DIFFERENTIAL MERGER EFFECTS:
the case of the personal computer industry

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PRELIMINARY AND INCOMPLETE

ABSTRACT

In many markets there exist distinct customer segments that differ in their underlying preferences and purchasing patterns. This information is of particular importance when evaluating the welfare effects of mergers. Using an empirical structural model, I estimate demand for the personal computer industry both for the overall market and for three major segments (Home, Small Business and Large Business) in the late nineties. The resulting estimates are used to simulate the welfare effects of the biggest merger in the history of this industry between Hewlett-Packard and Compaq and a second hypothetical merger between Dell and Compaq. The differential effects of these mergers across segments and time demonstrate that this kind of analysis can be very valuable to both firms and competition authorities.

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1 Introduction

Economic analysis of the competitive effects of mergers in differentiated product industries is of great interest both for academics and policymakers. The basic aim of the analysis is to determine whether the removal of the comptetitive constraints the merging firms' products place on each other is likely to lead to higher prices after the merger. The nature of competition and the large number of brands in such industries render traditional methods of concentration measures inappropriate for policy recommendation. However, recent advances in structural methods that combine demand estimation with a game theoretic model of the competitive market structure made such merger simulations feasible for a variety of industries.[1] Although these methods are based on static models and are more indicative of the short run effects, antitrust authorities increasingly base their reviews on such simulations to identify potentially anticompetitive mergers. As Baker (1997) notes, "because the simulation procedure necessarily combines estimates and assumptions about which there may be significant uncertainty, the output of the procedure - a set of projected price changes- is better viewed as an indicator of the strength of incentives, rather than a forecast."

This paper follows this general methodology and attempts to evaluate the welfare effects of the biggest ($23 billion) merger in the history of the personal computer industry between Hewlett-Packard and Compaq[2] and a second hypothetical merger between Dell and Compaq. Using a combination of datasets that covers the leading personal computer manufacturers over 26 quarters in the US, I estimate a random coefficients discrete choice model of demand (McFadden (1973), (1978), (1981); Berry (1994); Berry, Levinsohn and Pakes (1995; henceforth BLP); Nevo (2001)). The resulting estimates in combination with a Nash-Bertrand equilibrium assumption are used to recover marginal costs. The new postmerger equilibrium price vector is simulated under a variety of assumptions for these two mergers.

Two dimensions are added to the above general framework that are shown to be important at least for this industry. The first one relates to the differential effects of

[1] Examples include beer (Baker and Bresnahan (1985), Hausman, Leonard and Zona (1994) and Pinkse and Slade (2004)), automobiles (Berry and Pakes (1993), Invaldi and Verboven (2003)), long distance telecommunications (Werden and Froeb (1994)), ready-to-eat cereals (Nevo (2000a)), carbonated soft drinks (Dube (2004)) and airlines (Peters (2001)).

[2] This merger was not challenged by neither the US Federal Trade Commission nor the European Competition Commission.

a merger on various segments of the economy. This cross sectional aspect, although explicitly recognised, for example, by the European Competition Commission ("*Because, among other elements, individual consumers show different purchasing patterns,..., the market for PCs could be broken down between consumers and commercial customers.*"[3]) for the HP-Compaq merger, has not been studied so far in any other industry. Using data on three major segments (Home, Small Business and Large Business) I demonstrate that this kind of analysis can be very valuable to both firms and competition authorities. Although the HP-Compaq merger, for example, is predicted to increase profits of the merged firm when using the aggregate data, segment analysis draws a different conclusion: the combined firm would lose money from an attempt to take advantage of its full product line both in the home and in the small business segment, with only a small increase in profits in the large business segment. More fundamentally, the effects from any merger will vary across different segments according to the relevant position of the firms involved and the aggregate level of elasticity in the market. A hypothetical merger between Dell and Compaq in 1998 would have resulted in a negative consumer surplus and a negative overall welfare for the home segment, whereas the welfare results would have been positive and sizable for the other two segments. Hence, segment analysis can become a useful tool for policymakers to evaluate more accurately the differential impact of a merger in other markets where there are distinct customer segments.

The second dimension is related to the evolution of the market. For the fast changing PC industry, important insights can be gained by simulating the same merger at different points in time. In the HP-Compaq case, it is shown that the same merger three or six years earlier would have reduced consumer welfare by a smaller amount than in 2001. Moreover, combining the aforementioned cross sectional analysis with the time dimension reveals some important patterns in the demand of the different segments. Although this does not constitute a dynamic analysis of the market, it provides regulators with a better picture of the trends in the industry that can be informative for the overall evaluation of a merger.

The rest of the paper is organized as follows. Section 2 describes briefly the main aspects of the evolution of the personal computer industry most relevant to our period of study. Section 3 presents the data used in this article. The empirical framework and

[3]Case No COMP/M. 2609-HP/COMPAQ, Office for Official Publications of the European Communities.

estimation used are discussed in sections 4 and 5. Results are presented in section 6 and the final section concludes.

2 The Personal Computer Industry

The pace of technical change in personal computing has been extremely fast throughout its history. Competition, on the other hand, has change radically in the late ninenties from the period when the first IBM PC was introduced. Langlois (1992) and Steffens (1994) provide excellent historical reviews of the personal computer industry and Breshnahan and Greenstein (1999) present an integrated analysis of the evolution of the whole computer industry. Here, I am going to focus on two main aspects of the evolution of personal computer industry that are relevant for our period of analysis.

The early emergence of the IBM PC platform[4] served as a coordinating mechanism due to IBM's historic decision to use other firms' technology in key functions (most notably, Intel for the microprocessor and Microsoft for the operating system), but also to have an open architecture,[5] in the sense that any user could add non-IBM hardware and software. This open architecture meant that platform components were interchangeable and consequently, all market participants could share the benefits of the technological progress. Moreover, interchangeable components meant that buyers could ensure backwards compatibility, hence avoiding losses on software or training investments (sunk costs). On the other hand, the IBM PC platform provided not only a focal point for the innovative efforts from all sellers, but also it led to the transition from the vertically integrated suppliers to the an horizontal market structure of vertically disintegrated specialized firms (see figures 1 and 2). During the early eighties the ideal business organization model was that of the "IBM" style: a vertically integrated structure where a firm could offer all the products and all the services that customers might wanted. Gradually though, during the late eighties, the structure of the industry was transformed into vertical disintegrated layers of firms specializing into particular stages of the value chain. Customers now can choose their preferred specification from a wide variety of vendors. That is also what Bresnahan and Greenstein (1999) called "divided technical leadership", i.e. the supply of key platform

[4]Following Bresnahan and Greenstein (1999), a computer platform can be defined as a "bundle of standard components around which buyers and sellers coordinate efforts".

[5]In contrast with the other long-lived platform, Apple Macintosh, which had a closed hardware architecture, in the sense that Apple maintained exclusive control over its interfaces.

components by multiple firms. Under divided technical leadership, there is no single firm that controls the direction of the platform. Frequently, various firms might have dominant positions in different layers (for example, Intel in microprocessors and Microsoft in the operating system), but because technically there are no given boundaries, there is fierce competition between firms from other layers trying to extent their dominance to new areas.

The consequence of the new horizontal structure for personal computer manufacturers was twofold. First, they reduced their R&D expenditures[6] and concentrated on collecting the various parts of the final product from companies in different layers of the platform. Technical knowledge was not the critical advantage anymore and the simplicity of assembly and ease with which components could be purchased, lowered the entry barriers for potential new assemblers. As we can see from figure 4, that led, on the one hand, to a surge in the aggregate market share of small producers (denoted as "Others") and on the other hand to the rise of the "Dell phenomenon". Based on a new business model, which was taking advantage of the new industry structure, firms like Dell or Gateway became major players within very short period of time.

Second, Intel became the main supplier and innovator of the single most imporant component of any personal computer: the microprocessor.[7] During the late ninenties, there was a surge in the number and variety of new processors, as can be seen in figure 3. Intel tried to achieve greater segmentation of the market both by selling a greater range of vertically differentiated processors and by cutting the average life cycle of each processor (Song (2003)). Personal computer manufacturers amplified this phenomenon by offering an ever increasing number of products that were not only different in their "basic" characteristics (such as the microprocessor, RAM or speed) but also in a variety other dimensions (CD-ROM, modem, DVD, monitor size etc). Therefore, during our period of intertythere was an increase of competition in the personal computer market due to the change in the industry structure and the entry of new firms, but also greater market segmentation due to the increased variety of products that became available.

[6] "R&D spending by most PC manufaturers has declined over the past four years from an industry average of just 4% of sales to about 2% of sales. In sharp contrast, Intel, the dominant supplier of microprocessors to the PC industry, ploughed 8% of revenues or $1.3bn, into R&D last year. Microsoft, the leading PC software supplier, spent $890m on R&D last year, or 15% of its sales" (Financial Times, 10/2/1996).

[7] I will use the words microprocessor, processor or CPU interchangably.

3 The Data

Estimation of a product level differentiated demand sytem requires data on prices, quantities and characteristics of each model marketed in every period. Identifying the various models and construct my dataset with all the relevant characteristics constituted a major part of this study. Quarterly data on quantities and prices[8] between 1995Q1 and 2001Q2 was taken from the personal computer tracker (PC Tracker), an industry census conducted by International Data Corporation's (IDC). IDC is a well-known market research firm in the information technology sector and it covers extensively the whole computer industry. The PC Tracker gathers information both from the major vendors and component manufacturers, but also from the various channel distributors,[9] which makes it one of the best available datasources for the PC industry.[10]

The available dataset provides disaggregation by manufacturer, brand name, form factor,[11] chip type (e.g. 5th Generation) and processor speed bandwidth (e.g. 200-300 MHz). The need to supplement this data with additional characteristics led me to concentrate on the US market and on the top nine producers.[12] I then matched each observation with more detailed characteristics from various PC magazines.[13] Hence, the unit of observation in this data is defined as a manufacturer, brand, form factor, processor type (e.g. Pentium II), processor speed (e.g. 266 MHZ) combination. Finally, in order to

[8] Prices are defined by IDC as "the average end-user (street) price paid for a typical system configured with chassis, motherboard, memory, storage, video display and any other components that are part of an "average" configuration for the specific model, vendor, channel or segment". Prices were deflated using the Consumer Price Index from BLS.

[9] IDC claims that it covers more than 80% of the US market.

[10] Various datasets from IDC have been used both in economics (Foncel and Ivaldi, 2001; VanReenen, 2003; Pakes, 2003) and in management (Bayus, 1998; Bayus and Putsis, 1999, 2001).

[11] Form factor means whether the PC is a desktop, notebook or ultra portable.

[12] These manufacturers are: Acer, Compaq, Dell, Gateway, Hewlett-Packard, IBM, NEC, Sony and Toshiba. Apple was excluded due to the fact that I was unable to match more detail characteristics in the way its processors were recorded by IDC.

[13] The characteristics data was taken from PC magazines (PC Magazine, PC Week, PC World, Computer Retail Week, Byte.com, Computer User, NetworkWorld, Computer World, Computer Reseller News, InfoWorld, Edge: Work-Group Computing Report, Computer Shopper) and Datasources. To be consistent with the IDC definition of price, I assign the characteristics of the median model per IDC observation if more than two models were available. The justification for this choice is that I prefered to keep the transaction prices of IDC, rather than substitute them with the list prices published in the magazines. An alternative approach followed by Pakes (2003) would be to list all the available products by IDC observation with their prices taken from the magazines and their sales computed by splitting the IDC quantity equally among the observations. Although, clearly, both approaches adopt some ad hoc assumptions, qualitatively the results would be the same. Both list and transaction prices experienced a dramatic fall over this period and the increase in the number and variety of PCs offered would have been even more amplified with the latter approach.

reduce the dimension of the characteristics space, instead of using the seventeen processor type dummies (table 1) and the speed of each chip as separate characteristics, I merge them using CPU benchmarks for each computer.[14] Despite the large number of small producers, the PC industry is rather concentrated with the top five firms accounting for the 52% and the top ten firms for the 72% of the aggregate sales. Table 2 shows the average percentage shares of the nine firms that included in my sample. They account for the 65% of total sales, with 60% and 61% for the home and small business segment, while they reach 76% in the large business segment.

IDC also provides information on the identity of the PC buyers at an aggregate level, distinguishing among the following segments: Large, Medium and Small Business, Small Office, Government, Education and Home.[15] In the analysis below I focus on three segments: Home, Small Business (where Small Business and Small Office were merged) and Large Business (where Large and Medium Business were merged). One important characteristic of the data is that any given model is sold at the *same* price across the different customer segments. In other words, personal computer manufacturers are not able to price discriminate among their different buyers and there are no arbitrage opportunities. The only thing that distinguishes the various customer segments is the type and quantities of computers that they are buying.[16] The three segments account for an average 89% of all PC sales, with the biggest being the Home segment (37%), followed by the Large Business (30%) and the Small Business (22%). The potential market size for the home segment is assumed to be the number of US households (taken from the Current Population Survey), whereas for the small and large business is the total number of employees as reported in the Statistics of US Businesses.[17]

[14] CPU benchmarks were obtained from *The CPU Scorecard* (www.cpuscorecard.com). Bajari and Benkard (2002) were the first to use this variable.

[15] According to IDC definitions a Small Office is a non-residential business site with less than 10 employees. Similarly, Small Business is a business site with 10 to 99 employees, Medium Business with 100 to 499 employees and a Large Business with 500 or more employees. The Home segment includes all the home purchases, regardless of usage (home office, work-at-home or consumer applications).

[16] The fact that prices are the same across segments seems to be more of a problem for the large business segment (where customers are probably buying larger quantities) rather than the two other segments. Despite the fact that there is anecdotal evidence that PC manufacturers tend to compete on non-price dimensions (such as customer support or IT consulting), if we assume, for example, that the prices for large businesses are 15% lower their current level, that would have no effect on the elasticites derived from the simple IV logit. In the random coefficients model, I would expect a small reduction in the elasticities (although I have not run this specification yet), which it would not change the overall differences among segments.

[17] Although these potential market sizes seem problematic, I performed various robustness checks by reducing the market sizes or by fitting different diffusion curves (not reported here). None of the results

Tables 3-6 provide sales weighted means of the variables that are used in the specifications below, both for the overall market and the different segments. These variables include quantity (in units of 1000), price (in \$1000 units), benchmark (in units of 1000), RAM (in units of 100MB), monitor size and dummies for the CD-ROM (1 if standard, 0 otherwise), internet (1 if modem or ethernet included as standard, 0 otherwise) and desktop. The choice of these variables was based on two criteria: first, to include characteristics that would capture technological innovation (like the benchmark and RAM) and trends in related markets (like the modem/ethernet for internet and CD-ROM for multimedia) and second, the characteristics to be relevant both for the overall market but also for the three segments individually.

The pace of innovation and competition in this industry is such that, even thought the data covers only seven years (26 quarterly observations), several interesting trends are evident. The number of products rises from 88 in the first quarter of 1995 to 277 in the second quarter of 2001, following an upward trend. At the same time, the core characteristics of the computers, benchmark and RAM, follow an amazing on average quarterly growth of 13% and 11% respectively. Given that we consider the same nine firms through time, these statistics demonstrate both the faster innovation delivered from the different layers of the computer industry, but also the higher market segmentation through product proliferation that Intel and the PC manufacturers are trying to achieve. Also, new components, such as the CD-ROM and the internet peripherals, although installed in 68% and 51% of the new PCs at the beginning, diffuse very quickly and become virtually standards at the end of the sample. Even more spectacularly, this fast technological progress is accompanied by equally rapidly falling prices. In real terms, sales-weighted average price of PCs has fallen by 45% in the late ninenties.[18] The combination of falling prices and technological improvements meant that portable computers became affortable for more consumers, which can be seen by the negative trend of the market share of desktops. Finally, there are some revealing differences among the variable means in the different segments. For instance, large businesses seem to buy more expensive PCs on average, with better core characteristics and with a stronger preference for portable computers, while lagging slightly behind the other sectors in the adoption of peripherals.

change in any fundamental way.

[18] There is also an extensive empirical literature using hedonic regressions that documents the dramatic declines in the quality adjusted price of personal computers. See, for example, Dulberger (1989), Gordon (1989), Triplett (1989), Berndt, Griliches and Rappaport (1995) and Pakes (2003).

4 The Empirical Framework

The empirical strategy, first proposed by Baker and Bresnahan (1985), consists of a structural estimation of demand and supply and subsequent use of these results in order to evaluate the competitive effects of the mergers. The econometric techniques that I employ follow those found in recent studies of differentiated products, such as Berry (1994), Berry and Pakes (1993), BLP and Nevo (2000a).

4.1 Demand

Demand specification and estimation is very crucial in this framework, both from an econometric viewpoint but also because it will affect the subsequent calculations. Recent advances in the discrete choice and industrial organization literature allow the recovery of structural demand parameters even from aggregate data. Depending on the assumptions made in various parts of the framework, there is a range of possible alternative models of demand that can be estimated. A full empirical comparison of these methods is beyond the scope of this article, hence, I focus here on the model I use for the analysis below. Except for small differences, the setup is identical to the one outlined in BLP and Nevo (2001).

Assume that the conditional indirect utility, $u_{ij}(\theta)$, is a function of observed and unobserved product $j = 1, ..., J$ and consumer $i = 1, ..., I$ characteristics and model parameters $\theta = (\theta_1, \theta_2)$ and takes the following form

$$u_{ij}(\theta) = \delta_j(\theta_1) + \mu_{ij}(\theta_2) \quad V_{ij} + \epsilon_{ij}. \tag{1}$$

The first term, is the mean utility derived from consuming good j, which is common to all consumers, and is given by

$$\delta_j = x_j\beta \quad \alpha p_j + \xi_j, \tag{2}$$

where α is the marginal utility of income; x_j and β are vectors of the observed product characteristics and the associated taste parameters, respectively; and ξ_j denotes utility derived from characteristics observed to the consumers and the firms, but unobserved to the

econometrician. Unobserved characteristics might include unquantifiable variables such as firm reputation for reliability, prestige effects of certain brands or after-sales service quality. The crucial point is that since these characteristics are observed by market participants, they will be correlated with the equilibrium prices and hence, the price coefficient will be biased towards zero. Instrumental variable techniques can not straighforwardly be applied, given that both p_j and ξ_j enter the market share equation in a nonlinear way. Berry (1994) made a important contribution by developing a general method that allows the use of instrumental variables to a large class of discrete choice models.

The second term, represents a deviation from that mean, which is individual specific and can be written as

$$\mu_{ij} = \sum_k \sigma_k x_{jk} \nu_{ik} + \sigma_p p_j \nu_{ip} + \epsilon_{ij} \tag{3}$$

where x_{jk} is the kth characteristic of product j, for $k = 1, ..., K$. Each consumer i has $K + 1$ idiosyncratic tastes for the K observed characteristics and the price, $\nu_i = (\nu_{ip}, \nu_{i1}, ..., \nu_{iK})$ is a vector of random draws from a multivariate normal distribution with zero mean and an identity covariance matrix[19] and ϵ_{ij} are shocks that are identically and independently distributed across products and consumers with a Type I extreme value distribution.[20] Notice that μ_{ij} depends on the interaction of consumer specific preferences and product characteristics. More precisely, each consumer i derives $(\beta_k + \sigma_k \nu_{ik}) x_k$ utility from every kth product characteristic. BLP show that allowing for substitution patterns to depend on consumer's heterogeneous tastes (i.e. $\mu_{ij} \neq 0$) is crucial in order to get more realistic demand elasticities.[21] The intuition behind this formulation is that consumers

[19] The choice of this distribution is ad hoc and although the multivariate normal is the most popular choice (e.g., BLP; Nevo, 2000a, 2001), other possibilities have also being explored (e.g., Petrin, 2002). To the best of my knowledge, there is no paper that examines this assumption theoretically or empirically.

[20] This particular assumption although facilitates the estimation by insuring nonzero purchase probabilities and smooth derivatives for the market share equation, has recently being critisized. Petrin (2002), for example, shows that welfare changes from the introduction of new products are overstated due to the presence of this idiosyncatic error term. Alternative models, like the probit model of Goolsbee and Petrin (2003) are prohibited for the current application given the number of products in each period. Finally, recent work by Berry and Pakes (2002) and Bajari and Benkard (2003) that attempts to correct for the influence of this error has not yet produced an empirically feasible alternative.

[21] When μ_{ij} is zero, the only source of heterogeneity among consumers is based on the i.i.d. ϵ_{ij}'s. In terms of elasticities, that implies that all the consumers have the same expected ranking over products. In other words, consumers would substitute more towards the most popular products independently of their characteristics and the characteristics of the products that they were buying before.

who attach a higher utility, for example, to laptop computers would more likely substitute towards other laptops rather than desktops.

The specification of the demand system is completed with the introduction of an "outside good". Allowing consumers the possibility of not purchasing any of the personal computers offered by these firms is essential, because otherwise a uniform price increase would not change the quantities purchased. The indirect utility of the outside option is

$$u_{i0} = \xi_0 + \sigma_0 \nu_{i0} + \epsilon_{i0}. \tag{4}$$

where the price of the outside good is normalized to zero. Since relative levels of utility can not be identified, the mean utility of one good has to be normalized to zero. As is customary, I normalize ξ_0 to zero. The term ν_{i0} accounts for the unobserved variance of the outside alternatives and implies the presence of a random coefficient on the constant term in the utility of the inside goods.

Each consumer is assumed to purchase one good per period[22] from the available choice set that provides him with the highest utility. Given the assumption on the distribution of ϵ_{ij}, the probability that consumer i purchases good j is given by the multinomial logit choice probability (McFadden, 1973)

$$\Pr(j \mid x, i) = \frac{\exp\left(\delta_j + \sum_{k=1}^{K} \sigma_k x_{jk} \nu_{ik} + \sigma_p p_j \nu_{ip}\right)}{1 + \sum_{l=1}^{J} \exp\left(\delta_m + \sum_{k=1}^{K} \sigma_k x_{mk} \nu_{ik} + \sigma_p p_m \nu_{ip}\right)} \tag{5}$$

Market shares for each product, s_j, are obtained by aggegating over consumers and their vector of unobservable tastes. This integral is solved numerically via aggregation by simulation, using a technique introduced by Pakes (1986).

[22] Although this assumption seems reasonable for home or small business users, it might not be applicable to the large business segment. Hendell (1999) for example observes PC data on large firms and models explicitly the choice of multiple products. Without more dissagregate information his techniques can not be applied in the current data, hence if this phenomenon is widespread this model can be seen as an approximation to the true choice model.

4.2 Supply and equilibrium

There are F multiproduct firms, each having a portfolio, Γ_f, of the $j = 1, ..., J$ different products in the PC market. The profit function of each firm f can be expressed as

$$\Pi_f = \sum_{j \in \Gamma_f} (p_j \quad mc_j) \, M s_j(p), \tag{6}$$

where $s_j(p)$ is the predicted market share of brand j, which depends on the prices of all the available brands, M is the market size and mc_j is the constant marginal cost of production. If we assume that there exists a pure-strategy Bertrand-Nash equilibrium in prices[23] and that all the prices that support it are strictly positive, then the price p_j of any product produced by firm f must satisfy the first-order condition

$$s_j(p) + \sum_{r \in \Gamma_f} (p_r \quad mc_r) \frac{\partial s_r(p)}{\partial p_j} = 0 \tag{7}$$

This system of J such equations can be inverted in order to solve for the marginal costs. Define

$$\Omega^{pre}_{jr}(p) = \begin{cases} \partial s_j(p)/\partial p_r, & \text{if } r \text{ and } j \text{ are produced by the same firm;} \\ 0, & \text{otherwise.} \end{cases} .$$

Then, marginal costs (in vector notation) are given by

$$mc = p \quad \Omega^{pre}(p)^{-1} s(p). \tag{8}$$

The vector of markups in (8) depends only on the parameters of the demand system and the equilibrium price vector. Therefore, by using the estimated demand parameters we can compute price-cost margins and marginal costs without using any actual cost information. These calculations are based upon the consistency of the demand coefficients and the equilibrium assumption. Although, I do not formally test the firm conduct

[23] Caplin and Nalebuff (1991) have shown the existence of a pure strategy Nash equilibrium under fairly general conditions, assuming single product firms. There are no theoretical papers that generalize their results for multiproduct firms. I follow the rest of the literature and assume its existence and uniqueness.

assumption, it seems well suited for this industry and particular period, as we will see in the results section. For the merger simulation, I use the same equilibrium assumption and the new postmerger industry structure matrix Ω^{post}. The postmerger equilibrium price vector, p^*, solves

$$p^* = \widehat{mc} + \Omega^{post}(p^*)^{-1}s(p^*), \tag{9}$$

where $\widehat{mc}$ are the marginal costs given by the demand estimates and the premerger ownership structure for the whole industry. Since firms can not price discriminate among different customers, I use the same postmerger equilibrium price and marginal cost vectors for the various segments.

As it is clear from equation (9), the estimates of postmerger prices rely on several assumptions. First, the conduct assumption remains the same before and after the merger. Although this can not be tested ex-ante, its validity has to be questioned for every merger. Second, the marginal costs and the number of products are held constant in their premerger level. Given that many mergers advocate cost efficiencies, one could quantify these changes and calculate different price effects based on the modified vector of marginal costs. Following Nevo (2000a), I calculate the necessary cost efficiencies that would leave the postmerger equilibrium prices unchanged and assess their plausibility. Third, the postmerger elasticities are calculated based on the demand parameters that were obtained with the premerger data. This implicity assumes that consumer preferences and the value of the outside good stay the same after the merger. Although this might be true in the short run, changes in the strategy of the merged firms that affect price sensitivity or changes outside the particular industry that influence demand for this product, could potentially render this assumption unrealistic.

4.3 Consumer Welfare

The results from the structural model can also be used to calculate changes in the consumer welfare due to the merger. As in Nevo (2000a) and Petrin (2002), I use compensating variation to calculate the dollar amount that would leave a consumer indifferent before and after the merger. Assuming that the marginal utility of income is fixed, McFadden (1981) and Small and Rosen (1981) show that the compensating variation fo individual i

is given by

$$CV_i = \frac{\ln\left[\sum_{j=0}^{J} \exp\left(V_{ij}^{post}\right)\right] \quad \ln\left[\sum_{j=0}^{J} \exp\left(V_{ij}^{pre}\right)\right]}{\alpha_i} \tag{10}$$

where $\alpha_i = \alpha + \sigma_p \nu_{ip}$ is the price coefficient for each individual and V_{ij}^{pre} and V_{ij}^{post}as defined in (1) are computed using the premerger prices and postmerger predicted prices, respectively. Aggregating over i and multiplying by the market size, we get the mean compensating variation. These calculations rely on the assumptions that first, the value of the each product's unobserved characteristic, ξ_j, does not change, and second, that the utility from the outside good remains constant.

5 Estimation

My estimation strategy closely follows Berry (1994) and BLP. The error term is defined as the unobserved product characteristics, ξ_j, that enter the mean utility. In order to compute these unobserved characteristics, I solve for the mean utility levels, δ, by solving the implicit system of equations

$$s\left(x, p, \delta; \theta_2\right) = S \tag{11}$$

where $s\left(.\right)$ is the vector of the calculated market shares and S is the vector of the observed market shares. Essentially, this finds the vector δ, given the nonlinear parameters θ_2, that matches the predicted to the observed market shares. Berry (1994) shows that this vector exists and is unique under mild regularity conditions on the distribution of consumer tastes and in this model it is numerically calculated using BLP's contraction mapping algorithm. Once this inversion has been computed, the error term is calculated as $\xi_j = \delta_j\left(x, p, S; \theta_2\right) \quad \left(x_j\beta + \alpha p_j\right)$.

Given a set of instruments, $Z = [z_1, ..., z_M]$, a population moment condition can be written as $E[Z'\xi(\theta^*)] = 0$, where $\xi(\theta^*)$ is the above defined structural error term evaluated at the true value parameters. Then, following Hansen (1982), an optimal GMM estimator takes the form

$$\widehat{\theta} = \arg\min_{\theta} \widehat{\xi}(\theta)' Z A^{-1} Z' \widehat{\xi}(\theta), \tag{12}$$

where $\widehat{\xi}(\ )$ is the sample analog to $\xi\ (\ )$ and A is a consistent estimate of the $E\left[Z'\xi\xi'Z\right]$.

The intuition behind this procedure is straighforward. The structural residuals were defined above as the difference between the mean utility and the one predicted by the linear parameters, $\theta_1 = (\alpha, \beta)$. The purpose of the GMM estimator is simply to minimize the distance between these two predictions. At the true parameter value θ^*, the population moment condition is equal to zero, so the estimates would set the sample analog of the moments, i.e. $Z'\widehat{\xi}$, equal to zero. If there are more independent moment equations than parameters, we can not set all the sample analogs exactly to zero, but as close to zero as possible. By using the inverse of the variance-covariance matrix of the moments, we give less weight to those moments that have the higher variance. The weight matrix is calculated using the usual two step procedure, starting with an initial matrix given by $Z'Z$. In principle, the supply function could also been added in the estimation process in order to increase efficiency. Here I am estimating only the demand function in conjunction with a smooth simulator for the product market shares, which allows me to utilize faster quasi-Newton search methods.[24] Finally, as Berry, Linton and Pakes (2003) note, in order to obtain consistent and asymptotically normal estimators for the parameters the number of simulation draws need to grow at the square growth of the number of products. Since this was infeasible in my personal computer, I settled for (the "second best" solution that seem to perform quite good in their Monte Carlo simulations) a number of draws that was more than ten times larger than the average number of products in my sample.

The asymptotic variance of $\sqrt{n}\left(\widehat{\theta} \quad \theta^*\right)$ is given by

$$\left(\Gamma'\Gamma\right)^{-1}\Gamma'\left(\sum_{i=1}^{3} V_i\right)\Gamma\left(\Gamma'\Gamma\right)^{-1} \tag{13}$$

where Γ is the gradient of the moments with respect to the parameters, evaluated at the true parameter values and approximated by its sampling analog. There are three possible

[24] The seach was performed by using both the Nelder-Mead (1965) non-derivative simplex serach method and the quasi-Newton method based on analytic gradient. For more details see the appendix in Nevo (2000b).

sources of variance: the process generating the product characteristics, V_1, the consumer sampling process, V_2, and the simulation process, V_3. The first component is given by the variance of the moment conditions and approximated using its sampling analog. Given that the sample size is taken to be the household population of the US, the contribution of the second component is assumed to be negligible. Moreover, to account for the variance introduced by the simulation, I calculated the third component by bootstrapping fifty times the moment conditions to obtain an estimate of their variance across different sets of simulation draws.[25]

5.1 Instruments

Identification of the GMM estimator in (12) requires a vector of instrumental variables. As in many other studies, I assume that the unobserved product level errors are uncorrelated with observed product characteristics. In other words, the assumption is that the location of products in the characteristics space is exogenous. For the present study, this assumption can be defended on the grounds that, as mentioned before, most of the R&D and the components that are built in the personal computers are produced by other firms and not the PC manufacturers.

I experimented with various types of instruments that have been suggested in the recent literature. More specifically, in the spirit of the studies by Hausman, Leonard and Zona (1994), Hausman (1996), Nevo (2000a, 2001) and Hausman and Leonard (2002) I tried to use prices of the same models of PCs in Canada[26] as instruments for the US prices. The fact that these two are neighbouring countries with very close trade relationships, imply that prices of PCs in Canada have the same cost component and only demand factors are different. Moreover, they could be partially immune from the Bresnahan (1996) critique of these instruments, in the sense that aggregate shocks (such as a national advertising campaigns) that affect the US demand would be uncorrelated with the Canadian demand. The disadvantage is that I have very little variation cross-sectionally (only one instrument for each price).

[25] Due to the fact that firm and processor generation specific dummy variables are included in the estimation and also there is a high turnover of products (see also Pakes, 2003, p. 1586), I do not aggregate over moment restrictions for models across any dimension.

[26] Given that I examine only these top nine manufacturers, I was able to match each model with the same model sold in Canada over the same period. The dataset on the Canadian models and prices is also from IDC. These prices were also deflated using the Canadian price index.

The second set of instruments follows directly the approach taken by BLP. They used the sums of the values of the same observed characteristics of other products offered by each firm and the sums of the values of the same characteristics of products offered by other firms. Given the previous assumption on exogeneity, characteristics of other products will be correlated with price since the markup for each model will depend on the distance from its nearest competitors. These type of instruments have been used successfully in the study of many industries. For this application, I consider the sums on the three core PC characteristics: speed, RAM and hard disk.[27]

Lastly, I use a modified version of the previous instruments in the spirit of the study by Bresnahan, Stern and Trajtenberg (1997). They used as instruments functions of the observed characteristics segmented according to their proposed clustering of the PC market during the late eighties. My modification is much simpler: I calculate the same instruments as BLP but also condition them on the form factor of each computer. The argument is that competition must be more intense, given the choice for desktop or laptop, than it would be for the full portfolio of products of each firm.

6 Results

I turn now on the demand estimates from a simple logit model and the random coefficients logit model. After discussing their implications in terms of elasticities and markups, I move on to the analysis of the merger simulations.

6.1 Demand Estimates

The logit model is used in order to examine the importance of instrumenting the price and to test the different sets of instrumental variables discussed in the previous section. Table 7 reports the results obtained from regressing $\ln(S_j) \quad \ln(S_0)$ on prices, characteristics and time dummy variables. In columns 1 and 2 ordinary least squares was used. Despite the increase in the fit of the regression in column 2 when I include firm dummies, the coefficient on RAM has still a negative sign (implying that *ceteris paribus* consumers dislike higher to lower RAM) and the majority (58.4%) of products are predicted to have

[27] Since one of the characteristics is the constant term, the number of own firm products and rival firm products become also instruments.

inelastic demands.

The last five columns use different instrumental variables in order to control for the endogeneity of prices. In column 3, Canadian prices of the same models were used. The coefficient on price increases, in line with previous research, but the coefficient on RAM remains negative and approximatelly a quarter of the products has still inelastic demand. Columns 4 and 5 use the BLP and "modified" BLP instruments. As it is clear from the table, the second set of instruments seems to be more effective in controlling for the endogenous prices, giving more plausible results in terms of both the coefficients and the elasticities. All the coefficients are significant and have the expected sign, with the benchmark being valued more than the RAM and the CD-ROM availability more than the internet peripherals. The desktop dummy indicates that consumers attach a greater value to the mobility of laptop computers, whereas the only possibly surprising result is the small negative coefficient on monitor size. Lastly, the generation dummies indicate that the sixth generation of processors had increased utility relative to the forth generation more than any other generation of processors. The Hansen-Sargan test of overidentified restrictions cannot be rejected at the 10% level of significance, despite the large number of observations. Combinations of these two sets of instruments with the Canadian prices in the last two columns, do not seem to improve the results, hence I use the modified BLP instruments for the subsequent estimations.

Table 8 reports results from the random coefficient model. Column 1 replicates column 5 from the previous table to ease comparisons. Due to the difficulty of the full model estimation, a parsimonious list of random coefficients has been selected. As Bresnahan, Stern and Trajtenberg (1997) suggested, because of the modularity of personal computers and the ease with which consumers can re-configure their machines, not all characteristics have the same importance. For example, consumers might choose a computer that does not have a modem or a CD-ROM as standard not because they do not value it, but simply because they can buy it afterwards and possibly arbitrage any price differences. To the extent that this re-configuration can be easily done, we would not be able to capture consumers heterogeneous preferences along these dimensions. Hence, I focus here on random coefficents for benchmark (which is the combination of the processor and the speed of each PC) and desktop. The argument is that these variables are essential characteristics of every computer and cannot be as easily altered as other core characteristics (such as RAM or hard disk) or peripherals (such as the modem or the CD-ROM). Results from

the full model are shown in column 2. Identification of the random coefficients is derived from observing multiple markets (where a market here is defined as the whole market at each period) with changes in the observed distribution of characteristics. Despite the fact that we have a short panel of only six an a half years (compare with twenty years for BLP for example), the pace of the evolution of the PC market is such that gives us some confidence that we can identify these parameters. For the whole market, three out of four coefficients and in the segment estimations (table 11) eight out of twelve coefficients have Z-statistics greater than one. The large majority of the rest of the coefficients retain their signs and significance as in the IV regressions.

The advantage of using the full model can be seen more clearly in table 9, where estimated markups and percentage margins are summarized for different models. Markups derived from the OLS regression are too high and they imply (from (8)) that the majority of brands have negative marginal costs. Results from the IV regression still predict an average markup of 19 percent, which reaches 30.4 percent at the 90th percentile. Markups and profit margins seem much more realistic in the random coefficient model with an average of 15.7 percent and a median of 14.7 percent over the whole period.[28] The advantage of the model stems from its ability to estimate more realistic substitution patterns among the various machines at each period. A small sample of those are given in table 10. In the first half of the table I present five models marketed by Acer in the first quarter of 1995 and their main characteristics. Markups rise almost monotonically with price (in contrast with the logit model which would predict a higher markup for the lower priced model) for the desktops, with the laptop having the highest one. In the second half of the table, elasticities and semi-elasticities (percentage change in market shares for model i from a \$500 change in the price of j) of these five models are presented. Most fundamentally, cross price elasticities are now driven by how close in the characteristics space models are, rather than been equal as it is the case for the logit model.

Similar results hold for each segment separately but for brevity are not reported here. Mean and median markups, for example, for the home segment were 12.6 and 11.5 percent respectively, which I believe are more reasonable in comparison with the 36 and 22 percent that Goeree (2003) reports for the same market during 1996-1998 or the 2.7

[28] Reports and surveys in the Financial Times (10/2/1996 and 4/3/1998) were placing the gross profit margins in the order of 20% in 1996 and around 10% in 1998. Given that my sample includes all the big PC manufacturers, it seems that the derived margins fall within the reality of the market.

mean markup for 1999 that Foncel and Invaldi (2001) report. One way to summarize the implications of the estimates from the different segments is by looking at the aggregate demand elasticities[29] for personal computers. Figure 5 plots these aggregate elasticities over time. Two important phenomena become apparent. First, the aggregate elasticity for the whole market is increasing over time, i.e. consumers become less sensitive. At first this seems counterintuitive; given that the market is approaching maturity one would expect that the demand for PCs would become more, rather than less, elastic. One reason for this pattern is the income effect: rapidly falling (even quality adjusted) prices meant that the purchase of a PC became a smaller share of the budget over time. More importantly though, the personal computer itself developed from being an awkward and unfriendly tool for specialists into an indispensable part of every day life. Developments in software and in related industries widened its application and for a lot of people the use of a personal computer is considered as a necessity nowadays. Finally, as mentioned before, the processor manufacturers (most notably Intel) tried throughout this period to achieve better segmentation of the market by increasing the variety of vertically differentiated products available in the market. This effort translated into a larger number of vertically differentiated personal computers[30], which meant that over time cross price elasticities decreased as competition became more localized. All these underlying reasons, gave also rise to the second phenomenon which is the convergence in the aggregate elasticities between segments. Notice that it is the aggregate elasticity of the home segment that experiences the largest rise. Home byuers became less elastic over time due to both their higher income elasticity and their higher usage of the various developments in other peripherals (such as the CD-ROM or the DVD, the internet and the lately the digital photography) used in conjuction with the personal computer. These findings have direct consequences for the merger evaluations, hence, I now turn to these results.

[29] Aggregate demand elasticity is calculated as the percentage change in total market share from a one percent increase in the price of all products in the market.

[30] It is worth noting that a recent critisism of the logit type of models pertains to their inability to control for the number of products available in the market as expressed in Ackerberg and Rysman (2002). I believe that my application here is immune to their critique precisely because of the vertically differentiated nature of the products introduced. In fact, I run some specifications in the IV logit model with their additive correction model and the coefficient was always insignificant. Another way to see that is that although the aggregate elasticity (for the whole market for example) is almost monotonically increasing, the number of models in the market does not follow the same pattern as can be seen in table 3.

6.2 Merger Analysis

Postmerger equilibrium is simulated using the demand estimates and calculated marginal costs for the whole market. First, assuming that marginal costs remain the same before and after the merger, I simulate the merger between Hewlett-Packard (HP) and Compaq and a hypothetical merger between Dell and Compaq at three different periods (1995Q2, 1998Q2 and 2001Q2). The purpose of this exercise is to examine the differential effects that these two mergers would have depending at which point in time would have taken place. Second, following Nevo (2000a), I am examining the necessary cost reductions in order for these two mergers to have no effect on the equilibrium prices. These results are summarized in table 12.[31] As it is clear, the effect that the merger would have on prices is a combination of the relevant position of the firms involved and the aggregate level of elasticity in the market. In line with the previous results on aggregate elasticities, any merger would raise prices more in 2001 rather than in 1998 or 1995. For the HP-Compaq merger, for example, the median percentage price increase would be 0.32 in the first period, 0.92 in the second and 1.62 in the third. On the other hand, the same across time effect is true for the hypothetical merger between Dell and Compaq, although the induced median price increases would be higher: 0.52 in 1995, 1.10, in 1998 and 2.83 in 2001. Therefore, being able to calculate the aggregate elasticity and simulate the merger at different points in time gives a sense of the industry dynamics that could be useful for the merger evaluation by the relevant competition authority.

The second half of table 12 presents various statistics of the following counterfactual: what would be the cost reductions necessary for the merger to have no effect on prices? On the case of the most relevant merger, for example, between HP and Compaq in 2001 the average required cost efficiency is 2.5 percent, with the maximum being 7.3 percent, which are both realistic.[32] On the contrary, a merger between Dell and Compaq at the same period would need to achieve a much higher level of cost savings (4.9 percent on average, with a maximum of 15.1). The picture that emerges from this thought exercise

[31] It is worth noting that as Berry and Pakes (1993) mention, the random coefficient model is flexible enough that even though a price setting behavior is assumed, pairs of prices are allowed to act as strategic complements or as strategic substitutes. In other words, what I find is that when a merger raises the prices of the merging firms, prices of the rivals went either way (although the majority of them, and hence the mean and median, were positive).

[32] Although there were no announcements of specific targets for the PC segment of the merged companies, the overall target was a 5-10 percent cost reductions according to the CEO of HP Ms C. Fiorina (Financial Times, 1/5/2002).

is overall the same as before: larger cost decreases would be required over time to offset any price increases from the merger. These results are closely associated with price and quantities calculations, nonetheless it provides yet another perspective on which a merger can be assessed.

The results on prices and quantities, although indicative, do not provide us with any criteria in order to judge the magnitude of these effects. The right tool in order to do such comparisons is the consumer welfare. Table 13, provides the consumer surplus and the changes in firm's revenues and profits as a result of the merger. According to the estimates the HP-Compaq merger would result in a \$2.03 millions loss from the consumers point of view, but on a positive \$18.08 millions overall welfare increase. Notice that the profits of the merged firms are increasing, which is due to the increase in prices, despite the fall in revenues. The companies that benefit the most from that increase in prices are Dell (with a \$9.49 millions increase in profits), Gateway (with a \$2.91 millions) and IBM (with \$2.53 millions). Although the present calculations are based on a number of assumptions being satisfied, they certainly provide an explanation as to why these companies did not complain at all about the merger: if the merged companies were to raise prices, these firms would benefit the most from such a strategy.[33] In line with the previous results, the same merger would have had a smaller effect on consumer surplus if it would happened earlier and a merger between Dell and Compaq would have been much more harmful to consumers at any point in time.

Using the predicted postmerger prices and marginal costs from the aggregate data, I also calculate the consequences of these mergers on each segment separately. It is worth recalling that since prices for each brand are the same across segments, changes in prices, quantities and welfare are derived from the variation in the portfolio of products that each segment has and their differences with respect to the estimated elasticities. Table 14 summarizes the predicted percentage changes in prices and quantities for the different segments. Due to the convergence in aggregate elasticities, the merger between HP and Compaq in 2001 is predicted to raise prices (median percentage increase is 1.7 for home, 1.63 for small and 1.52 for large) and reduce quantities (median percentage decrease is 8.83 for home, 8.53 for small and 7.78 for large) in a similar way across segments. In

[33] Critics of the merger like Mr. Hewlett insisted that competitors like IBM and Dell stand to gain the most from the merger. "HP's rivals raised almost no objections to the merger. We are not surprised. We believe Dell, Sun and IBM must be delighted at the prospect of a merger that would so greatly distract and damage two of their rivals" (Red Herring, 8/5/2002).

1995 though, the same merger would have raised prices by a median 0.32 percent, but it would have had very different implications for quantities: median percentage reduction for home is 2.83, whereas only 1.89 for small and 1.68 for large. The same is true for the other merger between Dell and Compaq, with even more amplified results. In 1995 this merger would have raised prices by a median 0.52 percent, but the median reduction in quantities would have been 4.18 for home, 2.64 for small and 2.28 for large. The same merger in 2001 would have had a much larger impact both on prices and quantities across the various segments.

This variation in prices and quantities becomes more meaningful if we examine the predicted changes in consumer surplus and firms variable profits. Tables 15, 16 and 17 present these results for the home, large business and small business segments respectively. Notice the common trend across segments in these tables: the increase of the consumers loss due to any merger and the corresponding increase in aggregate profits over time. Despite this similarity, some important differences become apparent. In the case of the HP-Compaq merger in 2001, for example, segment analysis reveals that the combined company would lose money from an attempt to take advantage of its full product line in all segments (-1.33$ millions in home and -0.21$ millions in the small business), except a slight increase (0.09$ millions) in profits in the large business segment. That would certainly cast doubt on the decision of the two firms to merge at least in the PC market and is consistent with the view expressed by many industry experts that the merger was more of a defensive move[34] targeted directly to the large business segment[35], rather than an attempt to monopolise the market. Hence, from the firm's point of view, a segment analysis would give a more comprehensible picture of the strengths and weaknesses of a possible merger. On the other hand, segment analysis is also valuable from a public policy perspective. Average consumer loss from the HP-Compaq merger in 2001, for example, is much higher for the home segment than for the other segments, but interestingly enough this is not the case for all mergers across time. Another example is the hypothetical Dell-Compaq merger in 1998. In that case we have a negative consumer surplus and a negative overall welfare for the home segment, whereas the welfare results are positive and sizeable for the other two segments. Knowledge of these differential effects among segments can

[34] "The HP-Compaq deal, which would consolidate the world's second and third largest PC makers, is thus best seen as a defensive move in a shrinking industry" (The Economist, 29/9/2001).

[35] "Fiorina (CEO of HP) and other HP executives insist that they must sell PCs to compete for lucrative corporate customers" (The Boston Globe, 9/7/2003).

provide regulators with valuable information for the assessment of the overall impact of the proposed merger.

7 Conclusion

This paper estimates a structural demand model for the US personal computer market and simulates two mergers in order to evaluate their welfare consequences both for the overall market and for three distinct aggregate segments. The first merger examined was the biggest so far merger on the industry between Hewlett-Packard and Compaq, whereas the second was a hypothetical merger between Dell and Compaq. Postmerger equilibrium outcomes are simulated at three different point in time and welfare implications are calculated for each segment separately.

Adding to the growing recent empirical literature on merger simulation, the contribution of this study relates to two dimensions. First, analysing the time dimension of the effects by simulating a given merger at different periods, provides us with an approximation of the market dynamics and trends. Since the whole methodology followed here is inherently static in nature, this task does not constitute a dynamic analysis of the merger effects. On the other hand, given that a complete treatment of the dynamics is much more demanding in terms of assumptions and comptutation,[36] there are important insights to be gained as shown for the PC industry by performing this much simpler exercise. The second dimension is associated with the segment analysis. Evidence from the HP-Compaq merger seems to suggest that this kind of analysis can be very useful in indicating the strengths and weaknesses of a potential merger. Moreover, the diverse welfare implications of mergers for different segments could be used from policymakers to evaluate them more effectively.

A limitation of this method of merger evaluation is that it focuses exclusively on price competition. Nonprice strategies (e.g. advertising, brand life cycles) either from the merged firm or from its competitors can have direct welfare implications. However, incorporating such dimensions would require an empirical model of dynamic decisions, which is beyond this research.

[36] For such a dynamic treatment see Gowrisankaran (1999).

8 References

Baker, J. P. and T. F. Bresnahan (1985). "The Gains from Merger or Collusion in Product-Differentiated Industries", *Journal of Industrial Economics*, 33, 427-444.

Bajari, P. and C. Benkard (2003). "Demand Estimation with Heterogeneous Consumers and Unobserved Product Characteristics: A Hedonic Approach", Working Paper, Dept. of Economics, Stanford University.

Bayus, B. L. (1998). "An Analysis of Product Lifetimes in a Technologically Dynamic Industry", *Management Science*, 44 (June), 763-775.

Bayus, B. L. and W. Putsis (1999). "Product Proliferation: An Empirical Analysis of Product Line Determinants and Market Outcomes", *Marketing Science*, 18 (2), 137-153.

Bayus, B. L. and W. Putsis (2001). "An Empirical Analysis of Firm Product Line Decisions", *Journal of Marketing Research*, 38 (February), 110-118.

Berry, S. (1994). "Estimating Discrete-Choice Models of Product differentiation", *RAND Journal of Economics*, Vol. 25, pp. 242-262.

Berry, S. and Pakes, A. (1993). "Some Applications and Limitations of Recent Advances in Empirical Industrial Oranization: Merger Analysis", *American Economic Review*, 83, 247-252.

Berry, S. and Pakes, A. (2002). "The Pure Characteristics Demand Model", *mimeo*, Harvard University.

Berry, S., Levinson, J., and Pakes, A. (1995). "Automobile Prices in Market Equilibrium", *Econometrica*, Vol. 63, pp. 841-90.

Berry, S., Linton, O., and Pakes, A. (2003). "Limit Theorems for Estimating the Parameters of Differentiated Product Demand Systems", *mimeo, Harvard University.*

Berndt, E., Griliches, Z. and Rappaport N. (1995). "Econometric estimates of price indexes for personal computers in the 1990's", *Journal of Econometrics*, 68, pp. 243-268.

Bresnahan, T. and S. Greenstein (1999). "Technological Competition and the Structure of the Personal Computer Industry", *Journal of Industrial Economics*, 47, 1-40.

Bresnahan, T., S. Stern and M. Trajtenberg (1997). "Market Segmentation and the

Sources of Rents from Innovation: Personal Computers in the late 1980s", *RAND Journal of Economics*, 28, S17-S44.

Caplin, A. and Nalebubuff, B. (1991). "Aggregation and Imperfect Competition: On the Existence of Equilibrium", *Econometrica*, Vol. 59, pp. 25-59.

Dube, J.P. (2004). "Product Differentiation and Mergers in the Carbonated Soft Drink Industry", *mimeo*, University of Chicago Graduate School of Business.

Dulberger E. (1989). "The application of an hedonic model to a quality adjusted price index for computer processors," in Jorgenson and Landau eds., Technology and capital formation, MIT Press.

Foncel, J. and M. Invaldi (2001). "Operating System Prices in the Home PC Market", *mimeo*, University of Toulouse.

Goeree, A. S. (2003). "Advertising in the US Pesonal Computer Industry", *mimeo*, Faculty of Economics and Econometrics,University of Amsterdam.

Goolsbee A. and Petrin A. (2003). "The Consumer Gains from Direct Broadcast Satellites and the Competition with Cable TV," Forthcoming in Econometrica.

Gordon R. (1989) "The postwar evolution of computer prices", in Jorgenson and Landau eds., Technology and capital formation, MIT Press.

Gowrisankaran, G. (1999). "A Dynamic Model of Endogenous Horizontal Mergers," *RAND Journal of Economics*, Vol. 30, pp. 56-83.

Hansen, L. (1982). "Large Sample Properties of Generalized Method of Moments Estimators", *Econometrica*, 50, 1029-1054.

Hausman J. A., G. Leonard and J. D. Zona (1994). "Competitive Analysis with Differentiated Products", *Annales D' Economie at de statistique*, 34, 159-180.

Hausman J. A. and G. Leonard (2002). "The Competitive Effects of a New Product Introduction: A Case Study", *The Journal of Industrial Economics*, 3, 235-261.

Hausman J. A. (1996). "Valuation of New Goods Under Perfect and Imperfect Competition", In T. F. Bresnahan and R. Gordon, eds., *The Economics of New Goods*. Chicago: National Bureau of Economic Research.

Hendel, I. (1999). "Estimating Multiple Discrete-Choice Models: An Application to

Computerization Returns", *Review of Economic Studies*, Vol. 66, pp. 423-446.

Invaldi, M. and F. Verboven (2003). "Quantifying the Effects from Horizontal Mergers in European Competition Policy", *mimeo*.

Langlois, R. (1992). "External Economies and Ecomic Progress: The Case of the Microcomputer Industry", *Business History Review*, 66, 1-60.

McFadden, D. (1973). "Conditional Logit Analysis of Qualitative Choice Behavior", in P. Zarembka, eds., *Frontiers of Econometrics*, New York, Academic Press.

McFadden, D. (1978). "Modeling the Choice of Residential Location", in A. Karlgvist, et al., eds., *Spatial Interaction Theory and Planning Models*, Amsterdam: North-Holland.

McFadden, D. (1981). "Econometric Models of Probabilistic Choice", in C.F. Manski and D. McFadden, eds., *Structural Analysis of Discrete Data*, MAss.: MIT Press.

Nelder, J. A. and R. Mead (1965). "A Simplex Method for Function Minimization", *Computer Journal*, Vol. 7, 308-313.

Nevo, A. (2000a). "Mergers with Differentiated Products: The Case of the Ready-to-eat Cereal Industry", *RAND Journal of Economics*, 31, 3, 395-421.

Nevo, A. (2000b). "A Practitioner's Guide to Estimation of Random Coefficients Logit Models of Demand", *Journal of Economics & Management Strategy*, 9(4), 513-548.

Nevo, A. (2001). "Measuring Market Power in the Ready-to-Eat Cereal Industry", *Econometrica*, 69, 307-342.

Pakes, A. (1986). "Patents as Options: Some Estimates of the Value of Holding European patent Stocks", *Econometrica*, 54, 755-84.

Pakes, A. (2003). "A Reconsideration of Hedonic Price Indices with an Application to PC's", *American Economic Review*, 93, 5, pp.1578-1596.

Peters, C. (2001). "Evaluating the performance of merger simulation: Evidence from the US Airline Industry", *mimeo*, Nortwestern University.

Petrin A. (2002). "Quantifying the Benefits of New Products: The Case of the Minivan", *Journal of Political Economy*, 110, 705-729.

Pinkse J. and M. Slade (2004). "Mergers, Brand Competition, and the Price of a

Pint", *European Economic Review* Vol. 48, No. 3, p.617-643.

Small, K. A. and S. Rosen (1981). "Applied Welfare Economics with Discrete Choice Models", *Econometrica*, Vol. 49, pp. 105-130.

Song M. (2003). "Measuring Consumer Welfare in the CPU Market", Working Paper, School of Economics, Georgia Institutes of Technology.

Steffens, J. (1994). *New Games: Strategic Competition in the PC Revolution*, Pergamon Press, NY.

Triplett, J. (1989). "Price and technological change in a capital good", in Jorgenson and Landau eds., Technology and capital formation, MIT Press.

Werden, G. J. and Froeb, L. M. (1994). "The effects of mergers in Differentiated Products Industries: Logit Demand and Merger Policy", *Journal of Law, Economics and Organization*, Vol. 10, pp. 4017-426.

Werden, G. J. (1997). "Simulating Unilateral Competitive Effects from Differentiated Product Mergers", *Antitrust*, 11, 27-31.

Figure 1
The Old Vertical Computer Industry-
Circa 1980

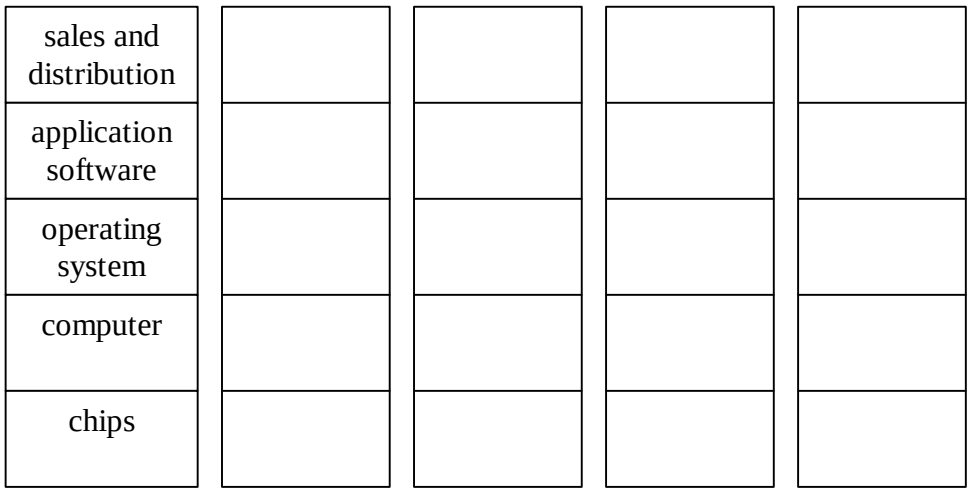
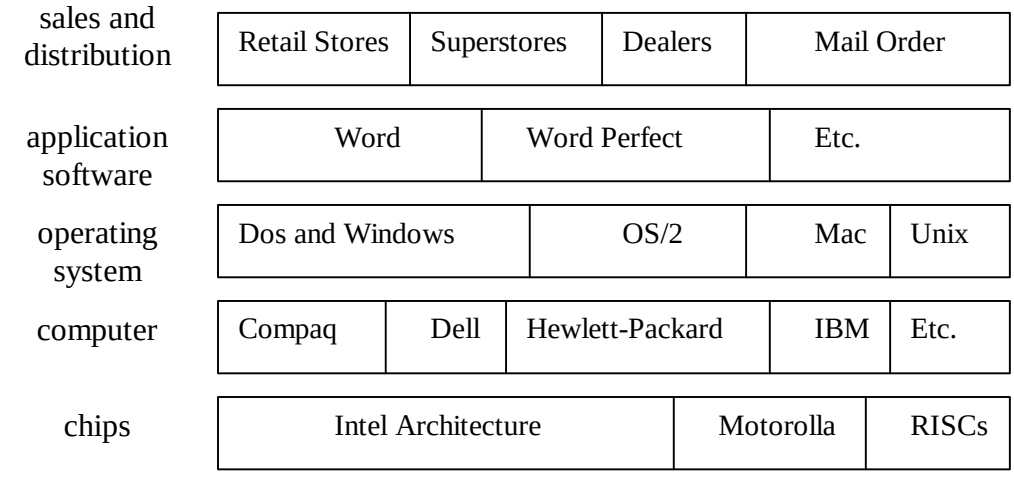
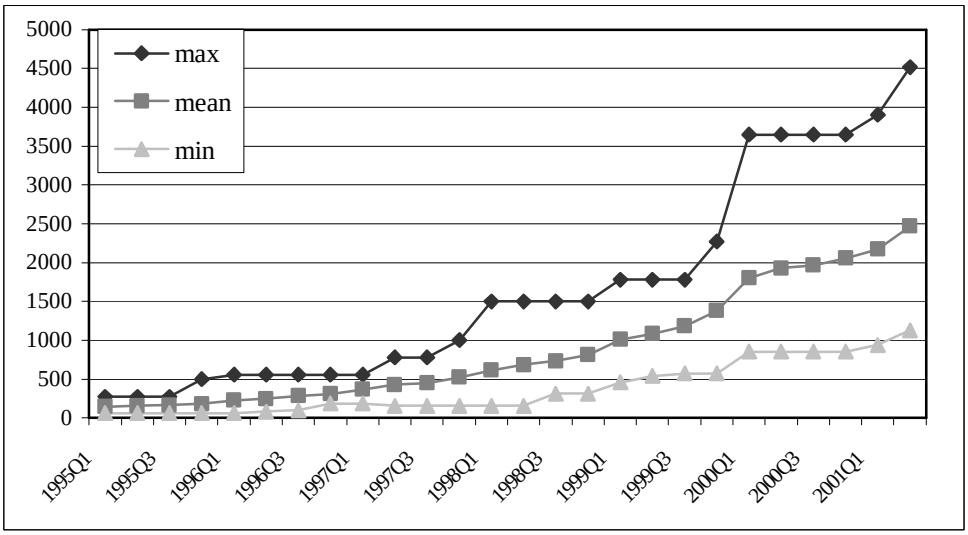


Figure 2
The New Horizontal Computer Industry-
Circa 1995 (not in scale)



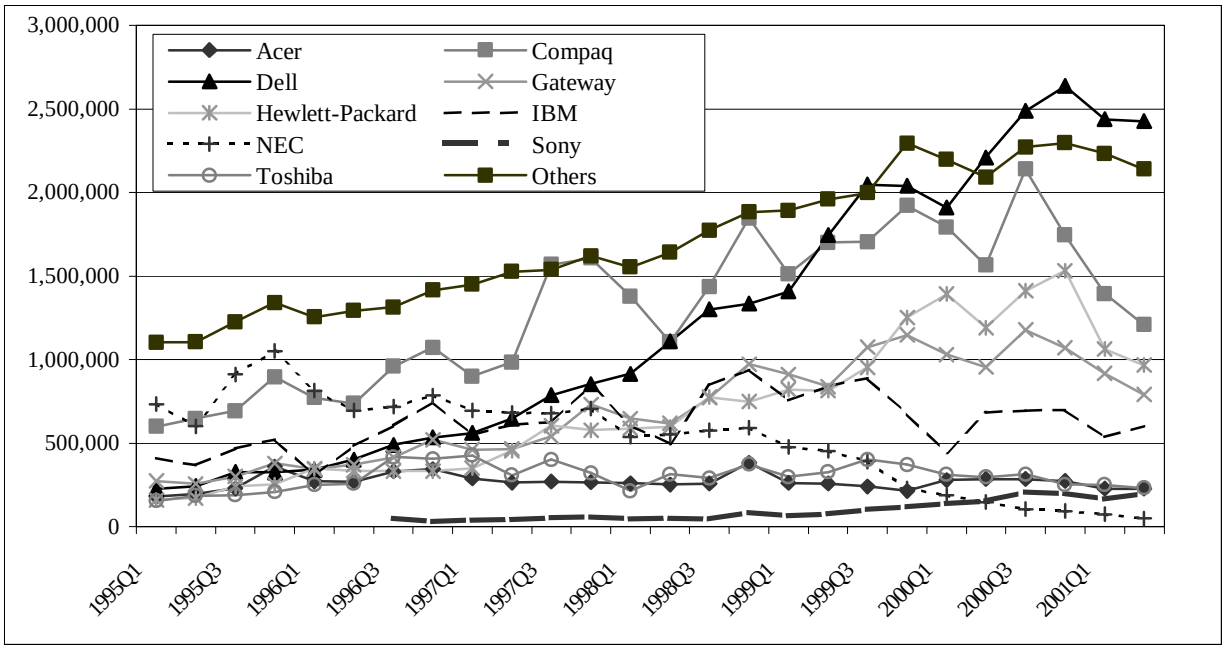
Notes: Figure 1 and 2 are taken from Grove, A. (1996), *Only the Paranoid Survive*. Bantom.

Figure 3
The evolution of CPU benchmark



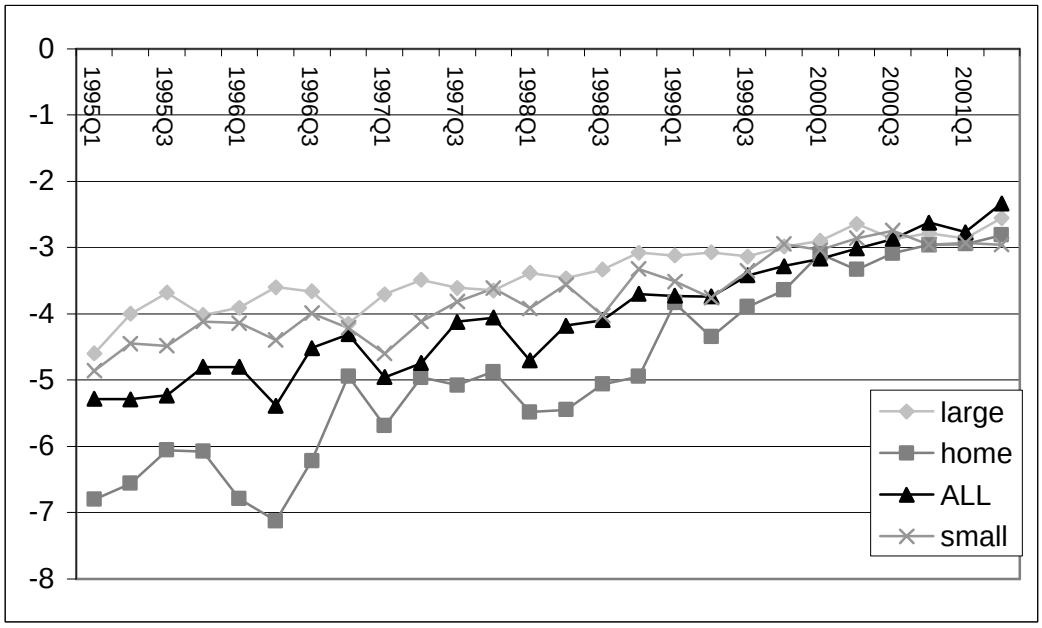
Notes: CPU benchmarks were obtained from The *CPU Scorecard* (www.cpuscorecard.com). They are essentially numbers assigned to each processor-speed combination based on technical and performance characteristics.

Figure 4
Aggregate sales of PCs for the US market (1995Q1-2001Q2)



Notes: "Others" is a code given by IDC to very small non-branded PC manufacturers.

Figure 5
Aggregate Personal Computer Elasticities for the whole market and individual segments of the US economy



Notes: Aggregate demand elasticity is calculated as the percentage change in total market share from a one percent increase in the price of all products in the market.

Table 1
Personal Computer Processors by Generation

PC	CPU	Firm
FORTH GENERATION	80486SX	Intel
	80486DX2	Intel
	80486DX4	Intel
	AMD486DX2	AMD
FIFTH GENERATION	Pentium	Intel
	Cyrix586	Cyrix
	CyrixMediaGX	Cyrix
	Pentium MMX	Intel
SIXTH GENERATION	Pentium Pro	Intel
	Pentium II	Intel
	Pentium III	Intel
	Pentium III 1GHz	Intel
	Celeron	Intel
	AMD K6	AMD
	AMD K6-2	AMD
	AMD K6-3	AMD
SEVENTH GENERATION	Athlon	AMD
	Pentium 4	Intel

Table 2
Sample Market Coverage

Firm	Average Percentage Unit Share			
	Whole Market	Home Segment	Large Segment	Small Segment
Acer	3.31	2.16	3.10	6.43
Compaq	14.75	13.67	17.91	12.26
Dell	12.65	3.96	21.69	13.15
Gateway	7.61	10.52	4.00	5.94
Hewlett-Packard	7.46	9.25	8.62	4.87
IBM	7.37	4.51	10.66	8.93
NEC	7.18	12.98	3.26	4.57
Sony	0.74	1.23	0.21	0.94
Toshiba	3.60	1.46	6.35	3.92
Overall	64.66	59.74	75.79	61.02

Notes: Numbers shown are average market shares for the period 1995Q1-2001Q2 for each firm in every segment and in the whole market.

Table 3
Descriptive Statistics for the whole market

Period	No. of models	Quantity	Price	Benchmark	RAM	CD-ROM	Internet	Monitor size	Desktop
1995Q1	88	28.701	2.410	0.140	0.103	0.678	0.513	12.050	0.815
1995Q2	106	23.083	2.370	0.155	0.114	0.690	0.516	11.636	0.799
1995Q3	112	27.673	2.222	0.176	0.130	0.784	0.578	12.390	0.839
1995Q4	118	31.433	2.208	0.192	0.133	0.796	0.597	12.212	0.834
1996Q1	127	25.287	2.285	0.221	0.142	0.847	0.604	12.376	0.813
1996Q2	125	26.559	2.264	0.237	0.150	0.879	0.617	12.367	0.791
1996Q3	124	32.358	2.260	0.264	0.158	0.931	0.665	12.930	0.786
1996Q4	143	31.272	2.108	0.293	0.177	0.933	0.670	13.421	0.780
1997Q1	160	24.719	2.116	0.363	0.219	0.931	0.643	12.169	0.773
1997Q2	195	20.984	2.038	0.413	0.245	0.943	0.659	12.069	0.781
1997Q3	222	22.629	1.998	0.476	0.277	0.977	0.711	11.336	0.792
1997Q4	241	22.572	1.912	0.525	0.313	0.962	0.731	11.672	0.816
1998Q1	245	19.502	1.939	0.609	0.375	0.941	0.783	12.189	0.817
1998Q2	253	18.217	1.903	0.708	0.434	0.961	0.749	12.414	0.795
1998Q3	250	22.883	1.801	0.792	0.489	0.968	0.770	12.898	0.802
1998Q4	182	36.279	1.758	0.915	0.600	0.939	0.845	13.313	0.808
1999Q1	156	37.409	1.674	1.051	0.724	0.944	0.812	15.058	0.811
1999Q2	156	39.256	1.607	1.119	0.771	0.931	0.835	15.822	0.790
1999Q3	136	48.581	1.536	1.259	0.857	0.941	0.889	16.083	0.791
1999Q4	149	48.340	1.465	1.447	0.946	0.944	0.879	15.980	0.795
2000Q1	203	33.184	1.411	1.753	0.958	0.982	0.869	14.060	0.797
2000Q2	226	28.448	1.437	1.933	1.018	0.977	0.855	14.234	0.753
2000Q3	237	32.061	1.381	1.995	1.016	0.978	0.875	14.267	0.752
2000Q4	287	26.080	1.337	2.171	1.056	0.978	0.887	14.868	0.775
2000Q1	249	24.715	1.324	2.390	1.103	0.980	0.871	15.069	0.765
2000Q2	277	19.326	1.331	2.725	1.231	0.975	0.886	15.225	0.730
ALL	4767	27.804	1.752	1.114	0.624	0.934	0.777	13.706	0.789

Note: All the entries in the last seven columns are sales weighted means.

Table 4
Descriptive Statistics for the Home Segment

Period	No. of models	Quantity	Price	Benchmark	RAM	CD-ROM	Modem	Monitor size	Desktop
1995Q1	67	16.206	2.065	0.147	0.105	0.735	0.673	14.139	0.917
1995Q2	78	11.614	1.992	0.161	0.113	0.765	0.681	13.995	0.891
1995Q3	85	15.477	1.916	0.181	0.129	0.859	0.767	14.263	0.927
1995Q4	87	19.069	1.929	0.197	0.134	0.867	0.787	14.196	0.926
1996Q1	76	16.962	2.032	0.223	0.147	0.928	0.842	14.689	0.946
1996Q2	82	12.720	1.996	0.231	0.148	0.929	0.808	14.545	0.920
1996Q3	83	18.474	2.036	0.264	0.160	0.974	0.856	14.635	0.924
1996Q4	92	19.611	1.729	0.291	0.174	0.988	0.892	15.040	0.955
1997Q1	101	15.157	1.747	0.364	0.228	0.986	0.875	12.607	0.956
1997Q2	125	10.517	1.641	0.393	0.238	0.991	0.900	13.265	0.944
1997Q3	141	12.655	1.665	0.460	0.263	0.998	0.919	11.561	0.950
1997Q4	153	13.882	1.663	0.521	0.306	0.997	0.908	12.971	0.967
1998Q1	150	11.551	1.730	0.620	0.366	0.999	0.901	13.852	0.965
1998Q2	163	8.674	1.702	0.731	0.443	0.999	0.867	13.703	0.961
1998Q3	167	11.356	1.660	0.824	0.514	0.999	0.873	13.423	0.955
1998Q4	134	18.841	1.575	0.933	0.623	0.998	0.849	13.132	0.930
1999Q1	117	19.906	1.485	1.030	0.798	0.983	0.888	15.059	0.922
1999Q2	119	17.462	1.395	1.125	0.886	0.941	0.914	15.538	0.887
1999Q3	107	23.779	1.325	1.243	0.940	0.924	0.949	16.041	0.904
1999Q4	114	29.071	1.278	1.425	0.978	0.923	0.914	16.231	0.902
2000Q1	167	19.321	1.229	1.755	0.876	0.988	0.874	14.147	0.900
2000Q2	169	14.631	1.226	1.891	0.938	0.981	0.860	14.674	0.857
2000Q3	179	17.442	1.151	1.906	0.904	0.976	0.878	14.701	0.863
2000Q4	199	16.198	1.112	2.112	0.988	0.973	0.861	15.688	0.886
2000Q1	167	13.873	1.097	2.361	1.059	0.971	0.806	16.739	0.874
2000Q2	195	9.285	1.122	2.727	1.221	0.959	0.798	16.799	0.828
ALL	3317	15.494	1.504	1.118	0.627	0.957	0.863	14.602	0.913

Note: All the entries in the last seven columns are sales weighted means.

Table 5
Descriptive Statistics for the Large Business Segment

Period	No. of models	Quantity	Price	Benchmark	RAM	CD-ROM	Ethernet	Monitor size	Desktop
1995Q1	74	10.909	2.841	0.133	0.105	0.610	0.126	9.942	0.703
1995Q2	88	10.422	2.704	0.151	0.117	0.620	0.149	9.616	0.721
1995Q3	93	11.105	2.549	0.172	0.133	0.699	0.153	10.419	0.752
1995Q4	98	11.782	2.516	0.186	0.132	0.708	0.152	9.926	0.732
1996Q1	104	10.987	2.551	0.220	0.137	0.796	0.186	10.391	0.699
1996Q2	103	13.334	2.440	0.240	0.151	0.861	0.252	11.090	0.702
1996Q3	99	15.250	2.444	0.266	0.156	0.902	0.277	11.427	0.671
1996Q4	114	13.688	2.439	0.294	0.177	0.887	0.234	11.845	0.625
1997Q1	129	12.135	2.412	0.363	0.213	0.896	0.090	11.598	0.633
1997Q2	156	11.567	2.255	0.424	0.248	0.918	0.127	11.214	0.690
1997Q3	181	11.874	2.210	0.488	0.286	0.962	0.177	11.043	0.695
1997Q4	193	11.036	2.123	0.530	0.321	0.931	0.216	10.634	0.706
1998Q1	204	9.751	2.095	0.610	0.388	0.892	0.380	10.902	0.727
1998Q2	219	9.484	2.011	0.697	0.431	0.937	0.340	11.693	0.710
1998Q3	215	11.298	1.884	0.777	0.480	0.949	0.410	12.442	0.725
1998Q4	146	17.407	1.896	0.911	0.590	0.890	0.441	13.475	0.736
1999Q1	131	17.539	1.821	1.069	0.667	0.919	0.426	15.078	0.739
1999Q2	127	21.545	1.733	1.120	0.701	0.931	0.436	16.056	0.740
1999Q3	118	22.238	1.696	1.273	0.792	0.957	0.419	16.121	0.709
1999Q4	127	19.140	1.664	1.475	0.923	0.972	0.389	15.728	0.685
2000Q1	160	13.709	1.617	1.770	1.060	0.971	0.401	13.939	0.697
2000Q2	197	12.977	1.602	1.985	1.087	0.978	0.431	13.930	0.696
2000Q3	210	13.956	1.563	2.078	1.109	0.983	0.449	13.747	0.686
2000Q4	253	10.988	1.545	2.223	1.112	0.989	0.493	13.905	0.703
2000Q1	219	11.653	1.489	2.418	1.126	0.994	0.508	13.583	0.709
2000Q2	246	9.419	1.469	2.729	1.248	0.995	0.606	14.067	0.707
ALL	4004	12.888	1.939	1.136	0.635	0.920	0.354	12.957	0.705

Note: All the entries in the last seven columns are sales weighted means.

Table 6
Descriptive Statistics for the Small Business Segment

Period	No. of models	Quantity	Price	Benchmark	RAM	CD-ROM	Ethernet	Monitor size	Desktop
1995Q1	86	7.356	2.439	0.137	0.097	0.665	0.064	11.156	0.786
1995Q2	103	6.057	2.417	0.152	0.110	0.682	0.087	11.180	0.781
1995Q3	109	6.890	2.310	0.173	0.126	0.771	0.095	11.820	0.806
1995Q4	115	7.787	2.330	0.193	0.132	0.778	0.091	11.485	0.793
1996Q1	124	6.288	2.299	0.218	0.141	0.787	0.097	11.463	0.761
1996Q2	120	7.529	2.283	0.240	0.151	0.848	0.163	11.795	0.776
1996Q3	115	8.428	2.327	0.262	0.157	0.909	0.158	12.574	0.746
1996Q4	132	8.388	2.260	0.295	0.180	0.907	0.128	13.004	0.712
1997Q1	149	5.763	2.235	0.360	0.215	0.900	0.053	12.427	0.700
1997Q2	181	5.375	2.164	0.421	0.248	0.926	0.094	12.039	0.730
1997Q3	201	5.423	2.099	0.478	0.279	0.970	0.144	11.547	0.723
1997Q4	214	5.541	2.004	0.525	0.311	0.957	0.184	11.212	0.743
1998Q1	214	4.936	1.987	0.589	0.364	0.939	0.268	11.886	0.744
1998Q2	228	4.904	1.956	0.699	0.428	0.958	0.255	12.123	0.744
1998Q3	231	6.040	1.851	0.776	0.470	0.959	0.310	12.978	0.728
1998Q4	164	9.370	1.828	0.890	0.579	0.923	0.272	13.342	0.725
1999Q1	148	8.170	1.758	1.055	0.688	0.919	0.254	15.020	0.736
1999Q2	147	8.911	1.678	1.106	0.733	0.917	0.273	15.785	0.739
1999Q3	133	10.817	1.616	1.263	0.828	0.945	0.253	16.088	0.739
1999Q4	143	10.194	1.558	1.452	0.910	0.943	0.275	15.828	0.733
2000Q1	200	6.581	1.516	1.717	0.991	0.987	0.257	14.047	0.710
2000Q2	223	6.279	1.510	1.911	1.031	0.968	0.309	14.013	0.676
2000Q3	233	6.633	1.502	2.021	1.068	0.972	0.336	14.377	0.655
2000Q4	281	5.273	1.438	2.203	1.099	0.966	0.322	14.890	0.672
2000Q1	241	5.333	1.403	2.385	1.138	0.969	0.361	15.007	0.677
2000Q2	267	4.591	1.380	2.715	1.215	0.960	0.428	15.090	0.629
ALL	4502	6.563	1.856	1.068	0.600	0.918	0.233	13.456	0.723

Note: All the entries in the last seven columns are sales weighted means.

Table 7
Results from Logit Demand for the whole market[a]

	OLS		IV				
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Price	-0.33**	-0.47**	-0.69**	-0.78**	-3.00**	-0.69**	-0.68**
	(0.030)	(0.031)	(0.048)	(0.267)	(0.504)	(0.048)	(0.049)
Constant	-9.22**	-9.49**	-8.89**	-8.64**	-2.34*	-8.88**	-8.91**
	(0.177)	(0.187)	(0.220)	(0.772)	(1.451)	(0.233)	(0.233)
Benchmark	0.32**	0.32**	0.44**	0.49**	1.76**	0.45**	0.44**
	(0.088)	(0.084)	(0.086)	(0.176)	(0.308)	(0.082)	(0.082)
RAM	-0.35**	-0.31**	-0.16*	-0.09	1.47**	-0.16*	-0.16*
	(0.090)	(0.089)	(0.095)	(0.207)	(0.416)	(0.096)	(0.096)
CD-ROM	0.09*	0.13*	0.15*	0.16*	0.31**	0.15*	0.15*
	(0.076)	(0.077)	(0.079)	(0.082)	(0.129)	(0.081)	(0.081)
Internet	0.22**	0.34**	0.32**	0.31**	0.13*	0.32**	0.32**
	(0.058)	(0.055)	(0.055)	(0.060)	(0.094)	(0.055)	(0.055)
Monitor Size	-0.02**	-0.02**	-0.02**	-0.02**	-0.06**	-0.02**	-0.02**
	(0.005)	(0.005)	(0.005)	(0.006)	(0.012)	(0.005)	(0.005)
Desktop	0.62**	0.57**	0.41**	0.34*	-1.31**	0.41**	0.41**
	(0.057)	(0.056)	(0.062)	(0.203)	(0.380)	(0.063)	(0.063)
5^{th} Generation	0.36**	0.33**	0.38**	0.40**	0.96**	0.38**	0.38**
	(0.111)	(0.117)	(0.122)	(0.139)	(0.244)	(0.131)	(0.131)
6^{th} Generation	0.26*	0.27*	0.47**	0.55*	2.59**	0.47**	0.46**
	(0.149)	(0.150)	(0.156)	(0.285)	(0.524)	(0.161)	(0.161)
7^{th} Generation	1.00**	0.97**	1.05**	1.08**	1.88**	1.05**	1.05**
	(0.263)	(0.262)	(0.262)	(0.274)	(0.442)	(0.287)	(0.286)
Firm Dummies	no	yes	yes	yes	yes	yes	yes
Fit/Test of Over	0.1301	0.2286	-	30.857	15.35	74.441	31.285
Identification[b]			-	(15.086)	(18.47)	(20.09)	(16.82)
1^{st} Stage R^2			0.700	0.451	0.446	0.701	0.700
1^{st} Stage F-test			259.09	82.58	77.76	219.78	227.98
Instruments[c]							
Canada prices			X			X	X
IV				X			X
IV2					X	X	
Own price elasticity							
Mean	-0.68	-0.99	-1.43	-1.61	-6.23	-1.44	-1.42
Standard	0.29	0.42	0.61	0.69	2.65	0.61	0.60
Median	-0.64	-0.92	-1.33	-1.51	-5.82	-1.34	-1.32
% of inelastic demands	88.44%	58.38%	23.79%	16.45%	0	23.12%	24.29%

[a] Dependent variable is $\ln(S_{jt})-\ln(S_{0t})$. Based on 4,767 observations for the whole market. All regressions include time dummy variables. Asymptotically robust s.e. are reported in parentheses.

* Z-statistic>1.

** Z-statistic>2.

[b] Adjusted R^2 for the OLS regressions and the Hansen-Sargan test of over identification for the IV regressions with the 10% critical values in parentheses.

[c] Canada prices are the prices of the same models in Canada; IV are the characteristics, the sums of the values of the same characteristics of other products offered by the same firm, the sums of values of the same characteristics of all products offered by other firms, the number of products belonging to the same firm and the number of products of other firms; IV2 are the same as IV, except that I also condition on the form factor.

Table 8
Results from the random coefficients model for the whole market[a]

	IV[b]	Random coefficients[c]
Variables	(1)	(2)
Means		
Price	-2.996**	-4.885**
	(0.504)	(1.065)
Constant	-2.345*	-2.220
	(1.451)	(4.663)
Benchmark	1.760**	0.853
	(0.308)	(5.872)
RAM	1.467**	1.497**
	(0.416)	(0.543)
CD-ROM	0.313**	0.352*
	(0.129)	(0.186)
Internet	0.135*	0.122*
	(0.094)	(0.101)
Monitor Size	-0.056**	-0.055**
	(0.012)	(0.013)
Desktop	-1.314**	-2.539*
	(0.380)	(1.627)
5^{th} Generation	0.955**	1.351**
	(0.244)	(0.502)
6^{th} Generation	2.590**	3.623**
	(0.524)	(1.460)
7^{th} Generation	1.884**	1.833**
	(0.442)	(0.552)
Standard Deviations		
Price		1.002**
		(0.297)
Constant		2.451*
		(2.421)
Benchmark		1.252
		(2.961)
Desktop		1.832*
		(1.661)

[a] Based on 4,767 observations for the whole market. All regressions include firm and time dummy variables. Asymptotically robust s.e. are reported in parentheses.
* Z-statistic>1.
** Z-statistic>2.
[b] This is the same as column (5) in table X.
[c] Parameters estimated via the two-step GMM algorithm described in the estimation section. The standard errors reported take into account the variance introduced through the simulation by bootstrapping the relevant component of the variance in the moment conditions.

Table 9
Estimated Markups and Margins for the whole market (1995Q1-2001Q2)

	OLS Logit	Instrumental Variable Logit		Random Coefficient Logit	
Statistic	(1)	(2)	(3)	(4)	(5)
Median	2113.20	334.66	17.22%	282.27	14.69%
Mean	2114.30	334.82	19.14%	295.18	15.76%
10%	2109.40	334.04	10.61%	238.02	11.30%
90%	2121.80	336.01	30.36%	359.48	21.73%
Standard Deviation	4.64	0.73	8.58%	66.47	4.80%

Notes: Columns (1), (2) and (4) give the estimated markups from the various estimations over the whole sample (4,767 observations). Columns (3) and (4) give the margins, defined as markups divided by observed prices. All prices have been deflated using the CPI.

Table 10
A sample from 1995Q1 of estimated
own and cross price elasticities and semi-elasticities

Model	Form	Brand	Price	Bench	Sales	Markup
Acer	D	AcerPower	2,476	97	28,783	292.260
Acer	D	AcerPower	3,382	272	7,196	345.650
Acer	D	AcerPower	2,775	142	23,986	309.130
Acer	D	Acros	2,506	97	25,154	293.920
Acer	N	Acros	2,785	217	4,791	309.170
	-8.6538	0.0126	0.0362	0.0345	0.0073	
	-174.720	*0.186*	*0.652*	*0.688*	*0.130*	
	0.0369	-10.0350	0.0392	0.0331	0.0079	
	0.745	*-148.379*	*0.706*	*0.660*	*0.142*	
	0.0387	0.0143	-9.1781	0.0344	0.0076	
	0.782	*0.212*	*-165.380*	*0.686*	*0.136*	
	0.0390	0.0128	0.0363	-8.7141	0.0073	
	0.787	*0.189*	*0.654*	*-173.843*	*0.131*	
	0.0389	0.0145	0.0378	0.0345	-9.2418	
	0.785	*0.214*	*0.681*	*0.688*	*-165.933*	

Notes: The first half of the table gives the sample of models for which own and cross price elasticities are calculated in the second half. Cell entries in the second half are indexed *i,j*, where *i* indexes row and *j* column. The first number gives the elasticity, whereas the second number gives the percentage change in market share of *i* from a $500 change in the price of *j*.

Table 11
Results of the demand estimation for the different segments[a]

	Home Segment			Large Business Segment			Small Business Segment		
	OLS	IV	Random Coefficients	OLS	IV	Random Coefficients	OLS	IV	Random Coefficients
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Means									
Price	-0.76**	-5.07**	-5.515**	-0.29**	-2.58**	-5.427**	-0.39**	-3.31**	-4.978**
	(0.071)	(0.540)	(1.604)	(0.034)	(0.448)	(1.532)	(0.032)	(0.555)	(1.997)
Constant	-10.64**	1.29	-0.074	-9.22**	-2.53*	-3.573	-8.97**	-0.43	0.378
	(0.327)	(1.743)	(17.730)	(0.199)	(1.336)	(8.396)	(0.188)	(1.670)	(6.282)
Benchmark	0.27**	2.73**	0.827	0.38**	1.70**	2.553*	0.13*	1.70**	1.167
	(0.130)	(0.390)	(2.653)	(0.093)	(0.292)	(1.995)	(0.095)	(0.329)	(1.382)
RAM	-0.08	0.83**	0.756**	-0.36**	1.26**	1.445**	-0.29**	1.65**	1.546**
	(0.156)	(0.270)	(0.271)	(0.095)	(0.364)	(0.495)	(0.091)	(0.429)	(0.580)
CD-ROM	0.04	0.46**	0.359*	0.22**	0.31**	0.354**	0.29**	0.32**	0.304*
	(0.136)	(0.211)	(0.202)	(0.079)	0.125)	(0.154)	(0.081)	(0.136)	(0.163)
Internet	1.20**	0.83**	0.830**	0.18**	0.62**	0.683**	-0.05	0.80**	0.759**
	(0.079)	(0.120)	(0.137)	(0.070)	(0.138)	(0.185)	(0.068)	(0.211)	(0.313)
Monitor Size	-0.01*	0.02*	0.022*	-0.05**	-0.09**	-0.092**	0.01**	-0.04**	-0.043**
	(0.008)	(0.012)	(0.012)	(0.007)	0.012)	(0.016)	(0.005)	(0.015)	(0.021)
Desktop	1.30**	-2.57**	-4.836**	0.37**	-1.30**	-3.383**	0.54**	-1.84**	-7.457*
	(0.101)	(0.555)	(2.278)	(0.063)	(0.333)	(1.515)	(0.059)	(0.461)	(5.599)
5^{th} Generation	0.34*	1.66**	1.641**	0.28**	0.89**	1.418**	0.34**	1.08**	1.341**
	(0.184)	(0.400)	(0.395)	(0.119)	(0.240)	(0.472)	(0.121)	(0.266)	(0.424)
6^{th} Generation	0.76**	4.69**	4.725**	0.03	2.17**	3.427**	0.48**	3.19**	3.704**
	(0.238)	(0.687)	(0.706)	(0.159)	(0.479)	(0.889)	(0.155)	(0.583)	(1.110)
7^{th} Generation	1.79**	3.53**	3.389**	0.28	1.36**	1.702*	0.54**	2.04**	
	(0.363)	(0.605)	(0.668)	(0.282)	(0.459)	(1.276)	(0.264)	(0.537)	

Table 12
Predicted percent changes due to mergers in prices, quantities and marginal costs

		1995Q2				1998Q2				2001Q2			
		HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq	
		%p	%q	%p	%q	%p	%q	%p	%q	%p	%q	%p	%q
Merging	Mean	0.43	-3.22	0.61	-4.54	0.90	-5.66	1.30	-7.78	1.71	-7.37	3.24	-14.03
	Median	0.32	-2.11	0.52	-3.09	0.92	-5.57	1.10	-7.44	1.62	-7.58	2.83	-12.47
Non-Merging	Mean	0.01	0.34	0.01	0.52	0.01	0.75	0.02	1.39	0.02	1.51	0.06	4.47
	Median	0.01	0.34	0.01	0.52	0.01	0.83	0.02	1.36	0.01	1.51	0.04	4.49
		%mc		%mc		%mc		%mc		%mc		%mc	
Merging	Mean	0.5		0.7		1.1		1.6		2.5		4.9	
	Median	0.4		0.7		1.1		1.4		2.3		4.1	
	Max	1.4		1.3		2.6		2.9		7.3		15.1	
	Min	0.2		0.4		0.4		0.8		0.9		1.6	

Notes: The first half of the table shows the percentage changes in prices and quantities due to different mergers in three distinct periods. The second half presents the percentage reductions in marginal costs required in order for the postmerger prices to remain unchanged.

Table 13
Predicted changes in variable profits and consumer surplus due to mergers (in millions of dollars)

	1995Q2				1998Q2				2001Q2			
	HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq	
Consumer Surplus	-0.48		-0.88		-1.19		-2.15		-2.03		-3.30	
Average consumer surplus (in $)	-0.0024		-0.0044		-0.0056		-0.0102		-0.0091		-0.0148	
Profits/Revenues	2.31	-44.60	3.37	-55.38	9.23	-93.29	15.22	-178.27	20.11	-39.13	44.23	-163.30
Acer	0.24	1.97	0.33	2.84	0.60	3.72	1.09	6.77	0.94	3.99	2.49	10.60
Compaq	0.34	-24.10	0.48	-32.60	1.00	-66.80	1.28	-123.90	1.40	-59.20	-0.48	-170.24
Dell	0.28	2.22	-0.06	-43.04	2.79	15.00	1.42	-128.80	9.49	34.90	11.49	-146.70
Gateway	0.31	2.37	0.43	3.46	1.43	8.37	2.56	14.89	2.91	11.93	8.19	33.11
HP	-0.07	-34.20	0.29	2.66	0.18	-73.24	2.83	16.40	1.13	-55.60	10.02	37.43
IBM	0.40	2.85	0.60	4.37	1.17	7.49	2.16	13.73	2.53	13.78	7.40	40.07
NEC	0.60	3.10	0.94	4.95	1.37	7.51	2.46	13.32	0.16	0.82	0.44	2.20
Sony	0.00	0.00	0.00	0.00	0.14	1.00	0.26	1.80	0.77	5.26	2.36	15.79
Toshiba	0.20	1.19	0.36	1.98	0.55	3.66	1.16	7.52	0.78	4.99	2.32	14.44
Total Welfare	1.82		2.48		8.04		13.06		18.08		40.94	

Notes: Calculated changes in variable profits, revenues and consumer surplus as a result of the mergers. All numbers are in millions of dollars, except for the average consumer surplus which is in dollars. Total welfare is calculated as consumer surplus plus profits.

Table 14
Predicted percent changes due to mergers in prices and quantities for the different segments

			1995Q2				1998Q2				2001Q2			
			HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq	
			%p	%q	%p	%q	%p	%q	%p	%q	%p	%q	%p	%q
Home	Merging	Mean	0.42	-4.49	0.62	-6.45	0.96	-9.12	1.38	-12.16	1.78	-8.26	4.18	-22.05
		Median	0.32	-2.83	0.52	-4.18	0.96	-9.68	1.46	-11.49	1.70	-8.83	3.96	-23.70
	Non-Merging	Mean	0.01	0.08	0.01	0.16	0.01	0.62	0.02	0.54	0.02	2.69	0.05	5.46
		Median	0.01	0.12	0.01	0.30	0.01	0.16	0.02	0.22	0.00	2.76	0.03	5.53
Large	Merging	Mean	0.42	-2.80	0.64	-4.39	0.86	-5.12	1.28	-6.88	1.62	-7.46	3.24	-13.56
		Median	0.32	-1.68	0.52	-2.28	0.90	-5.22	1.09	-6.40	1.52	-7.78	2.83	-12.88
	Non-Merging	Mean	0.01	1.02	0.01	1.33	0.01	1.26	0.02	2.61	0.02	1.24	0.05	4.75
		Median	0.01	1.10	0.01	1.55	0.01	1.49	0.02	2.35	0.01	0.99	0.04	4.00
Small	Merging	Mean	0.43	-3.13	0.61	-4.29	0.90	-5.73	1.30	-7.45	1.72	-8.17	3.27	-15.59
		Median	0.32	-1.89	0.52	-2.64	0.92	-5.58	1.10	-6.88	1.63	-8.53	2.83	-14.65
	Non-Merging	Mean	0.01	0.61	0.01	0.99	0.01	0.72	0.02	1.76	0.02	0.84	0.06	3.03
		Median	0.01	0.87	0.01	1.42	0.01	1.11	0.02	0.74	0.01	0.74	0.04	2.89

Notes: Percentage changes in prices and quantities due to different mergers in three distinct periods are calculated for the three different segments with the postmerger prices and marginal costs taken from the calculations for the whole market.

Table 15
Predicted changes in variable profits and consumer surplus due to mergers (in millions of dollars) for the Home segment

	1995Q2				1998Q2				2001Q2			
	HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq	
Consumer Surplus	-0.10		-0.21		-0.46		-0.72		-1.15		-1.31	
Average consumer surplus (in $)	-0.0010		-0.0021		-0.0045		-0.0070		-0.0108		-0.0123	
Profits/Revenues	1.20	2.53	1.22	-1.77	0.71	-39.73	-0.08	-51.40	6.24	-28.89	7.26	-75.43
Acer	0.03	0.18	0.04	0.37	0.12	0.67	0.12	0.67	0.16	0.58	0.22	0.78
Compaq	-0.19	-5.05	-0.30	-7.94	-1.02	-26.13	-2.62	-49.56	-0.61	-28.66	-6.01	-87.11
Dell	0.01	0.06	-0.19	-5.34	0.34	1.83	-1.12	-20.98	3.38	13.37	-1.11	-45.33
Gateway	0.06	0.35	0.11	0.83	0.83	4.90	0.86	4.59	3.05	12.37	5.85	22.99
HP	-0.09	-2.42	0.01	0.05	-1.42	-31.68	0.75	3.57	-0.72	-32.43	6.23	20.66
IBM	1.20	8.99	1.25	9.28	0.40	2.51	0.42	2.46	0.19	0.95	0.40	1.98
NEC	0.19	0.63	0.34	1.35	1.29	6.95	1.33	6.60	0.01	0.05	0.02	0.10
Sony	0.00	0.00	0.00	0.00	0.17	1.21	0.18	1.25	0.68	4.28	1.45	9.14
Toshiba	-0.02	-0.21	-0.03	-0.37	0.00	0.00	0.00	0.00	0.10	0.60	0.22	1.36
Total Welfare	1.10		1.02		0.25		-0.79		5.08		5.95	

Notes: Calculated changes in variable profits, revenues and consumer surplus as a result of the mergers. All numbers are in millions of dollars, except for the average consumer surplus which is in dollars. Total welfare is calculated as consumer surplus plus profits.

Table 16
Predicted changes in variable profits and consumer surplus due to mergers (in millions of dollars) for the Large Business segment

	1995Q2				1998Q2				2001Q2			
	HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq	
Consumer Surplus	-0.19		-0.38		-0.44		-0.89		-0.50		-1.56	
Average consumer surplus (in $)	-0.0031		-0.0061		-0.0064		-0.0130		-0.0066		-0.0207	
Profits/Revenues	3.64	-9.86	4.19	-11.96	6.49	-35.23	11.93	-76.61	7.70	-18.83	21.09	-86.49
Acer	0.16	1.43	0.22	1.92	0.35	2.26	0.74	4.73	0.42	1.76	1.35	5.73
Compaq	0.33	-11.71	0.44	-14.71	0.68	-30.95	1.41	-56.35	0.10	-27.92	-0.16	-75.63
Dell	0.38	3.22	-0.01	-26.80	2.94	17.10	1.95	-75.00	4.96	17.30	7.90	-76.80
Gateway	0.15	1.23	0.20	1.69	0.61	3.70	1.24	7.60	0.36	1.57	1.24	5.52
HP	0.29	-21.17	0.68	6.61	0.18	-38.95	2.70	16.85	-0.01	-21.63	3.94	17.73
IBM	2.27	17.24	2.40	18.21	0.90	6.13	1.87	12.27	1.52	7.75	5.39	27.93
NEC	0.18	1.07	0.30	1.81	0.27	1.68	0.61	3.83	0.07	0.34	0.23	1.14
Sony	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.59	0.32	2.39
Toshiba	-0.12	-1.17	-0.02	-0.69	0.56	3.80	1.41	9.46	0.22	1.41	0.88	5.50
Total Welfare	3.45		3.80		6.05		11.03		7.20		19.53	

Notes: Calculated changes in variable profits, revenues and consumer surplus as a result of the mergers. All numbers are in millions of dollars, except for the average consumer surplus which is in dollars. Total welfare is calculated as consumer surplus plus profits.

Table 17
Predicted changes in variable profits and consumer surplus due to mergers (in millions of dollars) for the Small Business segment

	1995Q2				1998Q2				2001Q2			
	HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq		HP and Compaq		Dell and Compaq	
Consumer Surplus	-0.10		-0.21		-0.10		-0.30		-0.25		-0.47	
Average consumer surplus (in $)	-0.0026		-0.0056		-0.0025		-0.0075		-0.0059		-0.0115	
Profits/Revenues	0.96	-9.47	1.53	-12.21	2.44	-12.76	5.60	-34.19	2.49	-8.95	6.36	-41.86
Acer	0.16	1.36	0.24	2.10	0.35	2.14	0.86	5.33	0.32	1.30	1.01	4.12
Compaq	0.20	-7.19	0.38	-9.43	0.12	-16.73	0.58	-28.67	-0.08	-10.37	-0.51	-28.57
Dell	0.15	1.23	-0.08	-12.62	0.90	5.05	0.71	-31.87	1.27	3.67	0.97	-40.06
Gateway	0.17	1.43	0.27	2.34	0.47	2.78	1.16	7.01	0.38	1.50	1.34	5.21
HP	-0.02	-8.26	0.21	2.08	-0.07	-10.03	0.62	3.95	-0.13	-9.34	1.06	3.53
IBM	0.14	1.03	0.23	1.69	0.36	2.22	0.88	5.48	0.42	2.20	1.47	7.46
NEC	0.14	0.85	0.25	1.51	0.22	1.19	0.54	3.01	0.03	0.17	0.10	0.52
Sony	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.99	0.48	3.22
Toshiba	0.02	0.08	0.03	0.12	0.10	0.62	0.26	1.57	0.14	0.93	0.45	2.71
Total Welfare	0.86		1.32		2.34		5.30		2.24		5.89	

Notes: Calculated changes in variable profits, revenues and consumer surplus as a result of the mergers. All numbers are in millions of dollars, except for the average consumer surplus which is in dollars. Total welfare is calculated as consumer surplus plus profits.