.36	2.29	45.79
PC brand ads (10 mil.$2000)	0.41	0.69	-0.28	-8.35
Num. obs.	4708	619		

Table 5: Descriptive Statistics by CPU Manufacturer (feb 19)

Finally, we use surveys on PC purchases from Forrester Research from 2002 through 2005. These data have information about individual consumers' PC and CPU choices, although they are not detailed at the product level. For example, we observe whether a survey respondent bought a PC in the last year, some characteristics of the PC such as PC firm and CPU manufacturer (Intel, AMD, Apple[14] , Other, or Don't know) if purchased.

4 Demand for CPUs

Following Berry, Levinsohn, and Pakes (1995) (BLP) and Sovinsky Goeree (2008) we model the demand for PCs as a random-coefficient logit. The demand for CPUs can be inferred from the demand for a PC model as a PC comes equipped with a single CPU. When

[14] During the data time period, Apple PCs used only IBM chips.

consumers purchase computers, they choose a combination of PC firm and CPU type.[15] There are T markets, indexed by $t = 1, 2, ..., T$, each with I_t consumers, indexed by i. A home market consumer chooses from J products, indexed $j = 1, ..., J$, where a product is a PC vendor (i.e., Acer), PC vendor brand (i.e., Aspire), platform type (i.e., Notebook), CPU vendor (i.e., Intel), CPU family (i.e., Pentium 4), CPU speed (i.e., 1600/1799 MHz) quarter combination.

Product j characteristics are price of the PC (p) and non-price observed attributes of the PC (x), which include the platform and PC vendor dummy variables, dummy variables for whether the processor is manufactured by Intel, processor speed, the age of the CPU and the CPU benchmark score.

Advertising is an additional characteristic that may impact consumer demand.[16] Given the difference in advertising campaigns across firms and CPU suppliers, we allow advertising by PC firms (a_{jt}^{pc}) to have different effect on consumer utility than advertising done by CPU vendors (a_{jt}^{cpu}). Finally, attributes unobserved to the researcher but known to consumers and producers (ξ) may influence utility. The indirect utility consumer i obtains from j at time t is

$$u_{ijt} = \delta_{jt} + \mu_{ijt} + \epsilon_{ijt}, \tag{1}$$

where

$$\delta_{jt} = x'_{jt}\beta + a_{jt}^{\text{pc}}\gamma + a_{jt}^{\text{cpu}}\lambda + \xi_{jt}$$

captures the base utility every consumer derives from product j and mean preferences for x_j are captured by β. The composite random shock, $\mu_{ijt} + \epsilon_{ijt}$,[17] captures heterogeneity in

[15] Many websites which provide CPU performance comparisons, such as CPUScoreCard.com, categorize CPUs depending on computer type (i.e., desktops or laptops), and they compare CPUs within the same computer type. Considering that CPU chips intended to be used in desktops and laptops are different due to different requirements, we can think that the choice of CPU type includes the choice of computer type. Song (2007) and Salgado (2008b) modeled consumers' choice of CPU type although consumers more often buy computers, rather than CPU chips without computers.

[16] It is reasonable to conjecture that all consumers know of the existence of Intel processors, therefore we do not model Intel advertising as impacting the consumer's choice set, but rather as impacting utility directly. We assume that consumers know all firms and processor types when making a purchase decision.

[17] Choices of an individual are invariant to multiplication of utility by a person-specific constant, so we

consumers' tastes for product attributes, and ϵ_{ijt} is a mean zero stochastic term distributed i.i.d. type I extreme value across products and consumers.

We observe various levels of aggregation of advertising expenditures by PC firms. These include firm-specific advertising (i.e., advertising for Dell), firm-brand specific advertising (i.e., Dell Presario), firm-platform advertising (i.e., Dell Notebooks), and firm-brand-platform advertising (i.e., Dell Presario Notebooks). CPU vendor advertising is at the firm level (i.e., Intel) and at the CPU level. We allow each type of PC firm advertising and CPU advertising to have a different impact on utility, as captured by the vectors γ and λ.[18] The a_{jt}^{pc} is a vector of PC advertising variables aggregated at different levels and a_{jt}^{cpu} is a vector of CPU advertising variables aggregated at different levels. For sake of exposition, we define $a_{jt} = \{a_{jt}^{\text{pc}\prime} \quad a_{jt}^{\text{cpu}\prime}\}'$.

The μ_{ijt} term includes the interactions between observed consumer attributes (D_{it}), unobserved (to the econometrician) random consumer tastes (ν_i), and observed product attributes (x_j), and the interactions between observed consumer attributes ($\widetilde{D}_{it}$) and advertising variables, where $\widetilde{D}_{it}$ is a subset of D_{it}. Specifically,

$$\mu_{ijt} = \alpha \ln(y_{it} - p_{jt}) + {x_{jt}}'(\Omega D_{it} + \Sigma \nu_i) + a'_{jt} \Upsilon \widetilde{D}_{it} \qquad \nu_i \sim N(0, I_k). \tag{2}$$

where y_{it} is income of individual i (in market t). The Ω matrix measures how tastes vary with x_j. We assume that ν_i are independently and normally distributed with a variance to be estimated. Σ is a scaling matrix. Υ matrix captures how advertising's impact varies by observed consumer characteristics.

Consumers have an "outside" option, which includes purchase of a computer with non-Intel or non-AMD processor (such as IBM chips exclusively used by Apple computers during the sample period)[19] , a PC manufactured by a small firms[20] , and self-assembled PCs.

fix the standard deviation of the ϵ_{ijt}.

[18] We also consider a specification in which we allow for nonlinear effects of advertising.

[19] Apple Computer is included in the outside option for CPU's because they used IBM processors during the sample period (2002:Q2 - 2005:Q4).

[20] These include Everex, Medion, Micro Electronics, Motion Computing, MPC, NEC, Sharp, and Velocity Micro.

Normalizing p_{0t} to zero,[21] the indirect utility from the outside option is

$$u_{i0t} = \alpha \ln(y_{it}) + \xi_{0t} + \epsilon_{i0t}.$$

We normalize ξ_{0t} to zero, because we cannot identify relative utility levels.

The (conditional) probability that consumer i purchases product j is

$$s_{ijt} = \frac{\exp\{\delta_{jt} + \mu_{ijt}\}}{{y_{it}}^{\alpha} + \sum_r \exp\{\delta_{rt} + \mu_{irt}\}}. \tag{3}$$

The ${y_{it}}^{\alpha}$ term in the denominator is from the presence of the outside good. Let $\zeta_i = (y_{it}, D_{it}, \nu_i)$ be the vector of individual characteristics. We assume that the consumer purchases at most one good per period,[22] that which provides the highest utility, U. Let $R_j \equiv \{\zeta : U(\zeta, p_j, x_j, a_j, \xi_j, \epsilon_{ij}) \geq U(\zeta, p_r, x_r, a_r, \xi_r, \epsilon_{ir}) \quad \forall r \neq j\}$ define the set of variables that results in the purchase of j given the parameters of the model. The home market share of product j is

$$s_{jt} = \int_{R_j} dG(y, D, \nu, \epsilon) = \int_{R_j} s_{ijt} dG_{y,D}(y, D) dG_{\nu}(\nu) \tag{4}$$

where $G(\cdot)$ denotes the respective distribution functions. The second equality follows from independence assumptions. The conditional probability that i purchases j, s_{ij}, is given in (3).

Note that this implies that the market share for firm f of processor type c is given by

$$\begin{aligned} s_{fct} &= \sum_{j \in \mathcal{J}_c \cap \mathcal{J}_f} \int_{R_j} \frac{\exp\{\delta_{jt} + \mu_{ijt}\}}{{y_{it}}^{\alpha} + \sum_r \exp\{\delta_{rt} + \mu_{irt}\}} dG_{y,D}(y, D) dG_{\nu}(\nu) \\ &= \sum_{j \in \mathcal{J}_c \cap \mathcal{J}_f} s_{jt}(p, a) \end{aligned} \tag{5}$$

where $\mathcal{J}_f$ are the set of products produced by firm f and $\mathcal{J}_c$ are the set of products with a CPU of type c. Note that processor market share is a function of PC prices and advertising of all PC products. Demand of firm f for CPU processor c at time t is $\mathcal{M}_t s_{fct}$, where $\mathcal{M}_t$ is

[21] The effect of changes over time in prices of the outside option is captured by the relative attractiveness of goods to the outside option.

[22] This assumption may be unwarranted for some products for which multiple purchase is common. However it is not unreasonable to restrict a consumer to purchase one computer per quarter. Hendel (1999) examines purchases of PCs by businesses and presents a multiple-choice model of PC purchases.

the market size given by the total number of PCs sold each quarter. The observed market share of a processor is given by the number of units sold of that processor divided by the total number of processors sold. The total number of observations is 5,327.

4.1 Estimation Technique

We implement the econometric technique found in many studies of differentiated products, such as BLP (1995, 1998) and Nevo (2000). The parameters are $\theta = \{\alpha, \beta, \gamma, \lambda, \Sigma, \Omega, \Upsilon\}$. Under the assumption that the observed data are the equilibrium outcomes, we estimate the parameters simultaneously using generalized method of moments (GMM).

Following BLP, we restrict the model predictions for j's market share to match observed shares. We solve for $\delta(S, \theta)$ that is the implicit solution to

$$S_t^{obs} - s_t(\delta, \theta) = 0 \tag{6}$$

where S_t^{obs} and s_t are vectors of observed and predicted shares respectively. We substitute $\delta(S, \theta)$ for δ when calculating the moments.[23] The first moment unobservable is

$$\xi_{jt} = \delta_{jt}(S, \theta) - x_j'\beta. \tag{7}$$

We use the Forrester data to construct CPU manufacturer choice micro moments. Petrin (2002) shows how to combine macro data with data that links average consumer attributes to product attributes to obtain more precise estimates. We augment market share data with data relating consumers to product characteristics as in Sovinsky Goeree (2008). The micro data we have connect consumers to processor manufacturer. We combine the processor firm choice data with product level data to obtain more precise estimates of the parameters of the taste distribution (Ω) and the parameters of advertising effectiveness (Υ). The demographic characteristics for these moments (denoted D_{it}) are given by the Forester data, which are linked directly to purchases and advertising exposure.

Let B_i be a $R \times 1$ vector of processor manufacturer choices for individual i. Let b_i be a realization of B_i where $b_{ir} = 1$ if a CPU produced by $r =$\{Intel, AMD\} was chosen.

[23] As discussed in Dube et al (2011) we use a precise tolerance level for the contraction mapping. For more details see section 7.2.

Define the residual as the difference between the vector of observed choices and the model prediction given (δ, θ) :

$$\mathcal{B}_i(\delta, \theta) = b_i - E_\nu E[B_i \mid D_{it}, \delta, \theta]. \tag{8}$$

For example, the element of $E_\nu E[B_i \mid D_{it}, \delta, \theta]$ corresponding to Intel for consumer i is

$$\sum_{c \in \mathcal{J}_{intel}} \sum_{j \in \mathcal{J}_c} \int_{R_j} \frac{\exp\{\delta_{jt} + \mu_{ijt}\}}{y_{it}^{\alpha} + \sum_r \exp\{\delta_{rt} + \mu_{irt}\}} dG_\nu(\nu),$$

where the summand is over products sold by Intel, the integral is over the assumed distribution of ν. The population restriction for the micro moment is $E[\mathcal{B}_i(\delta, \theta) \mid (x, \xi)] = 0$. Let $\mathcal{B}(\delta, \theta)$ be the vector formed by stacking the residuals $\mathcal{B}_i(\delta, \theta)$ over individuals.

We use GMM to find the parameter values that minimize the objective function, $\Lambda' Z A^{-1} Z' \Lambda$, where A is an appropriate weighting matrix which is a consistent estimate of $E[Z' \Lambda \Lambda' Z]$ and Z are instruments orthogonal to the composite error term Λ. Specifically, if Z_ξ, $Z_\mathcal{B}$ are the respective instruments for each disturbance/residual, the sample moments are

$$Z' \Lambda = \begin{bmatrix} \frac{1}{J} \sum_{j=1}^{J} Z_{\xi,j} \xi_j(\delta, \beta) \\ \\ \frac{1}{N} \sum_{i=1}^{N} Z_{\mathcal{B},i} \mathcal{B}_i(\delta, \theta) \end{bmatrix}$$

where $Z_{\xi,j}$ is column j of Z_ξ. Joint estimation takes into account the cross-equation restrictions on the parameters that affect both the macro and micro moments, which yields more efficient estimates.

The market shares in (4) must be simulated. As in BLP, the distribution of consumer demographics is an empirical one. As a result there is no analytical solution for predicted shares, making simulation necessary. The simulator for the market share is the average over individuals of choice probabilities. An outline of the technique follows. We sample a set of "individuals" where each consists of $(v_{i1}, \ldots, v_{ik})$ taste parameters drawn from a multivariate normal; demographic characteristics, $(y_i, D_{i1}, \ldots, D_{id})$, drawn from the Forrester data in the case of the macro moments and data in the case of the micro moments. To construct the market share constraints we draw J uniform random variables for each individual. For a given value of the parameters, we compute the probability she would buy each product. The market share simulator is the average over individuals of the choice probabilities. The process is similar for the micro moment constraints, but we take R draws for each product-individual pair. The simulator for individual product choice probabilities is the average over the R draws. Individual firm choice probabilities are the sum over the products offered by each firm.

Using the results of Pakes and Pollard (1989), this estimator is consistent and asymptotically normal. As the number of pseudo random draws used in simulation $R \rightarrow \infty$ the method of simulated moments covariance matrix approaches the method of moments covariance matrix. To reduce the variance due to simulation, we employ antithetic acceleration (for an overview of simulation techniques see Stern, 1997 and 2000). Geweke (1988) shows if antithetic acceleration is implemented during simulation, then the loss in precision is of order $1/N$ (where N are the number of observations), which requires no adjustment to the asymptotic covariance matrix. The reported (asymptotic) standard errors are derived from the inverse of the simulated information matrix which allows for possible heteroskedasticity.[24]

4.2 Identification

Following the literature, we assume that the demand unobservables (evaluated at the true value of the parameters, Θ_0) are mean independent of a vector of observable product characteristics, (x) :

$$E\left[\xi_{jt}(\Theta_0) \mid x_{jt}\right] = 0. \tag{9}$$

We do not observe ξ_{jt}, but market participants do. This may lead to endogeneity of price and advertising. For example, some products may have higher quality, which is unobserved by researchers, and PC firms may set higher prices and/or determine their ad expenditures based on quality. Also, a CPU manufacturer may advertise more when the PCs with its CPU are of higher quality. To account for the potential endogeneity of price and advertising, we employ instrumental variables.

BLP show that variables that shift markups are valid instruments for price in differentiated products models and Sovinsky Goeree (2008) shows that variables that shift markups

[24] The reported standard errors do not included additional variance due to simulation error.

are valid instruments for advertising.[25]

Given (9) and regularity conditions, the optimal instrument for any disturbance-parameter pair is the expected value of the derivative of the disturbance with respect to the parameter (evaluated at Θ_0) (Chamberlain, 1987). Optimal instruments are functions of advertising and prices. We form approximations to the optimal instruments as in Sovinsky Goeree (2008)[26] , by evaluating the derivatives at the expected value of the unobservables ($\xi = \omega = 0$). The instruments will be biased since the derivatives evaluated at the expected values are not the expected value of the derivatives. However, the approximations are functions of exogenous data and are constructed such that they are highly correlated with the relevant functions of prices and advertising. Hence the exogenous instruments will be consistent estimates of the optimal instruments.[27]

One set of instruments we use is chosen to reflect competitive pressure. Competitive pressure for a model is likely to affect price and advertising choices (via their first-order conditions) but does not impact consumer utility from purchasing the model. We also use the characteristics of other products of the same PC firm and those of other PC firms as instruments for price and advertising. In particular, we use the sum of the values of the characteristics - mobile platform, performance benchmark (PassMark point), CPU speed - of other products offered by the same PC firm and the sum of the values of the characteristics of all the products offered by other PC firms. In addition, we construct variables that capture technological change. Technological change affects production cost and hence would be related to the level of price and advertising but unrelated to consumer utility. In particular, we use a series of interactions between CPU cohort[28] dummy variables and time (year-

[25] Products which face more competition (due to many rivals offering similar products) will tend to have lower markups relative to more differentiated products. Advertising for j depends on j's markup. Pricing FOCs show the optimal price (and hence markup) for j depends upon characteristics of all of the products offered. Therefore, the optimal price and advertising depends upon the characteristics, prices, and advertising of all products offered. Thus optimal instruments will be functions of attributes and cost shifters of all other products.

[26] This was introduced in BLP(1999). See Reynaert and Verboven (2012) for a discussion of the benefits of using optimal instruments.

[27] One could also use a series approximation as in BLP to construct exogenous instruments.

[28] CPU cohort is the set of CPU models which have the first sales record in the same quarter.

quarter) dummy variables and a series of interactions between PC cohort[29] dummy variables and time (year-quarter) dummy variables. These variables are intended to proxy the change in production cost over time (e.g., declining production cost due to learning by doing).

Using optimal instruments for micro moments.

An informal identification argument follows. Associated with each PC is a mean utility, which is chosen to match observed and predicted market shares. All variation in sales would be driven by variation in product attributes if consumers were identical. Variation in product market shares corresponding to variation in the observable attributes of those products (such as CPU speed) is used to identify the parameters of mean utility (β).

A PC may have attributes that provide more utility to certain types of consumers. For instance, if young male adults prefer to use their PC to play games, then young male consumers may place a higher valuation on CPU speed relative to other cohorts. Identification of the taste distribution parameters (Σ, Ω) relies on information on how consumers substitute (see equation (2)). There are two issues that merit attention. First, new product introductions are common in the PC industry. Variation of this sort is helpful for identification of Σ. The distribution of unobserved tastes, ν_i, is fixed over time, but the choice set of available products is changing over time. Variation in sales patterns over time as the choice sets change allows for identification of Σ. Second, we augment the market level data with micro data on CPU manufacturer choice. The extra information in the micro data allows variation in choices to mirror variation in tastes for product attributes. Correlation between $x_j D_i$ and choices identifies the Ω parameters. The individual-level data contain useful information on ad exposure across households. Variation in advertising exposure and variation in advertising expenditures corresponding to variation in observable consumer characteristics $(\widetilde{D}_i)$ identifies Υ.

4.3 Preliminary Demand Estimates

First, we present results from a series of probit regressions of the probability of purchasing a PC in 2002 for use at home as given in the Forrester data. The estimates are presented

[29] PC cohort is the set of PC models which have the first sales record in the same quarter.

in Table 6 and illustrate the importance of observed product heterogeneity in PC purchases. The results indicate that the form factor of the PC is important as well as firm fixed effects. Finally, the opportunity to add-on certain items (such as a flat-screen monitor) increases the probability of purchase. As columns (4)-(6) illustrate, consumers value PCs with a Intel or AMD processor even after controlling for other product characteristics. Furthermore, the results suggest the valuation of processor type is not constant over time (Column 6).

Variables		Dependent Variable: Whether Bought a PC in the past year (1)	(2)	(3)	(4)	(5)	(6)
Laptop		0.535***	0.473***	0.395***	0.527***	0.473***	0.474***
		(0.010)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)
Processor Manufacturer	Intel				0.139***	0.021***	0.071***
					(0.008)	(0.008)	(0.015)
	Intel and 2003						-0.056**
							(0.022)
	Intel and 2004						-0.085***
							(0.022)
	Intel and 2005						-0.061***
							(0.020)
	AMD				0.511***	0.344***	0.484***
					(0.016)	(0.016)	(0.028)
	AMD and 2003						-0.232***
							(0.044)
	AMD and 2004						-0.139***
							(0.045)
	AMD and 2005						-0.230***
							(0.041)
PC Manufacturer	Acer	-0.416***	-0.367***	-0.202***	-0.396***	-0.346***	-0.346***
		(0.042)	(0.043)	(0.045)	(0.042)	(0.043)	(0.043)
	Apple	-0.035*	-0.107***	-0.363***	0.093***	-0.055***	-0.050**
		(0.019)	(0.019)	(0.022)	(0.019)	(0.020)	(0.020)
	AST	-1.052***	-1.018***	-0.868***	-1.024***	-0.988***	-0.988***
		(0.166)	(0.167)	(0.174)	(0.167)	(0.168)	(0.168)
	Compaq	-0.056***	-0.089***	-0.125***	-0.045***	-0.078***	-0.078***
		(0.012)	(0.012)	(0.013)	(0.012)	(0.013)	(0.013)
	Dell	0.457***	0.350***	0.131***	0.486***	0.387***	0.386***
		(0.010)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
	Emachines	0.348***	0.311***	0.128***	0.371***	0.332***	0.334***
		(0.017)	(0.018)	(0.019)	(0.017)	(0.018)	(0.018)
	Fujitsu	-0.526**	-0.623***	-0.625**	-0.491**	-0.589**	-0.593**
		(0.231)	(0.238)	(0.255)	(0.231)	(0.238)	(0.238)
	Gateway	-0.163***	-0.253***	-0.317***	-0.135***	-0.222***	-0.223***
		(0.013)	(0.013)	(0.014)	(0.013)	(0.013)	(0.013)
	HP	0.089***	0.021*	-0.093***	0.112***	0.046***	0.046***
		(0.011)	(0.012)	(0.012)	(0.011)	(0.012)	(0.012)
	IBM	-0.279***	-0.259***	-0.169***	-0.247***	-0.232***	-0.232***
		(0.019)	(0.020)	(0.021)	(0.020)	(0.020)	(0.020)
	Sony	0.358***	0.096***	-0.114***	0.366***	0.120***	0.119***
		(0.025)	(0.026)	(0.027)	(0.025)	(0.026)	(0.026)
	Toshiba	0.195***	0.149***	0.055*	0.215***	0.173***	0.172***
		(0.027)	(0.028)	(0.030)	(0.027)	(0.028)	(0.028)
PC Add-ons	Broadband Adapter		0.229***	0.157***		0.223***	0.220***
			(0.012)	(0.012)		(0.012)	(0.012)
	DVD		0.447***	0.266***		0.435***	0.436***
			(0.008)	(0.008)		(0.008)	(0.008)
	CD Rom		0.044***	0.015		0.029***	0.029***
			(0.010)	(0.011)		(0.010)	(0.010)
	Flat Panel Monitor		0.581***	0.421***		0.580***	0.582***
			(0.010)	(0.011)		(0.010)	(0.010)
	Webcam		-0.128***	-0.184***		-0.140***	-0.136***
			(0.014)	(0.015)		(0.014)	(0.014)
Operating System	Windows 95 or 98			-0.918***			
				(0.014)			
	Windows ME			-0.195***			
				(0.016)			
	Windows 2000			-0.236***			
				(0.016)			
	Windows NT			-0.064*			
				(0.035)			
	Windows XP			0.442***			
				(0.014)			
Observations		167221	167221	167221	166246	166246	166246

Notes:Standard errors are in parenthesis. *** indicates significant at 1%; ** at 5% and * at 10%. All regressions include time dummies.

Table 6: Probit Regressions of PC Purchase (in 2002)

Table 7 presents probit estimates of purchase probabilities that illustrate the importance of product and individual observed heterogeneity for PC purchases. The independent variable is again whether the individual bought a PC in the past year. We start by including demographic variables (Column 1). We can see all the estimates on the coefficients of demographic variables are statistically significant. Once we include a laptop dummy and CPU type (Intel dummy and AMD dummy), some demographic variables become less significant (Column 2). Not surprisingly, the results indicate individuals are more likely to purchase a PC with an Intel or AMD processor than non-branded processors. Whether the computer is a laptop is also a significant factor in the purchase decision. After controlling for PC add-ons (Column 3) and Operating System dummy variables (Column 4), preference for a laptop and a PC with Intel or AMD processor have less impact on PC purchase probability. Overall, the results suggest that PC characteristics affect the purchase decision after controlling for demographics and that certain demographics are more important than others in the purchase decision.

Dependent Variable: Whether Bought a PC in the past year				
Variables	(1)	(2)	(3)	(4)
Laptop		0.518***	0.477***	0.409***
		(0.011)	(0.011)	(0.011)
Intel Processor		0.118***	0.024***	-0.018**
		(0.008)	(0.008)	(0.009)
AMD Processor		0.491***	0.351***	0.225***
		(0.016)	(0.017)	(0.018)
Demographics				
Age	-0.005***	-0.004***	-0.002***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Male	0.046***	0.014*	0.006	0.016**
	(0.007)	(0.007)	(0.007)	(0.008)
White	0.031**	0.028**	0.031**	0.003
	(0.012)	(0.013)	(0.013)	(0.014)
Married	0.037***	0.052***	0.039***	0.025**
	(0.009)	(0.009)	(0.009)	(0.010)
Presence of Teenagers	0.145***	0.156***	0.134***	0.113***
	(0.009)	(0.009)	(0.010)	(0.010)
Income > $100,000	0.176***	0.100***	0.047***	0.024**
	(0.009)	(0.010)	(0.010)	(0.010)
Income < $25,000	-0.083***	-0.003	0.046***	0.073***
	(0.008)	(0.008)	(0.008)	(0.009)
Fixed Effects				
Firm		Included	Included	Included
Year	Included	Included	Included	Included
PC-Add ons			Included	Included
Operating System				Included
Observations	163,187	160,982	160,982	160,982

Notes: Standard errors are in parenthesis. *** indicates significant at 1%; ** at 5% and * at 10%.

Table 7: PC purchase Probability on PC Characteristics and Demographics

Table 8 presents multinomial logit estimates of the choice of CPU manufacturer. The results show that there is significant consumer observed heterogeneity with respect to CPU choices. Given that a consumer purchased a PC in the past year, brand CPUs are preferred by a male, single, or higher-income household to non-brand CPUs. Among brand CPUs, the choice probability of a particular CPU varies with demographics. The presence of teenagers in the household makes purchase of an Intel or Apple less likely, but doesn't significantly impact the purchase of an AMD processor. Being young and being white are significantly and positively associated with the choice of Intel or AMD processors.

Dependent Variable: CPU in a PC purchased in the past year (Base: Non-Intel/AMD/Mac or unknown)			
Variables	Intel	AMD	Apple CPU
Age	-0.018***	-0.030***	-0.001
	(0.001)	(0.002)	(0.004)
Male	0.702***	1.141***	0.543***
	(0.025)	(0.046)	(0.123)
White	0.166***	0.161**	0.344
	(0.043)	(0.082)	(0.224)
Married	-0.139***	-0.237***	-0.404**
	(0.032)	(0.058)	(0.158)
Presence of Teenagers	-0.110***	-0.041	-0.445***
	(0.031)	(0.055)	(0.162)
Income > $100,000	0.371***	0.353***	0.297*
	(0.035)	(0.061)	(0.156)
Income < $25,000	-0.649***	-0.705***	-0.422***
	(0.028)	(0.052)	(0.146)
Observations	39,536		

Notes: Laptop dummy, Firm dummies, and year dummies included

SE in parenthesis. *** significant at 1%, ** at 5%, * at 10%

Table 8: CPU Purchase Estimates

4.4 Structural Demand Estimates

In Table 9 we present results from a Multinomial Logit PC-CPU demand model with aggregate market data, where only product characteristics are included as explanatory variables.[30] Advertising variables are aggregated at the brand-platform level. How we allocate advertising expenditure to PC brand-platform level is detailed in data section 4. We also include the squared value of the sum of general promotions and brand combination advertising that can be attributed to a given brand to allow for decreasing or increasing return to advertising. In every model specification, PC-firm-specific dummy variables and time-specific dummy variables are included.

The first specification (Column 1) illustrates the importance of observed product characteristics for PC/CPU choice. The results imply that processor speed and performance (benchmark) have a significant and positive effect on utility. This is reasonable as it suggests consumers prefer faster and better-performing CPU chips. However, the age of the CPU

[30] Estimates from a nested logit model (with laptop and desk-based PC nests) indicate that purchases do not take place in this nested structure in the sense that the estimated coefficient on the substitutability between the nests is often larger than one.

does not impact consumers valuations of the PC, while the age of the PC does. A likely explanation is that age captures the popularity or consumer awareness of a PC model or a CPU. If a product has been on the market for a while, it may imply either that consumers like the product, due to attractive qualities unobserved by the researcher, or that the product is well-known to potential buyers. Surprisingly, consumers place a lower valuation on the PC if it is a laptop, but this finding is not robust across specifications. Finally, conditional on CPU speed and the performance benchmark, consumers place a lower value on CPUs manufactured by Intel.

As we discussed earlier, prices may be correlated with the structural error term and hence endogenous. In Column (2) we include instruments for price. The impact of price on demand becomes much more negative, which is consistent with price being a proxy for higher quality. The rest of the estimates do not change with the exception of the valuation of Intel and the valuation of laptop, which are no longer significant.

In specification (3), PC characteristics are taken out and advertising variables are added. As compared with the price coefficient estimate from specification (1), the price coefficient is estimated to be smaller (i.e. more negative). This suggests that advertising variables may be correlated with unobserved product attributes and we need to correct for the possible correlation between advertising and unobserved high quality. We also find that consumers marginal valuation of PC advertising is positive, while the valuation of firm level CPU advertising is negative and statistically insignificant.

In specification (4) we allow the effect of advertising to be different across PC firms. The results suggest some firms are more effective at advertising their products than others, but otherwise the coefficient estimates do not change much. Specifications (5) and (6) include all explanatory variables (PC characteristics, CPU characteristics, and advertising variables), but specification (5) instruments only for price while specification (6) instruments for both price and advertising. We have more elastic demand when using specification (6). Again, this suggests that advertising is correlated with unobserved product attributes.

The parameter on the Intel dummy variable is negative or insignificant in all specifications after other PC/CPU characteristics and CPU advertising amount are taken into account. This result is consistent with the preliminary regression result in Table 6 that shows that the purchase probability is actually higher when a PC is powered by AMD chip than by an Intel chip.

Advertising at the CPU level is not valued by consumers in most specifications but has a positive and significant impact in specification (6) after instrumenting for CPU ads. Advertising by a PC firm at the brand level is always positive and significant. In particular, when evaluated at the average value, a one unit increase in PC advertising at the brand level leads to a 0.99 increase in the utility level (specification (5)). When advertising variables are instrumented, there is a larger positive impact of advertising on demand at the PC level: when evaluated at the average value, one unit increase in PC advertising at brand level leads to 1.43 increase in the utility level (specification (6)). Note that a more positive advertising effect after instrumenting for advertising suggests that advertising may be negatively correlated with unobserved product qualities. That is, firms may engage in more advertising when they have lower-quality products. This result appears reasonable given that the low-end processor of Intel, Celeron was heavily advertised during the period. The positive impact of PC advertising implies that CPU firms can enhance CPU sales by inducing PC firms to advertise PCs that contain their chip. This provides us with the pro-competitive justifications for Intel's marketing campaign: promoting CPU sales by subsidizing PC advertising. We will test whether the benefit of promoting CPU sales by subsidizing PC advertising exceeds the cost of the marketing subsidy. If not, the marketing campaign may be driven by anticompetitive motives.

	Variables	(1)	(2)	(3)	(4)	(5)	(6)
		Dependent Variable: ln(Market Share) - ln(Share of Outside Goods)					
Price		-0.286***	-1.047*	-0.515***	-0.337***	-1.765***	-2.228***
		(0.0855)	(0.609)	(0.0671)	(0.0647)	(0.541)	(0.643)
PC Characteristics	Laptop	-0.178**	0.146			0.410*	0.497*
		(0.0711)	(0.266)			(0.236)	(0.292)
	Older PC	0.906***	0.858***			0.655***	0.582***
		(0.122)	(0.128)			(0.114)	(0.145)
	PC Age	0.126***	0.138***			0.0940***	0.0904***
		(0.0222)	(0.0241)			(0.0215)	(0.0238)
CPU Characteristics	Intel	-0.510***	-0.233	-0.0104	-0.000200	0.502	-2.060
		(0.103)	(0.244)	(0.231)	(0.221)	(0.319)	(1.308)
	ln(Benchmark)	0.371**	0.851**	0.575***	0.415***	1.315***	1.362***
		(0.155)	(0.414)	(0.128)	(0.120)	(0.371)	(0.434)
	ln(Speed)	1.594***	1.731***	1.381***	1.108***	1.625***	1.724***
		(0.106)	(0.149)	(0.0883)	(0.0847)	(0.135)	(0.166)
	Older CPU	-0.0906	-0.0641	0.487***	0.494***	0.237**	0.192
		(0.113)	(0.116)	(0.0922)	(0.0832)	(0.107)	(0.129)
	CPU Age	0.00524	-0.0101	0.0994***	0.0960***	0.0360*	0.0226
		(0.0174)	(0.0206)	(0.0135)	(0.0131)	(0.0186)	(0.0229)
Advertising	CPU ad			-0.0259	0.0945	-0.139	4.186***
				(0.187)	(0.174)	(0.193)	(1.360)
	CPU ad squared			-0.00803	-0.0370	0.0167	-0.868***
				(0.0306)	(0.0278)	(0.0321)	(0.253)
	PC ad			2.352***		2.363***	3.496***
				(0.0830)		(0.0862)	(0.302)
	PC ad squared			-0.294***		-0.304***	-0.581***
				(0.0216)		(0.0223)	(0.133)
Included Controls							
	IV for Price		Included			Included	Included
	IV for Advertising						Included
	PC Advertising				Included		
	PC Advertising Squared				Included		
	PC Firm Fixed Effects	Included	Included	Included	Included	Included	Included
Observations		5,327	5,327	5,327	5,327	5,327	5,327
R-squared		0.498	0.491	0.597	0.649	0.575	0.470
Median (Own) Price Elasticity		-0.336	-1.231	-0.605	-0.396	-2.075	-2.619

Notes:Standard errors are in parenthesis. *** indicates significant at 1%; ** at 5% and * at 10%. All regressions include time dummies.

Table 9: Multinomial Logit Estimates of PC/CPU Demand (feb 19)

<Insert Table 10 Random Coefficients/Micro Moments Results>

Discussion of Table 10

5 Marginal Marketing Revenue

Intel's marketing campaign provided support to PC firms that advertised PCs with Intel chips. One of the benefits of the TAP approach is it allows us to circumvent modeling

Intel's profit maximization problem. This is beneficial both because the test (and model) would become very complicated and the data necessary to estimate such a model do not exist, in particular firm-specific rebate rates are not publicly available. Suppressing time notation, the total marketing/ad revenue (TMR) of Intel from PC sales is

$$TMR = \sum_{c \in \mathcal{J}_{intel}} \sum_{f} (p_c^{CPU} - mc_c)\mathcal{M} s_{fc}(p, a), \tag{10}$$

where $\mathcal{J}_{intel}$ is the set of products with an Intel CPU; p_c^{CPU} is the price of CPU c; mc_c is the marginal production cost of CPU c and $s_{fc}(p, a)$ is market share of processor c sold by firm f given in equation (5), which depends on the product price (i.e., PC price, p) and advertising (a).[31]

One issue to address in the PC advertising data is that advertising may involve more than one product. For example, PC firms often engage in general promotions both by platform type and across all platforms (e.g., Acer Laptop Computer; Acer Various Computers) or PC brands may be jointly advertised (e.g., Acer Veriton & Travelmate Computers Combo). We will require a composite measure of advertising expenditures by product that includes all advertising done for that product (so it should include all group advertising). Following Sovinsky Goeree (2008) we compute product advertising expenditures as a weighted average of group advertising for that product where the weights are a function of the number of products in that group. Specifically, suppressing the time subscript, let $\mathcal{G}_j$ be the set of all product groups that include product j with group $\mathcal{H} \in \mathcal{G}_j$. Then composite product ad expenditures for product j are given by

$$a_j^{\text{total pc}} = \sum_{\mathcal{H} \in \mathcal{G}_j} \frac{\lambda_{\mathcal{H}} a_{j\mathcal{H}}^{\text{pc}}}{|\mathcal{H}|}.$$

where the sum is over the different groups that include product j.We also estimate a non-linear specification to allow for increasing or decreasing returns to group advertising.

Intel's marginal revenue from the marketing campaign for firm f is given by

[31] The CPU price is the listed price. In practice, many PC firms paid less than listed price as Intel granted discounts on CPU prices to selected firms. As a results our measure of the TMR will be larger than what it would be if we had the purchase price. Thus our measure of TMR makes the TAP results more stringent than what they would be if we had the purchase price.

$$MMR_f = \mathcal{M} \sum_{\substack{j,r \in \mathcal{J}_f \cap \\ c \in \mathcal{J}_{intel}}} (p_c^{CPU} - mc_c) \frac{\partial s_j(p,a)}{\partial a_r^{\text{total pc}}}. \quad (11)$$

As we discussed previously, we have data on p_c^{CPU} and mc_c. We can use these data together with the demand side estimates to compute the marginal revenue of advertising dollars spent by PC firm f on Intel chips.

6 Marginal Marketing Cost

We focus primarily on Intel and its agreements with Dell. This is for two reasons. First, both Intel and Dell were examined separately by antitrust authorities for related antitrust violations. Hence, we have a wealth of information on the amount of Intel's advertising subsidy to Dell, relative to other PC firms, especially during the period $2002-2005$. Second, antitrust investigations have produced written evidence that Intel's agreements with Dell were intended to exclude their main rival (AMD) from the market, which provides a good test for our model.

We also apply the TAP test to Intel's rebates to HP and Toshiba, who were also investigated by antitrust authorities as part of the Intel case. In addition, we examine the predatory nature of Intel's rebates with Gateway. This latter application serves as a robustness check of our test as there is no evidence that Gateway was involved in anticompetitive behavior with Intel over this period.[32]

6.1 Measuring Costs of "Intel Inside" Campaign

AVC of marketing campaign is total marketing subsidy paid by Intel/total advertising by PC firm for PCs with Intel chip. Suppose that PC firms increase advertising expenditures more as Intel increases spending on the marketing program, that is, there are increasing return to scale of the marketing program. Then average variable cost would be larger than marginal cost and the test may lead to a false positive of predation. In contrast, if PC firms

[32] Most large PC firms were involved in the Intel case. Gateway is the largest PC firm that was not under investigation in the Intel case.

tend to be less responsive to Intel's marketing subsidy as the amount of subsidy increases, average variable cost would be smaller than marginal cost and the test would be lenient.

We use a variety of measures of the average variable cost (AVC) of the marketing/ad campaign as a proxy for the marginal cost of the marketing program, which is in the same spirit as using average variable production cost as a proxy for the marginal cost in Areeda-Turner (1975) test of predatory pricing. The AVC of the marketing/ad campaign is computed by dividing the total dollar amount of the ad subsidy that Intel paid to a PC firm by total PC firm advertising for PCs powered by an Intel chip.

Quarter	Rebate Rate on CPU purchases (1)	Meet the Competition Program (MCP) Percentage Rebate Payment (2)	Lump Sum Payment (3)	Total MCP Payments (4)	Dell's Operating Income (5)	MCP % of Operating Income (6)
2002Q1	6%	$61m	-	$61m	$590m	10%
2002Q2	6%	$57m	$3m	$60m	$677m	9%
2002Q3	6%	$59m	$12m	$71m	$758m	9%
2002Q4	6.3%	$77m	$7m	$84m	$819m	10%
2003Q1	6.3%	$91m	$8m	$99m	$811m	12%
2003Q2	6.3%	$106m	$6m	$112m	$840m	13%
2003Q3	6.3%	$105m	$40m	$145m	$912m	16%
2003Q4	7%	$118m	$82m	$200m	$981m	20%
2004Q1	8.7%	$137m	$70m	$207m	$966m	21%
2004Q2	12% + var.	$210m	-	$210m	$1,006m	21%
2004Q3	12% + var.	$250m	-	$250m	$1,095m	23%
2004Q4	12% + var.	$293m	$75m	$368m	$1,187m	31%
2005Q1	12% + var.	$307m	$81m	$388m	$1,174m	33%
2005Q2	12% + var.	$313m	$119m	$432m	$1,173m	37%
2005Q3	12% + var.	$339m	-	$339m	$754m	45%
2005Q4	12% + var.	$423m	$60m	$483m	$1,246m	39%
2006Q1	12% + var.	$405m	$318m	$723m	$949m	76%

Source: p.14 MCP table from "Securities and Exchange Commission vs. Dell", U.S. District Court of Columbia Summary Statement

Table 11: Rebate amounts paid by Intel to Dell

We construct four measures of the observed marginal cost of the marketing/ad campaign based on either actual expenditures paid by Intel (as shown in Table 11) or on an assumed percentage rebate rate.

($\mathbf{MC}_1$) This measure is constructed as the total payment of Intel to Dell as given in the case files divided by total advertising by Dell for PCs powered by an Intel chip. Table 10 (column 4) provides the total payment of Intel's rebates to Dell. Basically Intel provided discounts on CPU prices and sometimes provided a lump-sum payment. At the end of 2001, Intel began a program in which it agreed to give Dell a six percent rebate on all of Dell's CPU purchases (this came to be called the "Meet Competition Program (MCP))."[33] These rebates are treated as a reduction in marketing expenses in accounting by Dell. We can see that rebate rates as well as lump-sum payments have significantly increased between 2002 and 2005. Relative to the operating income, the total amount of rebates were over 70% by 2006 (column 6).

($\mathbf{MC}_2$) The second measure is the total rebate amount as a percentage of sales of PCs (across all segments sold by Dell) given in column 6 divided by total advertising by Dell for PCs powered by an Intel chip.[34] The rebates to Dell can be used for advertising in all segments including servers. Ours is a model of household demand (due to data limitations) so when we construct MC_2 we assume that the rebates are used in each sector in proportion to sector market shares. Hence MC_2 is MC_1 multiplied by the percentage of Dell's revenue from PC sector in each quarter.

($\mathbf{MC}_3$) This measure is a proxy for the marginal cost that we would have in the absence of antitrust documents. The publicly announced subsidy takes the form of a fixed percentage rebate of CPU purchases made by the PC firm with zero lump-sum payments. To compute this measure we assume six percent of all Dell's CPU purchases from Intel are rebated. We recompute the total expenditure of the marketing program to Dell (i.e., we compute column 4 assuming column 1 is always six percent and column 3 is zero). We then divide the total expenditure by total advertising by Dell for PCs powered by an Intel chip.

[33] It was orginally called the "Mother of All Programs (MOAP)."

[34] The second measure is the total rebate amount multiplied by a percentage of revenue from PC sales (across all segments - that is, PCs and servers - sold by Dell) divided by total Dell advertising on Intel powered CPUs.

($\mathbf{MC}_4$) This measure provides a further lower bound on marginal costs. According to the Intel Inside website, Intel would provide a three percent rebate on purchases if marketing featured the Intel logo. To compute this measure we assume the rebate rate is three percent and there are no lump sum payments. Hence MC_4 is half of MC_3.

Notice that the last two measures of marginal cost (MC_3 and MC_4) do not rely on information obtained by antitrust officials but are based only on publicly available information. Therefore, MC_3 and MC_4 can be used to construct the TAP test for other PC manufacturers. In addition, these two measures provide a benchmark as they are computed based on the assumption that the marketing program has been executed as in normal periods or as Intel describes on their website. The other two measures (MC_1 and MC_2) are computed based on actual payments, which reflect any potential anticompetitive cost increase.

We would like to point out a limitation of applying TAP to Intel. The main issue concerns situations where a predator operates in multiple markets, which makes it difficult to determine how to allocate costs across markets. PC firms are active in markets for home consumers, but also in markets for education, business, and government consumers. Also they sell servers as well as PCs. Fortunately, our advertising data allow us to differentiate PC advertising from advertising for non-PC products. However, we include general promotions at the firm-level as an advertising expenditure in the home segment. If general promotions affect sales in every market segment, then they should be allocated across all segments. In this case, our measure of the average cost of the marketing program is likely to underestimate the actual average cost. The marginal revenue of the marketing program would likewise be underestimated, as we cannot allow for spillovers of advertising across segments (due to data restrictions).

6.2 TAP Results

We apply the TAP test to the case of Intel. Specifically, we consider the potential predatory nature of Intel's marketing program over the period 2002 to 2005. We run TAP based on preliminary demand estimation results from specification (6). Intel's marginal revenue from the marketing campaign for firm f is given by

$$MMR_f = \mathcal{M} \sum_{\substack{j,r \in \mathcal{J}_f \cap \\ c \in \mathcal{J}_{intel}}} (p_c^{CPU} - mc_c) \frac{\partial s_j(p,a)}{\partial a_r^{\text{total pc}}}.$$

where $\mathcal{J}_{intel}$ is the set of Intel CPUs and $\mathcal{J}_f$ are the set of products produced by firm f. We compute the marginal revenue from the advertising campaign earned in that time period (i.e., ours is not a dynamic model). Estimating a dynamic model of demand and computing the associated marginal revenue that arises from a dynamic profit function would introduce considerable difficulties with respect to estimation and data requirements. However, we conduct robustness checks of our TAP results that consider the potential brand building effect of advertising. We discuss this in more detail in section 7.2.

The estimated marginal revenue of Intel's marketing subsidy to Dell and its 95 percent confidence interval is given in Table 12, along with the marginal cost of the marketing campaign computed in four different ways as described in section (2).[35] When the marginal cost measure is above the 95 percent confidence interval for marginal revenue, we conclude that the marketing program is not consistent with profit maximization and, more specifically, that there was an excessive marketing subsidy. Then the test result is "positive". The final column indicates for which of the four measures of marginal cost the TAP result is positive.

[35] Since the marginal revenue of the marketing program is a linear combination of utility parameters, the confidence interval around the estimate of the marginal revenue can be computed easily. MC_1 is Intel's total payment to Dell divided by the total advertising expenditure of Dell on PCs powered by Intel CPU; MC_2 is MC_1 multiplied by the fraction of revenue from PC sales (= PC sales/(PC sales + server sales); MC_3 is six percent of Intel's revenue from selling CPUs to Dell ($= 0.06 \cdot \mathcal{M} \sum_{c \in \mathcal{J}_{intel}} \sum_{j \in \mathcal{J}_c \cap \mathcal{J}_{Dell}} s_j p_c^{CPU}$); MC_4 is three percent of Intel's revenue from selling CPUs to Dell (so $MC_4 = MC_3/2$).

Time	Computed Marginal Revenue Est.	95% conf. Interval		Observed Marginal Cost (1)	(2)	(3)	(4)	TAP Result Positive in	# Years (1)	# Years (4)
2002Q1	1.45	(1.22	1.69)	34.54	31.12	3.33	1.66	1,2,3	5.9	0.3
2002Q2	0.88	(0.73	1.02)	45.62	40.70	3.73	1.87	all	13.0	0.5
2002Q3	1.23	(1.03	1.43)	53.31	48.05	5.90	2.95	all	10.9	0.6
2002Q4	2.22	(1.85	2.58)	91.86	82.59	13.02	6.51	all	10.4	0.7
								all		
2003Q1	2.95	(2.46	3.45)	352.14	315.44	44.78	22.39	all	29.8	1.9
2003Q2	2.38	(1.98	2.77)	192.68	171.66	17.50	8.75	all	20.3	0.9
2003Q3	3.02	(2.52	3.52)	140.80	126.81	13.61	6.80	all	11.6	0.6
2003Q4	2.92	(2.45	3.40)	93.19	82.75	7.57	3.79	all	8.0	0.3
								all		
2004Q1	3.35	(2.79	3.91)	682.73	607.55	56.66	28.33	all	51.0	2.1
2004Q2	1.95	(1.62	2.27)	345.53	306.09	18.57	9.28	all	44.3	1.2
2004Q3	1.72	(1.44	2.00)	133.28	118.52	7.39	3.69	all	19.4	0.5
2004Q4	2.05	(1.71	2.39)	192.46	171.46	8.55	4.27	all	23.4	0.5
								all		
2005Q1	6.30	(5.24	7.35)	390.02	340.19	15.51	7.75	all	15.5	0.3
2005Q2	4.38	(3.65	5.11)	370.16	323.16	11.29	5.65	all	21.1	0.3
2005Q3	4.43	(3.68	5.17)	348.36	307.69	15.68	7.84	all	19.7	0.4
2005Q4	5.85	(4.87	6.83)	340.69	298.21	13.24	6.62	1,2,3	14.56	0.28

Notes: Unit: $ (inflation adjusted - base: 2000)

Table 12. TAP Results of Intel's Marketing Campaign for Dell's Advertising of Intel-Powered PCs

It is worth to note the following two points. First, the marginal revenue estimates imply that 1$ PC advertising tends to increase Intel's revenue by more than 1$ (except in the second quarter of 2000). Thus, if all of Intel's payment to Dell are used for marketing PCs powered by Intel CPU, then the results suggest that Intel gains more than its cost by subsidizing Dell. However, our measures of marginal cost are much larger than 1, that is, PC advertising expenditure falls short of Intel's marketing subsidy to Dell in reality.[36] This implies that Intel needs to incur more than 1$ to induce Dell to spend 1$ more on advertising.

Second, MC_3 and MC_4 are significantly smaller than MC_1 and MC_2. Considering

[36] There are a few reasons why marginal costs may be larger than one. First, while, in principle, the marketing subsidy should have been used only for marketing, case files indicate that stock analysts had doubt about the use of the subsidy. The subsidy was actually a huge amount that accounts for a significant portion of operating profits. Second, marketing may be broadly defined to include more than advertising. For example, it may encompass training employees in how to sell PCs.

that MC_1 and MC_2 are computed based on the actual payment whereas MC_3 and MC_4 are computed by assuming the rebate rate applied in the normal periods, our results suggest that Intel has paid much more to Dell than described in their Intel Inside marketing campaign.

The TAP results show that marginal cost, for all measures, is above the 95 percent confidence interval of marginal revenue estimates in most periods. Exceptions are when MC_4 is compared to marginal revenue in the beginning of the anticompetitive period and at the end of the anticompetitive period. Even in these cases, MC_4 is larger than the estimated marginal revenue. Comparisons of marginal revenue to the actual-payment-based marginal cost is consistent with predatory marketing.

We do not have the data on Intel's actual payment to other firms and thus cannot compute MC_1 and MC_2 for firms other than Dell. Although, we can compute MC_3 and MC_4 if we assume fixed rebate rates. The anticompetitive charges were mainly about Intel's payment to Dell, but other PC firms such as HP and Toshiba were also involved in the case. Tables 13 presents the TAP results for HP and Toshiba, respectively. Both the marginal revenue and marginal cost measures tend to be lower in the cases of HP and Toshiba than in the case of Dell. Our TAP results show evidence of predation with Toshiba in 2003 and 2004. During this period the TAP results are positive for both measures of marginal cost.

We do not have a dynamic part of demand, that is, long-term effect of advertising, in our model. As a simple check, we can use the static MR in each period, which we already have. The concern is that the firm is considering the MR in many periods in the future and this is what should be compared to MC. We can get a "static" version of the dynamic MR by summing the MR over many periods and comparing this to one period MC. For instance, we could say in order for the MC_1 for Dell to not be predatory we would have to believe that Intel is choosing that amount of advertising taking into account the impact of MR 10 periods in advance. In the last two columns of Table 12, we added the number of periods (in years) over which MR should be summer to rationalize the cost of advertising. The first of the two is based on MC_1 - which is the highest MCestimate - and the second one is based on MC_4 - which is the lowest MC estimate.

Specifically, we take a very generous assumption about Intel's advertising campaign that Intel is very optimistic and thinks that current advertising would have the same effect (that is, the same MR) in the future periods too (for some while). Then we can just compute: $T = MC/MR$ where MC is our computed MC and MR is our estimate. Then, we can say that, if Intel thinks that advertising will have the same effect on future sales as in the current period for T time periods, then the advertising expenditure can be justified (that is, the present value of MR and MC are equalized). Since it may be easier to catch the idea about how long it would take for advertising to be rationalized by dynamic optimization (even if we are very generous, thinking that Intel is allowed to expect the same MR as the current MR for some future periods). In the table, we computed calculated $T/4 = (MC/MR)/4$ so that we can see how many years we need to rationalize Intel's advertising choice.

PC firm	HP						Toshiba					
	Computed MR			Observed MC		TAP Result	Computed MR			Observed MC		TAP Result
Time	Est.	95% conf. Interval		(3)	(4)	Positive in	Est.	95% conf. Interval		(3)	(4)	Positive in
2002Q1	-0.02	(-0.32	0.28)	0.11	0.05		0.13	(0.11	0.15)	0.14	0.07	
2002Q2	1.04	(0.89	1.19)	0.26	0.13		0.26	(0.22	0.29)	0.09	0.04	
2002Q3	1.20	(1.01	1.39)	0.27	0.13		0.66	(0.56	0.76)	0.16	0.08	
2002Q4	-5.68	(-9.93	-1.43)	0.12	0.06	3,4	0.62	(0.53	0.72)	0.45	0.22	
2003Q1	-0.42	(-1.30	0.46)	0.09	0.05		0.34	(0.29	0.40)	1.37	0.68	3,4
2003Q2	0.15	(-0.34	0.64)	0.11	0.05		0.21	(0.18	0.25)	0.82	0.41	3,4
2003Q3	0.36	(-0.25	0.97)	0.17	0.09		0.31	(0.26	0.36)	1.47	0.74	3,4
2003Q4	0.59	(-0.45	1.64)	0.30	0.15		0.44	(0.37	0.51)	1.45	0.72	3,4
2004Q1	-0.07	(-0.80	0.66)	0.14	0.07		0.34	(0.28	0.40)	0.99	0.50	3,4
2004Q2	0.32	(-0.01	0.66)	0.13	0.07		0.36	(0.30	0.42)	0.99	0.50	3,4
2004Q3	0.59	(0.31	0.87)	0.20	0.10		0.43	(0.36	0.49)	0.48	0.24	3
2004Q4	0.37	(-0.04	0.77)	0.17	0.09		0.99	(0.84	1.14)	0.29	0.15	
2005Q1	2.47	(0.80	4.15)	0.17	0.08		1.96	(1.65	2.27)	0.35	0.17	
2005Q2	4.90	(4.12	5.68)	0.33	0.17		1.99	(1.67	2.32)	0.42	0.21	
2005Q3	6.91	(5.90	7.92)	0.57	0.29		2.94	(2.45	3.42)	0.72	0.36	
2005Q4	6.31	(5.18	7.43)	0.41	0.21		2.97	(2.49	3.44)	0.49	0.24	

Unit: $ (inflation adjusted - base: 2000)

Table 13. TAP Results for HP and Toshiba

We are also interested in what TAP would show with other PC firms not involved in the case. Since most PC firms not investigated for the case are small, we consider only Gateway, which has a significant market share but is not involved in the case. Table 14 presents the

TAP results. We can see that marginal cost measures tend to either fall in the 95 percent confidence interval of marginal revenue or just below the interval. The result provides a nice contrast to the test result for Dell as we do not find excessive advertising for Gateway for both measures of marginal costs in any period. This result also supports the idea that the Intel's marketing program, if conducted as described, is driven by profit maximization rather than anticompetitive purposes for the case of Gateway. Overall, the findings with other PC firms seem to suggest that our model, despite its simplicity, represents demand reasonably well and captures the important features of the marketing program.

PC firm	Gateway					
	Computed Marginal Revenue			Observed Marginal Cost		TAP Result
Time	Est.	95% conf. Interval		(3)	(4)	Positive in
2002Q1	0.56	(0.37	0.76)	0.14	0.07	
2002Q2	0.38	(0.28	0.49)	0.10	0.05	
2002Q3	0.47	(0.38	0.55)	0.16	0.08	
2002Q4	0.78	(0.66	0.90)	0.26	0.13	
2003Q1	0.87	(0.75	1.00)	0.20	0.10	
2003Q2	0.47	(0.40	0.54)	0.20	0.10	
2003Q3	0.50	(0.43	0.58)	0.17	0.08	
2003Q4	0.56	(0.47	0.64)	0.15	0.07	
2004Q1	0.66	(0.56	0.76)	0.78	0.39	3
2004Q2	0.40	(0.34	0.47)	0.50	0.25	3
2004Q3	0.52	(0.44	0.60)	0.37	0.18	
2004Q4	0.15	(0.96	1.34)	2.66	1.33	3
2005Q1	4.52	(3.77	5.28)	6.37	3.18	3
2005Q2	3.59	(3.00	4.19)	2.64	1.32	
2005Q3	4.72	(3.94	5.51)	4.21	2.11	
2005Q4	5.72	(4.80	6.64)	1.79	0.90	

Unit: $ (inflation adjusted - base: 2000)

Table 14. TAP Results for Gateway

7 Robustness and Other Considerations

7.1 Motive, Recoupment, and Efficiency Motives

In this section, we discuss the industry background that speaks to the motives for predation, the prospect of successful predation and recoupment, and dynamic efficiency. Intel is a dominant firm in the CPU industry with about 80 percent of worldwide CPU sales. Its major (and only effective) rival is AMD, holding about 18 percent market share (Mercury Research, 2007). In 1999 and 2003, respectively, AMD introduced two new chips, the Athlon for personal computers and the Opteron for servers. These AMD chips were the high-end products intended to compete with Intel. By introducing these 64-bit processors, AMD enabled PC operating systems to handle large amounts of information more fastly and accurately (as compared to a 32-bit OS system). These attributes were welcomed by experts and consumers and it was generally agreed that these AMD chips were better-performing and cheaper than Intel counterparts. The case files denote that the Athlon "was almost universally recognized as being superior to Intel's then current top model for PCs, the Pentium III" (pp.14-15, Complaint, US District Court of Columbia, SEC vs. Dell) and that "Opteron garnered virtually unanimous industry acclaim; AMD had succeeded with an innovative product design yielding performance advantages which effectively "leapfrogged" Intel." (pp.14-15, Complaint, US District Court of Delaware, State of New York vs. Intel). In addition, Table 5 of section 3.2 provides a supporting evidence from the data. The threat of new, high-performance processors from AMD may have induced Intel to engage in anticompetitive actions. These events provide the motive for Intel's predatory behavior. Indeed, many jurisdictions in the world accused Intel of using various anticompetitive tactics against AMD starting in 2002.

We are particularly interested in Intel's marketing subsidies. Predation involves short-run profit sacrifice and long-run recoupment. The TAP test is used to establish short-run profit sacrifice. However, we now turn to industry characteristics to examine the ease (or difficulty) with which Intel could successfully drive AMD out of the market and recoup lost profits by maintaining market power for a sufficiently long period after AMD's exit.

There are a number of factors that make long-run recoupment of profits likely to be successful in the CPU industry. To remain as a valid competitor in a rapidly changing, high-technology industry like the CPU industry, firms need to secure constant cash flows and keep investing in innovation. The CPU industry is capital-intensive, hence firms will incur substantial costs to construct and maintain manufacturing plants (called "fabs"). If a firm does not have sufficient internal funding, it must obtain external funding at market rates. According to industry experts, Intel is able to fund its fabs with revenue, while AMD must secure funding at market rates, which significantly raises AMD's cost of capital. Furthermore, obtaining external financing is complicated due to agency problems. Typically investors require firms to show a positive prospect of future profits, which is often based on current performance. Predation would make the future prospect of the prey look lower (and potentially negative) and ultimately induce it to exit the market. Thus, predation in the CPU market would be consistent with the long-purse (deep-pocket) theory of predation.

Second, since firms are continuously innovating, they may be uncertain about how consumers will react to new products. New processors can have different characteristics possibly appealing to a different market segment from current customers. As mentioned before, the beginning of the anticompetitive use of the marketing program coincides with AMD's introduction of high-performance chips. By engaging in predatory behavior, Intel could send a (wrong) signal about the demand for new chips, which is consistent with the demand signaling theory (test-market theory) of predation.

Lastly, economies of scale exist in the CPU industry. The substantial investment in plants and technologies are sunk. Therefore, a firm needs to secure a certain amount of sales in order to recover the sunk costs and stay in business. It is easier for a dominant firm to exclude a rival and prevent new entrants in the presence of economies of scale. In this sense, predation is likely to be successful in driving AMD out of a market and Intel is likely to keep high profit margins for a sufficiently long time.

The CPU industry is inviting to predatory behavior for these reasons, and Intel is an incumbent with a dominant market share. Given that Intel's recoupment is very likely as a monopolist due to high entry barriers and that predation can successfully lead to exclude AMD in the CPU industry, showing sacrifice of short term profits would support that the marketing program is predatory.

The TAP test examines if the return on advertising (i.e., how it impacts demand) is high enough to justify marketing expenditures (as these are directed at increasing demand). Short-term profit sacrifice may be justified by dynamic efficiency reasons. Although the cost-based approach is widely used to show profit sacrifice in predatory pricing cases, pricing below cost does not necessarily mean the behavior is predatory. Short-term profit sacrifice can be rationalized by potential dynamic efficiency reasons such as learning-by-doing, promotional purposes (e.g., introductory prices), or network externalities. Our demand model includes only the current, short-term effect of advertising, hence the potential long-run benefit of the marketing program is not taken into account. However, just as the efficiency reasons for pricing below marginal cost are not usually applicable to an already dominant, incumbent firm with a large customer base, here too an unprofitable advertising subsidy by Intel is not easily justified by efficiency reasons. Intel should already have achieved an efficient scale of operation, so learning-by-doing does not seem to justify short-term profit sacrifice. Given that Intel has been present for a long time and consumers already know about Intel and that the anticompetitive actions have been going on for four years, promotional motives are an unlikely explanation for short-term profit sacrifice. In addition, network externalities are not strong in the CPU market. For example, PC purchase guides, such as *Consumer Reports,* do not list the size of the customer base using Intel processors as an important factor for consumers to consider when purchasing a PC.

Our main concern is the brand-loyalty-building effect of the marketing program. Advertising is generally believed to build goodwill and this may be a reason for Intel to invest in marketing at the expense of short-term profits. Notice that, this incentive is constant across all periods, while the predatory motive is more pronounced during the period of AMD's new chip introductions. To consider this the TAP test includes two measures of marginal cost (MC_3 and MC_4) that serve as competitive benchmark as they are based on listed rebate rates that would have been applied prior to 2001/2002. In contrast, MC_1 and MC_2 are based on actual payment post AMD's introduction of the new chips. Hence, these measures would include brand loyalty building incentives plus anticompetitive motives, while MC_3 and MC_4 would be driven only by brand loyalty building incentive. We find that MC_1 and MC_2 (based on actual payment) are much larger than MC_3 and MC_4 for Dell. The results suggest that an anticompetitive motive induced Intel to sacrifice even more short-term profits as the difference between marginal marketing revenue and marginal costs are much larger when using MC_1 and MC_2. Also it is worth to note that, if advertising can establish strong brand loyalty, predatory marketing can be even more harmful as it would work as an endogenous entry barrier, deterring further entries and making recoupment even more likely. We provide further robustness checks regarding brand-loyalty in section 7.2.

7.2 Robustness Checks and Specification Tests

In this section, we conduct robustness checks of the model as it relates to brand-loyalty building of advertising, cost pass-through, and model specification to insure the objective function did not converge to a local minimum (Knittle and Metaxoglou, 2008).

to be completed

8 Policy Implications

Price and quantity are not the only strategic variables that can be used for anticompetitive purposes. Advertising is another important strategic variable commonly employed by firms. However, antitrust authorities typically try to establish anticompetitiveness through pricing, but do not address the strategic use of advertising and, more generally, marketing campaigns. While the heart of the anticompetitive actions of Intel was their Intel-Inside marketing program, considerations of advertising/marketing predation where not at the forefront of the antitrust case. In this paper we focus on non-price anticompetitive behavior arising from marketing/advertising with a focus on the Intel case.

Our paper proposes a Test of Advertising Predation (TAP) that can be used to detect non-price predatory behavior. We provide a general Test of Advertising Predation (TAP) based on the presumption that, if a firm's marketing campaign is not predatory, marketing expenses should be profit maximizing and so should result in sufficient increased product demand to justify costs. To construct TAP, first we model consumer's demand for PCs from which we infer demand for CPU processors. Specifically, we estimate a random-coefficient model of demand for a PC-CPU, where the coefficients on PC and CPU characteristics and advertising vary with demographics.[37] Second, we compute Intel's marginal revenue from the marketing subsidy using the demand side estimates. That is, we compute the marginal revenue of advertising dollars spent on Intel chips at the firm or product level.[38] The marginal revenue of the marketing program depends on the parameters of consumer utility (including advertising), CPU price and marginal manufacturing cost.

Test results suggest short-term profit sacrifice by Intel, supporting the predatory use of the Intel Inside campaign. To rationalize the short-term profit sacrifice, there should be something Intel can gain from the marketing program other than increasing CPU sales by boosting the willingness-to-pay for a PC. Antitrust authorities found evidence that the marketing subsidy is paid on anticompetitive condition that limits the use of AMD processors. This condition aimed at driving AMD out of a market and the prospect of future profit as a monopolist as a result would have rationalized the short-term profit sacrifice.

Our method can be used to guide antitrust authorities in future cases as it provides a general framework for testing for anticompetitive use of marketing campaigns. Computing the test requires little extra estimation over the typical demand estimation usually undertaken by antitrust authorities. Furthermore, the advertising data necessary to estimate the model parameters is usually not so difficult to obtain. Thus TAP is practical and easy to implement. Applying to the Intel case, this paper shows that our test can be used to show the predatory use of advertising/marketing. In addition, the benefit of looking at the advertising side is that, unlike predatory pricing which accompanies low price in the short term, predatory advertising/marketing does not have a clear benefit for consumers, even in the short term. In the long run, predatory marketing can be harmful if it has a long-lasting

[37] In previous literature that estimates CPU demand, it is generally assumed that final consumers directly purchase the CPU. We think it is more realistic to model consumers' choice of a CPU-PC combination. In addition, since we are interested in the effect of PC advertising on CPU demand, and PC advertising does not directly affect CPU demand, we model a consumer's discrete choice over CPU-PC combinations.

[38] We do not model strategic decisions of PC firms and Intel. This makes the test we develop more stringent. Rather, PC firms' CPU choices are assumed to simply reflect consumers' demand, and not affected by the marketing campaign. Intel was accused of giving refunds to PC firms in the Intel Inside marketing program on the exclusionary condition that they limit the use of AMD chips. This implies the marketing program would affect PC firms' CPU choice and, hence, its anticompetitiveness would be even larger.

effect by establishing goodwill, which may become an endogenous entry barrier for potential competitors.

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A Appendix

Platform		Processor Core	Brand Name	Speed (Frequency: MHz)
Desktop	Mainstream	Willamette	Pentium 4	1300 - 2000
		Northwood		1600 - 3400
		Prescott		2260 - 3800
		Smithfield*	Pentium D	2667 - 3200
	Value	Tualatin	Pentium III	1000 - 1400
			Celeron	900 - 1400
		Willamette	Celeron	1500 - 2000
		Northwood		1600 - 2800
		Prescott	Celeron D	2133 - 3460
Mobile	Mainstream	Northwood	Mobile Pentium 4-M	1200 - 2600
		Prescott	Mobile Pentium 4	2300 - 3460
		Banias	Pentium M	1200 - 1800
		Dothan		1300 - 2267
	Value	Tualatin	Mobile Celeron	1000 - 1330
			Mobile Pentium III-M	866 - 1333
		Northwood	Mobile Celeron	1400 - 2500
		Banias	Celeron M	1200 - 1500
		Dothan		1200 - 1700
	Low-Power	Tualatin LV	Mobile Pentium III-M	733 - 1000
		Tualatin ULV		700 - 933
		Tualatin LV	Mobile Celeron	650 - 1000
		Tualatin ULV		650 - 800
		Banias LV	Pentium M	1100 - 1300
		Banias ULV		900 - 1100
		Dothan LV		1400 - 1600
		Dothan ULV		1000 - 1300
		Banias ULV	Celeron M	600 - 900
		Dothan ULV		900 - 1000

Notes: * Dual-core processor
Low-power mobile PCs are mini-notebook, tablet, and ultraportables.
(LV: low-voltage; ULV: ultra-low-voltage)

Table A1. Product Cross-Reference from Processor Core to Brand Name (i.e. Marketing Name) in Sample (Q1:2002 - Q4:2005)