Modeling the Demand for Optional Classes of Local Measured Telephone Service

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Introduction

Traditionally, local telephone service has been priced by charging customers a flat rate; that is, after paying a single fee, customers may call as much or as little as they desire without affecting their bills. Recently, however, telephone companies have considered, and in some cases implemented usage sensitive pricing schemes or measured service.

Garfinkel and Linhart (1979) cite several reasons for the recent attractiveness of local measured service, or LMS. First, deregulation in the toll and terminal equipment markets has led to increased competition. Revenues from these markets had been used to subsidize local telephone service. The implementation of LMS would enable local telephone service to generate revenues and diminish the need for subsidization. Second, rising energy prices have led to decreased travel, and hence increased telephone usage. Under a flat rate pricing scheme this increased usage does not generate additional revenues as would be the case under LMS. Thirdly, as urban areas have become larger, customers have insisted on local access to larger and larger areas. This service could be provided by simply increasing the flat rate, but this would make telephone service too expensive for some customers. Fourth, LMS will promote a more efficient allocation of resources since it will be a step toward bringing prices more in line with marginal costs. Fifth, inflation has caused the flat rate to increase, pricing some customers out of local telephone service. Finally, Garfinkel and Linhart suggest that it is now technologically possible to monitor local telephone usage at a cost of $5 per year per line, down from $60-$75 per line in 1970.

Auerbach and Pellechio (1978) and Murphy (1972) take another view of measure of service options, and suggest that the introduction of optional classes of measured service is simply another form of price discrimination. The customer selects the pricing option, and the monopolist is able to charge different prices to different customer groups without acquiring any information on their demand curves.

Optional measured service is becoming, and in some cases has become, a reality. Despite this fact, empirical work on optional classes of local telephone service has been scarce. Infosino (1977, 1979) has done the only empirical work to date on optional classes of local telephone service. His model predicts the percentage of customers choosing each class of telephone service, but it is purely a mechanical predicting device, not founded upon economic theory. This paper provides an examination of the choice of class of local telephone service in a discrete choice framework, based upon economic theory. This study aims to fill a void in the empirical work on optional classes of local telephone service.

Measured service experiments have been under way in a number of states for several years. In one experiment authorized by a state public service commission, a telephone utility has permitted customers in several locations to choose whether they wish to be billed under the flat rate pricing scheme, or one of two measured options. The measured options have been designated low-use measured and standard-use measured. The company has collected usage data on those individuals participating in the experiment. Additional data on other demographic, economic, and social variables were collected via questionnaire. This information comprises the data set analyzed herein.

The demand for local measured service options is modeled in a discrete choice framework. The dependent variable is the choice of class of service, either flat, low-use measured or standard-use measured. The choice is a function of the economic, demographic, and social variables. A nested logit model of the class of service decision is estimated for two reasons. The first reason is its ease of computation relative to other methods which could be used to estimate the model. The second reason is that it is flexible enough to account for similarity among alternatives. The low-use and standard-use options are more alike than the flat rate and either of the two measured options. This similarity in the choice set can be easily handled by the nested logit procedure.

The Model

The decision to choose a class of local telephone service can be modeled in a discrete choice framework. Èach customer chooses to be billed under either a flat rate pricing scheme, or one of the two measured options. The remainder of this section traces the evolution of the multinomial logit model from random utility maximization, and then the relation of multinomial logit model to the nested multinomial logit.

Assume that each household possesses an indirect utility function U which depends on household income M, the price of a composite good P_x, and the price parameters reflecting the choice of class of service made by the household. Each pricing option will be represented by three parameters: the access charge P_a, the usage charge or charge per call P_c, and A, the usage allowance. The consumer's indirect utility function may then be denoted by

$$U = U\ (P_a,\ P_c,\ A,\ M,\ P_x).$$

Now assume that each household chooses a pricing option from a set of options offered by the local telephone authority. Each pricing option or price vector P^i is composed of an access charge, a usage charge, and a calling allowance, thus $P^i = (P_a^i, P_c^i, A^i)$. If $P_c^i = 0$ and the calling allowance A^i is infinite or very large, the traditional flat rate pricing scheme is produced.[1] If each household is faced with m price vectors from which to choose, the household should choose the combination of prices and allowances that permits the most utility to be obtained. Since income and the prices of other goods do not vary across choices, the utility function above may be simplified for the choice process to

$$U = U\ (P_a, P_c, A).$$

If the maximum utility attainable given price vector P^i is denoted by U^i, the household's task is to choose the maximum maximorum, that is to select k so that

$$U^k = \max\ [U^1, U^2, \ldots, U^m],$$

and then $P^k = (P_a^k, P_c^k, A^k)$ would be the pricing scheme selected.

The utility maximizing model of class of service choice can be very easily modified for use empirically. The problem will be cast as an expected utility maximization problem. Let U^{ij} represent the perceived attractiveness of price vector P^i to the jth household. Let V^{ij} denote the actual attractiveness of price vector P^i to the jth household. Since the perceived attractiveness may not equal the actual attractiveness due to some lack of foresight on the part of individuals, a stochastic component ε_{ij} is introduced to denote the errors between the two. Thus,

$$U^{ij} = V^{ij} + \varepsilon_{ij},$$

and the perceived attractiveness of each choice is a random variable. This is the classic random utility model (see Da Ganzo, 1980, or Maddala, 1982, for a discussion). Since random elements have been introduced, questions about choices must now be answered in terms of probabilities. In terms of the above, the probability that price vector P^k is chosen by household j is given by $Pr(P^k) =$

$$Pr[U^{k,j} > \max (U^{1,j}, \ldots, U^{k-1,j}, \ldots., U^{k+1,j}, \ldots, U^{m,j})]. \tag{1}$$

The familiar multinomial logit model may be developed from the above if some assumptions about U^{ij} are made. Recall that $U^{ij} = V^{ij} + \varepsilon_{ij}$. Assume that the non-stochastic component V^{ij} is a linear function of variables and parameters so that

$$V^{ij} = \beta' X_{ij} + \alpha_i' Z_j. \tag{2}$$

In this representation, X_{ij} is a vector of choice-specific variables which shall henceforth be called attributes. Attributes, like the expected bill under each class of service, vary from choice to choice. The vector of parameters for these attributes, β, does not vary from choice to choice. In the above, Z_j is a vector of individual specific variables such as income, age of head of household, number of telephones, and other variables which do not vary across choices. They will be henceforth referred to as characteristics. The vector of parameters for these characteristics, α_i, does vary from choice to choice.

If additionally, the disturbance term ε_{ij} is assumed to have an extreme value distribution whose cumulative distribution function is

$$F(\varepsilon_{ij}) = \exp\left[-e^{-\varepsilon_{ij}}\right],$$

the solution of (1) yields selection probabilities of the familiar logit form. If P_{ij} denotes the probability that individual j makes choice i, then

$$P_{ij} = \frac{\exp\left[V^{ij}\right]}{\sum_{k=1}^{m} \exp\left[V^{kj}\right]}$$

where V^{ij} is defined as (2). If a normalization is applied, the probabilities may be written

$$P_{ij} = \frac{\exp\left[V^{ij}\right]}{1 + \sum_{k=1}^{m-1} \exp\left[V^{kj}\right]} \qquad i=1, \ldots, m-1 \qquad (3)$$

and $P_{im} = 1/D$, where D is the denominator in the expression above.

The logit model and its extensions are presented by McFadden (1973, 1976, 1978, 1980) and Domencich and McFadden (1974). The parameters of the logit model presented above can be estimated by the method of maximum likelihood. The likelihood function is in this case of product of several probabilities. If Y_{ij} is a dummy variable taking on the value 1 if the jth household makes the ith selection, and zero otherwise, the likelihood function may be written

$$L = \prod_{j=1}^{n} P_{1j}^{Y_{1j}} \cdot P_{2j}^{Y_{2j}} \cdots P_{mj}^{Y_{mj}}.$$

The probabilities above are of the form given in (3) above. Differentiating the logarithm of the likelihood function leads to several nonlinear equations in α_i' and β. The values of α_i' and β which maximize the likelihood function may be found using an iterative procedure presented in Berndt, Hall, Hall, and Hausman (1974), and discussed in Maddala (1977).

This logit model may be used to estimate the rate choice problem, but there is a difficulty with using this formulation of the problem. One of the consequences of using logit analysis is that it implies the independence of irrelevant alternatives (IIA). The odds of making one choice over another does not depend on the size or composition of the choice set. As one can easily observe, ratios of probabilities of the type given by (3) are not influenced by variables affecting the remaining probabilities.

Logit models typically do not yield reasonable predictions when there is a large disparity in the degree of similarity between the alternatives. This may be the case in the price choice decision being analyzed. Each customer is faced with choosing between either the familiar, "old" flat rate, and the two "new" measured options. The newness of the measured options may, in the perceptions of the consumers, link them together. They may be viewed as being very similar since they are "new," but both are very different from the "old" flat rate. This interaction should be accounted for, but this logit formulation can not handle the problem.

An easy computational method for estimating choice models with similar alternatives is the nested multinomial logit or NMNL procedure outlined by McFadden (1978). The estimation of the NMNL models only requires the repeated use of multinomial logit, and thus NMNL is computationally feasible. To apply NMNL to the class of service problem, one must first examine the choice between the low-use measured option and the standard-use measured option. These selection probabilities and the implied α's and β's can be estimated using multinomial logit which has been outlined previously.

To illustrate how the NMNL procedure accounts for the similarity between the two measured options, one may develop the NMNL procedure from the MNL models previously discussed. Let V_1 denote the linear combination of variables and parameters affecting the probability of the selection of the flat rate, the let V_{21} and V_{22} denote the corresponding linear combinations for the selection of the low-use measured option and the standard-use measured option, respectively. If the MNL procedure were used to estimate the selection probabilities, they would have the familiar form

$$\Pr(\text{Flat rate}) = \frac{\exp[V_1]}{\exp[V_1] + \exp[V_{21}] + \exp[V_{22}]} \tag{4}$$

in the case of the flat rate, for example. The NMNL procedure attempts to take account of the similarity in the two measured options by combining their impact into a single new variable called the inclusive value. This inclusive value may be denoted by I and defined

$$I = \log(\exp[V_{21}] + \exp[V_{22}]). \tag{5}$$

The inclusive value depends on parameters that must be estimated, namely the α's and β's in V_{21} and V_{22}. These parameters may be estimated using MNL, and only information on the customers who choose measured service. The probabilities in this first stage of estimation may be written

$$\Pr(\text{Low-use}|\text{Measured}) = \frac{\exp[V_{21}]}{\exp[V_{21}] + \exp[V_{22}]}.$$

The probability is a conditional probability because the estimation is performed for only those individuals choosing measured service. After the parameters have been estimated using only information on those individuals who choose measured service, the inclusive value may be generated for all individuals, even those who selected the flat rate. Thus, the inclusive value is included as a variable in the second stage, and by substituting (5) into (4) an algebraically equivalent expression is

$$\Pr(\text{Flat rate}) = \frac{\exp[V_1]}{\exp[V_1] + \exp\,[I]}. \tag{6}$$

In order to allow the measured branch to be discounted, the inclusive value is assigned a coefficient of $1-\sigma$ in the second stage. The above expression becomes

$$\Pr(\text{Flat rate}) = \frac{\exp[V_1]}{\exp[V_1] + \exp[(1-\sigma)I]},$$

or, in the form in which the estimation is performed

$$\Pr(\text{Flat rate}) = \frac{\exp[V_1 - (1-\sigma)I]}{\exp[V_1 - (1-\sigma)I] + 1}. \tag{7}$$

The value of σ allows the contributions of the measured options to be discounted if customers do not view them as separate choices. For example, the two polar cases are $\sigma=0$ and $\sigma=1$. If $\sigma=1$ for instance, the above expression becomes

$$\Pr(\text{Flat rate}) = \frac{\exp[V_1]}{\exp[V_1] + 1}.$$

This is exactly the form the probabilities would take in a two choice MNL model. In this case the two measured options have been "fully" discounted in the sense that consumers are either choosing flat or measured, and have been unable to discriminate between the two measured options. At the other extreme $\sigma=0$ implying that consumers view the measured options distinctly. In this case equation (7) becomes

$$\Pr(\text{Flat rate} = \frac{\exp[V_1]}{\exp[V_1] + \exp[V_{21}] + \exp[V_{22}]}$$

which is actually equation (4). Customers view the measured options distinctly so that no discounting occurs and MNL models could be justified.

The coefficient of the inclusive value, $1-\sigma$, is an index of the similarity between the low-use measured service option and the standard measured service option. As $1-\sigma$ increases, or σ gets smaller, the options are viewed as being less similar. As σ increases, or $1-\sigma$ gets small, the choices are being viewed by households much less distinctly.

The NMNL formulation allows the class of service choice problem to be analyzed in a decision tree framework. There are many reasons why it is appropriate to estimate such a model here. First, the NMNL procedure is computationally easy, involving only repeated application of the MNL estimation procedure outlined previously. McFadden argues that numerical experiments indicate that NMNL models give nearly identical fits as HEBA models which allow the use of a decision tree framework. McFadden (1978) has shown that if the coefficient of the inclusive value lies between 0 and 1, the NMNL is consistent with random utility maximization, making it again well founded theoreticallly.

Additionally, it will be very useful to examine the magnitude of σ, the approximate correlation[2] between the two measured options. This coefficient will give an indication as to how customers view these options, which may provide information on whether or not measured service has been successfully marketed. If the coefficient indicates that the choices are viewed as being quite similar, perhaps measured service is not well understood by the public, at least not to a degree which permits discrimination of different measured options. Furthermore, the NMNL approach will permit concentration on the measured/flat decision which is of primary importance for predicting revenues. Bills do not differ as much between measured options as they do between either measured option and the flat rate. Thus, revenues will be much more greatly affected by the measured/flat decision. It is apparent that the NMNL has much to commend it as the technique used to evaluate the class of service decision.

RESULTS

The estimated coefficients in the low-use measured versus standard-use measured decision are presented in column one of Table 1. The logarithm of the odds of choosing low-use measured over standard-use measured may be interpreted as a linear function of these variables. A positive sign on a coefficient indicates that an increase in the corresponding variable will lead to an increase in the likelihood that the customer subscribes to the low-use option. A negative sign on a coefficient implies the opposite. Each variable will be discussed in turn.

The first estimated coefficient is that of the estimated bill. The estimated bill was determined by using the customer's perceptions of his average number of calls per day, and his average call length. These numbers were then used to construct an approximate bill under each of the three pricing schemes. The estimated bill was used to represent customer perceptions of each option, or the relative attractiveness of each option to a customer. In a sense the idea of using the customer's perceived calling patterns rather than actual calling patterns may make this variable a more useful measure. Several studies have found that customers do not tend to be very accurate in their estimation of their calling frequency.

TABLE 1

RESULTS OF THE NESTED LOGIT ESTIMATION

VARIABLE	EQUATION LOW-USE VS. STANDARD USE	 FLAT VS. MEASURED
Estimated bill (low-standard in equation 1 and flat-standard in equation 1)	-0.822 (0.242)*	-0.006 (0.012) [0.012]**
Intercept	0.078 (0.758)	-2.286 (0.683) [0.799]
Number of years in present home	0.185 (0.058)	0.201 (0.050) [0.067]
Number of telephones		0.880 (0.217) [0.220]
Estimated average length of call	-0.058 (0.045)	0.032 (0.036) [0.042]
Dummy variable = 1 if person feels he/she is low caller		-0.818 (0.326) [0.364]
Dummy variable = 1 if some social activity by household member	-0.395 (0.397)	
Age of household head	0.133 (0.092)	0.056 (0.085) [0.112]
Dummy variable = 1 if person is professional or technical worker		0.067 (0.379) [0.472]
Dummy variable = 1 if person is manager, official, or proprietor	0.202 (0.467)	0.624 (0.421) [0.587]

TABLE 1

CONTINUED

VARIABLE	EQUATION: LOW-USE VS. STANDARD USE	EQUATION: FLAT VS. MEASURED
Dummy variable = 1 if person is sales or clerical worker	0.897 (0.574)	0.049 (0.491) [0.698]
Dummy variable = 1 if person is craft worker or foreman	1.442 (0.618)	0.869 (0.525) [0.613]
Dummy variable = 1 if person is semi-skilled worker	-2.211 (0.923)	1.147 (0.942) [0.955]
Dummy variable = 1 if person is service worker	-1.338 (0.719)	-0.932 (0.645) [0.693]
Income category	-0.042 (0.017)	-0.022 (0.013) [0.016]
Interaction (high) educational level x low local calls	0.881 (0.380)	
Inclusive value		-0.570 (0.280) [0.413]
- log likelihood	106.315	131.995

*Figures in parentheses are standard errors.

**Figures in brackets are the adjusted standard errors. For discussion refer to note 3.

Most customers tend to overestimate their telephone usage. However, as far as selecting a pricing structure, the perceived amount of calling rather than the actual seems to be the appropriate measure.

As a consequence of normalizations required by the estimation, the variable is actually the difference between the customer's perceived bill under the low-use measured option, and the perceived bill under the standard-use measured option. Due to some special problems the estimation of this coefficient creates, it will be discussed in a later section of the paper.

The next variable to be discussed is the number of years in the present home. This variable has a positive impact on the probability of the low-use measured option being selected. Although the connection between calling rates and numbers of years in present home was established in the previous chapter, the positive sign of this coefficient may not be a contradiction. For only those customers choosing measured options, an increase in the number of years in the home may lead to diminished calling, and thus increase the probability of the selection of the low-use option. Those customers selecting measured options typically generate lower calling volumes than customers choosing the flat rate option. Those customers have, on average, fewer people in the household and fewer telephones, and are generally employed in occupations which permit substitution for local telephone service. In this group an increase in the number of years in the present home may lead to fewer individuals in the household, and eventually, fewer calls. Thus, for those households choosing measured options, an increase in the number of years in the home may decrease calls, and increase the probability of the selection of the low-use measured option.

The estimated average length of a phone call seems to provide useful information about the selection of class of service. As is to be expected, those individuals who believe that their calls are long are less likely to choose the low-use measured option. The estimated length of call provides some information as to an individual's perception of himself as a caller.

The next variable to be discussed is a dummy variable which has the value one if a member of the household is engaged in some social activity. As anticipated, this social activity may lead to increased telephone usage, and a decreased probability of choosing the low-use option. This expectation seems reflected by the estimated coefficient which has a negative sign.

The next variable is the age of the head of the household. Increases in this variable are seen to have the effect of increasing the probability of the low-use option being chosen. For many of the same reasons that were discussed under the effects of the number of years in the present home, the increased age should lead to decreased calls, and an increased probability of the low-use option being selected.

Before proceeding to the next six variables, a preface may be useful. The next six variables to be discussed are all dummy variables for various employment categories. At first glance their inclusion in a class of service choice model may not seem justified. This is not the case, however, because economic theory suggests that the demand function for a commodity depends on the prices of substitutes, among other things. This is the case with the demand for local telephone calls. Various occupations, specifically office-type jobs, provide much greater possibilities for substituting local calls that normally would be made in the household. Individuals in occupational categories enjoying the option of free local telephone service may exercise this option, and subsequently reduce the number of local calls originating in the household. This implies that individuals in occupations with business telephones may be more likely to choose a measured option. Individuals in occupations without access to business telephone service may be expected to lean toward a flat rate service, other factors being held equal. This substitution just described certainly occurs now in the market for long distance calls, which are frequently made from the office. The evidence about to be presented suggests that to a degree the same phenomenon occurs in the market for local calls.

The first variable to be discussed from the set of occupational dummies takes on the value one if the person is a manager, an official, or a proprietor. As suggested previously, these individuals may be able to make considerable local calls from their work sites, and thus need not call from the home. Such a circumstance permits subscription to the relatively inexpensive low-use measured option. This is indicated by the positive sign or the estimated coefficient of this variable.

The next occupational dummy has the value one if the individual is a sales or clerical worker. Once again due to the possibilities for substitution at work, these individuals are more likely to subscribe to the low-use measured option. The positive sign on the estimated coefficient reflects the anticipated effect.

The next dummy variable has the value one if the individual is a craft worker or foreman. At first glance this coefficient should have a negative sign; however, some occupations in this category are more office oriented than others, and the actual mix of occupations is unknown. The possibility that the office oriented occupations occurred with greater frequency could account for this result.

The next occupational dummy is that of semi-skilled worker. This group is not office oriented, and one would not anticipate that this group had substantial substitution possibilities. This expectation is reflected in the negative sign of the estimated coefficient.

The final occupational dummy variable is for the service worker category. This group also is not generally office oriented, and must thus place the local calls from the household. The estimated negative sign of the coefficient of this variable suggests that this is indeed the case.

The negative sign of the estimated coefficient of the income category variables indicates that increases in income decrease the probability of the low-use measured option being selected. Once again, due to the optional nature of the experiment, measured service was selected if it was less expensive. The low-use measured option has the potential to be the least expensive choice of the three rates, so it is not surprising that increases in income diminish its selection probability.

The final variable included in the equation is an interaction variable which includes those individuals who are highly educated low callers. These individuals may have the easiest time understanding measured service, and measured service may afford them more benefits than moderate or heavy callers. It is not surprising that membership in this group greatly increases the probability of the low-use measured option being selected.

The Flat Versus Measured Choice

The estimated coefficients in the flat versus measured decision are

TABLE 2

NET IMPACT OF VARIABLES ON THE FLAT VS. MEASURED CHOICE

VARIABLE	ADJUSTED COEFFICIENT
Intercept	-2.322
Number of years in present home	0.117
Number of telephones	0.880
Estimated average length of call	0.058
Dummy variable = 1 if person feels he/she is low caller	-0.818
Dummy variable = 1 iof some social activity by household member	0.180
Age of household head	-0.004
Dummy variable = 1 if person is professional or technical worker	0.067
Dummy variable = 1 if person is manager, official, or proprietor	0.532
Dummy variable = 1 if person is sales or clerical worker	-0.360
Dummy variable = 1 if person is craft worker or foreman	0.211
Dummy variable = 1 if person is semi-skilled worker	2.155
Dummy variable = 1 if person is service worker	-0.322
Income category	-0.002
Interaction (high educational level x low local calls)	-0.402

presented in column two of Table 1. In Table 2 the adjusted coefficients are given. These adjustments account for the fact that a change in a variable in the first stage, or the low-use versus standard-use decision, will affect the selection probabilities in the second stage, or flat versus measured decision. The logarithm of the odds of choosing flat over measured is a linear function of the variables in Table 2.

The following discussion will show how the influence of characteristics may occur through the inclusive value. As was indicated previously, the probability of selecting the flat rate in stage two is given by

$$\Pr(\text{Flat rate}) = \frac{\exp[V_1 - (1-\sigma)I]}{\exp[V_1-(1-\sigma)I] + 1},$$

where $I = \log(\exp[V_{21}] + \exp(V_{22}])$. The odds in favor of choosing the flat rate are then

$$\frac{\Pr(\text{Flat rate})}{1-\Pr(\text{Flat rate})} = \exp[V_1 - (1-\sigma)I].$$

The natural logarithm of the odds is thus

$$\log(\text{odds}) = V_1 - (1-\sigma)I.$$

The above expression may be differentiated with respect to the characteristics Z_j to yield

$$\frac{\partial \log(\text{odds})}{\partial Z_j} = \frac{\partial V_1}{\partial Z_j} - (1-\sigma)\frac{\exp[V_{21}]\frac{\partial V_{21}}{\partial Z_j} + \exp[V_{22}]\frac{\partial V_{22}}{\partial Z_j}}{\exp[V_{21}] + \exp[V_{22}]},$$

but $V_{22} = 0$ due to a normalization necessary in order to identify the parameters. Thus, the above can be written

$$\frac{\partial \log(\text{odds})}{\partial Z_j} = \frac{\partial V_1}{\partial Z_j} - (1-\sigma)\frac{\partial V_{21}}{\partial Z_j}(\Pr(\text{Low-use measured}|\text{Measured})),$$

where $\frac{\partial V_1}{\partial Z_j}$ represents the estimated coefficient of some characteristic in the flat versus measured column of Table 1, and $\frac{\partial V_{21}}{\partial Z_j}$ is the estimated coefficient of the same characteristic, if one exists, presented in the low-use versus standard-use column of Table 1. The results of these calculations are given in Table 2. With this knowledge the impacts of the explanatory variables can be discussed.

The first variable is the difference between the bill under the flat rate option and the standard-use measured option. As suggested previously this coefficient will be discussed in a later section.

The next variable to be examined is the number of years in the present home. The coefficient of this variable is significant, and adjusted coefficient indicates a positive effect on the likelihood of choosing the flat rate, which is the expected direction of influence. The longer a family remains in one location, the more interaction occurs between the family and the neighborhood. This interaction is both social and business related. Households remaining in areas longer have more people to call, and thus for those households a greater advantage results from subscribing to the flat rate.

The number of telephones in a household seems to exert a significant positive influence on the probability of the flat rate being chosen. This direction of impact seems correct, and may be substantiated by either of two arguments, both of which suggest that larger numbers of telephones are related to larger numbers of calls. Originally, all customers participating in the study were subscribing to flat rate service. Consider a customer's decision to purchase a second telephone. T... ost of making a telephone call must include some valuation of the individual's time to get to the telephone, though the marginal price of a telephone call is zero under the flat rate pricing scheme. The cost of answering the telephone should also include this time cost. An increase in the number of telephones will decrease the time spent traveling to the telephone. If this time saving is valued more than the price of an additional telephone, the customer is better off with additional telephones. The cost of not having additional phones is directly related to telephone usage, since more trips are required. Thus, customers with several telephones must on average be more frequent users of the telephone than customers with fewer telephones. The direction of the effect may also be defended on the grounds of privacy. Individuals may desire separate lines for reasons of confidentiality. These individuals perhaps move in different social circles, and thus the number of potential calls is greatly multiplied.

The average length of a call estimated by the subscriber has a significant positive effect on the probab lity of choosing the flat rate. One might suspect that those individua s who believe their average call length is large are heavy callers. This plausible hypothesis is substantiated by the empirical results.

The next variable is a dummy variable which equals one if the customer feels he is a low caller. The coefficient of this dummy variable is negative and significant. This is precisely to be expected since low callers may benefit from choosing one of the measured options instead of the flat rate.

The next variable included via the inclusive value is a dummy variable which equals one if some household member is involved in some social activity such as club membership or church groups. Engaging in social activities probability increases telephone use. Increased telephone usage should lead to an increased likelihood of choosing the flat rate. This suggestion is borne out by the positive sign of the adjusted coefficient for this variable.

The next variable to be examined is the age of the household head. The estimated coefficient is positive, but not significant, and the adjusted coefficient is negative. The direction of impact of this variable cannot be ascertained. As age increases, more social contacts are made thereby suggesting they should make more calls increasing the probability of choosing the flat rate. However, as previously suggested, the work of Brandon and Mahan indicates that the elderly make fewer calls, which thus increases the probability of their choosing a measured option. The results of the analysis of the data from this experiment are inconclusive.

The first coefficient estimated for the group of employment dummies is that for the "professional or technical worker group." Included in this category are occupations like engineer, scientist, doctor, teacher, and clergy. These occupations are office oriented, and thus one might expect the estimated coefficient to be negative. It is positive, although not significant, as is the adjusted coefficient. It is not possible to determine the frequencies with which various occupations are present in the group. The possibilities for substituting local calls is not the same for all occupations within a group, and the results could have been influenced by a disproportionate representation of some occupation with relatively little office substitution possibilities.

Another possible explanation of this employment group result may lie in the fact that the opportunity cost of calling from the office may be very large for some occupations. For example, lawyers and doctors certainly have telephones available for use during their workdays, but the cost of their use in terms of foregone earnings may be too large. This certainly does not preclude the use of secretaries by doctors and lawyers for some local calls, however some calls may be of a type that must be made by the doctor or lawyer--calling one's spouse, for example. The composition of the employment category and the foregone earnings may account for the estimated coefficient.

The next occupational dummy variable is for the "manager, official, or proprietor" group. Included in this category are occupations like executives, store managers, farm owner or manager, postmaster, and other supervisory personnel. The positive sign for this coefficient is unexpected, but this category may include many self-employed people whose residential and commercial telephone use may be combined to a degree. This could account for the fact that workers in this category had a greater tendency to select the flat rate.

The next category to be examined is that of "sales or clerical workers." Included in this category are secretaries, bookkeepers, bank tellers, cashiers, postal workers, telephone operators, and sales people. One might expect that this group has some possibility for substituting local calls at the worksite. This tendency is reflected in the negative adjusted coefficient for this variable.

The next coefficient estimated for the group of employment dummies is that of the "craft worker or foreman" group. Included in this employment group are carpenters, plumbers, engravers, line installers and repairers, radio and TV repairers, machanics, bakers, upholsterers, and other similar occupations. Most of the occupations listed above are not office oriented, and thus do not present possibilities for the substitution of local calls. The fact that the bulk of local calls must originate in the hosehold is reflected in the positive sign of the adjusted coefficient of the "craft worker or foreman" employment dummy.

The next employment category is the "semi-skilled worker" group. Occupations like deliveryman, brakeman, factory worker, welder, parking attendant, textile weaver, mineworker, and others are included in this group. These occupations are also in general not office oriented, and thus customers in these occupations may have larger home calling burdens. These large home calling burdens should be reflected by an increased probability of choosing the flat rate. This hypothesis is again substantiated by the positive sign of the adjusted coefficient of this income group.

The final employment dummy used is for individuals in the "service-worker" category. Included in this group are barbers, police officers, practical nurses, airline flight attendants, janitors, cooks, housekeepers, and others. The adjusted coefficient of this variable is negative. The negative sign may be justified because many of these occupations provide opportunities for free local telephone use. Those individuals using business phones for personal calls may be able to save by choosing one of the measured options.

The next coefficient is that of income category. The estimated coefficient is negative, and so is the adjusted coefficient. It seems that over the range of incomes in the sample, increase in income primarily affect measured users. Additional income causes these individuals to switch from low-use measured to standard-use measured. The flat versus measured choice is unaffected, and this is reflected in the very low adjusted coefficient.

Another variable which has an effect through the inclusive value is a dummy interaction variable. This variable is the product of high educational level and low local calls. Membership in this group should predispose one toward either of the measured options. This is equivalent to saying that membership in the group should decrease the probability of the flat rate being selected. This is again evident in the negative sign of the adjusted coefficient estimate.

The final coefficient estimated is that of the inclusive value. The value of the estimated coefficient, -0.570 corresponds to a value of σ equal to 0.430, which approximately measures the correlation between the two measured options. This value provides much useful information. First, the fact that the value lies in the unit interval indicates that the nested model estimated is consistent with random utility maximization, and thus firmly theoretically based. Second, the fact that the correlation is large indicates that customers are not easily discriminating the two measured options, and that customers view the options as being very similar. The inability of the customers to distinguish the measured options can be explained in several ways. The measured options may not have been successfully marketed or sold to the public, due to insufficient effort by the marketing department of the telephone company, or it may be simply that the public finds measured service a difficult subject to comprehend.

The impact of the marketing of measured service or its acceptance rate may not be as large as the effect of the expense of the flat rate. In the data analyzed herein the flat rate remained at its previous, relatively low, level. Thus, the cost of not understanding measured service, or the flat rate price, was really not very great. It seems logical that when the flat rate is increased, the cost of not understanding measured service will increase, and customers will begin to seriously examine the measured options. After the flat rate is increased, the price incentive to investigate measured service will have been established. The perceived similarity of the measured options should diminish under the condition of increasing flat rates.

For purposes of comparison, the results of the 2-choice logit estimation are given in Table 3. The estimation of this case may be interpreted as an estimation of the nested logit model in which the correlation between the two measured service options is perfect, that is $\sigma=1$. Notice how consistently Table 3 corresponds to Table 2. This occurs because of the high degree of similarity between the two measured options, and is in fact further evidence supporting the contention that these choices are highly correlated.

The Effect of Increasing the Flat Rate

It is likely that local telephone companies will increase the flat rate when measured service is implemented for general residential use. In this section some predictions based on the results in the first two sections will be made concerning the impact of this increase or the subscription or "take rate" of flat rate pricing. Following this discussion an analysis of customer decisions based on the break points will be presented.

The coefficient of the estimated bill is critical in determining what effect an increase in the flat rate wil have on the number of custom-

TABLE 3

RESULTS OF THE 2-CHOICE LOGIT ESTIMATION (σ=1)

VARIABLE	FLAT VS. MEASURED
Estimated bill	-0.022* (0.012)
Intercept	-2.462 (0.681)
Number of years in present home	0.134 (0.039)
Number of telephones	0.837 (0.216)
Estimated average length of call	0.037 (0.033)
Dummy variable = 1 if person feels he/she is low caller	-1.000 (0.297)
Age of household head	0.002 (0.079)
Dummy variable = 1 if person is professional or technical worker	0.051 (0.376)
Dummy variable = 1 if person is manager, official, or proprietor	0.364 (0.396)
Dummy variable = 1 if person is sales or clerical worker	-0.491 (0.411)
Dummy variable = 1 if person is craft worker or foreman	1.460 (0.458)
Dummy variable = 1 if person is semi-skilled worker	0.949 (0.917)
Dummy variable = 1 if person is service worker	-0.695 (0.641)
Income category	-0.010 (0.012)
- log likelihood	132.007

*Figures in parentheses are standard errors.

ers choosing an option. As was noted earlier, there is a single estimated coefficient for each attribute, thus there should be a single estimate of the coefficient of the estimated bill. This is not the case. The nested logit procedure yields multiple estimates of the coefficients of attributes. The "estimated bill" coefficient in the first stage, or β_1, was -0.822. The second stage estimate was $\beta_2 = -0.006$. These estiamtes must be resolved if the model is to be used for prediction.

The solution employed herein is to combine the two estimates β_1 and β_2 into a single estimate β by finding the variance-minimizing linear combination of β_1 and β_2. A linear combination is chosen so that the estimator β will be consistent. Thus, the task is to choose a new estimate β, so that,

$$\beta = \lambda\beta_1 + (1-\lambda)\beta_2.$$

The variance of β is then

$$\mathrm{var}(\beta) = \lambda^2\beta_1^2 + (1-\lambda)^2\sigma_2^2 + 2\lambda(1-\lambda)\sigma_{12},$$

where σ_1^2 is the variance of β_1, σ_2^2 is the variance of β_2, and σ_{12} is covariance between β_1 and β_2. Minimization of the expression leads to a solution for λ in terms of σ_1^2, σ_2^2, and σ_{12}. Application of this procedure implies that $\beta = -0.013$.

In order to assess the impact of increases in the flat rate one must examine the derivative of the probability of choosing the flat rate with respect to the price of the flat rate. Previously, the following was shown

$$\frac{\partial P_{ij}}{\partial X_i} = \beta P_{ij}(1-P_{ij}).$$

If the above expression is evaluated with P = .85 to reflect the probability of selecting the flat rate from the entire sample, $\frac{\partial P_{ij}}{\partial X_i} = -0.002$. This result indicates that, at least for some range around the current flat rate price, changes in the flat rate have a negligible effect on the number of subscribers.

Further evidence of this lack of sensitivity of the "take rate" to price of flat service is found in Figure 1. This graph illustrates bill-minimizing behavior in terms of number of calls where each call is of length three minutes. Survey results indicate that the average number of monthly calls by households subscribing to the flat rate is in the vicinity of 175 calls per month. As Figure 1 illustrates, at this number of calls the flat rate would have to increase nearly 100% to make its price comparable to the bill under either of the measured options. Thus, it seems clear that increases in the flat rate would have to be very large to affect behavior at the typical 175 call level. Of course it is also possible that customers might elect to switch to measured service and "repress" or cut down their usage in order to avoid large bills under the flat rate pricing scheme. As Figure 1 suggests, the current flat rate expenditure on either measured option would only purchase about 75 calls each month, less than half the number of calls usually made by flat rate subscribers. This represents a great compromise in the number of local calls made each month. The truth may lie somewhere between these scenarios. The empirical results suggest that the flat "take rate" will not be influenced by price increases of a moderate type. Increases of 50% in flat rate price, normally a large increase, probably will not affect

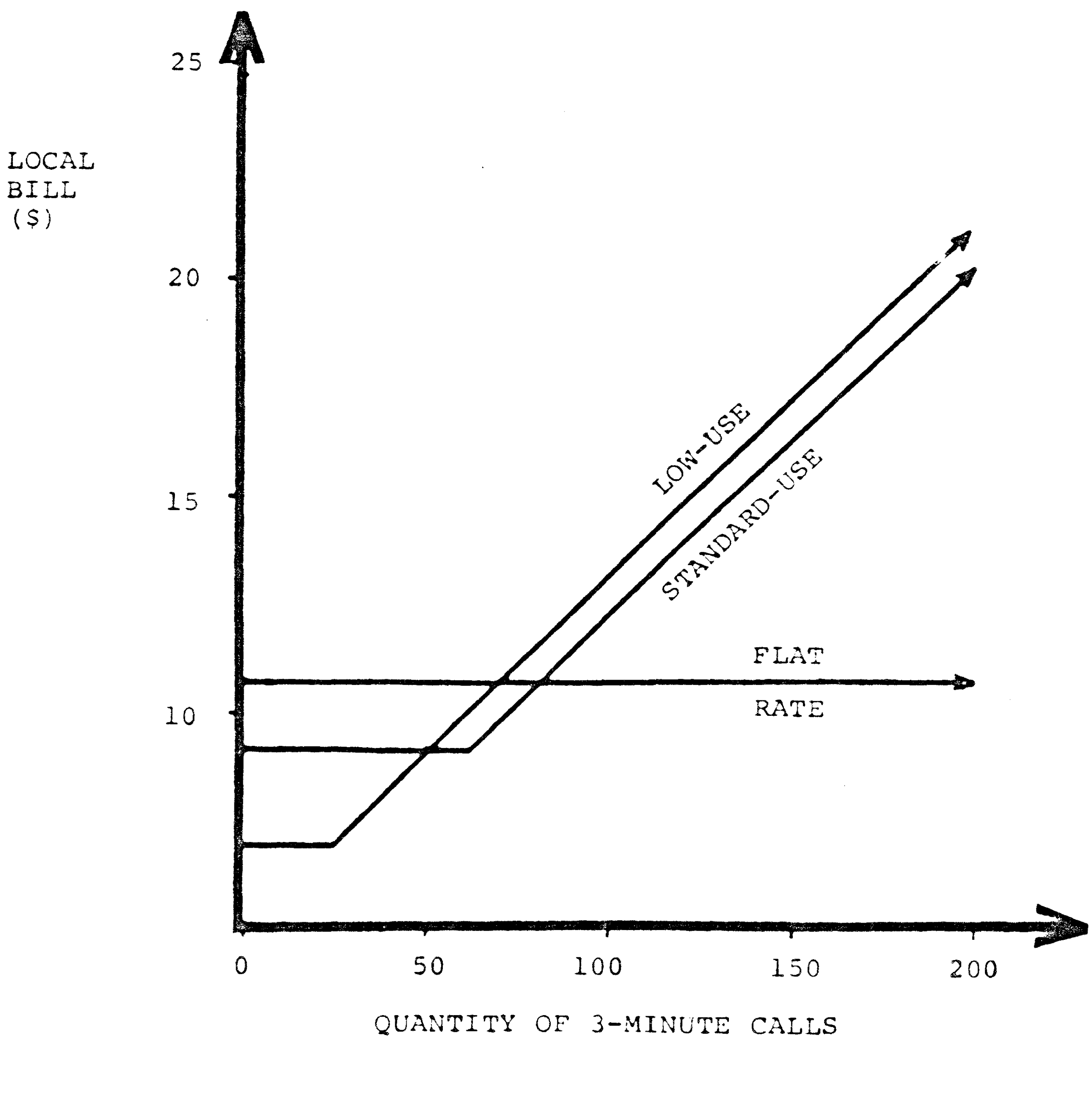

Figure 1. Bill as a Function of the Number of 3-Minute Calls.

the "take rate." The empirical results and the analysis of the bill-minimizing customer behavior both suggest that this insensitivity is the case.

Selected Elasticity Estimates

Table 4 gives some selected elasticities calculated at the means of the variables. These elasticities reflect the impact a 1% change in each variable would have on the proportion of customers subscribing to the flat rate option. The table is based primarily on variables that were of special importance or highly significant. These results suggest that the number of telephones in the household greatly increases the flat rate subscription. It is also apparent that the length of time one spends in a neighborhood increases the probability of choosing flat rate. Thus, one might expect flat rate subscription to be high in older neighborhoods. Another obvious result is the striking similarity between the elasticities estimated by NMNL and the 2-choice logit method. This is consistent with the presumption that the measured options are similar, and could be pooled into a single measured category with little loss of information.

Conclusions

The implementation of measured service at some time in the near future is certain. There are several reasons why measured service looks like the trend of the future in the pricing of local telephone calls.

Regulatory changes occurring in the telecommunications industry included competition in the toll market, which has reduced revenues from which local service had previously been subsidized. The loss or reduction of market power in the toll and terminal equipment markets will lessen subsidies available for local service. Local service could be salvaged

TABLE 4

SELECTED ELASTICITY ESTIMATES CALCULATED AT THE MEANS

VARIABLE	ESTIMATION METHOD NMNL	ESTIMATION METHOD 2-CHOICE MNL
Estimated bill	-0.021	-0.035
Number of years in present home	0.098	0.113
Number of telephones	0.226	0.215
Dummy variable = 1 if person feels he/she is low caller	-0.071	-0.087
Income category	-0.007	-0.034*

*These elasticities were calculated using coefficients whose t-ratios were less than one in absolute value.

by simply increasing the flat rate, but this would price some customers out of the market for a telephone. Since universal service at reasonable prices is one of the goals of the telephone industry, this solution is not satisfactory.

LMS could be used, in the absence of subsidies from the toll and terminal equipment markets, to provide low cost local telephone service. By offering low access charges, LMS still provides service at a low connection fee, thereby still permitting the attainment of a universal service goal. By charging separately for usage, LMS will bring customers' bills more in line with the costs they impose on the system. Customers who make excessive numbers of local calls would, under LMS, have large bills. Infrequent callers would have low monthly bills. This would eliminate the subsidy from low callers to high callers which occurs under a flat-rate pricing scheme. LMS could solve the revenue problem caused by the subsidy loss without making telephone service too expensive for some to afford.

Rising energy prices have made the telephone more prominent in household search activities. This has led to increased telephone traffic, but under flat rate pricing no additional revenues are generated. LMS would cause additional traffic to generate additional revenues.

In addition, increased urbanization has increased the demand for local calls, but no increases in revenues occur under flat rate pricing schemes. LMS provides a solution to this problem.

Finally, LMS has now become practical because the costs of monitoring a line have dropped to only $5 per line per year. Increased technology has made LMS a possibility that can be explored.

Murphy (1977) provides a different perspective of the implementation of LMS options. He argues that the provision of LMS options is actually a form of price discrimination. It is well known that a monopolist could perfectly price discriminate if enough information on individual demands was available and arbitrage was expensive. In the case of local telephone service, arbitrage would be relatively expensive, and the collection of information on individual demands would be very costly. However, the provision of LMS options then provides an explicit metering system for local calls. The consumers essentially identify themselves. This metering system also provides a hedge against shift in the demand for local calls in the future. Proper selection of these LMS options would permit a discriminating monopolist to increase profits without gathering data on individual demands. Thus, LMS options may be presented to fill the gap when present cross subsidies are eliminated.

In all likelihood, LMS will soon become a reality, but the absence of empirical research creates uncertainty about implementation of LMS options. This research provided some insight into what customer groups preferred measured service. One of the strongest empirical results was that LMS appealed to well-educated low callers. Due to the pricing schedules presented in the measured options, low callers nearly always chose LMS because they could reduce their bills. The well-educated group is composed of individuals who are able to understand the more complex LMS price schemes. Because of the pricing options offered, only low callers switched to LMS in order to reduce their bills.

Another finding of this study is the perceived similarity between the low-use measured option, and the standard use measured option. The approximate correlation coefficient between the two was .43. In light of the pricing schedules offered, this is really no surprise. Based on the number and duration of calls customers believed they made each month, the average bills for the area were as follows: low-use, $20.73; standard-use, $20.29; and flat rate, $10.65. The difference between the low-use and standard-use bills was only 44 cents. In addition to not differing monetarily, the measured options were both new, and presented very similar pricing schemes. The similarity of the measured options was certainly enhanced by the low charge under the flat rate. If the flat rate were substantially increased, customers would carefully examine LMS options in order to avoid large bills. This careful examination would lead to increased discrimination between the two measured options. Thus, the high similarity is probably only a manifestation of the experimental design.

Mitchell and Park (1981) note that substitution of local calls from homes to businesses may result from optional measured service. These new results presented here suggest that customers who have telephones available at their worksites do select measured service, and shift some calls to the worksite, thereby reducing their bills. This tendency is reflected in the estimated coefficients of some of the occupational category dummy variables. It is not possible to assess the amount of traffic that might be switched to businesses based on the results of this research. The matter should be explored further.

NOTES

[1]When the marginal price is zero for additional calls, there is still a time cost. The time related cost component of the price of a call may result for several reasons. It may partially be due to opportunity cost factors related to foregone earnings or foregone household consumption. This interpretation is somewhat tempered by the fact that possibly several individuals in the household have access to the telephone, and some customers, like children, may have to forego little in order to use the telephone. This component may also refer to the excludability of telephone use. If one individual is using the telephone, no others may use the phone. In addition, no incoming calls may be received. All of these factors relate cost to length of call.

[2]McFadden was unable to prove that σ is the correlation. By numerical methods he did find the relation, $\sigma \leq \rho \leq \sigma + 0.045$, thus σ is approximately equal to the correlation coefficient.

[3]The correction of the covariances in the second stage is given by Amemiya (1978). If Σ_2 denotes the estimated variance-covariance matrix in the second stage, Σ_1 denotes the variance-covariance matrix in stage one, and Σ_{21} denotes the covariance matrix between the first and second stage estimates, the adjusted variance-covariance matrix of stage two or Σ_2^* is thus,

$$\Sigma_2^* = \Sigma_2 + \Sigma_2 \Sigma_{21} \Sigma_1 \Sigma_{12} \Sigma_2.$$

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