Is Intel's Marketing Campaign Predatory?

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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. Specifically, we examine whether Intel's choice of processor marketing via PC firms is consistent with predatory behavior. There is suggestive evidence that Intel used it's "Intel Inside" marketing campaign for predatory purposes. First, PC firms were given funds to use in advertising their Intel-based computers. Second, under the "Intel Inside" program firms were generously reimbursed for marketing expenditures. However, the funds and rebates were given if PC firms restricted sales of Intel's main rival's chips, where rebates amounted to $1.5 billion in 2001. 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 the 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. Our test results suggest that Intel sacrificed short-term profit via its marketing campaign suggesting Intel's marketing campaign was predatory.

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1 Introduction

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 payments, marketing loyalty rebates and threats to persuade computer manufacturers, including Dell and Hewlett-Packard (HP), to limit their use of AMD (Intel's main rival) processors. U.S. antitrust authorities have focused on whether the loyalty rebates used by Intel were a predatory device in violation of the Sherman Act. The European Commission (EC) has brought similar charges and imposed a 1.06 billion Euro fine on Intel for abuse of a dominant position.[2]

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. 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. 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."[3]

Our paper proposes a Test of Advertising Predation (TAP) that can be used to detect non-price predatory behavior. The TAP test has the flavor of current cost-based tests of

[2] South Korean and Japanese antitrust authorities also imposed fines on Intel for breach of antitrust regulations.

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

predatory pricing in that we propose that marketing/advertising predation has two components: short-term profit sacrifice and long-term recoupment. Given high entry barriers in the CPU industry and the potential for advertising to establish a barrier to entry, we argue that recoupment of profits is likely.[4] Thus, the focus of this paper is on the nature of predatory marketing/advertising as a short-term profit sacrifice.[5] We develop a test based on a structural approach that allows us to disentangle the potential positive impact of the marketing program from the anticompetitive predatory effect.

There are two primary aims to this paper. The first is to provide a framework to test if firms are using marketing/advertising campaigns in an anticompetitive fashion. 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 second is to determine 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).

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. Second, we compute Intel's marginal revenue from the marketing subsidy using the demand side estimates. The marginal revenue of the marketing program depends on the parameters of consumer utility (including advertising), CPU price and marginal manufacturing cost. We compare the estimated marginal revenue to a number of avoidable incremental (marketing) cost measures to determine if the marketing campaign involves the sacrifice of short-term profits (i.e., if the campaign is predatory).

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[4] The industry is capital intensive and R&D intensive, which results in high barriers to entry. There have been only two main competitors in the CPU industry, Intel and AMD, and no effective entry or exit. We discuss this in section 2.

[5] 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).

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). TAP results suggest short-term profit sacrifice by Intel over this period, which indicates that the Intel Inside campaign was used for predation.

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). While there is a vast theoretical literature on predation there are relatively few empirical studies, and these focus exclusively on pricing predation.[6]

This paper is structured as follows. We describe the TAP test for predatory behavior in section 2. We discuss the data in section 3. In sections 4 and 5, we develop the model and

[6] 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 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.

describe the estimation technique. In section 6, we present estimation results. In sections 7 and 8, we discuss the TAP results and policy implications.

2 Test of Advertising Predation (TAP)

Predation is composed of two phases: short-run profit sacrifice and long-run recoupment. That is, predation can be seen as an investment in long-run market power. In this section, we develop a Test of Advertising Predation (TAP) that is focused on the first component of predatory behavior. We discuss why the Intel Inside campaign is a useful application of the TAP test and provide details of how to implement the test.

The Intel Inside campaign provides marketing support for firms that sell 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 and over 2,700 PC firms were participants (Moon and Darwall, 2005). We consider the potential predatory nature of Intel's marketing program over the period 2002 to 2005.

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.[7] 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

[7] 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.

"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 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, whom 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.[8]

Our Test of Advertising Predation (TAP) is based on the presumption that, if the marketing/advertising 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.[9] 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.[10] The marginal revenue of the market-

[8] 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.

[9] 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.

[10] We do not model strategic decisions of PC firms over which CPUs to offer. This makes the test we develop more stringent. Rather, we model the short-run decisions of PC firms' CPU choices, which are assumed to not be affected by the marketing campaign. Intel was accused of giving refunds to PC firms

ing program depends on the parameters of consumer utility (including advertising), CPU price and marginal manufacturing cost. We provide details of the specific equation for the marginal revenue in section 4.2.

The TAP test concerns if the return to Intel from advertising done by PC firms is high enough to justify their marketing expenditures (i.e., firm rebates). Assuming there are no spillovers from the marketing campaign by one firm to another, Intel's marketing campaign should equate the marginal revenue generated by the campaign to the marginal costs for each firm. We compare the marginal marketing revenue to a variety of measures of the actual costs of the marketing campaign to determine if the marketing campaign was optimal.[11] More specifically, if we find that the marginal revenue of the marketing campaign was below the marginal cost of marketing campaign, it supports a predatory use of the marketing campaign.[12]

Alternatively, the marginal cost of the marketing program could be estimated by explicitly modeling how the marketing program works. However, the actual form of the marketing program is quite complicated, inconsistent over time, not exactly executed as publicly stated, and rather ad-hoc, especially during allegedly anticompetitive periods. These issues raise practical difficulties in explicitly modeling the correct form of the marketing program. In addition, the form of the marketing program is very specific to Intel and may not be generally applicable to other cases. One of the benefits of the TAP approach is it allows us to

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.

[11] Whether advertising is over- or under-supplied relative to the social optimal depends on whether its primary purpose is to provide information or to complement the advertised product/persusade the consumer, as well as the nature of competition. Most results indicate that non-informative advertising is over-supplied in equilibrium. We consider the market for CPUs over a time period (2002-2005) in which is reasonable to conjecture that consumers were aware of CPUs, making it less likely that adverting was providing information. Predatory advertising is defined as advertising more than the profit maximizing amount, which is also more than the socially optimal amount for non-informative advertising, hence, even in the short run, predatory advertising can be welfare decreasing. See Bagwell (2007) for an overview of the theoretical advertising literature.

[12] According to the Areeda-Turner predatory pricing test, a price below cost is evidence of predation. Analogously, we consider marginal revenue of marketing below marginal cost as evidence of marketing predation. Notice if marginal revenue is above marginal cost it still implies that marketing is not consistent with profit maximization, however advertising is lower than the optimal level.

circumvent modeling Intel's profit maximization problem (and marketing program). 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.

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.

		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

Table 1: 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 1) or on an assumed percentage rebate rate.

(**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 1 (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))."[13] 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).

(**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.[14] 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.

(**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

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

[14] 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.

is zero). We then divide the total expenditure by total advertising by Dell for PCs powered by an Intel chip.

(**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.

2.1 TAP Limitations

We would like to point out some limitations to the TAP test. One issue concerns 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 predatory marketing/advertising as there are few fixed or sunk components to advertising expenditures.

Another 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).

Finally, aside from practical difficulties, average variable cost may not be a good proxy for marginal cost in the presence of returns to scale. 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 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. Our test results reflect the assumption that PC firms' responsiveness to Intel's marketing program is constant.[15]

2.2 Motive, Recoupment, and Efficiency Motives

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. 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. Experts agree that these

[15] 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.

chips were better-performing and cheaper than Intel counterparts (see section 3 for more evidence). 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 7.1.

3 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 Media Dynamics Inc., 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. We discuss each in turn.

Quarterly PC and CPU sales from Gartner Group are at the model level, where a model 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.[16] We focus on the market for US home consumers for two primary rea-

[16] For each model we know the processor vendor (Intel, IBM, AMD, or other), the processor type (46 types), platform type (10 types; with two general platform type group of desktop or mobile) and processor speed (22 types).

sons. 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%	65.65
IBM/Lenovo	535	0.23%	21.78 / 11.45 **
Sony	360	2.93%	5.08
Systemax	507	0.36%	0.20
Toshiba	294	3.54%	4.19
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. **21.78 is IBM 11.45 is Lenovo.

Table 2. Market Shares and Advertising Expenditures by PC Firms

Advertising data from Kantar Media Group consist of PC-related advertising expenditures. These include general firm promotions, general PC promotions, PC-brand advertising, and brand-specific advertising, both by form factor and across all form factors.[17] The advertising data is quite detailed, sometimes even at the level of a specific product (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 different between the two datasets. Kantar Media Group uses a model name, such as Aspire AS5735; whereas, Gartner Group defines 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 2 shows the market share and total PC-related advertising expenditures by PC firm in the entire sample.

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

In-Stat provides data on CPU prices and manufacturing costs for selected processors and time periods.[18] We need to match our PC data (CPU 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.[19] In our PC data, we know the brand name (that is, the marketing name, e.g., Pentium 4) and speed (frequency) of the CPU in a given PC. The same processor core is often used to make processors that are marketed under different brand 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 marketed as Pentium 4 and as Celeron for desktop computers. The same CPU brands used the next-generation processor core "Northwood" in later periods. The data are matched based on platform group (whether desktop or mobile), type (whether mainstream, value, or ultraportable), marketing name of a CPU, CPU speed, year, and quarter.[20] We provide the product cross-reference in Table A1[21] 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. 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

[18] 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."

[19] 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, the data cover only a subset of our sample.

[20] 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 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, 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.

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

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. Table 3 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. So, 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	SD	Min	Max
CPU price	1020	146.98	57.14	49	317
CPU MC	1020	36.64	5.77	26	57

Table 3. CPU price and CPU MC (marginal cost) of Dell Intel-based PCs

Table 4 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.

	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 4: Percent and Market Share of PCs by CPU Type

CPU characteristics include whether the CPU manufacturer is Intel; a (continuous) CPU quality benchmark, that compares the relative speeds of different CPUs (collected by Pass-

Mark[22]); log value of CPU speed[23] ; if a CPU chip used in a model is sold in the first quarter of the data period, i.e., 2002:Q1, denoted *Older CPU*[24] ; and *CPU age*, number of quarters since the first sales record of a CPU if *Older CPU* = 0.

As the summary statistics in Table 5 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) and 19% were shipped in the first quarter of the data period, i.e., 2002:Q1.[25] If the PC is not an *Older PC* then *PC age* indicates a mean of 1.6 quarters since the PC was first shipped. About 19% of the models were first shipped before the first quarter of 2002 and about 36% of CPUs in the PC were shipped before the first quarter of 2002. *PC age* equals zero if the PC is an *Older PC* and equals the number of quarters since the PC model was first shipped otherwise. Similarly,*CPU age* is zero if CPU in the PC is an *Older CPU*, and otherwise is the number of quarters since the CPU was first shipped. 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 manufacturers spent an average 23 million dollars on general firm promotions and chip 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

[22] 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.

[23] When CPU speed data is not available from Gartner's data, we used the average speed of the CPU family.

[24] 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.

[25] We created *Older PC* dummy variable because the data is truncated in 2002:Q1 and we do not know exactly when the first shipment of the PC model occurred.

advertising.[26]

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 5. Descriptive Statistics

Table 6 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 can see that the PC models with Intel chips are priced higher and advertised significantly

[26] 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:

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

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.

more at the CPU level.[27] 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	45.78
PC brand ads (10 mil.$2000)	0.41	0.69	-0.27	-8.34
Num. obs.	4708	619		

Table 6: Descriptive Statistics by CPU Manufacturer

Finally, we use surveys on PC purchases from Forrester Research surveys 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[28] , Other, or Don't know) if purchased. In addition, they include information on advertising exposure, which allows us to link demographics to firm and CPU advertising. Given that ad exposure is very relevant to the effectiveness of advertising, this information is useful to determine heterogenous advertising effects over different demographic groups.

[27] Over this time frame, there was advertising of Microsoft products that featured Intel chips. Intel's chip advertising expenditures includes advertising that was done with Microsoft.

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

4 Model and Estimation Technique

4.1 CPU Demand

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 consumers purchase computers, they choose a combination of PC firm and CPU type.[29] 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.[30] 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

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

[29] 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.

[30] 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.

where

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

captures the base utility every consumer derives from product j and mean preferences for x_j are captured by β. The composite random shock, $\mu_{ijt} + \epsilon_{ijt}$,[31] captures heterogeneity in 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.[32] The a^{pc}_{jt} is a vector of PC advertising variables aggregated at different levels and a^{cpu}_{jt} is a vector of CPU advertising variables aggregated at different levels. For sake of exposition, we define $a_{jt} = \{a^{\text{pc}\prime}_{jt} \quad a^{\text{cpu}\prime}_{jt}\}'$.

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. The 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

[31] Choices of an individual are invariant to multiplication of utility by a person-specific constant, so we fix the standard deviation of the ϵ_{ijt}.

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

the sample period), a PC manufactured by a small firms[33] , and self-assembled PCs.[34] Normalizing p_{0t} to zero,[35] 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,[36] 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

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

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

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

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

[36] 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.

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 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.

4.2 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

$$TMR = \sum_{c \in \mathcal{J}_{intel}} \sum_{f} (p_c^{CPU} - mc_c)\mathcal{M} s_{fc}(p, a), \tag{6}$$

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).[37]

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

[37] 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.

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

$$MMR_f = \mathcal{M} \sum_{\substack{j,r \in \mathcal{J}_f \cap \\ c \in \mathcal{J}_{intel}}} (p_c^{CPU} - mc_c) \frac{\partial s_j(p,a)}{\partial a_r^{\text{total pc}}}. \tag{7}$$

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.

5 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

$$S_t^{obs} - s_t(\delta, \theta) = 0 \tag{8}$$

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.[38] The first moment unobservable is

$$\xi_{jt} = \delta_{jt}(S,\theta) - x_j'\beta. \tag{9}$$

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, or Other\} was chosen. Define the residual as the difference between the vector of observed choices and the model prediction given (δ,θ) :

$$\mathcal{B}_i(\delta,\theta) = b_i - E_\nu E[B_i \mid D_{it},\delta,\theta]. \tag{10}$$

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

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[38] As discussed in Dube et al (2011) we use a precise tolerance level for the contraction mapping. For more details see section 7.1.

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 $R \to \infty$ 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.[39]

5.1 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) :

$$E\left[\xi_{jt}(\Theta_0) \mid x_{jt}\right] = 0. \tag{11}$$

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 are valid instruments for advertising.[40] One set of instruments we use is the number of products per firm, this 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, PC and CPU ages - 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.

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

[40] 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.

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[41] dummy variables and time (year-quarter) dummy variables and a series of interactions between PC cohort[42] 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).

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 ad exposure corresponding to variation in observable consumer characteristics $(\widetilde{D}_i)$ identifies Υ.

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

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

6 CPU Demand Estimation Results

6.1 Preliminary Regressions

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 in Table 7 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 7: Probit Regressions of PC Purchase (in 2002)

Table 8 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 8: PC purchase Probability on PC Characteristics and Demographics

Table 9 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 9: CPU Purchase Estimates

6.2 Structural Results

In Table 10 we present results from a Multinomial Logit PC-CPU demand model with aggregate market data, where only product characteristics are included as explanatory variables.[43] 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

[43] 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 7 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 affect 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		Dependent Variable: ln(Market Share) - ln(Share of Outside Goods) (1)	(2)	(3)	(4)	(5)	(6)
Price		-0.286***	-1.047*	-0.522***	-0.348***	-1.806***	-2.261***
		(0.0855)	(0.609)	(0.0669)	(0.0647)	(0.541)	(0.642)
PC Characteristics	Laptop	-0.178**	0.146			0.425*	0.510*
		(0.0711)	(0.266)			(0.236)	(0.292)
	Older PC	0.906***	0.858***			0.651***	0.578***
		(0.122)	(0.128)			(0.114)	(0.145)
	PC Age	0.126***	0.138***			0.0939***	0.0901***
		(0.0222)	(0.0241)			(0.0215)	(0.0238)
CPU Characteristics	Intel	-0.510***	-0.233	-0.00972	0.0282	0.517	-2.053
		(0.103)	(0.244)	(0.231)	(0.219)	(0.319)	(1.305)
	ln(Benchmark)	0.371**	0.851**	0.582***	0.429***	1.344***	1.390***
		(0.155)	(0.414)	(0.128)	(0.120)	(0.372)	(0.434)
	ln(Speed)	1.594***	1.731***	1.382***	1.115***	1.632***	1.730***
		(0.106)	(0.149)	(0.0882)	(0.0848)	(0.135)	(0.166)
	Older CPU	-0.0906	-0.0641	0.485***	0.498***	0.239**	0.194
		(0.113)	(0.116)	(0.0922)	(0.0832)	(0.107)	(0.129)
	CPU Age	0.00524	-0.0101	0.0993***	0.0964***	0.0355*	0.0224
		(0.0174)	(0.0206)	(0.0135)	(0.0131)	(0.0186)	(0.0229)
Advertising	CPU ad			-0.0239	0.0730	-0.140	4.166***
				(0.187)	(0.172)	(0.193)	(1.357)
	CPU ad squared			-0.00828	-0.0335	0.0171	-0.862***
				(0.0306)	(0.0277)	(0.0321)	(0.253)
	PC ad			2.353***		2.368***	3.480***
				(0.0828)		(0.0861)	(0.300)
	PC ad squared			-0.294***		-0.304***	-0.576***
				(0.0216)		(0.0224)	(0.132)
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	0.650	0.575	0.471
Median (Own) Price Elasticity		-0.336	-1.231	-0.613	-0.409	-2.122	-2.658

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

Table 10: Multinomial Logit Estimates of PC/CPU Demand

7 Test of Advertising Predation (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 7.1.

The estimated marginal revenue of Intel's marketing subsidy to Dell and its 95 percent confidence interval is given in Table 11, along with the marginal cost of the marketing campaign computed in four different ways as described in section (2).[44] 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.

[44] 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 $MC_4 = MC_3/2$).

	Computed Marginal Revenue			Observed Marginal Cost				TAP Result
Quarter	Est.	95% conf. Interval		(1)	(2)	(3)	(4)	Positive in
2002Q1	1.45	(1.22	1.69)	34.54	31.12	3.33	1.66	1,2,3
2002Q2	0.88	(0.73	1.02)	45.62	40.70	3.73	1.87	all
2002Q3	1.23	(1.03	1.43)	53.31	48.05	5.90	2.95	all
2002Q4	2.22	(1.85	2.58)	91.86	82.59	13.02	6.51	all
								all
2003Q1	2.95	(2.46	3.45)	352.14	315.44	44.78	22.39	all
2003Q2	2.38	(1.98	2.77)	192.68	171.66	17.50	8.75	all
2003Q3	3.02	(2.52	3.52)	140.80	126.81	13.61	6.80	all
2003Q4	2.92	(2.45	3.40)	93.19	82.75	7.57	3.79	all
								all
2004Q1	3.35	(2.79	3.91)	682.73	607.55	56.66	28.33	all
2004Q2	1.95	(1.62	2.27)	345.53	306.09	18.57	9.28	all
2004Q3	1.72	(1.44	2.00)	133.28	118.52	7.39	3.69	all
2004Q4	2.05	(1.71	2.39)	192.46	171.46	8.55	4.27	all
								all
2005Q1	6.27	(5.22	7.32)	390.02	340.19	15.51	7.75	all
2005Q2	4.36	(3.64	5.09)	370.16	323.16	11.30	5.65	all
2005Q3	4.40	(3.67	5.14)	348.36	307.69	15.67	7.83	all
2005Q4	5.83	(4.85	6.80)	340.69	298.21	13.25	6.63	1,2,3

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

Table 11. 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.[45] This implies that Intel needs to incur more than 1$ to induce Dell to spend 1$ more on

[45] 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.

advertising.

Second, MC_3 and MC_4 are significantly smaller than MC_1 and MC_2. Considering 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 12 and 13 present 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.

	Computed Marginal Revenue			Observed Marginal Cost		TAP Result	
Time	Est.	95% conf. Interval		MC3	MC4	MC3	MC4
2002Q1	-0.02	(-0.32	0.28)	0.11	0.05		
2002Q2	1.04	(0.89	1.19)	0.27	0.13		
2002Q3	1.20	(1.01	1.38)	0.27	0.13		
2002Q4	-5.68	(-9.93	-1.43)	0.12	0.06	positive	positive
2003Q1	-0.42	(-1.30	0.46)	0.09	0.05		
2003Q2	0.15	(-0.34	0.64)	0.11	0.05		
2003Q3	0.36	(-0.25	0.97)	0.17	0.09		
2003Q4	0.59	(-0.45	1.64)	0.30	0.15		
2004Q1	-0.07	(-0.80	0.66)	0.14	0.07		
2004Q2	0.32	(-0.01	0.66)	0.13	0.07		
2004Q3	0.59	(0.31	0.87)	0.20	0.10		
2004Q4	0.37	(-0.04	0.77)	0.17	0.09		
2005Q1	2.47	(0.80	4.15)	0.17	0.08		
2005Q2	4.90	(4.12	5.68)	0.33	0.17		
2005Q3	6.91	(5.90	7.92)	0.57	0.29		
2005Q4	6.31	(5.18	7.43)	0.41	0.21		

Unit: $ (inflation adjusted - base: 2000)

Table 12. TAP Results for HP

	Computed Marginal Revenue			Observed Marginal Cost		TAP Result	
Time	Est.	95% conf. Interval		MC3	MC4	MC3	MC4
2002Q1	0.13	0.11	0.15	0.14	0.07		
2002Q2	0.25	0.22	0.29	0.09	0.04		
2002Q3	0.66	0.56	0.75	0.16	0.08		
2002Q4	0.62	0.52	0.71	0.42	0.21		
2003Q1	0.34	0.28	0.40	1.37	0.68	positive	positive
2003Q2	0.21	0.18	0.25	0.82	0.41	positive	positive
2003Q3	0.31	0.26	0.36	1.47	0.74	positive	positive
2003Q4	0.44	0.37	0.51	1.45	0.72	positive	positive
2004Q1	0.34	0.28	0.40	0.99	0.50	positive	positive
2004Q2	0.35	0.30	0.41	0.99	0.50	positive	positive
2004Q3	0.43	0.36	0.49	0.49	0.24	positive	
2004Q4	0.98	0.83	1.14	0.30	0.15		
2005Q1	1.94	1.63	2.25	0.34	0.17		
2005Q2	1.97	1.66	2.29	0.46	0.23		
2005Q3	2.92	2.44	3.40	0.72	0.36		
2005Q4	2.95	2.48	3.43	0.49	0.25		

Unit: $ (inflation adjusted - base: 2000)

Table 13. TAP Results for 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.

Time	Computed Marginal Revenue Est.	95% conf. Interval		Observed Marginal Cost MC3	MC4	TAP Result MC3	MC4
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	0.89	0.26	0.13		
2003Q1	0.87	0.74	1.00	0.25	0.12		
2003Q2	0.47	0.40	0.54	0.20	0.10		
2003Q3	0.50	0.43	0.57	0.17	0.08		
2003Q4	0.55	0.47	0.64	0.15	0.07		
2004Q1	0.66	0.56	0.76	0.78	0.39		
2004Q2	0.40	0.34	0.47	0.50	0.25		
2004Q3	0.52	0.43	0.60	0.37	0.18		
2004Q4	1.15	0.96	1.34	2.66	1.33	positive	
2005Q1	4.50	3.75	5.25	6.37	3.18	positive	
2005Q2	3.58	2.98	4.17	2.64	1.32		
2005Q3	4.70	3.92	5.48	4.21	2.11		
2005Q4	5.69	4.78	6.61	1.79	0.90		

Unit: $ (inflation adjusted - base: 2000)

Table 14. TAP Results for Gateway

7.1 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.

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.[46] 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.[47] 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

[46] 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.

[47] 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.

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 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)