Electronic Substitution in the Household-Level Demand for Postal Delivery Services*

by

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December 1996

*I would like to thank Matt Shum for outstanding research assistance. Financial support for this research was provided by the Markle Foundation and the National Science Foundation.

Abstract

This paper quantifies the shift in the household-level demand for postal delivery services over time and determines the extent to which it can be attributed to the appearance of alternative modes of communication versus the concomitant rise in the relative price of postal delivery services. The two major results to emerge from this analysis are: (1) postal price increases of the magnitude recently enacted on January 1, 1995 should lead to significant reductions in aggregate household-level expenditures on postal delivery services, and (2) annual increases in the pervasiveness of personal computer technology in the household at historical rates leads to reductions in aggregate household-level expenditures on postal delivery services that are at least as large as those that would result from a postal price increase on the order of 10 percent.

1. Motivation

The past decade has witnessed a dramatic increase in the number of available modes of interpersonal communication and in the range of quality of these modes in terms of speed, reliability, and flexibility. Many of these modes have experienced substantial price reductions over this same time period; for instance, the price of long-distance telephone service has fallen continuously; both the purchase price of FAX machines and the cost of using these machines have declined; on-line information services such as America Online or CompuServe, which charge a zero price for incremental messages sent to other subscribers to their service and to users of the Internet, have experienced explosive growth in the number of subscribers. All of these modes of communication provide attractive alternatives to traditional postal delivery services supplied by the United States Postal Service (USPS).

The relative attractiveness of long-distance telephony, FAX communication and electronic mail is enhanced by the steadily increasing price of postal delivery services over the past decade. From January 1, 1986 to January 1, 1995, the price of a one-ounce First-Class letter increased from $0.22 to $0.32, a more than 45% increase in nine years. This combination of higher prices for postal delivery services and the growing number of viable alternative modes of communication has led to dire predictions about the future demand for postal delivery services. However, aggregate pieces delivered by the USPS has continued to steadily increase up to the present time. Off of 166.4 billion pieces delivered in 1992, growth in pieces delivered was 2.9% in 1993 and 3.4% in 1994. For 1994, the percentages of the various classes by volume are: First-Class, 54%; Second-Class, 6%; Third-Class, 39%; and all other classes, 1%. Third-Class, principally advertising circulars and mail-order catalogues, has steadily increased its share of pieces delivered. The number of First Class pieces delivered has continued to grow, but the bulk of this growth has come from pre-sorted First-Class.

In fact, from 1993 to 1994, single-piece volume fell by 0.2 percent, but a 6.8 percent increase in pre-sorted First-Class resulted in a net 2.4 percent increase in total First Class volume (USPS, 1994). The increasing share of pieces delivered going to Third Class mail and pre-sorted First Class, both of which are used primarily by businesses, seems to signal a shift by households away from the consumption of postal delivery services.

The purpose of this paper is to quantify this shift in the household-level demand for postal delivery services from 1986 to 1994 and determine the extent to which it can be attributed to the appearance of alternative modes of communication versus the concomitant increasing relative price of postal delivery services. Specific questions addressed are: What are the own-price, cross-price and expenditure elasticities of household-level demand for postal delivery services and how have these magnitudes changed over time? What is the impact of the increasing penetration of home-computing technology on postal demand? What household characteristics predict differences in household-level postal demand? How has the aggregate demand for postal delivery services by U.S. households changed over this time period?

To perform this analysis, we use the Bureau of Labor Statistics (BLS) Consumer Expenditure Survey (CES), which is a national probability sample of U.S. households generated from the 1980 Census 100-percent detail file. The BLS administers two distinct surveys to different samples of households: (1) the Quarterly Interview Survey and (2) the Diary Survey. These surveys differ in the number of goods that they cover, the length of time they survey a household, and the kinds of background questions asked about the household. For the Diary Survey, each household is requested to keep two one-week diaries of all expenditures over consecutive weeks. For the Interview Survey, the household is interviewed every three months over a 15-month period; this survey also asks questions about durable goods holdings—cars, housing, and personal computers.

Both surveys collect information on household characteristics—hours of work of the head and spouse, occupation of the head and spouse, age and race of the head and spouse, marital status of the head, number of children, dwelling type and income. This information can be used to link durable goods holdings across the Interview Survey sample and the Diary Survey sample.

The Diary Survey is the source of data on household-level consumption of postal delivery services. The Interview Survey is used to estimate a probit model of the probability of personal computer ownership as a function of household characteristics common to both surveys. Each of the 49,089 households from the Diary Survey for the years 1986 to 1994 is then assigned an estimated probability of computer ownership using the coefficient estimates from the Interview Survey probit model using the common household demographic characteristics across the two surveys.

Because the purchases of each household in the Diary Survey are only recorded for two weeks, a household's purchases of postal delivery services can differ substantially from its consumption of these services. For example, a household can purchase and store these services in the form of blocks or rolls of stamps, using these stamps later to consume postal delivery services. The fact that, for the sample period, approximately 67 percent of all households do not purchase any postage during the two-week Diary Survey period attests to the empirical relevance of this difference. The distinction between consumption and purchases within the two-week sample period creates various complications for the proper recovery of the structure of household-level demand for postal delivery services. The observed purchases of postal delivery services are the combination of actual (but unobserved) consumption and a frequency of purchase process.

A considerable amount of across-household heterogeneity exists in the demand for postal delivery services. The probability of computer ownership affects both the consumption of postal

delivery services and the frequency of purchase of postage. A higher household-level probability of computer ownership predicts a decreased amount of consumption of postal delivery services and a reduced probability of postage purchase during the two-week Diary Survey period by that household. The results from estimating the model of postage expenditures pooling all of the years in the sample imply substitutability between the consumption of telecommunications services and the consumption of postal delivery services.

In order to investigate how the structure of postal demand has changed from 1986 to 1994, we estimated the model allowing for changes over time in the parameters determining the own- and cross-price and expenditure elasticities of household-level demand for postal delivery services. Perhaps the most surprising result to emerge from this analysis is a substantial increase in the absolute value of the own-price elasticity of demand for postal delivery services over time. For example, the own-price elasticity in 1986 is approximately -0.76, but by 1994 this magnitude is -1.3. This trend toward a more price-elastic demand has potentially dire consequences for the ability of the USPS to raise revenues from households through future postage price increases. These results yield an expenditure elasticity of demand decline from 0.36 in 1986 to 0.25 in 1994, indicating that higher expenditure and income households are increasingly substituting away from postal delivery services as their preferred mode for interpersonal communications. There is also an increasing degree of substitutability between postal delivery services and telecommunications services, indicating that, to greater extent in recent years, declines in the price of telecommunications services should bring about decreases in the household-level demand for postal delivery services. When we quantify how the impact of personal-computing technology and Internet use on the household-level demand for postal delivery services changes over time, we find that, for most years in the sample, a higher probability of ownership of a personal computer is associated with an increased demand for

postal delivery services. However, particularly in 1993 and 1994, when subscribership to on-line services and access to the Internet in general became widespread, an increased probability of computer ownership predicts a decline in the household-level demand for postal delivery services.

Because we have a weight giving the number of households in the U.S. represented by each household in the Diary Survey sample each year, we can use these weights to compute estimates of the aggregate household-level demand for postal delivery services as well as the aggregate price elasticities of the demand for postal delivery services. This enables us to assess the likely revenue consequences to the USPS from future postal price increases given the aggregate demand relations we have estimated. We find that, for a 10% increase in the price of postage, the most recent year's aggregate own-price elasticity estimate implies a 2.7% reduction in the revenues that the USPS can expect to receive from U.S. households. We can also compute an aggregate elasticity of household-level demand for postal services with respect to the probability of computer ownership. Using the aggregate elasticity estimate for 1994, and assuming a 17 percent increase in the probability of computer ownership for all households in the sample (a plausible increase given that the estimated penetration of personal computers in the household has more than tripled from 1988 to 1994), yields a 2.7 percent decline in the aggregate demand for postal delivery services, or a 2.7 reduction in annual household-level revenues, the same percentage decline in revenues brought about by the 10 percent price increase.

The remainder of the paper proceeds as follows. The next section discusses the data sources used in my analysis and provides some summary statistics on the changes in the household-level demand for postal delivery services over time. This section also presents estimates of the model for the probability of personal computer ownership as a function of household characteristics common to the Diary Survey and Interview Survey. The next section presents our the econometric model for

the observed purchases of household-level postal delivery services. This is followed by a discussion of the results from estimating the model and the answers to the questions posed earlier about the structure of household-level demand for postal delivery services that this econometric modeling effort provides. The paper closes with a summary of results and a discussion of topics for future research.

2. Predicting Computer Ownership and Trends in Postage Expenditures

In this section I first discuss the two major data sources used in the analysis. This is followed by a presentation of the estimates of the probability of computer ownership models estimated using the Interview Survey data. These models are then used to impute a probability of computer ownership for each household in the Diary Survey. The parameter estimates are of some independent interest given the rapid increase in the fraction of households owning personal computers—from 7% in 1988, the first year in which the Interview Survey collected this information, to 25% in 1994, the last year of data currently available. In order to motivate the household-level demand estimation results presented later, summary statistics on household postage and telephone consumption from 1986 to 1994 are given. Finally, I describe the annual changes in the percent of U.S. households owning personal computing technology up to the present time.

As noted above, the Diary Survey is the source of data on postage consumption. This survey collects all expenditures for each sampled household for two consecutive one-week periods. Each sampled household completes a weekly diary document listing every purchase, the good and the amount, made within that one week period (except expenditures incurred while away from home, overnight or longer). Every year the Diary sample is re-drawn, with each day of the week having an equal probability of being the first day of the reference week for a sampled household. With the exception of the last 6 weeks of the year, when the Diary sample size is doubled to increase the

coverage of expenditures unique to the holiday season, the number of Diary Surveys administered is uniformly distributed throughout the year.

For my analysis, total postage expenditures for each household is the sum of all purchases of postage during the two-week sample interval. Figure 1 presents a histogram of the number of purchases of postage during the two-week diary period. From the figure it is clear that the vast majority of households that purchase postage during their Diary Survey period only make one purchase. For this reason, the subsequent empirical analysis focuses on the decision to purchase within the two-week period, rather than on the number of purchases made.

The Interview Survey is the source for computer ownership data at the household-level. Beginning with the 1988 survey, households were asked whether they owned a personal computer. Because the Diary Survey and Interview Survey collect the same household characteristics, these variables can be used to match households that share these characteristics across the Interview Survey and Diary Survey samples. The Interview Survey is used to collect information on major expenditure items on a retrospective basis. Each household selected to appear in this sample is interviewed quarterly for five consecutive quarters for these major expenditures and the above household characteristics in addition to their income. As a result of this sampling scheme, 20 percent of the Interview Survey sample is rotated each quarter.

The probability of computer ownership model utilizes all available household characteristics variables that are common to the Interview and Diary Surveys to predict the probability of computer ownership using a probit model. Let X_i denote the vector of household characteristics for the ith household in the Interview Survey. Let y_i^* denote the latent propensity of household i to own a computer. We assume that the household owns a computer if $y_i^* \geq 0$ and does not if $y_i^* < 0$. The event of computer ownership is denoted by the indicator variable y_i, which takes on the value 1 if

the household owns a computer and zero otherwise. The propensity to own computers is determined by $y_i^* = X_i'\beta + \epsilon_i$, where ϵ_i is an independent identically distributed N(0,1) random variable across households. The log-likelihood function for this model is:

$$L(\beta) = \sum_{i=1}^{N} y_i \ln(\Phi(X_i'\beta)) + (1-y_i)\ln(1-\Phi(X_i'\beta)),$$

where N is the number of households in the Interview Survey during the year under consideration and $\Phi(t)$ is the standard normal distribution function. Given the maximum likelihood estimate of β, an estimate of the probability of computer ownership as a function of X_i can be computed as $\Phi(X_i\hat{\beta})$, where $\hat{\beta}$ is the maximum likelihood estimate of β. Taking the values of X_i for each observation in the Diary Survey for the same year as the Interview Survey, we compute $\Phi(X_i'\hat{\beta})$, the estimated probability of computer ownership for that Diary Survey observation. This estimated probability is used in the model for postage expenditures to measure the extent of electronic substitution in the consumption of postal delivery services.

Table 1 gives the maximum likelihood estimates of the elements of β for 1988, the first year this information was collected in the Interview Survey, and for 1994, in order to quantify the changes in these probit coefficient estimates over time. This same probit model is estimated separately for each year from 1988 to 1994. To compute the probability of computer ownership for each household during each year of the Diary Survey, we use the probit model parameter estimates from that same year's Interview Survey data. Because computer ownership information was not collected for 1986 or 1987 in the Interview Survey, the parameter estimates from the model estimated for 1988 are used to compute estimated probabilities of computer ownership for all observations from the Diary Surveys in 1986 and 1987.

I now describe the time series behavior of the sample averages of household-level postage purchases and telephone expenditures from the Diary Survey database. Table 2 gives the sample average, minimum and maximum household-level purchases of postage and local and long-distance telephone services during the two-week interview period for each year from 1986 to 1994 in nominal dollars. This table shows an initially increasing average consumption of postal delivery services from 1986 to 1989 and then a steady decline from 1990 to 1994. On the other hand, telephone consumption shows a steady increase throughout the sample period. This table also gives these same magnitudes as shares of total nondurable goods expenditure during the two-week Diary Survey time interval. Viewed relative to total non-durable goods expenditures, the downturn in household-level postage expenditures is even more pronounced. Figure 2 plots the monthly Consumer Price Index (CPI) price indexes for postage and the composite of local and long-distance telephone services, non-seasonally adjusted and normalized to have January 1986 equal to one. This figure shows the large relative price increase in postage versus telephone service over the sample period. These increases in the price of postage later in the sample period, and the accompanying reduction in average household-level purchases, is indicative of a price-elastic demand which brings about reductions in total expenditures in response to a price increase. On the other hand, telephone services expenditures increase over the sample, despite a slight upward trend in the telephone services price index over time.

Table 3 gives the sample average percent of households in the Interview Survey that own computers for each year from 1988 to 1994. This percentage has nearly quadrupled over the 8-year sample period. This magnitude almost doubled from 1988 to 1989, the same time period in which average household-level expenditures on postal delivery services began to decline. The inverse relation between these two trends suggests the importance of accounting for the relationship between

computer ownership and the consumption of postage delivery services in constructing an econometric model of household-level postage expenditures.

3. Econometric Model of Postal Delivery Services Expenditures

The econometric model of household-level postage expenditures accounts for the infrequency of purchases of postal delivery services within the two-week sampling interval of the Diary Survey, yet is still consistent with the basic features of consumer demand theory. This model is specified with postage expenditures as a share of total non-durable expenditures within the two-week Diary Survey period as the dependent variable. The range of real (in January 1986 dollars) total non-durable goods expenditures in the two-week Diary Survey period for all years in the sample is $25 to $1,700, so there is a considerable amount of variability across households in the share total expenditures going to postal delivery services. This model gives rise to a joint distribution of postal expenditure shares across all the households during the sample period, which is then used to estimate the parameters of the econometric model by maximum likelihood techniques.

Before describing the details of the model, we require the following notation. Let y_i^* denote the share of total non-durable expenditures going to postage *consumption* and y_i the share of total non-durable goods expenditures going to postage *expenditures*, by the ith household for the two-week interval. Let x_i equal the vector of ratios of the logarithm of prices to total non-durable goods expenditures—$\ln(p_j/M)$, where p_j is the price of the jth good and M is total non-durable goods expenditures—and other demographic variables assumed to shift postage consumption across households. We enter prices and total non-durable goods expenditures as ratios in order to impose the theoretical restriction of homogeneity of degree zero of the resulting demand function in prices and total non-durable goods expenditures. Let w_i denote the indicator random variable that equals 1 if the household purchases postage within the two-week interval and 0 otherwise. The purchase

probability can be written as $pr(w_i = 1) = \Phi(z_i'\theta)$, with z_i equal to the vector of household characteristics that shift the propensity to purchase postage; $\Phi(t)$, the standard normal distribution function; and θ, a vector of parameters to be estimated.

Assume that $\log(y_i^*) = x_i'\beta + \epsilon_i$, where $\epsilon_i \sim N(0,\sigma^2)$ and $y_i = w_i y_i^*/\Phi(z_i'\theta)$. The relation $y_i = w_i y_i^*/\Phi(z_i'\theta)$ implies that if a purchase of postage occurs in the two-week interval ($w_i = 1$), the household buys the inverse of its postage purchase probability in that two-week interval ($1/\Phi(z_i'\theta)$) times its observable demand for postal delivery services for the two-week interval, y_i^*. Consider a simple numerical example to illustrate this aspect of the econometric model. Suppose the household's unobservable two-week demand for postal delivery services is \$10.00 and its probability of purchasing postage within any two-week interval is 0.5. This implies that when it does purchase postage, it will buy \$20.00 = \$10.00/0.5 worth to maintain its rate of consumption given its purchase frequency.

Because $\log(y_i^*)$ is assumed to be normally distributed, y_i^* must therefore only take on positive values. This model assumes that all households consume a non-zero (although it can be extremely small) amount postal delivery services within a two-week time period. Let Y equal the vector of all postal expenditure shares, $(y_1, y_2, .., y_N)$, where N is the number of households in the sample. The demand for postal delivery services function and the equation relating consumption to purchases via the purchase probability function yields the log-likelihood function for Y:

$$\log L(Y) = \sum_{0} \log(1 - \Phi(z_i'\theta))$$

$$+ \sum_{+} [- \log\sigma + \log\phi((\log(y_i) + \log\Phi(z_i'\theta) - x_i'\beta)/\sigma) + \log\Phi(z_i'\theta) - \log(y_i)]$$

Variants of this model are discussed in Blundell and Meghir (1987) and Deaton and Irish (1984). In Wolak (1997) we consider three other forms for this combination purchase frequency and latent

demand for postal delivery services model of postal expenditures which differ in terms of their assumptions about the unobserved demand for postal delivery services. Because all four competing models give rise to joint densities of Y, non-nested hypothesis testing techniques developed by Vuong (1989) can be used to determine which model provides a statistically significantly superior description of the underlying data generation process. The non-nested hypothesis testing results reported in Wolak (1997) find that this *log-infrequency of purchase* model which implies non-zero consumption of postal delivery services for all households provides a clearly statistically superior description of the observed household-level expenditure patterns relative to the other three models. Other reasonableness checks of the four models found further support for the superiority of the log-infrequency of purchase of postal delivery services model considered here.

Variables Entering Demand and Purchase Probability Functions

Consumer theory provides a strong guide as to what should enter x_i, the determinants of the demand for postal delivery services. Because $y_i^* = \exp(x_i'\beta + \epsilon_i)$ is an expenditure share demand function, it follows that the own-price, the prices of all other goods consumed by the household and total non-durable expenditures should enter x_i. Consequently, we enter the logarithms of the price of postage, price of telephone services, an index of the prices of other non-durable goods besides postage and telephone services, and total nondurable expenditures. We also enter demographic variables describing the characteristics of the household which should alter its consumption of postal delivery services such as race, number of children, martial status, education, occupation, and age of the head, and the probability of computer ownership.

Economic theory provides less guidance for what variables should enter in z_i, the determinants of the purchase probability. There are a number of reasons why the probability of purchasing postage should differ across households. A major determinant of these differences is the

opportunity cost to the household of making a purchase. If it were costless to purchase postage, then all households would purchase only when at least one household member actually consumed postal delivery services. Under these circumstances, the purchase probability within the two-week sample interval would exactly equal one for all households consuming any postal delivery services during this time interval. Consequently, we expect household characteristics that predict the opportunity cost of purchasing postage to be important predictors of this probability—the geographic area in which the household resides, the number of children in the household, the marital status of the head, the education of the spouse and head, the occupation, age, hours of work of the head and spouse, household income, and the probability of computer ownership.

Tables 4 gives estimates of the parameters of this two-equation model for postal expenditures. As noted above, we impose homogeneity of degree zero in price and total expenditure on the share equations by requiring that the coefficient on the logarithm of the price index for other non-durable goods equal the sum of coefficients on the prices of postage and telephone services minus the coefficient on the logarithm of total non-durable expenditures. Table 11 gives a list of the variable definitions used in all of the models. The household demographic variables significantly improve the predictive power of the model, indicating the presence of deterministic differences in postage consumption and frequency of purchase across households based on these observable characteristics. The standard errors estimates in Table 4 are computed using the misspecification-robust standard error estimates discussed in White (1982). Using these covariance matrix estimates makes the inferences drawn robust to various forms of misspecification of the distributional assumptions used to derive the joint density of Y..

Figure 3 plots the smoothed density of household-level expected postal delivery services consumption within the two-week period for the log-frequency of purchase model.[1] There is a large

range in the density of expected two-week consumption of postage, with a significant positive skew. Figure 4 plots the smoothed density of household-level purchase probabilities from this model. Although this density of purchase probabilities is centered at 0.32, many households have estimated purchase frequencies above and below this value. Table 5 gives the probability derivatives associated with the postage purchase probability for this model. This table shows that increases in the probability of personal computer ownership significantly reduces the purchase frequency of postal delivery services.

Table 6 gives the mean household-level elasticities of postage demand with respect to the prices of postage, telephone services, other non-durable goods and total non-durable expenditures. The structure of the log-frequency of purchase of model implies price and expenditure elasticities which do not vary across households. The last row of Table 6 gives the sample mean of the elasticity demand with respect to the probability of computer ownership. Because this elasticity varies across households, the sample standard deviation of the household-level elasticities is reported below it. This mean elasticity implies that increases in the probability computer ownership bring about reductions in the demand for postal delivery services at the household-level.

To address the question of the impact of the increasing number of low-cost alternatives to postal delivery services and the increasing price of postal delivery services over the past decade on the demand for postal delivery services, we enlarge the specification of the demand function to allow for time-varying own- and cross-price elasticities, total non-durable expenditure elasticities and elasticities with respect to the probability of computer ownership. This requires interacting each of these five variables—$\ln(p_{postage})$, $\ln(p_{phone})$, $\ln(p_{other})$, ln(total non-durable expenditures), and the probability of computer ownership—with an annual time trend and including these variables in the vector of regressors, x_i, for the log-consumption share equation. An annual time-trend is also

interacted with the probability of computer ownership in the purchase probability equation. The remaining parameters in the consumption share equation and the purchase probability equation are assumed to be fixed over time. For these variables, the resulting parameter estimates are very similar to those reported in Table 4. There are changes in the coefficients on log-prices, log-total non-durable expenditure and probability of computer ownership variables that reflect the fact that we have included these variables interacted with a time trend in the model. The full set of parameter estimates is reported in Table 8.

Table 7 gives estimates of the sample average price, expenditure and probability of computer ownership elasticities for each year in the sample implied by this model. Recall that the only demand elasticity which varies across households is the one with respect to the probability of computer ownership. Consequently, the last column in this table presents the sample means of these elasticities estimates for each year. The own-price elasticity begins at -0.758 in 1986 and ends in 1994 with a value of -1.27. These two price elasticities have very different implications for the ability of the USPS to raise revenues from U.S. households through postage price increases. In general, an X% price increase of a product with a demand elasticity of ϵ increases total revenue from the sale of that product by $X(1 + \epsilon)$. Consequently, if the absolute value of ϵ is less than one—the product is inelastically demanded—total revenue will increase as a result of this price increase. This is the case for household-level postal delivery services demand for all years up until 1989. If, as is the case for the years following 1989, the elasticity of demand is greater than one in absolute value, price increases will bring about total revenue decreases. A natural question to ask is: How much revenue is lost from reductions in the household-level use of postal delivery services by these price increases?

A first step in answering this question is an estimate of annual aggregate household expenditures on postage. Table 9 gives estimates of the aggregate annual amount of postage expenditures computed using the sample of households for each year and the corresponding weights giving the number of households in the U.S. represented by each household in the sample. The documentation to the Diary Survey Public Use Tape describes the procedure we use to estimate annual aggregate household expenditures. The second column of this table gives estimates of the average annual expenditures per household on postage, using the procedure to compute this magnitude given in the Diary Survey Public Use Tapes documentation. For the sake of comparison, the third and fourth columns repeat these same two calculations for telephone services. The behavior of average annual household-level postage and telephone services expenditures over time is similar to the behavior of the sample means of the two-week expenditures on postage and telephone services given in Table 2.

Using these numbers and the elasticity estimates, I consider the revenue implications of the January 1, 1995 increase in the price of a one-ounce First Class letter from $0.29 to $0.32, a little more than a 10 percent price increase. From Table 9, the estimated annual aggregate household postage expenditures in 1994 are approximately $5 billion. Using the above equation and the own-price elasticity of -1.27 for 1994 yields a 2.7 percent reduction in annual aggregate expenditures, or approximately a $135 million reduction in annual revenues from sales of postal delivery services to U.S. households. To put these figures into perspective, we should note that, according to these estimates, sales to households is 10 percent of total USPS mail delivery revenues in 1994. Table 9 also gives total USPS revenues for each fiscal year, and the last column of the table gives the fraction of these revenues that come from expenditures by households. From 1987 to 1994, the share of annual revenues coming from expenditures by households has approximately halved. Given the

revenue loss calculation from reduced sales to households due to the recent First-Class postage price increase, we can expect further declines in the share of revenues coming from sales to households in the future.

To assess the impact of personal computing technology on the demand for postal delivery services, we perform a similar calculation assuming an equal percentage change in the probability of computer ownership across all U.S. households. Suppose that, as a result of the explosion in services offered via the Internet, the probability of computer ownership increases by 17 percent for all U.S. households. From Table 3, in 1994 the fraction of households owning a personal computer is 0.25. A 17 percent increase in this magnitude would make it 1.17 x 0.25 = 0.29, a reasonable increase in the penetration of computers over the course of a single year. There is a substantial amount of heterogeneity in the probability of computer ownership across households, so that the actual final probability of computer ownership (as result of this uniform 17 percent increase) for each household could be greater or less than this magnitude, although the average probability over all U.S. households would be equal to approximately 0.29. To illustrate this heterogeneity in estimated computer ownership probabilities, Figure 5 plots the smoothed density estimate of the probability of computer ownership for the 1994 Diary Sample. Although the sample mean of the probability of computer ownership is 0.24, there are values substantially above and below this value.

Using the U.S. population average elasticity of demand with respect to the probability of computer ownership for 1994 of -0.158 (computed by taking the average of the estimated household-level elasticities, weighted by the Diary Survey weights, over all of the households in the 1994 Diary Survey), implies a 2.7 percent decrease in the demand for postal delivery services. Assuming no accompanying change in the price of postal delivery services, this nationwide increase in probability of personal computer ownership implies a 2.7 percent reduction in revenues from household-level

postage expenditures, which is exactly the same reduction in revenues brought about by the 10 percent increase in the price of postal delivery services discussed above. Consequently, for the aggregate demand for postal delivery services by U.S. households, the increasing penetration of personal computing technology and the accompanying more widespread access to the Internet, should have significant adverse impacts on the revenues generated from households that rival those from substantial postage price increases.

The other elasticities in Table 7 show plausible trends over the sample period. For example, there appears to be an increasing degree of substitutability between postal delivery services and all other non-durable goods from 1986 to 1994. The expenditure elasticity shows a downward trend from 0.362 in 1986 to 0.251 in 1994. Another interesting result to emerge from this table is the initial slight complementarity between telephone services and postal delivery services, which shifts towards substitutability between these two goods from 1991 onwards.

4. Conclusions and Direction for Future Research

The two major results to emerge from this analysis are: (1) postal price increases of the magnitude recently enacted on January 1, 1995 should lead to significant reductions in aggregate household-level expenditures on postal delivery services, and (2) annual increases in the pervasiveness of personal computer technology at historical rates should lead to reductions in aggregate household-level expenditures on postal delivery services that are at least as large as those that would result from a postal price increase on the order of 10 percent.

Clearly, there are many caveats associated with these results. One obvious direction for future research is to investigate alternative functional forms for both the demand for postal delivery services and the frequency of purchase model. An additional extension would be to investigate models which explicitly utilize the number purchases made within the two-week Diary Survey

period. These kinds of models can allow own- and other prices to impact both the decision to purchase and the amount to consume. The relatively small number of multiple purchases observed may imply that multiple purchases in the two-week period occur primarily for non-economic reasons. This appears to be fruitful direction for future research given the potential large payoff in terms of a richer model for expenditures on postal delivery services.

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Footnotes

[1]All smoothed density estimates use a kernel density estimator with a Gaussian kernel. The automatic bandwidth selection procedure described in Silverman (1986) is used to determine the amount of smoothing.

Table 1--Selected Results from Computer Ownership Probits

	1988 Estimates		**1994 Estimates**	
	Estimate	*Std Error*	*Estimate*	*Std Error*
Constant	-3.03e+00	4.62e-01	-3.03e+00	4.62e-01
Feb.	-5.79e-01	1.80e-01	-5.79e-01	1.80e-01
March	-1.95e-01	1.40e-01	-1.95e-01	1.40e-01
April	1.18e+00	1.19e-01	1.18e+00	1.19e-01
May	1.17e+00	1.18e-01	1.17e+00	1.18e-01
June	1.33e+00	1.16e-01	1.33e+00	1.16e-01
July	1.20e+00	1.17e-01	1.20e+00	1.17e-01
August	1.23e+00	1.16e-01	1.23e+00	1.16e-01
Sept.	1.31e+00	1.13e-01	1.31e+00	1.13e-01
Oct.	1.31e+00	1.13e-01	1.31e+00	1.13e-01
Nov.	1.35e+00	1.14e-01	1.35e+00	1.14e-01
Dec.	1.46e+00	1.13e-01	1.46e+00	1.13e-01
Northwest	2.27e-01	1.26e-01	2.27e-01	1.26e-01
Midwest	1.54e-01	1.27e-01	1.54e-01	1.27e-01
South	1.38e-01	1.27e-01	1.38e-01	1.27e-01
West	2.34e-01	1.25e-01	2.34e-01	1.25e-01
SMSA	-7.28e-02	8.83e-02	-7.28e-02	8.83e-02
Homeowner	5.90e-02	2.55e-01	5.90e-02	2.55e-01
Renter	-5.75e-02	2.55e-01	-5.75e-02	2.55e-01
Dorm resident	2.37e-01	3.18e-01	2.37e-01	3.18e-01
Family size	-8.15e-02	5.38e-02	-8.15e-02	5.38e-02
Pers. < 18	1.63e-01	5.68e-02	1.63e-01	5.68e-02
Pers. > 64	5.03e-04	9.04e-02	5.03e-04	9.04e-02
# earners	5.85e-02	4.95e-02	5.85e-02	4.95e-02
# vehicles	5.97e-02	1.59e-02	5.97e-02	1.59e-02
White	-2.93e-01	2.16e-01	-2.93e-01	2.16e-01
Black	-4.23e-01	2.32e-01	-4.23e-01	2.32e-01
Male	1.16e-01	6.22e-02	1.16e-01	6.22e-02
Married	-2.91e-01	1.90e-01	-2.91e-01	1.90e-01
< HS	2.29e-01	8.89e-02	2.29e-01	8.89e-02
HS grad	5.66e-01	8.84e-02	5.66e-01	8.84e-02
College grad	8.14e-01	9.18e-02	8.14e-01	9.18e-02
Age	1.05e+00	1.24e+00	1.05e+00	1.24e+00
Age^2	-2.26e+00	1.43e+00	-2.26e+00	1.43e+00
Spouse's age	1.62e+00	1.00e+00	1.62e+00	1.00e+00
Spouse's age^2	-1.43e+00	1.27e+00	-1.43e+00	1.27e+00
Prof. occupation	1.98e-01	6.67e-02	1.98e-01	6.67e-02
Tech occupation	5.18e-02	6.86e-02	5.18e-02	6.86e-02
Self-employed	1.51e-01	9.64e-02	1.51e-01	9.64e-02
Retired	-4.99e-03	1.44e-01	-4.99e-03	1.44e-01
Hrs. of work	-2.28e-03	1.78e-03	-2.28e-03	1.78e-03
Spouse's hrs. of work	1.11e-03	1.87e-03	1.11e-03	1.87e-03
Positive income	3.59e-02	1.04e-02	3.59e-02	1.04e-02
Negative income (dummy)	1.38e-01	8.05e-02	1.38e-01	8.05e-02
Log-likelihood function value	-1881.159		-4554.942	
N	10122		9967	

Table 2--Average Expenditures and Shares by Year

		Mean	*Std Dev*	*Minimum*	*Maximum*
Year=1986	Postal share	0.01	0.02	0.00	0.62
N=5839	Postal expn. ($)	2.34	6.67	0.00	200.58
	Telephone share	0.04	0.08	0.00	0.82
	Telephone expn. ($)	16.00	32.76	0.00	400.00
Year=1987	Postal share	0.01	0.03	0.00	0.77
N=6024	Postal expn. ($)	2.61	9.51	0.00	399.98
	Telephone share	0.05	0.09	0.00	0.84
	Telephone expn. ($)	17.62	34.96	0.00	401.94
Year=1988	Postal share	0.01	0.03	0.00	0.75
N=5264	Postal expn. ($)	2.80	8.33	0.00	357.78
	Telephone share	0.05	0.09	0.00	0.82
	Telephone expn. ($)	18.21	35.53	0.00	429.65
Year=1989	Postal share	0.01	0.03	0.00	0.89
N=5317	Postal expn. ($)	3.02	8.20	0.00	214.00
	Telephone share	0.05	0.08	0.00	0.93
	Telephone expn. ($)	19.36	38.26	0.00	584.94
Year=1990	Postal share	0.01	0.02	0.00	0.39
N=5446	Postal expn. ($)	2.90	6.62	0.00	87.00
	Telephone share	0.05	0.09	0.00	0.78
	Telephone expn. ($)	20.29	41.07	0.00	551.00
Year=1991	Postal share	0.01	0.02	0.00	0.46
N=5550	Postal expn. ($)	2.51	7.08	0.00	120.55
	Telephone share	0.05	0.08	0.00	0.78
	Telephone expn. ($)	20.79	41.87	0.00	518.72
Year=1992	Postal share	0.01	0.02	0.00	0.75
N=5436	Postal expn. ($)	2.56	7.57	0.00	222.78
	Telephone share	0.05	0.09	0.00	1.00
	Telephone expn. ($)	23.66	45.78	0.00	729.16
Year=1993	Postal share	0.01	0.02	0.00	0.31
N=5299	Postal expn. ($)	2.23	6.85	0.00	122.37
	Telephone share	0.05	0.09	0.00	0.86
	Telephone expn. ($)	23.74	47.63	0.00	742.00
Year=1994	Postal share	0.01	0.02	0.00	0.72
N=4914	Postal expn. ($)	2.13	6.76	0.00	157.32
	Telephone share	0.05	0.09	0.00	0.90
	Telephone expn. ($)	25.55	48.83	0.00	520.00

Table 3--Annual Sample Percentages of Personal Computer Ownership for Interview Survey Sample		
Year	Number of Households	Percent Owning Personal Computer
1988	10,122	7.0
1989	9,907	14.5
1990	10,015	16.2
1991	9,878	17.4
1992	10,028	19.1
1993	10,097	22.3
1994	10.011	24.9

Table 4--Log Infrequency of Purchase Model
(Log-likelihood function value: 19070.6)

	Share equation		**Purchase probability**	
	Estimate	*Std. error*	*Estimate*	*Std. error*
Constant	-6.35e+00	1.76e-01	-6.12e-01	9.78e-02
Log $price_{post}$	-5.59e-02	1.93e-01		
Log $price_{tel}$	8.95e-02	1.08e-01		
nondur. expn	6.82e-01	1.29e-02		
northwest	2.66e-02	5.33e-02	-3.33e-02	3.05e-02
midwest	-5.13e-02	5.27e-02	-4.88e-02	3.01e-02
south	-8.43e-02	5.30e-02	-8.29e-02	3.02e-02
west	2.89e-02	5.44e-02	-5.92e-02	3.10e-02
smsa	-1.93e-01	4.12e-02	-5.21e-02	2.33e-02
famsize	-1.90e-02	1.70e-02		
pers. < 18	-3.82e-02	1.89e-02		
pers. > 64	4.85e-02	2.02e-02		
# earners	-1.35e-02	1.45e-02		
white	-3.38e-03	1.06e-01	3.66e-03	5.91e-02
black	-3.64e-01	1.13e-01	-1.43e-01	6.24e-02
male	-1.85e-01	2.60e-02	-5.42e-02	1.49e-02
married	2.46e-01	4.89e-02		
hsgrad	3.19e-01	3.13e-02	1.65e-01	1.77e-02
>HS, < college	4.52e-01	3.55e-02	2.73e-01	2.04e-02
college grad	6.48e-01	4.05e-02	3.89e-01	2.32e-02
age	1.22e+00	9.28e-02	1.64e-01	4.65e-02
spouse's age	3.40e-01	9.67e-02	5.12e-01	3.19e-02
prof. occupation	1.95e-01	3.19e-02	1.38e-01	1.91e-02
tech. occupation	1.06e-01	3.09e-02	9.40e-02	1.80e-02
self-employed	5.29e-02	4.65e-02	-1.28e-02	2.59e-02
retired	1.43e-01	3.78e-02	7.03e-02	2.29e-02
hrs. of work			-2.02e-04	3.58e-04
spourse's hrs. of work			3.63e-04	3.22e-04
positive income			1.03e-02	2.65e-03
negative income (*dummy*)			-1.52e-01	1.73e-02
comp. ownership prob.	-4.15e-01	1.08e-01	-7.90e-01	6.15e-02
December	3.94e-01	2.85e-02	5.67e-02	1.73e-02
σ	9.80e-01	5.32e-03		

Standard errors are heteroscedasticity-consistent in sense of White (1982).

Table 5--Purchase Probability Derivatives for Log Infrequency Model

	mean dP/dX	***Std. error***
Constant	-2.34e-01	2.02e-02
Northwest	-1.18e-02	1.01e-03
Midwest	-1.72e-02	1.48e-03
South	-2.93e-02	2.52e-03
West	-2.09e-02	1.80e-03
SMSA	-1.84e-02	1.58e-03
White	1.29e-03	1.11e-04
Black	-5.05e-02	4.35e-03
Male	-1.92e-02	1.65e-03
HS grad	5.83e-02	5.02e-03
> HS, < college	9.64e-02	8.30e-03
College grad	1.37e-01	1.18e-02
Age	5.80e-02	4.99e-03
Spouse's age	1.81e-01	1.55e-02
Prof. occupation	4.88e-02	4.20e-03
Tech. occupation	3.32e-02	2.86e-03
Self-employed	-4.51e-03	3.88e-04
Retired	2.48e-02	2.14e-03
Hrs. of work	-7.12e-05	6.13e-06
Spouse's hrs. of work	1.28e-04	1.10e-05
Positive income	3.64e-03	3.13e-04
Negative income (dummy)	-5.37e-02	4.62e-03
Comp. ownership prob.	-2.79e-01	2.40e-02
December	2.00e-02	1.72e-03

Table 6--Sample Mean Household-Level Elasticities from the log-infrequency model

		Log-Infrequency
ϵ_{pp}		-1.06
ϵ_{pt}		-7.64e-02
ϵ_{po}		6.48e-01
ϵ_{pm}		3.18e-01
$\epsilon_{p,comp}$	mean	-6.87e-01
	st. dev.	6.55e-02

Table 7--Sample Mean Elasticity Estimates: log infrequency model with time trend

	ϵ_{pp}	ϵ_{pt}	ϵ_{po}	ϵ_{pm}	$\epsilon_{p,comp}$
1986	-7.58e-01	-1.22e-01	5.18e-01	3.62e-01	1.18e-01
1987	-8.21e-01	-9.29e-02	5.66e-01	3.48e-01	9.19e-02
1988	-8.85e-01	-6.41e-02	6.15e-01	3.34e-01	7.06e-02
1989	-9.49e-01	-3.53e-02	6.63e-01	3.20e-01	6.64e-02
1990	-1.01e+00	-6.51e-03	7.12e-01	3.07e-01	3.81e-02
1991	-1.08e+00	2.23e-02	7.61e-01	2.93e-01	1.79e-03
1992	-1.14e+00	5.11e-02	8.09e-01	2.79e-01	-4.09e-02
1993	-1.20e+00	7.99e-02	8.58e-01	2.65e-01	-9.94e-02
1994	-1.27e+00	1.09e-01	9.06e-01	2.51e-01	-1.68e-01

Table 8--Log Infrequency Model with Time Trends
(Log-likelihood function value: 19195.2)

	Share equation		**Purchase probability**	
	Estimate	*Std. error*	*Estimate*	*Std. error*
Constant	-6.50e+00	1.76e-01	-7.28e-01	9.85e-02
log $price_{post}$	2.42e-01	5.33e-01		
(yearly trend)*log $price_{post}$	-6.36e-02	1.32e-01		
log $price_{tel}$	-1.22e-01	2.21e-01		
(yearly trend)*log $price_{tel}$	2.88e-02	4.67e-02		
log nondur. expn.	6.15e-01	2.09e-02		
(yearly trend)*log expn	8.70e-03	4.80e-03		
northwest	6.54e-03	5.32e-02	-4.97e-02	3.05e-02
midwest	-6.17e-02	5.26e-02	-5.78e-02	3.01e-02
south	-9.52e-02	5.29e-02	-9.16e-02	3.02e-02
west	-3.96e-03	5.44e-02	-8.67e-02	3.11e-02
smsa	-1.87e-01	4.12e-02	-4.95e-02	2.33e-02
famsize	-1.42e-02	1.70e-02		
pers. < 18	-4.19e-02	1.89e-02		
pers. > 64	5.19e-02	2.02e-02		
# earners	-2.28e-02	1.45e-02		
white	1.05e-01	1.07e-01	9.47e-02	5.99e-02
black	-2.41e-01	1.13e-01	-4.23e-02	6.32e-02
male	-2.04e-01	2.60e-02	-7.35e-02	1.50e-02
married	2.24e-01	4.89e-02		
hsgrad	3.12e-01	3.13e-02	1.60e-01	1.77e-02
>HS, < college	4.07e-01	3.59e-02	2.35e-01	2.06e-02
college grad	5.56e-01	4.17e-02	3.11e-01	2.39e-02
age	1.31e+00	9.31e-02	2.50e-01	4.70e-02
spouse's age	3.22e-01	9.66e-02	4.83e-01	3.19e-02
prof. occupation	1.45e-01	3.23e-02	9.55e-02	1.94e-02
tech. occupation	8.85e-02	3.09e-02	7.83e-02	1.80e-02
self-employed	3.34e-02	4.65e-02	-3.18e-02	2.60e-02
retired	1.36e-01	3.80e-02	6.44e-02	2.28e-02
hrs. of work			-3.16e-04	3.58e-04
spouse's hrs. of work			-9.02e-05	3.24e-04
positive income			7.79e-03	2.66e-03
negative income (*dummy*)			-1.60e-01	1.74e-02
comp. ownership prob.	1.09e+00	1.76e-01	7.22e-01	1.02e-01
yeartrend*comp. ownership	-2.16e-01	2.40e-02	-1.81e-01	1.19e-02
December	3.55e-01	2.87e-02	2.42e-02	1.75e-02
σ	9.79e-01	5.32e-03		

Standard errors are heteroscedasticity-consistent in sense of White (1982).

Table 9--Postal Revenue and Estimated Annual Household Expenditures

year	**Estimated Aggregate Postage Expn.** ($, billion)	**Estimated Average Postage Expn.** ($)	**Estimated Aggregate Telephone Expn.** ($,billion)	**Estimated Average Telephone Expn.** ($)	**Total USPS Annual Revenue** ($,billion)	**Revenue Share of House-holds** (%)
1986	5.07	58.19	36.70	421.67	29.12	17.39
1987	5.83	66.89	41.32	474.22	30.50	19.11
1988	5.85	65.87	42.64	480.38	33.92	17.23
1989	6.69	74.26	45.63	506.51	36.67	18.24
1990	6.38	69.88	50.11	549.16	37.89	16.83
1991	5.80	62.71	52.16	563.45	41.92	13.85
1992	6.06	64.20	59.79	633.04	44.72	13.56
1993	5.90	62.75	60.82	647.07	45.91	12.85
1994	5.05	54.35	64.19	690.65	47.75	10.58

Table 10--Consumer Expenditure Diary Survey Summary Statistics

Number of observations: 49089

	Mean	*Std Dev*	*Minimum*	*Maximum*
Postage purchase indicator	0.33	0.47	0.00	1.00
Nondurable expenditures	393.26	289.79	20.00	1698.08
Postage expenditures	2.57	7.60	0.00	399.98
Telephone expenditures	20.46	41.00	0.00	742.00
# postage purchases (in 2 wks)	0.45	0.78	0.00	11.00
Postage expn. share	0.01	0.02	0.00	0.89
Telephone expn. share	0.05	0.09	0.00	1.00
Nondurables prices (Jan 1986=1)	1.15	0.11	0.96	1.30
Telephone price (Jan 1986=1)	1.04	0.02	1.00	1.08
Postage price (Jan 1986=1)	1.18	0.13	1.00	1.32
Computer ownership prob.	0.16	0.16	0.00	0.98
Northwest	0.19	0.39	0.00	1.00
Midwest	0.23	0.42	0.00	1.00
South	0.26	0.44	0.00	1.00
West	0.21	0.41	0.00	1.00
SMSA	0.19	0.39	0.00	1.00
Homeowner	0.64	0.48	0.00	1.00
Renter	0.33	0.47	0.00	1.00
Dorm resident	0.01	0.10	0.00	1.00
Family size	2.61	1.50	1.00	16.00
Pers. < 18	0.74	1.13	0.00	12.00
Pers. > 64	0.29	0.60	0.00	5.00
# earners	1.44	1.00	0.00	9.00
# vehicles	1.65	1.13	0.00	21.00
White	0.89	0.31	0.00	1.00
Black	0.10	0.30	0.00	1.00
Male	0.65	0.48	0.00	1.00
Married	0.58	0.49	0.00	1.00
HS grad	0.31	0.46	0.00	1.00
> HS, < college	0.23	0.42	0.00	1.00
College grad	0.25	0.43	0.00	1.00
Age	0.47	0.17	0.15	0.90
Spouse's age	0.25	0.25	0.00	0.90
Prof. occupation	0.22	0.42	0.00	1.00
Tech. occupation	0.18	0.39	0.00	1.00
Self-employed	0.07	0.25	0.00	1.00
Retired	0.15	0.35	0.00	1.00
Hrs. of work	31.69	20.54	0.00	90.00
Spouse's hrs. of work	14.66	19.59	0.00	90.00
Positive income	2.66	2.65	0.00	48.64
Negative income (dummy)	0.12	0.33	0.00	1.00
December (dummy)	0.14	0.34	0.00	1.00

Table 11--Variable Definitions

Variable Name	***Definition***
Northwest	1 if household resides in Northwest Census region
Midwest	1 if household resides in Midwest Census region
South	1 if household resides in Census Southern region
West	1 if household resides in Census Western region (omitted category is rural residents in all regions)
SMSA	0 if household resides in a Census SMSA; 1 if not
Famsize	Number of members in household
Pers. < 18	Number of persons < 18 yrs of age in household
Pers. > 64	Number of persons > 64 yrs of age in household
# earners	Number of earners in household
White	1 if household head is white
Black	1 if household head is black (omitted category are Nat. Americans + other ethnic groups)
Married	1 if household head is married
Male	1 if household head is male
HS grad	1 if household head is high-school graduate
> HS, < college	1 if household head has some college education
College grad	1 if household head is college graduate (omitted category is high-school noncompleters)
Age	Age of household head
Spouse's age	Age of spouse (if applicable)
Prof. occupation	1 if household head is a professional
Tech. occupation	1 if household head is in a technical occupation
Self-employed	1 if household head is self-employed
Retired	1 if household head is retired
Hrs. of work	Weekly hours of work for household head
Spouse's hrs. of work	Weekly hours of work for spouse (if applicable)
Positive income	Household's income, if >0
Negative income (dummy)	1 if household income is negative
Comp. ownership prob.	Imputed computer ownership probability (details in paper) December 1 if survey month is December

Figure 1

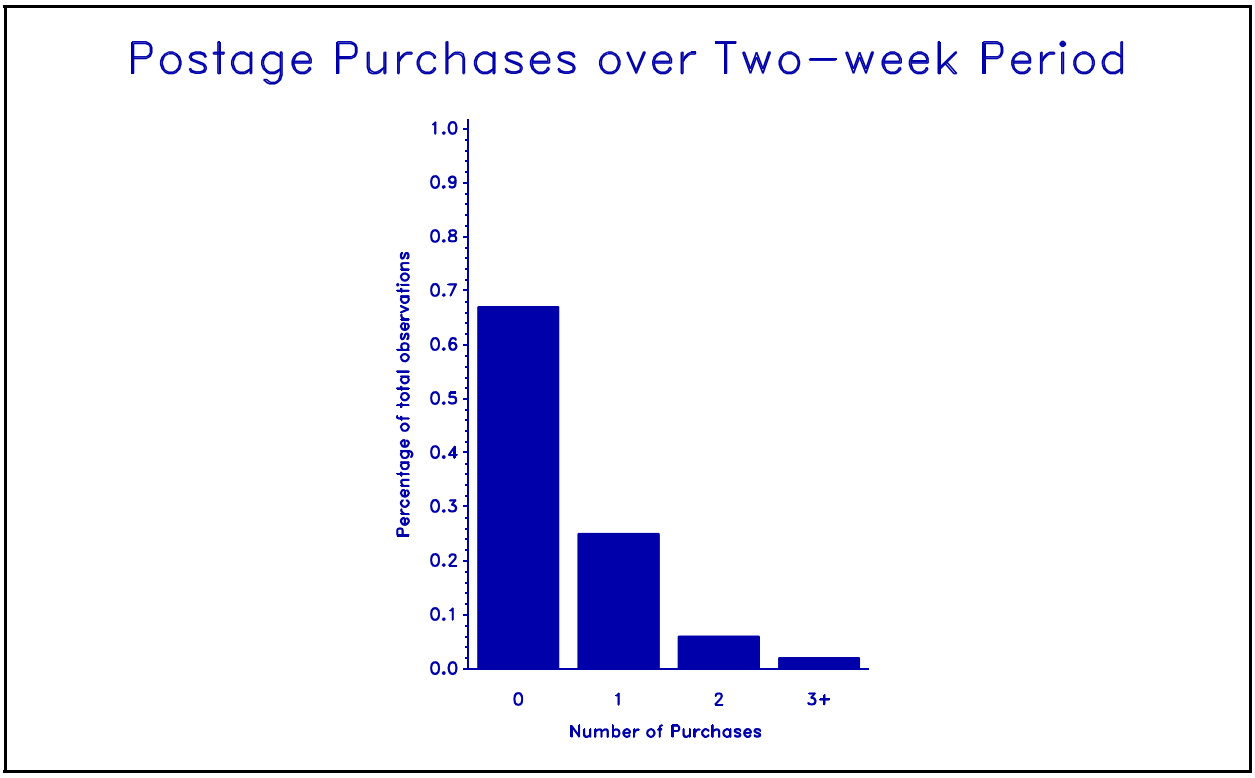

Postage Purchases over Two–week Period
Percentage of total observations
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3+
Number of Purchases

Figure 2

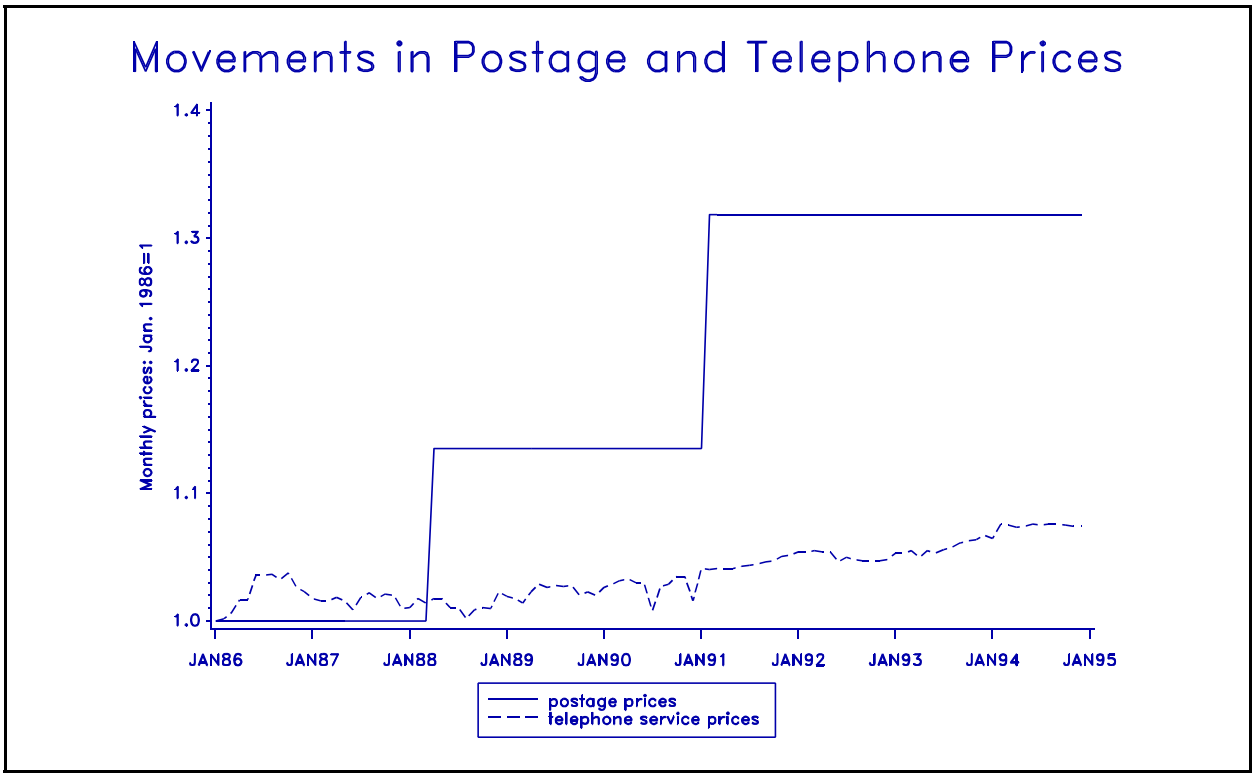

Movements in Postage and Telephone Prices
Monthly prices: Jan. 1986=1
1.4
1.3
1.2
1.1
1.0
JAN86
JAN87
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
postage prices
telephone service prices

Figure 3

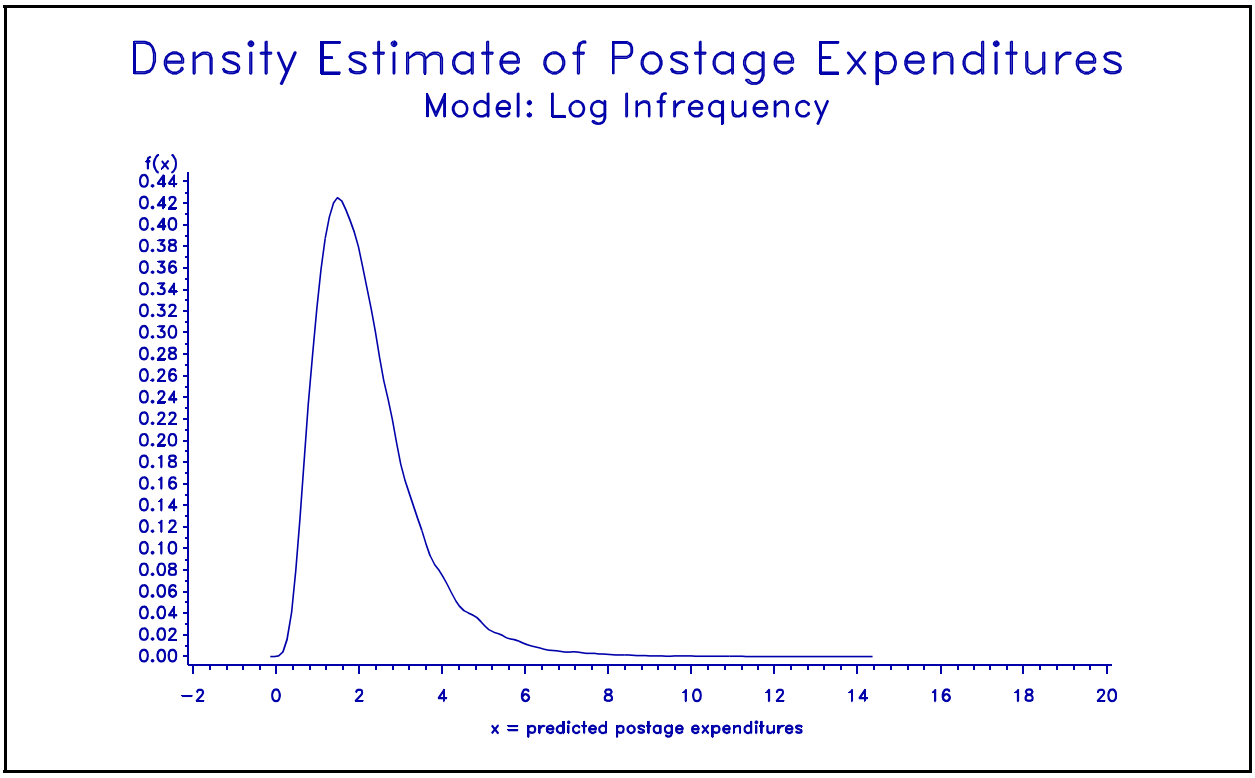

Density Estimate of Postage Expenditures
Model: Log Infrequency
f(x)
0.44
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−2
0
2
4
6
8
10
12
14
16
18
20
x = predicted postage expenditures

Figure 4

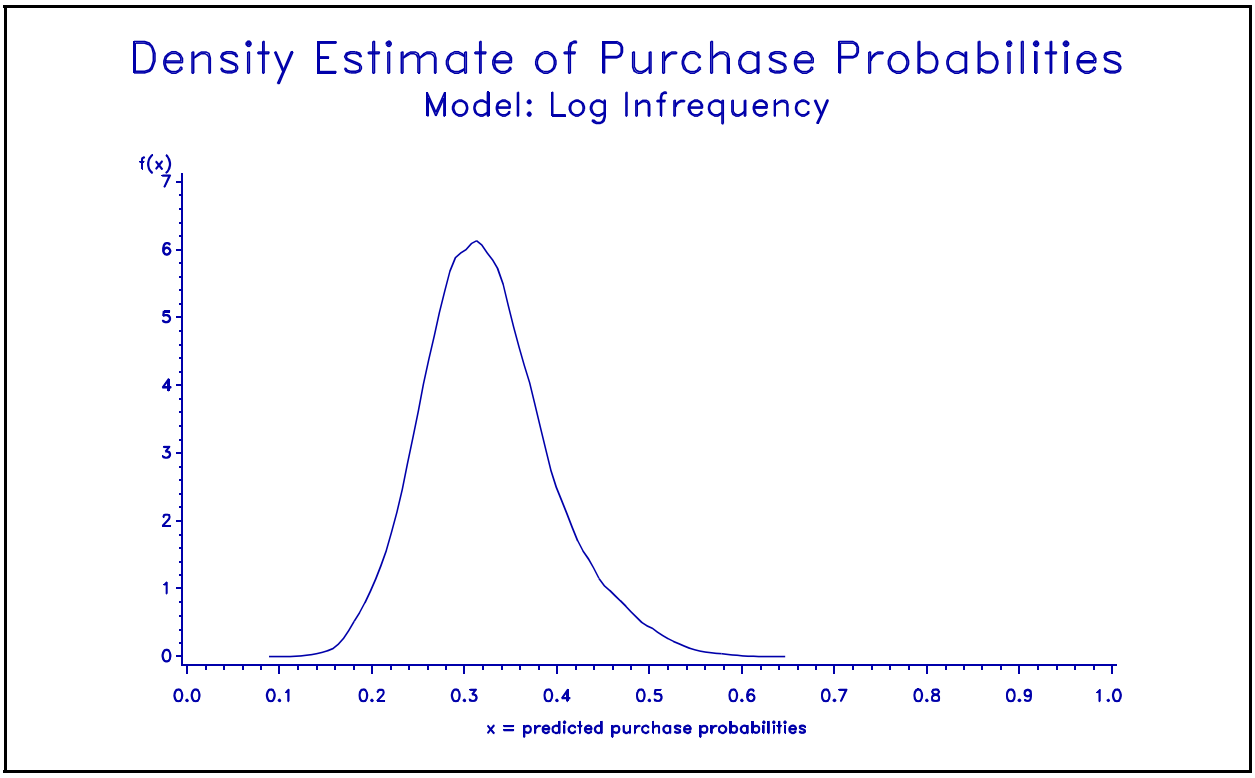
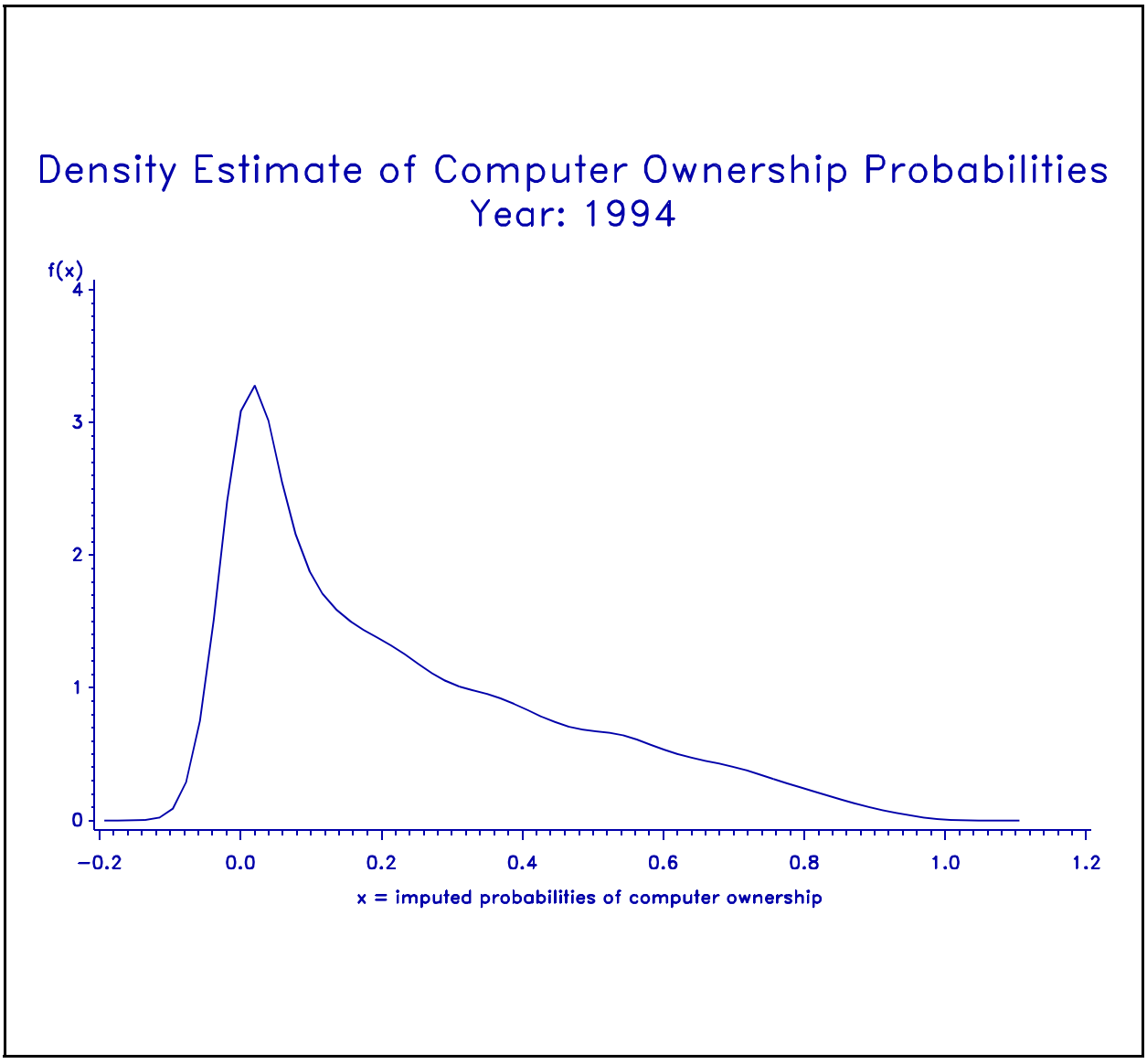

Density Estimate of Purchase Probabilities
Model: Log Infrequency
f(x)
7
6
5
4
3
2
1
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
x = predicted purchase probabilities

Figure 5


Density Estimate of Computer Ownership Probabilities
Year: 1994
f(x)
4
3
2
1
0
−0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
x = imputed probabilities of computer ownership