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PERSONAL COMPUTER BRAND LOYALTY

by

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Personal Computer Brand Loyalty

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BRAND LOYALTY TO PERSONAL COMPUTER BRANDS

Abstract

A Markov model shows the degree of brand loyalty to Apple, Compaq, IBM, and Wyse personal computers by large corporate customers of Businessland, a large reseller of personal computers in the late 1980s and early 1990s. Because Businessland temporarily lost its franchise to carry Compaq for half a year in the middle of our sample, the model captures the effect on Businessland's sales of rival brands when a name brand is eliminated and then reintroduced. Large corporate customers were brand-loyal and relatively price insensitive. Their loyalty did not diminish over time. They did not view IBM-compatible computers as perfect substitutes. Eliminating and then reintroducing a brand has different short- and long-run effects. It is difficult to explain which firms diversify, but, contrary to reports in the popular press, most firms used both Apple and IBM-compatible machines.

Keywords: Brand Loyalty; Markov Model; Multinomial Logit; Information Service; Product Compatibility; Networking

Brand Loyalty to Personal Computers Brands

"No one ever got fired for buying Big Blue."

1. Introduction

Do large corporations buy personal computers from the same manufacturer period after period? Using 1988-91 data from Businessland, formerly a large computer retailer, we examine brand loyalty in the computer industry. In particular, we examine the widely-held belief that some managers continue to buy "safe" brands such as IBM rather than take a chance on a less expensive IBM-compatible computer brand, such as Wyse, or an Apple Macintosh, which uses a different operating system. We find that some firms standardize on a single brand such as Apple, Compaq, or IBM, while some other firms freely mix various IBM compatible brands including clones or even IBM-compatible and Apple computers.[1]

For half a year in the middle of the period we study, Compaq did not permit Businessland to carry its brand. From this natural experiment, we determine how purchases of other brands were affected by the elimination and subsequent reintroduction of Compaq.

We use a Markov model to examine how brand choice depends on previous decisions and lagged prices (cf., Allenby and Lenk 1995; Kim and Rossi 1994; Carpenter and Lehmann 1985). Our study of brand loyalty of corporate buyers differs from most previous studies, which concentrated on brand loyalty of consumers (e. g., Hlavac and Little 1966; Jeuland 1979; Guadagni and Little 1983; Givon 1984; Lattin and McAlister 1985; Colombo and Morrison 1989; and Mannering and Winston 1991).

We examine eight main questions about the behavior of large corporate buyers. First, is the choice of brand of large corporate buyers sensitive to relative prices? Second, is brand loyalty stable over time? Third, are IBM-compatible computers viewed as perfect substitutes by purchasers? Fourth, how long does adjustment to the steady state take? Fifth, how does removing or reintroducing a brand affect market shares in the long run and in the short run? Sixth, when Compaq removed Businessland's franchise, did Businessland lose customers or sales, or did its customers switch to its other brands? Seventh, what firm characteristics determine whether the firm buys a single brand or diversifies? Eighth, do most firms buy only a single brand or do they diversify?

In the second section, the natural experiment is described. The Markov transition model is presented in the third section. The data are described in the fourth section. In the fifth section, the empirical results based on the Markov transition model are presented and analyzed. The implications of these results are illustrated using simulations in the sixth section. Other long-term trends in sales are considered in the seventh section. The last section contains a summary and conclusions.

2. Businessland's Natural Experiment

Businessland (BL) was one of the major national retailers of personal computers during our period of study from the first quarter of 1989 (1989:1) through the last quarter of 1991 (1991:4). Soon after the end of our sample period, another reseller, JWP, absorbed Businessland.

Businessland sold four brands of personal computers: the Apple Macintosh and three IBM-compatible brands. Two of the IBM-compatible brands, IBM and Compaq, are well-known national firms, while the third brand, Wyse, is a less well-known clone.

Many major firms including Shell, Chevron, Pacific Gas & Electric and Motorola, relied on Businessland for all or most of their personal computer purchases. To take advantage of quantity discounts, these firms probably bought all their Apple, Compaq, and IBM products from Businessland. We have no information on their purchases from other computer sellers, but it is possible that they also bought other IBM-compatibles or clones directly from manufacturers or from other retailers.

We use a Markov model to examine brand loyalty, where purchases this period depend on customers' characteristics and purchases in the previous period. In particular, we determine the percentage of customers who purchased a given brand last quarter purchase it this quarter.

In the fourth quarter of 1989 (1989:4), which is in the middle of our sample period, Compaq announced that BL no longer was authorized to sell its product. In the third quarter of 1990, Compaq again allowed Businessland to sell its machines. Based on this event, we divide our sample into six subperiods:

Period 1 (1989:1-1989:3): Businessland sells all four brands in each of these quarters.

Period 2 (1989:4): Compaq announces that Businessland may no longer sell its products, but some residual sales of Compaq machines by Businessland occur.

Period 3 (1990:1): No Compaq computers are sold by Businessland, but Compaqs were sold in the previous quarter (former Compaq customers must change their purchasing behavior).

Period 4 (1990:2): No Compaq are sold and none were sold in the previous quarter.

Period 5 (1990:3): Compaq is again sold by BL, but no customer bought Compaq from BL in the previous quarter.

Period 6 (1990:4-1991:4): All four brands are sold in each of these quarters and in the previous quarter.

Thus, in Periods 1, 2, and 6, all four brands were sold in each quarter and in the preceding quarter. In Periods 3, 4, and 5, Compaq was either not sold in each quarter or was not sold in the preceding quarter.

3. The Markov Model

We use a Markov model to capture changes in brand loyalty over time. In any quarter, t, each customer buys one or more brands of personal computers. Let $p_k^i(t)$ be the share of total expenditures on personal computers that are spent on brand k in quarter t by Firm i, where k = 1 is Apple, k = 2 is Compaq, k = 3 is IBM, and k = 4 is Wyse. Using maximum likelihood, multinomial logit, we estimate these shares as a function of lagged shares, $p_k^i(t\text{-}1)$, and other explanatory variables.[2]

Suppressing the firm superscript, i, for notational simplicity, we write the matrix **P** of transitional probabilities as

$$\mathbf{P} = \begin{pmatrix} P_{11} & P_{21} & P_{31} & P_{41} \\ P_{12} & P_{22} & P_{32} & P_{42} \\ P_{13} & P_{23} & P_{33} & P_{43} \\ P_{14} & P_{24} & P_{34} & P_{44} \end{pmatrix},$$

where each element of that matrix, P_{kj} is the share of brand j Firm i purchases in period t given the firm purchased only brand k in quarter t-1, and $\Sigma_{k=1}^{4} P_{kj} = 1$ for j = 1, 2, 3, 4.

The share of brand j purchased in quarter t, $p_j(t)$, is the sum of the weighted shares for each brand in quarter t-1, $p_k(t\text{-}1)$, where the weights are the appropriate transition probabilities, P_{kj}:

$$p_j(t) = \mathrm{P}_{1j}\, p_1^{\,i}(t - 1) + \mathrm{P}_{2j}\, p_2(t - 1) + \mathrm{P}_{3j}\, p_3(t - 1) + \mathrm{P}_{4j}\, p_4^{\,i}(t - 1). \qquad (1)$$

In matrix form, this expression is

$$p(t) = \mathbf{P}\, p(t - 1), \qquad (2)$$

where $\mathbf{p}(t) \equiv (p_1(t), p_2(t), p_3(t), p_4(t))'$.

We make the Markov (first-order stationarity) assumption that the shares of brands purchased before the t-1 quarter are irrelevant to determining shares in quarter t. We also examine whether the transition relationship between any two brands is constant over the quarters within each of our six periods. We assume that any structural shifts occurred between our six periods.

We also allow transition probabilities to vary across firms with different characteristics and over time in response to changes in relative prices.[3] That is, the share of expenditures on brand k by a firm depends on shares in the previous quarter, $p_k(t\text{-}1)$, and the other relevant firm characteristic and relative price variables, X_t.

Formally, we model this heterogeneity as

$$p_j(t) = F\left(\beta_j X_t + \alpha_{1j} p_1(t-1) + \alpha_{2j} p_2(t-1) + \alpha_{3j} p_3\right), \tag{3}$$

where $F(\cdot)$ is the logistic probability distribution. We do not include all the lagged shares on the right-hand side of Equation (3) because the shares sum to one. Maximum likelihood (ML) estimates of parameters α_{1j}, α_{2j}, α_{3j}, and β are consistent even with lagged state variables on the right-hand side (Amemiya, 1985).

Once we estimate the matrix of transitional probabilities, $\mathbf{P}$, we can determine both the steady state and the adjustment path. The steady state shares, $\mathbf{p}(\infty)$, are

$$\mathbf{p}(\infty)\,\mathbf{1}' = (\mathbf{P}')^{\infty}, \tag{4}$$

where $\mathbf{1}$ is a vector of ones (Amemiya, 1985). Because the rank of $\mathbf{I} - \mathbf{P}'$ is 2, $\mathbf{p}(\infty)$ is unique.

4. Data

Our data set consists of 12 quarters of Businessland's computer sales transactions to the 680 largest corporations. This data set was supplemented with firm characteristic variables obtained from *ComputerWorld* (100 corporations) and *InformationWeek* (500 corporations). After combining information from these data sources, we obtained a sample of 191 firms.

Using advertisements from computer magazines, we obtained prices for comparable machines sold by other vendors. The price universities charged students for Apple computers was used as a proxy for the lowest Apple price available from other vendors. Prices for IBM and Compaq computers were found in mail-order companies' advertisements. Prices from mail-order companies for IBM clones were used to establish competitive pricing for IBM compatibles such as Wyse. Care was taken to match prices on comparable machines (new, faster processors, such as 80386 and 80486 chips, were introduced during this period). All prices were deflated by the Consumer Price Index.

5. Empirical Results

We estimate maximum-likelihood multinomial logit Markov transition models based on data from individual periods and across periods. In the multiperiod estimates, we can constrain coefficients to be equal across periods.

The estimates in Table 1 cover Periods 1, 2, and 6 when BL carried all four brands and had carried all brands in the previous quarter. Table 1 reports two separate estimates of a multinomial logit model for these periods. In both estimates, the lagged share terms are included. In the first estimation model (the first three columns), seven relative prices terms are included, whereas in the second estimation model (the last three columns), the prices are dropped. The price terms are the identified price divided by the mail-order price of an IBM-compatible clone.[4]

BL did not carry Compaq in Periods 3 and 4. In Period 3, data on lagged Compaq sales are available; however such data are not available for Periods 4 and 5. Table 2 shows the Markov model estimated for Periods 3, 4, and 5 separately. Because each of these estimates involve only a single quarter, we cannot include relative price terms, which as constants. These models have different lagged variables on the right-hand-side, and the number of brands (left-hand-side variables) differ. We now use the estimates from these models to examine the first three questions we posed in the introduction.

5.1. Relative Prices Do Not Matter

Do market shares depend on relative prices? We examine this question only for the period in which all brands are carried, because those are the only periods for which we have enough observations to include relative price terms.

If firms choose their brands based on reputations for quality, brand loyalty, or other factors besides price, changes in relative prices do not affect market shares, and their coefficients are collectively zero. To test this hypothesis that relative price terms are irrelevant, we use a likelihood-ratio test based on the estimates with and without relative prices in Table 1. The likelihood-ratio-test statistic is 15.08. Comparing this statistic to $\chi^2_{.05}(21)$, we cannot reject the hypothesis that relative prices are irrelevant. Moreover, no single relative price coefficient is statistically significantly different from zero based on asymptotic *t*-statistics.[5]

Thus, it appears that corporate buyers are loyal to particular brands and not sensitive to price differences across brands. That these customers do not react to changes in prices at BL relative to those from other vendors suggests that they purchased from only BL during these periods, perhaps to obtain quantity discounts on all products.

5.2. Announcements, Availability, and Stability over Time

The costs of switching between differentiated brands and networking differentiated products are major reasons why users remain loyal to a brand. As various technologies have matured and standardized and the human capital of user's computer support staff has increased, the ability of firms to substitute between name-brand IBM compatibles and clones has increased. The differences between Apple and various IBM compatibles has narrowed with the development of software interchange programs, common operating systems, and networking, though there continue to be significant limits on users abilities to mix the two major standards. As different brands become more compatible and easier to network, the benefit of purchasing only a single PC brand is reduced. As a result, one might expect to find that firms become less loyal to brands over time and that buyers respond increasingly to relative price advantages of a brand as brands become more homogeneous over time.

Does the same model hold in each period? Formally, can we aggregate across periods? Again, we can examine this question only for those periods in which all four brands are carried (the other periods have to be estimated separately).

Table 3 shows the likelihood-ratio-test statistics on the restrictions that the slope and intercept coefficients are identical across periods for the models in Table 1. The test that Periods 1 and 2 are identical is a test that Compaq's announcement that BL was no longer authorized to sell its products had no effect on Compaq's share in the quarter of the announcement (during that quarter, Compaq computers still could be purchased). We fail to reject this hypothesis. That is, this test does not give us reason to believe that corporate buyers changed their purchasing behavior in the quarter in which Compaq made its announcement.

Similarly, based on the test statistics shown in Table 2, customers' behavior was the same in Period 6 as in Periods 1 and 2. That is, we cannot reject the null hypothesis that BL's customers had the same brand loyalty before BL lost its authorization and after BL again started carrying Compaq.

5.3. IBM-Compatibles are Not Viewed as Identical

Do consumers view the three IBM-compatible brands as identical? To answer this question, we use a variant of a likelihood-ratio test due to Cramer and Ridder (1991) for pooling states (brands) in a multinomial logit model. Cramer and Ridder use a multinomial logit in which all the right-hand side variables are identical for each state (as in our problem) and each state takes on the value one or zero. In our problem, firms may purchase a fraction of each state (brand).

Our question is whether the pooled brands have the same regressor coefficients apart from the intercept. The test statistic is distributed χ^2 with k degrees of freedom, where k is the number of restricted coefficients. As usual, the likelihood-ratio-test statistic is $2(L - \hat{L})$, where L is the log likelihood of the of the unconstrained model and $\hat{L}$ is the log likelihood of the constrained model.

To calculate the log likelihood of the constrained model, we can estimate the model with the reduced number of states to obtain an estimate of its maximum loglikelihood $\tilde{L}$. For example, if we are considering combining Compaq and IBM, we estimate a model with three possible states: Apple, Compaq-IBM, and Wyse. The restricted maximum loglikelihood, $\hat{L}$, is

$$\hat{L} = n_1 \log n_1 + n_2 \log n_2 - n \log n + \bar{L},$$

where n_1 is the share of Compaq times the total number of observations, n_2 is the share of IBM times the total number of observations, and $n = n_1 + n_2$.

Using our variant of the Cramer-Ridder test, we reject the hypotheses that Compaq and IBM can be pooled or that Compaq, IBM, and Wyse can be pooled. Using the specification where we ignore the relative prices, the test statistic that Compaq and IBM can be combined is 86.1 with 3 degrees of freedom as compared to the critical value of 9.35 using the 5 percent criterion. The test statistic for the merger of all three IBM-compatible brands is 102.5 with 6 degrees of freedom as compared to the critical value of 14.45 using the 5 percent criterion.

5.4. Marginal Effects

Because the multinomial logit specification is highly nonlinear, it is difficult to interpret the meaning of estimated coefficients directly. To show the effect of independent variables on the shares, we calculate the marginal effects of changing one of these variables for the model in Table 1 where relative prices are included.

The marginal effect of a change in one of the (continuous) explanatory variables, z, is $\partial p_j/\partial z$, $j = 1,..., 4$. The corresponding elasticity is $\delta_i = (\partial p_j/\partial z)(z/p_j)$, which we evaluate at the mean values of all the explanatory variables. It can be shown that

$$\delta_j = z(\beta_j - \bar{\beta}),$$

where

$$\bar{\beta} = \sum_{j=1}^{4} p_j \beta_j .$$

Thus, δ_j may differ from β_j both in sign and magnitude. For example, the coefficient on the lagged share of IBM variable in the Compaq equation is 0.51, while the elasticity is -0.49. That is, a one percent increase in IBM's share last period decreases Compaq's share this period by half a percent. The elasticity of the lagged share of IBM is -0.73 on Apple share, 0.83 on IBM's share, and -2.46 on Wyse's share. These and other elasticities are shown in Table 4. These elasticities show that the shares are very sensitive to changes in prices.

6. Transitions

Based on our multinomial logit estimates, we can simulate the Markov adjustment path. By examining the adjustment path, we can answer the next three questions from the introduction.

6.1. Length of Adjustment Period

How long does it take after a shock for the market shares to adjust to the new steady-state level? Figure 1 shows the adjustment paths of the shares of sales of each of the four firms for a firm that bought only Compaq in the initial period, assuming that the model without relative prices in Table 1 holds indefinitely. The figure shows that after 3 years (12 quarters), the shares are virtually at their steady-state values. Moreover, after only about a year and a half, most of the adjustment has occurred. We now turn to the question of how removing and reintroducing a brand affects shares in both the long and short runs.

6.2. *Steady-State Shares*

The steady states based on estimates for various periods are shown in Table 5. The steady state shares for the period when Businessland sold all four brands are 41.2% for Apple, 19.7% for Compaq, 30.7% for IBM, and 8.4% for Wyse, based on the model in which relative prices are not included on the right-hand side. If relative prices are included, the corresponding shares are 40.6%, 13.9%, 40.1%, and 5.4%. These steady-state shares differ from the mean values during this period of 34.1%, 13.0%, 47.2% and 5.7%.

During Period 3 (1990:1, the quarter in which Compaq is not sold, but Compaq was sold in the previous period), the steady-state shares are 40.2%, 43.1%, and 16.7% for Apple, IBM, and Wyse, respectively. If we normalize the shares of Apple, IBM, and Wyse to add to 100% during the period when Compaq was sold, their shares are 51.3%, 38.2%, and 10.5%, respectively. In other words, the shares of the three firms did not increase in equal proportions. Instead, the IBM-compatibles increased their share, whereas Apple's share was relatively unchanged.

During Period 4 (1990:2, Compaq is not sold in this quarter nor in the previous quarter), the steady-state shares of Apple, IBM, and Wyse were 42.7%, 52.1%, and 5.2. That is, again, most of the gain in share went to the IBM-compatibles.

6.3. *One-Quarter Adjustments From Compaq*

A somewhat different picture emerges if we look at a single quarter of adjustment, as shown in panel A of Table 6. Suppose a firm bought only Compaq in quarter t-1. What would it purchase in quarter t? The first two rows show the loss in Compaq's shares during the period in which all four brands were sold. The last row shows what happened to

Compaq's share in the first quarter during which Businessland could not sell Compaq (Period 3).

In Period 3 (1990:1) Apple's share of sales increased substantially, IBM's share increased moderately, and Wyse's share did not change much at all. The steady-state results above, however, show that Apple would have eventually lost this large one-quarter gain.

6.4. One-Quarter Adjustments to Compaq

From which firms did Compaq gain share when BL again carries this brand? Again, we look at the adjustment in a single quarter. The first two rows of Panel B of Table 6 represent the one-quarter gain by Compaq during the time when all four brands were sold. The third row shows how Compaq gained share in the first quarter after BL was again authorized to sell Compaq (Period 5).

According to the transition matrix for Period 5, 4.8% of Apple's share in the previous quarter, 0.7% of IBM's share, and 0.7% of Wyse's share went to Compaq in the first quarter during which BL could again sell Compaq. These results are surprising, as one might have expected most of Compaq's gain to come from the IBM compatibles' shares.

7. Businessland's Sales

Our analysis has focused on how the shares of Compaq and other brands have changed over time. In particular, we showed how the shares of brand purchases changed when BL stopped carrying Compaq computers. One could interpret these results as showing how customers shifted purchases from Compaq to other brands when BL lost its franchise. Is it possible, however, that these change in shares reflect Compaq customers shifting from BL to other retailers? That is, if customers' primarily loyalty was to Compaq instead of to BL, they may have started buying Compaqs from other retailers when BL could not sell Compaq computers.

7.1. Number of Customers over Time

One heuristic approach to examining this issue is to see if the number of major firms buying from BL changed by quarter. As shown in Table 7, the number of large firm customers per quarter did not change dramatically at the point when BL lost its Compaq franchise. In the fifth quarter, the number of firms dipped by four. In the next quarter, however, the number of firms increased by seven. In quarter seven, the first quarter during which BL could again sell Compaqs, the number of customers dropped by two. This lack of a pattern suggests that the largest customers loyalty did not depend critically on the Compaq franchise.

7.2. Change in Total Sales over Time

A second approach is to examine how total sales to major firms varied over time, as shown in Figure 2. The plot shows that BL sales of other brands rose during the period when BL did not carry Compaq.

Using cross-section, time-series data, we regressed the quarterly percentage change in sales on various firm characteristics and time. Table 8 shows the regression of the percentage change in sales of DOS (Compaq, IBM, and Wyse) central processing units (CPUs) and the regression of the percentage change in all CPUs (Apple, Compaq, IBM, and Wyse) on various explanatory variables. Explanatory variables include industry dummies; the shares of sales of

Apple, Compaq, and IBM computers (Wyse is the residual category) for the first three quarters; various measures of sales and staff per personal computer (PC); and dummies for the various quarters.

Based on t-tests, we can reject the null hypothesis that the industry coefficients are zero at the 0.05 level for utilities, which had declining computer sales over this period relative to the base industries. Sales for other identified industries did not differ from the base industries (construction, distribution/retailing, services, food processors, computer products and service [office equipment], media, and electronics).

For each 1 percent increase in the change in the ratio of information service (IS) employees per PC at the customer's site, the growth rate of DOS CPU sales increased by 0.12 percent. A 1 percent higher growth rate of customer revenue per PC led to a 0.2 percent greater growth of DOS CPU sales. For every 1 percent faster growth in a customer's PCs per employee, its DOS CPU purchases grew by 0.24 percent. These results are virtually the same in the regression for all CPUs. These effects have the same sign but are not statistically significant in the all-CPU regression.

Shares of brands purchased during the first three quarters did not have a statistically significant effect on the growth of purchases based on an F-test at using the 5 percent criterion.[6] There was no statistically significant drop in sales in the fifth or sixth quarters; however, there was a statistically significant increase in sales in the seventh quarter.[7]

Thus, the effects of disenfranchisement on total sales differs from our expectations. We would have expected a significant drop in the fifth and sixth quarters and a jump in sales in the seventh quarter. We only observe the increase in the seventh quarter.

7.3. Brand Loyalty and Businessland's Loss of Sales

If the loss of the Compaq franchise cost Businessland sales, it was presumably because some customers' loyalty was to Compaq rather than to BL. If so, we would expect that BL would be more likely to lose customers who had only bought Compaq prior to that time. There were, however, only 2 firms out of 192 who bought only Compaq.[8]

Indeed, most firms bought a mix of products. To examine the loyalty customers have to a single manufacturer over time, we use a multinomial logit model (Table 9) to examine which customers bought 1) only from Apple, 2) only from a single DOS manufacturer, 3) from several DOS manufacturers but not from Apple, or 4) from Apple and at least one DOS manufacturer.

The only characteristic of customers that affects brand loyalty associated with a single PC manufacturer over time is the number of IS staff per employee. One might expect that firms with a relative strong IS support would be more willing to diversify across products and to have both Apple and DOS computers, which are relatively difficult to network together. The results, however, are not completely consistent with this view. For every 1 percent increase in the ratio of IS staff to employee evaluated at the mean, the probability of buying only Apple increases by 1.8 percent, the probability of buying only a single DOS brand drops by 1 percent, the probability of buying from several DOS manufacturers but not from Apple falls by 1.3 percent, and the probability of buying both DOS and Apple products is relatively unchanged.

Perhaps surprisingly, we find that nearly three-quarters of large firms used both Apple and DOS computers during the late 1980s and early 1990s. This result is contrary to the story one read in newspapers and the trade journals at that time.

8. Conclusion

Based on a study of personal computer purchases by large corporate customers of Businessland, we draw the following eight conclusions about brand loyalty:

1. *Relative prices do not matter*: We cannot reject the hypothesis that corporate buyers ignore prices in choosing brands. These buyers fail to switch brands (or dealers) in response to lower prices. Thus, if these results still hold today, manufacturers and resellers of PCs should stress factors other than price to retain purchases of corporations.

2. *Brand loyalty is stable over time*: During periods in which the number of brands remain constant, we cannot reject the hypothesis that the coefficients of our brand loyalty model remain constant over time. This result is particularly striking because it holds both before and after the period in which Compaq removed Businessland's franchise. To the degree that brand loyalty serves as a barrier to entry, these results suggest that obtaining large shares of corporate buyers' business may be difficult for an entrant.

3. *IBM-compatible computers are not viewed as perfect substitutes*: Corporate consumers apparently do not view any pair of the IBM-compatible computer brands or all three together as perfect substitutes.

4. *Adjustment to the steady-state is rapid*: After a shock, market shares adjust most of the way to the steady state in about a year and a half. After three years, the adjustment is essentially complete.

5. *Removing and reintroducing a brand has different effects in the long and short runs*: In the long-run, Compaq customers shift to IBM Compatibles. When BL stopped carrying Compaq, the steady-state shares of the other two IBM-compatible brands rose much more than that of Apple. In contrast, Compaq customers shifted more to Apples in the short run than in the long run. In the first quarter after Businessland stopped carrying Compaqs, Apple's share rose substantially. When Compaqs were again carried, relatively more of the gain in Compaq's share came from Apple. These effects, however, did not persist in the long run.

6. *The loss of the Compaq franchise did not cause Businessland to lose corporate customers*: When Businessland lost its Compaq franchise, it suffered little loss of either corporate customers or sales. This stability of business suggests that customers were more loyal to Businessland than to Compaq, perhaps due to quantity discounts or service.

7. *Which firms diversify across brands is difficult to explain*: The only characteristic of firms that statistically significantly affects whether firms diversify over brands is the number of IS staff per employee. This effect, however, cannot easily be interpreted. Changes in whether Businessland had a Compaq franchise had little or no effect on diversification.

8. *Diversification across brands is common*: Very few firms bought only one brand. Indeed, contrary to reports in the media, three-quarters of Businessland's major corporate customers used both IBM-compatible and Apple computers in the late 1980s and early 1990s.

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Footnotes

1. Nationally distributed computers such as Wyse are frequently referred to as "compatibles" to distinguish them from the generic no-name "clones" sold only locally. We do not distinguish between these two terms.

2. Multinomial logit models have been used in studies of brand loyalty toward consumer goods: Hlavac and Little (1966) on buying an automobile at a particular dealership, Gensch and Recker (1979) on grocery store selection, Guadagni and Little (1983) on regular ground coffee.

3. One alternative to the Markov model is a zero-order Bernoulli process. Bass, Givon, Kalwani, Reibstein and Wright (1984) use a Markov model to show the existence of both zero order and non-zero order consumer choice behavior. They study frequently purchased and low-priced goods, whereas personal computers are less frequently purchased, higher-priced, durable goods. Mahajan, Green, and Goldberg (1982) use a conjoint technique to develop transition matrices as a function of brand price to project shares. Their shares are then related to brand prices but not to the last brand choices. Unlike their technique, our approach is modeled directly as a function of the transition probabilities. In contrast to most prior studies, our approach allows us to considers brand choice as a function of both firm characteristics, industry dummy effects, marketing mix variables, and prior brand choice purchases. We do not report, however, results for those variable that had low t-statistics.

4. We also experimented with including other firm-specific variables (described later in the paper). Because these variables are not collectively statistically significant nor do they improve the predictive power of the model, we do not include them in the regressions reported here.

5. This finding is similar to that of Guadagni and Little (1983) who present evidence of groups of consumers who are insensitive to price.

6. The F-statistic on the lagged shares restriction is 2.5, which is less than the critical value.

7. We experimented with interacting Compaq shares and these quarterly dummies; however, these coefficients were not statistically significantly different from zero at the 0.05 level.

8. Both these firms bought from BL prior to BL's loss of franchise of Compaq and resumed buying from BL when its franchise with Compaq was reinstated in the fourth quarter of 1990.

Table 1: Markov Transition Equations Estimated Using Multinomial Logit (Periods 1, 2, and 6)

	With Relative Prices			*Without Relative Prices*		
	Compaq	*IBM*	*Wyse*	*Compaq*	*IBM*	*Wyse*
Constant	0.825	-6.177	-9.898	-0.687	-1.213	2.085
	(0.15)	(-1.54)	(-0.78)	(-0.81)	(-1.32)	(3.51)
Lagged Apple Share	-1.932	-1.024	-6.402	-2.016	-0.845	-6.430
	(-2.05)	(-1.08)	(-6.77)	(-2.19)	(-0.88)	(-7.02)
Lagged Compaq Share	2.102	1.151	-4.492	2.030	1.277	-4.193
	(2.13)	(1.10)	(-3.62)	(2.09)	(1.21)	(-3.61)
Lagged IBM Share	0.508	3.304	-3.669	0.407	3.404	-3.905
	(0.54)	(3.50)	(-4.55)	(0.45)	(3.59)	(-4.90)
BL Apple Price	-0.669	5.407	10.943			
	(-0.12)	(1.43)	(0.85)			
BL Compaq Price	1.378	-3.209	-4.939			
	(0.59)	(-1.84)	(-1.03)			
BL IBM Price	-3.815	9.526	21.208			
	(-0.32)	(1.15)	(0.78)			
BL Wyse Price	1.589	-4.708	-10.481			
	(0.24)	(-1.05)	(-0.71)			
Apple University Price	1.868	-9.478	-20.472			
	(0.17)	(-1.26)	(-0.80)			
Compaq Mail-Order Price	5.429	-7.083	-16.736			
	(0.45)	(-0.87)	(-0.64)			

IBM Mail-Order Price	-4.777	8.647	18.448	
	(-0.42)	(1.13)	(0.74)	
Log-Likelihood		-548		-555
χ^2(df)		431		416
		(30)		(9)

Notes: The coefficients for Apple's share are normalized to zero. The prices are all relative to the mail-order price of an IBM-compatible clone. Asymptotic t-statistics are reported in parentheses below the estimated coefficients.

Table 2: Markov Equations Estimated Using Multinomial Logit (Periods 3, 4, and 5)

Period 3	*Compaq*	*IBM*	*Wyse*
Constant	NA	-0.813	2.461
		(-0.37)	(1.69)
Lagged Apple Share	NA	-0.644	-5.701
		(-0.29)	(-2.80)
Lagged Compaq Share	NA	-0.374	-6.053
		(-0.16)	(-2.03)
Lagged IBM Share	NA	2.382	-4.955
		(1.06)	(-2.45)
Log-Likelihood		-55.30	
χ^2(df)		61.34 (6)	

Period 4	*Compaq*	*IBM*	*Wyse*
Constant	NA	-0.813	0.501
		(1.07)	(0.513)
Lagged Apple Share	NA	-2.402	-3.702
		(-2.35)	(-2.48)
Lagged Compaq Share	NA	NA	NA
Lagged IBM Share	NA	0.805	-1.791
		(0.825)	(-1.312)

Log-Likelihood	-75.45
χ^2(df)	31.01 (4)

Period 5	*Compaq*	*IBM*	*Wyse*
Constant	-3.082	0.981	1.042
	(-0.73)	(0.91)	(0.96)
Lagged Apple Share	0.266	-2.772	-4.953
	(0.06)	(-2.25)	(-2.65)
Lagged Compaq Share	NA	NA	NA
Lagged IBM Share	0.060	0.860	-3.247
	(0.01)	(0.74)	(-1.96)
Log-Likelihood		-67.70	
χ^2(df)		416 (9)	

Notes: The coefficients for Apple's share are normalized to zero. Asymptotic t-statistics are reported in parentheses below the estimated coefficients.

Table 3: Likelihood Ratio Test Statistics

Hypothesis (degrees of freedom)	*Without Relative Prices*	*With Relative Prices*
Periods 1 and 2 are identical (12)	0.44	2.86
Periods 1 and 6 are identical (12)	3.08	3.38
Periods 1, 2, and 6 are identical (24)	2.92	5.92

Note: $\chi^2_{.05}(12) = 23.34$ and $\chi^2_{.05}(24) = 39.36$.

Table 4: Elasticities of Market Shares With Respect to Explanatory Variables

	Apple	Compaq	IBM	Wyse
Lagged Apple Share	0.31	-0.34	-0.03	-1.87
Lagged Compaq Share	-0.09	0.18	0.06	-0.68
Lagged IBM Share	-0.73	-0.49	0.83	-2.46
BL Apple Price	-8.92	-11.07	8.54	26.41
BL Compaq Price	3.12	6.05	-3.72	-7.41
BL IBM Price	-11.54	-21.21	12.61	42.23
BL Wyse Price	2.96	5.02	-3.13	-10.59
Apple University Price	13.99	19.45	-13.75	-45.92
Compaq Mail-Order Price	4.09	11.37	-5.41	-18.35
IBM Mail-Order Price	-6.20	-13.75	7.45	22.93

Table 5: Steady States

	Apple	*Compaq*	*IBM*	*Wyse*
Periods 1, 2, 6 (without relative prices)	41.2%	19.7%	30.7%	8.4%
Periods 1, 2, and 6 (with relative prices)	40.6%	13.9%	40.1%	5.4%
Period 3	40.2%		43.1%	16.7%
Period 4	42.7%		52.1%	5.2%

Table 6: One Quarter Adjustments

A. *One Quarter Adjustment to Compaq Leaving*

	Apple	*Compaq*	*IBM*	*Wyse*
Periods 1, 2, 6 (without relative prices)	16.6%	63.7%	17.7%	2.0%
Periods 1, 2, and 6 (with relative prices)	17.3%	63.0%	18.5%	1.3%
Period 3	75.0%		22.9%	2.1%

B. *One Quarter Adjustment to Compaq Reentering*

	Apple	*Compaq*	*IBM*	*Wyse*
Periods 1, 2, 6 (without relative prices)	5.5%	63.7%	7.0%	5.1%
Periods 1, 2, and 6 (with relative prices)	5.4%	63.0%	6.7%	5.3%
Period 5	4.8%		0.7%	0.7%

Table 7: Number of Customers

Quarter	Number of Large Firms
1989:1	95
1989:2	98
1989:3	94
1989:4	109
1990:1	105
1990:2	112
1990:3	110
1990:4	104
1991:1	103
1991:2	98
1991:3	101
1991:4	170

Table 8: Percentage Change in Sales of CPUs Regressed on Firm Characteristics

	DOS CPUs		*All CPUs*	
	Coefficient	*t-statistic*	*Coefficient*	*t-statistic*
Constant	-404.480	-8.68	-409.020	-8.69
Share Apple (Q1-Q3)	-63.940	-0.63	-61.073	-0.60
Share Compaq (Q1-Q3)	216.550	1.85	215.480	1.82
Share IBM (Q1-Q3)	26.403	0.27	27.500	0.28
Percentage change in revenue per PC	0.198	8.70	0.200	8.69
Percentage change in IS employees to total employees	0.121	5.36	0.118	5.18
Percentage change in PCs per employee	0.242	10.85	0.238	10.57
Consumer Goods and Services	-15.165	-0.48	-18.078	-0.56
High Tech, Aerospace, and Automotive	-31.336	-1.03	-32.481	-1.06
Metals, Machinery, and Tools	-8.461	-0.19	-9.354	-0.21
Health	-47.466	-1.37	-47.303	-1.35
Banks	-6.585	-0.20	-5.487	-0.17
Nonbank Financial	-0.501	-0.01	-1.311	-0.04
Insurance	-19.139	-0.58	-19.970	-0.60
Conglomerates	-12.728	-0.33	-14.911	-0.38
Utilities	-79.914	-2.10	-81.216	-2.11
Transportation	-24.232	-0.71	-25.388	-0.74
Chemicals and Fuel	-34.294	-1.14	-35.025	-1.16
Natural Resources	-58.957	-1.25	-59.193	-1.25
Telecommunications	-45.151	-1.52	-45.856	-1.53
Quarter 2	440.430	10.48	446.160	10.51
Quarter 3	501.850	5.32	504.010	5.30
Quarter 4	402.440	10.28	407.750	10.32
Quarter 5	429.560	10.64	435.680	10.69
Quarter 6	446.080	10.78	451.300	10.80
Quarter 7	553.760	16.11	558.650	16.10
Quarter 8	423.320	10.97	427.300	10.97
Quarter 9	444.490	11.13	451.830	11.21
Quarter 10	436.730	10.37	442.820	10.42
Quarter 11	472.150	11.88	476.850	11.88
Quarter 12	422.460	10.61	426.590	10.61
$\bar{R}^2$	0.86		0.87	

Table 9: Multinomial Logit on Number of Brands
Coefficients (Asymptotic t-statistics)

	Single DOS Brand	Several DOS Brands, but no Apples	Apple and DOS brands
Constant	1.025	1.273	15.982
	(0.001)	(0.001)	(0.01)
Revenues per employee	2.108	2.586	1.242
	(0.975)	(1.18)	(0.584)
IS staff per employee	-59.050	-64.890	-38.103
	(-2.31)	(-2.36)	(-1.73)
PCs per employee	0.054	0.074	0.033
	(0.07)	(0.04)	(0.01)
Expenditure on training per employee	1.993	18.601	2.344
	(0.75)	(-1.15)	(1.37)

	Predicted				
Actual	0	1	2	3	TOTAL
0	1	0	1	6	8
1	0	2	0	14	16
2	0	0	5	7	12
3	0	1	2	112	115
Total	1	3	8	139	151

Notes: The base category is "bought only Apple." The industry dummy coefficients are not reported in the table. None of those coefficients were statistically significantly different from zero at the 0.05 level.

Figure 1
Adjustment Path
(Firm Bought only Compaq in the Initial Period)

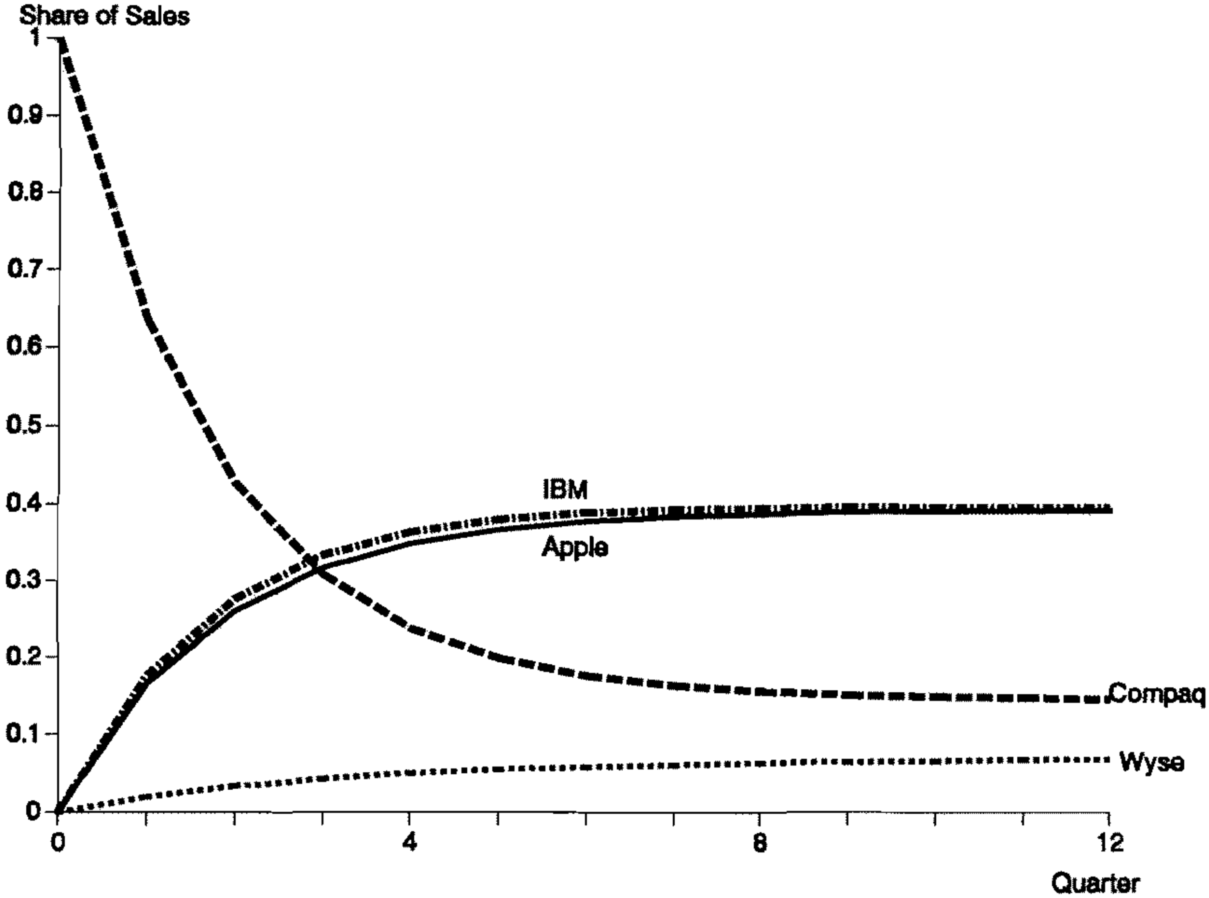
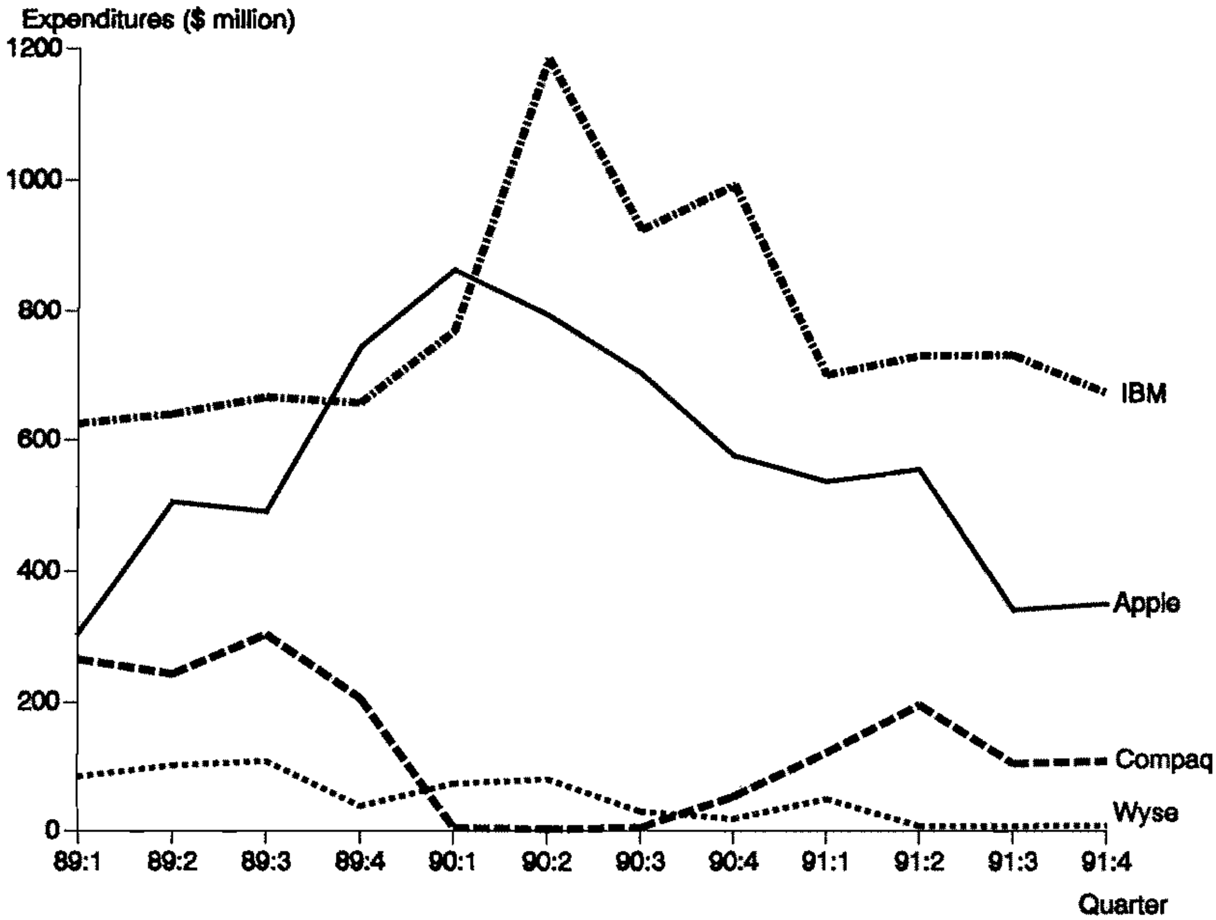


Figure 2: Total Expenditures



Note: Compaq computers were not sold 1990:1-1990:3.