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Estimation of Unbiased Price Elasticity of Calling Demand: Sequential Estimation on Tokyo Metropolitan Households†

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Since 1985, the Japanese government has been promoting competitive policies; consequently, new services have been aggressively introduced and the subscription for mobile phone service now exceeds that for plain old telephone service (POTS). To qualitatively evaluate the impact of these policies on households, an accurate price elasticity for neighboring telephone services is required. Using the micro data of households in the Tokyo Metropolitan Area between 1997 and 2000 as an example, the authors propose a two-step seemingly unrelated regressions estimate for household telephone demand that explicitly considers subscription decision-making, and prove the necessity of such a treatment to obtain an unbiased estimation.

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1. INTRODUCTION

In 1985, the Japanese telecommunications market was opened to competition. Thereafter, the number of telecommunications carriers has risen steadily, reaching at more than 13,000 today. Meanwhile, local and long-distance calling rates have dropped by 15%–25% and 80%–96%, respectively. New services have been aggressively introduced and subscription for a mobile phone service now exceeds that for a plain old telephone service (POTS). In an understatement, we can conclude that the Japanese telecommunications policies over the past several decades have been remarkably successful (Jitsuzumi, 2006) and have also been highly evaluated from the viewpoint of economic efficiency. However, the impact of these policies on income distribution is yet to be known, and therefore, it is possible that this success has been achieved at the expense of equality among consumers. Policymakers in the telecommunications sector need to make two considerations: (1) efficiency within the telecommunications sector and (2) fairness among the telecommunications users and related groups. Therefore, if the past market development has negatively influenced income equality among subscribers, some remedial policy initiatives need to be introduced.

In order to ascertain whether or not such an impact of inequality has indeed occurred, an accurate price elasticity for neighboring telephone services is needed. There exist several empirical attempts at such an estimation, although they are few due to the difficulty in building data sets (Table 1). However, all of these studies—with the exception of Okada and Hatta (1999), Kawamura *et al*. (2000), Nakamura (2004), and Nakamura and Jitsuzumi (2006)—fail to consider "the calling demands inter-relationship" between mobile phone and fixed telephone services; thus, their estimations are not applicable to the current situation in Japan, where the number of mobile phone subscribers is surpassing that of fixed telephone users, and some consumers (especially the younger generation) tend to subscribe only to mobile phone services. Conversely, Okada and Hatta (1999), Kawamura *et al*. (2000), Nakamura (2004), and Nakamura and Jitsuzumi (2006) explicitly take neighboring services into consideration, thereby rendering their estimated elasticities a much wider applicability. However, they do not consider consumers' subscription behavior, that is, their estimates assume that subscription to each telephone service is exogenously fixed. If consumers' subscription behavior and their telephone usage behavior were mutually related, then without considering their subscription choices, the estimated parameters in telephone usage demand functions would be biased. Therefore, the impact of a decline in the above-marginal calling price may not be accurately predicted.

Table 1 Previous Studies on Telephone Demand

In this article, by taking consumers' subscription choices into consideration in order to estimate the household demand for telephone services, the authors propose a two-step simultaneous equations household telephone demand system that explicitly considers subscription decision-making, and justify this approach to acquire the unbiased estimates.

In concrete terms, we estimate the model using the Heckman-Lee two-step method. In our framework, it is assumed that every household uses "I-POTS" (the incumbent NTT's[1] "plain old telephone service") and that they have to determine whether or not to subscribe to "NCC[2]-POTS" (new entrants' long-distance POTS) and/or "mobile phone service." Further, in order to endogenously determine the subscription to each telephone serviced, our model consists of selection equations and regression equations. In the first step, we estimated two probit selection equations, one for NCC-POTS and the other for mobile phones, assuming that two selection decisions were made sequentially. In the second step, we estimated the telecommunications expenditure function by following the Almost Ideal Demand System (AIDS), which was estimated using Zellner's iterative seemingly unrelated regressions (Deaton and Muellbauer, 1980). By following these steps, we can estimate the "unbiased" elasticity and statistically test whether or not subscription behavior should be considered. Our estimation proves that the subscription functions should be taken into consideration in order to estimate the telephone expenditure function; otherwise, the estimated parameters in the telephone expenditure function would contain a self-selectivity bias.

This paper is organized as follows. In the next section, we present our econometric framework for estimating the household telephone demand system. The data description is presented in Section 3; the estimated parameters and their significance levels are presented in Section 4. Section 5 concludes this article by providing a brief summary of our findings and presenting the simulation results for equivalent variations of uneven price declines; in addition, issues pertaining to the limitations of this paper and future research directions will be discussed in this section.

2. MODEL

2.1. Two-stage model

First, we will assume that each household faces the decision tree for subscribing to neighboring telecommunications services, as illustrated in Figure 1[3]. A household first decides whether or not to subscribe to NCC-POTS (Substage 1). Thereafter, it decides whether or not to subscribe to a mobile phone service (Substage 2). Then, each household belongs to any one of the following subscription patterns: (1) subscribing only to I-POTS; (2) subscribing to I-POTS and NCC-POTS; (3) subscribing to I-POTS and a mobile phone service; (4) subscribing to I-POTS, NCC-POTS, and a mobile phone service. Thereafter, they determine their budget allocation for the selected telephone services (Second stage).

Figure 1: Assumed decision-making mechanism

As we explained earlier, the household is assumed to determine the subscription pattern as a result of dynamic optimization[4]. Our econometric model is proposed in accordance

[1] Nippon Telegraph and Telephone Corporation is the incumbent telecommunications carrier in Japan that provides local and long-distance telephone service.

[2] New Common Carriers, or the competing long-distance service operators.

[3] We can also suppose that the household faces four subscription patterns at the same time and decides on a pattern among these. However, telecom demand system estimation (second stage estimation) is too complicated to estimate when we suppose simultaneously deciding subscription patterns. This is the reason why we suppose two substage sequential subscribing decision processes—a decision process in which a household first decides on NCC-POTS subscription and then decides on mobile phone subscription.

[4] Train (2003) explains various dynamic optimization applications. Indirect utility functions in his

with a sequential self-selection model in Lahiri (2000).

2.2. First Stage: Selection Equations

As mentioned earlier, we assumed that all households had already subscribed to I-POTS before the beginning of the first stage[5]. Then, at the beginning of the first substage, a rational individual household *i* faces the decision of whether or not to subscribe to NCC-POTS in addition to I-POTS. With regard to the subscription decision for NCC-POTS, we assumed that the decision to subscribe to NCC-POTS is made on the basis of the linear indirect utility function as illustrated below.

$$I_{i,NCC} = Z_{i,NCC}\alpha'_{NCC} + \varepsilon_{i,NCC}$$

where $I_{i,NCC}$ is calculated by subtracting the utility when subscribing to NCC-POTS from the utility when not subscribing to it. $\varepsilon_{i,NCC}$ is a normally distributed error term with mean 0. $Z_{i,NCC}$ is a vector of alternative specific variables and household *i*'s socio-demographic variables.

After substage 1, that is, after making the fixed phone subscription decision, the individual household *i* decides whether or not to subscribe to a mobile phone service at the beginning of the second substage. We also assumed that the decision to subscribe to a mobile phone service is made on the basis of the linear indirect utility function as illustrated below.

$$I_{i,mobile} = Z_{i,mobile}\alpha'_{mobile} + \varepsilon_{i,mobile}$$

where $I_{i,mobile}$ is calculated by subtracting the utility when subscribing to a mobile phone service from the utility when not subscribing to it. $\varepsilon_{i,mobile}$ is also assumed to be normally distributed. $Z_{i,mobile}$ is a vector of alternative specific variables and household *i*'s socio-demographic variables.

To estimate the mobile phone subscription decision, we can employ the probit model as before. However, the means of these error terms are generally not equal to 0 with only the NCC-POTS subscribers' sub-sample set (or only the NCC-POTS non-subscribers' sub-sample set). This difference represents a self-selection bias. Therefore, following an idea from Heckman-Lee's two-step method, we insert the inverse Mill's ratio calculated from the result of the NCC-POTS subscription estimation into the mobile phone subscription equation. For the NCC-POTS subscribers' sub-sample set, we will obtain the unbiased parameter by estimating the following equation:

$$I_{i,mobile} = Z_{i,mobile}\alpha'_{mobile} + \sigma_{NCC,mobile} \times \phi\left(Z_{i,NCC}\alpha'_{NCC}\right) / \Phi\left(Z_{iNCC}\alpha'_{NCC}\right)$$

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examples are assumed to be time-separable and linear. A similar analogy could be applied to the decision on telecom services subscription. We assumed the order of the decision-making process as first, the NCC-POTS subscription decision, followed by the mobile phone service subscription decision. This order is based on the historical order in which each service was introduced in Japan. We assumed that each household made the NCC-POTS subscription decision without considering the mobile phone subscription decision. In this sense, our estimation model considers the case of uncertainty with future effect.

[5] In our sample data, approximately 96% of households subscribed to I-POTS.

where $\sigma_{NCC,mobile}$ is the covariance between $\varepsilon_{i,NCC}$ and $\varepsilon_{i,mobile}$.

In order to confirm whether this sequential subscribing process is justified, we can statistically test the significance of $\sigma_{NCC,mobile}$ after the estimation.

After these estimations, each household's subscription pattern is determined.

2.3. Second Stage: Expenditure Function

In this section, we express the model for the telephone expenditures of a household that subscribes to all the three telephone services as follows:

$$\ln E(P_1, P_2, P_3; u) = a_0 + \sum_i a_i \ln P_i + \frac{1}{2}\sum_{i,j} b_{ij} \ln P_i \ln P_j + uc_0 P_1^{c_1} P_2^{c_2} P_3^{c_3}$$

where E is the total expenditure amount for all three telephone services. $u = \ln(E/P)/c_0 P_1^{c_1} P_2^{c_2} P_3^{c_3}$ is an indirect utility function. P_i denotes a price index of service *i*.

$$i, j \in \{1: I-POTS \quad 2: NCC-POTS \quad 3: mobile\ phone\}.$$

Due to the limited availability of our data, we assumed at this point that the telecommunications demand is separable from the demand for other goods. An AIDS model usually constitutes of the demand for all possible goods/services. However, we cannot make the price index of other goods (except telephone service) consistent with that of telephone services, which was constructed based on the Fisher Ideal Index as explained in Section 3. Therefore, the demand for all possible goods and services cannot be included in our AIDS model[6].

From the perspective of economic theory, an expenditure function requires the following conditions: additivity, symmetry, homogeneity, and concavity. We can impose all these conditions, with the exception of the concavity condition, into the estimation equations as linear constraints. The concavity condition can be examined after the estimation. We can derive the share equations for each telephone service using Shepherd's lemma. In addition, the estimation of the AIDS model also requires bias adjustment in our econometric framework. By imposing the abovementioned three linear constraints, our estimation model for the fourth case of "subscription to all three services" can be written as follows:

$$S_{I-POTS} = a_1 + b_{11} \ln \frac{P_1}{P_2} + b_{13} \ln \frac{P_1}{P_2} + c_1 \ln \frac{E}{P}$$
$$+ \sigma_{NCC,SI-POTS} \frac{\varphi(G_{NCC})\Phi(G^*_{mobile})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} + \sigma_{mobile,SI-POTS} \frac{\varphi(G_{mobile})\Phi(G^*_{NCC})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} \quad (1)$$

6 In our estimation, the expenditures include only the telephone service expenditures and not those incurred on all possible goods/services. In this sense, the estimated expenditure elasticity is not an ordinal expenditure elasticity but a telephone service expenditure elasticity. According to a household survey conducted in Japan, the average total telecommunications expenditure did not change considerably during our survey term.

$$S_{mobile} = a_3 + b_{13} \ln\frac{P_1}{P_2} + b_{33}\ln\frac{P_3}{P_2} + c_3 \ln\frac{E}{P}$$

$$+ \sigma_{NCC,Smob} \frac{\varphi(G_{NCC})\Phi(G^*_{mobile})}{\Phi_2\left(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile}\right)} + \sigma_{mobile,Smob} \frac{\varphi(G_{mobile})\Phi(G^*_{NCC})}{\Phi_2\left(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile}\right)} \qquad (2)$$

where P is an aggregate price index.

$G_{NCC} = Z_{NCC}\alpha'_{NCC}$, $G_{mobile} = Z_{mobile}\alpha'_{mobile}$,

$G^*{}_{NCC} = (Z_{NCC}\alpha'_{NCC1} - \sigma_{NCC,mobile} Z_{mobile}\alpha'_{mobile}) \Big/ \sqrt{1-\sigma^2_{NCC,mobile}}$

$G^*{}_{mobile} = (Z_{mobile}\alpha'_{mobile} - \sigma_{NCC,mobile} Z_{NCC}\alpha'_{NCC}) \Big/ \sqrt{1-\sigma^2_{NCC,mobile}}$

Φ_2 : standard bivariate normal CDF with correlation= $\sigma_{NCC,mobile}$

Share equations in a typical AIDS model do not contain the last two terms. These terms in equations (1) and (2) reflect the difference between the means of the error terms for the whole sample set and those for only all three of the service subscribers' sub-sample set[7].

The following price index function is consistent with that of an AIDS model under the additivity, symmetry, and homogeneity constraints. As in the case of share equations, the last two terms are included in the price index function for bias adjustment.

$$\ln\frac{P}{P_2} = a_0 + a_1 \ln\frac{P_1}{P_2} + a_3 \ln\frac{P_3}{P_2} + \frac{1}{2}b_{11}\left(\ln\frac{P_1}{P_2}\right)^2 + \frac{1}{2}b_{13}\left(\ln\frac{P_1}{P_2}\right)\left(\ln\frac{P_3}{P_2}\right) + \frac{1}{2}b_{33}\left(\ln\frac{P_3}{P_2}\right)^2$$

$$+ \sigma_{NCC,P} \frac{\varphi(G_{NCC})\Phi(G^*_{mobile})}{\Phi_2\left(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile}\right)} + \sigma_{mobile,P} \frac{\varphi(G_{mobile})\Phi(G^*_{NCC})}{\Phi_2\left(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile}\right)} \qquad (3)$$

We proceed to apply Zellner's iterative seemingly unrelated regressions procedure to estimate the two share equations with the price index function. After the estimation, in order to confirm whether it will be justified to incorporate subscription behavior into determining demands behavior for telecom services, we can statistically test the significance of the estimated σ s.

3. DATA DESCRIPTION

In this article, we use a data set constructed from the telecom expenditure surveys conducted by the Institute for Posts and Telecommunications Policy (IPTP)[8] between 1998 and 2001, combined with the telephone traffic data gathered by the Ministry of Posts and Telecommunications (MPT)[9] for the corresponding periods.

3.1. Questionnaire Data

The IPTP's telecom expenditure survey was designed to collect telephone usage data from individual households. This survey was conducted at approximately the same time over four consecutive years. The survey target was 15.6 million households in the Tokyo

[7] For a detailed explanation on these two terms, please refer to the Appendix.
[8] Currently reorganized as the Institute for Information and Communications Policy (IICP) of MIC.
[9] In January 2001, MPT was reorganized and combined with three other governmental sectors to form the Ministry of Internal Affairs and Communications (MIC).

Metropolitan Area, which includes 7 prefectures (Tokyo, Kanagawa, Chiba, Saitama, Gunma, Tochigi, and Ibaraki) and covers 33.8% of the national population. Questionnaire sheets were mailed to addressees who were selected using a stratified multistage random sampling method. In these surveys, respondents were requested to answer questions on several socio-demographic features as well as those on average monthly expenditures for I-POTS, NCC-POTS, and mobile phone service. The details of the survey's results for each year are summarized in Table 2. The total number of valid responses is 5,268 and the overall collection rate was 13.8%. The descriptive statistics of these respondents are summarized in Table 3.

As mentioned earlier, we consider four subscription patterns: (1) only I-POTS subscription; (2) I-POTS and NCC-POTS subscription; (3) I-POTS and mobile phone service subscription; and (4) subscription to all the three services (I-POTS, NCC-POTS, and mobile phone service). Table 4 lists the statistics for each pattern[10].

Table 2 Survey Specifications

Table 3 Descriptive Statistics of Respondents

Table 4 Descriptive Statistics for Subscription Patterns

3.2. Telephone Traffic Data

The Telecommunications Business Law—more specifically, the Telecommunications Business Report Rule (MPT ordinance No. 46 of 1988)—authorized MPT, and later its successor MIC, to collect telephone traffic data from facility-based telecommunication operators. In this article, the authors constructed a calling price index using these traffic data and used them in estimating calling expenditure functions.

With regard to fixed telephone services, i.e., I-POTS and NCC-POTS, we first calculated the average per-minute calling rate for each talking range bracket by using the revenue/call-duration/talking-range table. Then, by combining these rates with the Origin-Destination (OD) traffic data among the local calling areas, or message areas (MAs), we obtained an average unit calling rate of household subscribers in each MA. These unit rates were obtained for each destination media and were then aggregated into a Fisher-type calling price index. In order to guarantee transitive consistency across each year and MA, we modified the aggregation procedure by following the Elteto, Koves, and Szulc (EKS) method[11], as proposed by Nakamura (2001).

With regard to mobile services, their traffic data is compiled on the basis of prefecture areas, and not MAs; therefore, we employed the OD traffic data between prefectures and followed the same procedures used for fixed telephone services.

4. ESTIMATION

4.1. Estimation Parameters

Although there are four alternative subscription patterns, our interest lies in the cross-price elasticities for neighboring telephone services. Therefore, we will proceed to evaluate the fourth case of "subscriptions to all three services (I-POTS, NCC-POTS, and mobile phone service)."

[10] Please refer to Oishi (1998), Jitsuzumi and Ando (1999, 2000), and Nakamura and Yoshida (2001) for more detailed information on the demographics of mobile phone users.

[11] For details on the EKS method, see Kloek and Theil (1965).

First, we estimate the NCC-POTS subscription function considering the sampling weight[12]. Table 5 displays the estimated results for the NCC-POTS subscription function. Here, we construct the variable *Dprice_NCC* by subtracting the calling rate applicable to each household that subscribes only to I-POTS from the calling rate of those that subscribe to both NCC-POTS and I-POTS. The calling rate of those households that also subscribe to NCC-POTS is a weighted average of the I-POTS and NCC-POTS calling rates. For NCC-POTS subscribers, the weights are the expenditure shares for the respective services of the household. In the case of NCC-POTS non-subscribers, the weights are taken as the average of the area in which the households are located.

Table 5 Estimated Parameters for NCC-POTS Subscription Function

Most of the estimated parameters, with the exception of *Remote,* are statistically significant. The parameter for *Dprice_NCC* assumes a significantly negative value, which implies that the lower the NCC-POTS calling rate, the more likely it is for a household to subscribe to NCC-POTS. The sign of this parameter conforms to the sign required by the economic theory.

After reaching a decision on subscription for fixed phone services, the households proceed to decide on subscription for mobile phone services. The mobile phone service subscription function is also subject to alternative specific factors and socio-demographic factors as explanatory variables. However, in this instance, we differentiate the alternative specific variables handling from that for the NCC-POTS subscription function. Generally, the deciding factor for subscribing to a mobile phone service is influenced by the calling rate and basic charge inherent to a given plan. In contrast, there is no basic charge in the case of NCC-POTS subscription decision. With regard to mobile phone services, a low calling rate is paired with a high basic fee and vice versa, which implies negative colinearity, and thus, employing both rates as explanatory variables has a problematic impact on estimating the subscription function. Therefore, we decided to omit the basic charge from the explanatory variable set. However, omitting this variable differentiates the coefficients of the remaining variables (calling rate variable) in the utility functions. This is because the coefficient of calling rate in the utility function when subscribing to a mobile phone service is influenced by omitting the basic charge variable, although the calling rate coefficient when not subscribing to a mobile phone service is unaffected[13]. Therefore, we insert the following two calling rate variables: CRate_SUB and CRate_NOT. The former denotes the calling rate that a household is subject to when subscribing to NCC-POTS and I-POTS services, while the latter denotes the weighted average calling rate in the case where NCC-POTS, I-POTS, and a mobile phone service are subscribed to. In doing this, we can estimate two different coefficients.

Table 6 Estimated Parameters for the Mobile Subscribing Function

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[12] In estimating the mobile phone subscription function and the corresponding AIDS model, we also take the respective sampling weights into consideration.

[13] The utility function in the case of subscribing to a mobile phone service can be expressed as *Usub* = a**Crate_SUB* + b**Basic_Charge*. Those in the case of non-subscription is expressed as *Unot* = a**Crate_SUB* because there is no basic charge in this case other than the one for I-POTS. If the colinearity parameter between *Crate_SUB* and *Basic_Charge* is c, the utility function in subscribing to a mobile phone service could be expressed as *Usub* = (a + bc)**Crate_SUB*. Hence, the coefficients of the two calling rate variables (*Crate_SUB* and *Crate_NOT*) are different.

Table 6 shows the estimated results for the mobile phone subscription function. Most of the parameters are statistically significant. The parameter for *CRate_SUB* is negative, whereas that for *CRate_NOT* is positive; this is consistent with the signs required by economic theory. The parameter $\sigma_{NCC,mobile}$ is significantly different from 0. This suggests that the error terms of the NCC-POTS subscription function correlate with that of the mobile phone service subscription function. This implies that the estimated parameter would be biased without the last term in our mobile phone service subscription function. Given this knowledge, we could conclude that our approach is required to obtain an "unbiased" estimate for the mobile phone subscription function.

Finally, we proceed to the estimation of the expenditure function. Table 7 shows the estimated results for the households that subscribe to all I-POTS, NCC-POTS, and mobile phone services. The parameters in Table 7 are the same as those of equations (1), (2), and (3) in Section 2. By using our estimated parameters, we examined the concavity condition. Our estimation results meet this condition at the sample mean.

Table 7 Estimated Parameters for the Expenditure Function

The most noteworthy finding in Table 7 is that the parameters $\sigma_{NCC,SI\text{-}POTS}$, $\sigma_{mobile,I\text{-}POTS}$, $\sigma_{NCC,Smob}$, and $\sigma_{mobile,Smob}$ are statistically significant. This means that the error terms of both the subscription functions and the share equations are significantly correlated; further, this finding indicates the necessity of inserting the bias adjusted terms into the estimation functions in the final stage. In other words, as in the case of the above mobile phone subscription function estimate, it would be impossible to obtain the "unbiased" expenditure function parameters without the bias adjusted terms.

4.2. Measurement of Price Elasticity

Tables 8 and 9 present the estimated uncompensated and compensated "unbiased" price elasticities pertaining to the demand for each medium of telephone usage (I-POTS, NCC-POTS, and mobile phone service). These figures are evaluated at each variable sample's mean value.

As compared to the own price elasticity recorded from previous studies that used Japanese data, our estimation result for uncompensated own price elasticity for I-POTS almost assumes a similar level. However, our estimated elasticity level (in absolute value) is considerably larger than that of the other countries. The reason for this difference appears to be partly due to the difference in the time when our sample and those of the previous studies were collected. It is commonly believed that telephone service is a necessary commodity. At the time when the previous studies were conducted, there were no substitute goods for POTS. Conversely, we now have mobile phones and NCC-POTS that can be considered as substitutes for I-POTS. Thus, it is conceivable that the presence of substitutes increases the own price elasticity for I-POTS usage.

Table 8 Estimated Uncompensated Price Elasticity

Table 9 Estimated Compensated Price Elasticity

Our estimation reveals that the own price elasticity for NCC-POTS is larger in absolute value than that for I-POTS. In general, in Japan, using NCC-POTS does not require one to pay the basic charge or subscription fees (in our observed period). Therefore, consumers began using NCC-POTS only when its calling rate was lower than that of I-POTS because NCC-POTS requires an I-POTS subscription as an access line. Under these circumstances, a larger own price elasticity for NCC-POTS seems acceptable in this period.

More noteworthy is the small absolute value of the own price elasticity for mobile phone service (–0.82). In general, compared to POTS, a mobile phone service was regarded as a luxury service because during this period the mobile phone calling rate was much higher than it is today and it was considered to be one of the additional phone services. However, our estimation shows that consumers' mobile phone usage behavior would be less cost-sensitive.

For uncompensated cross-price elasticity, it is shown that the uncompensated cross price elasticities for I-POTS and NCC-POTS assumes a negative sign; those for I-POTS and mobile phone services, a positive sign; and those for NCC-POTS and mobile phone services, a negative sign. Thus, the relationship between I-POTS demand and NCC-POTS demand is gross substitutive, and the relationship between I-POTS and mobile phone service demand and that between NCC-POTS and mobile phone service demand are gross complimentary.

Conversely, if we observe the compensated cross-price elasticity, we note that all the estimated values are positive. This implies that all the three phone services are mutually substitutive.

5. CONCLUSIONS AND FURTHER RESEARCH

The purpose of this article is to obtain accurate and "unbiased" estimates of price elasticity for telephone services. In our previous researches (Kawamura, *et al.* (2000), Nakamura (2004), and Nakamura and Jitsuzumi (2006)), we applied the AIDS model without the bias adjusted terms (conditional expectations) in order to obtain the estimates of price elasticity. It is likely that the selectivity bias may have remained in our past researches. Therefore, in order to deal with such a bias, we proposed the application of Heckman-Lee's two-step method to the simultaneous demand equation system. Our estimation results show that there exists a statistically significant correlation between the error terms of both subscription functions and the error terms of share equations in the AIDS model. This result implies that the selectivity bias is indeed relevant. Therefore, it is reasonable to conclude that our two-step estimation procedure is justifiably required for obtaining an unbiased price elasticity.

In addition, the estimation of price elasticity for telephone services indicates the following:

- Usage demand for NCC-POTS is more elastic for own price change than usage demand for I-POTS and mobile phone services.
- All the three telephone services are mutually substitutive.
- The relationship between the demand for I-POTS and NCC-POTS is gross substitutive. Conversely, the relationship between the demand for I-POTS and mobile phone services as well as that between the demand for NCC-POTS and mobile phone services, are gross complimentary.

By using these estimations, we can simulate the impact of a decline in telephone calling rates on households through a policy impact analysis. Table 10 shows the impact of a decline in telephone calling rates on households. For example, the farthest column on the right-hand side of the second row shows the estimated change in the monthly equivalent variation of each household when mobile phone calling rates are reduced by 20%, with the I-POTS and NCC-POTS rates unchanged (i.e., 100%). Among the reduced rates of the three telephone services, the one with the most predominant effect on households appears to come from the reduction in the mobile phone service rates.

Table 10 Simulation Results for Equivalent Variation of Unequal Price Declines

Before concluding this article, it is necessary to briefly mention the remaining issues and possible directions for future research. The limitation in our estimated results from the AIDS model is that some of the parameters are not statistically significant. It is crucial to note that the estimation results could be improved by incorporating household attributes—for instance, the number of household members, family saving, etc.,—as the independent variables in the share equations. In addition, the specific decision-making sequence with regard to a household's telephone service subscription that is at the basis of our estimations is posited a priori. In other words, we posit that households first make the decision to subscribe to NCC-POTS service, and then, make a further, secondary decision on whether or not to subscribe to a mobile phone service. We determine this sequence of decision-making a priori. If a household's determined subscription decision for I-POTS, NCC-POTS, and a mobile phone service are simultaneous, a tri-probit model should be used to describe the decision to subscribe to all the three service categories. In this case, it might also be required that the expenditure function be re-estimated on the basis of information obtained from the tri-probit model in order to determine the subscription pattern.

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Appendix: Bias Adjustment Terms for the Simultaneous Equation Model

In this appendix, we explain the specification of the bias adjustment terms in our demand system under dynamic optimization. The reduced forms of our demand system in the fourth case "subscriptions to all three services" are given in the following simultaneous equation system:

$$Y_i = X_i \beta' + \upsilon_i$$

where Y_i : G x 1 vector, G is the number of equations; G = 3 in the case of "subscriptions to all three services."

X_i : 1 x K vector, where K is the number of independent variables,

β : K x G matrix, and, υ_i : G x 1 error term vector with the mean of each element with a whole sample set = 0

However, with only the sub-sample set of subscribers of all the three services, the expectations of υ_i's become the following conditional expectations that are not equal to 0:

$$E(Y_i) = E(X_i \beta') + E\langle \upsilon_i \,|\, \varepsilon_{i,NCC} > -Z_{i,NCC}\alpha'_{NCC},\ \varepsilon_{i,mobile} > -Z_{i,mobile}\alpha'_{mobile} \rangle$$

$$\Leftrightarrow Y_i = X_i \beta' + E\langle \upsilon_i \,|\, \varepsilon_{i,NCC} > -Z_{i,NCC}\alpha'_{NCC},\ \varepsilon_{i,mobile} > -Z_{i,mobile}\alpha'_{mobile} \rangle$$

where $\begin{pmatrix} \varepsilon_i \\ \upsilon_i \end{pmatrix} \sim N\left(0, \begin{pmatrix} \Sigma_{\varepsilon\varepsilon} & \Sigma'_{\upsilon\varepsilon} \\ \Sigma_{\upsilon\varepsilon} & \Sigma_{\upsilon\upsilon} \end{pmatrix}\right)$, $\quad \varepsilon_i : \{\varepsilon_{i,NCC} \quad \varepsilon_{i,mobile}\}'$

The above conditional expectations should be obtained for unbiased estimators. The resulting conditional expectations can be expressed as follows:

$$E\langle \upsilon_i \,|\, \varepsilon_{i,NCC} > -Z_{i,NCC}\alpha'_{NCC},\ \varepsilon_{i,mobile} > -Z_{i,mobile}\alpha'_{mobile} \rangle$$

$$= \quad -\frac{\Sigma_{21}\Sigma_{11}^{-1}}{\int_{-\infty}^{Z_{NCC}\alpha'_{NCC}} \int_{-\infty}^{Z_{mobile}\alpha'_{mobile}} f(\varepsilon) d\varepsilon_{mobile} d\varepsilon_{NCC}} \begin{pmatrix} \int_{-\infty}^{Z_{NCC}\alpha'_{NCC}} \int_{-\infty}^{Z_{mobile}\alpha'_{mobile}} \varepsilon_{NCC} f(\varepsilon) d\varepsilon_{mobile} d\varepsilon_{NCC} \\ \int_{-\infty}^{Z_{NCC}\alpha'_{NCC}} \int_{-\infty}^{Z_{mobile}\alpha'_{mobile}} \varepsilon_{mobile} f(\varepsilon) d\varepsilon_{mobile} d\varepsilon_{NCC} \end{pmatrix} \qquad \text{---(A1)}$$

where $f(\varepsilon) \sim N(0, \Sigma_{11})$

For notational simplicity, we hereafter omit *i*. In equation (A1), we should take $-\varepsilon$ as a measure; however, for simplicity, we change the variables to $\varepsilon_{NCC} = -\varepsilon_{NCC}, \varepsilon_{mobile} = -\varepsilon_{mobile}$ and use the letter ε as the measure.

For obtaining the value of (A1), each element of vector in (A1) is required. The first and second elements in this vector are expressed as follows[14].

[14] See Maddala (1983).

$$\int_{-\infty}^{Z_{NCC}\alpha'_{NCC}} \int_{-\infty}^{Z_{mobile}\alpha'_{mobile}} \varepsilon_{NCC} f(\varepsilon) d\varepsilon_{mobile} d\varepsilon_{NCC}$$

$$= \begin{matrix} -\varphi(Z_{NCC}\alpha'_{NCC})\Phi((Z_{mobile}\alpha'_{mobile} - \sigma_{NCC,mobile3} Z_{NCC}\alpha'_{NCC}) \Big/ \sqrt{1-\sigma^2_{NCC,mobile}}) \\ -\sigma_{NCC,mobile}\varphi(Z_{mobile}\alpha'_{mobile})\Phi((Z_{NCC}\alpha'_{NCC} - \sigma_{NCC,mobile} Z_{mobile}\alpha'_{mobile}) \Big/ \sqrt{1-\sigma^2_{NCC,mobile}}) \end{matrix}$$

$$\int_{-\infty}^{Z_{NCC}\alpha'_{NCC}} \int_{-\infty}^{Z_{mobile}\alpha'_{mobile}} \varepsilon_{mobile} f(\varepsilon) d\varepsilon_{mobile} d\varepsilon_{NCC}$$

$$= \begin{matrix} -\sigma_{NCC,mobile}\varphi(Z_{NCC}\alpha'_{NCC})\Phi((Z_{mobile}\alpha'_{mobile} - \sigma_{NCC,mobile} Z_{NCC}\alpha'_{NCC}) \Big/ \sqrt{1-\sigma^2_{NCC,mobile}}) \\ -\varphi(Z_{mobile}\alpha'_{mobile})\Phi((Z_{NCC}\alpha'_{NCC} - \sigma_{NCC,mobile} Z_{mobile}\alpha'_{mobile}) \Big/ \sqrt{1-\sigma^2_{NCC,mobile}}) \end{matrix}$$

By substituting the above two equations into equation (A1), equation (A1) can be calculated as follows:

$$E\langle \upsilon \,|\, \varepsilon_1 > -Z_1\alpha'_1, \varepsilon_3 > -Z_3\alpha'_3 \rangle$$

$$= \begin{pmatrix} \sigma_{NCC,SI-POTS} \dfrac{\varphi(G_{NCC})\Phi(G^*_{mobile})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} + \sigma_{mobile,SI-POTS} \dfrac{\varphi(G_{mobile})\Phi(G^*_{NCC})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} \\ \sigma_{NCC,Smob} \dfrac{\varphi(G_{NCC})\Phi(G^*_{mobile})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} + \sigma_{mobile,Smob} \dfrac{\varphi(G_{mobile})\Phi(G^*_{NCC})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} \\ \sigma_{NCC,P} \dfrac{\varphi(G_{NCC})\Phi(G^*_{mobile})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} + \sigma_{mobile,P} \dfrac{\varphi(G_{mobile})\Phi(G^*_{NCC})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} \end{pmatrix}$$

Finally, our reduced-form estimation equations were expressed as follows:

$$S_{I-POTS} = a_1 + b_{11}\ln\frac{P_1}{P_2} + b_{13}\ln\frac{P_1}{P_2} + c_1\ln\frac{E}{P}$$
$$+ \sigma_{NCC,SI-POTS} \frac{\varphi(G_{NCC})\Phi(G^*_{mobile})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} + \sigma_{mobile,SI-POTS} \frac{\varphi(G_{mobile})\Phi(G^*_{NCC})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})}$$

$$S_{mobile} = a_3 + b_{13}\ln\frac{P_1}{P_2} + b_{33}\ln\frac{P_3}{P_2} + c_3\ln\frac{E}{P}$$
$$+ \sigma_{NCC,Smob} \frac{\varphi(G_{NCC})\Phi(G^*_{mobile})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} + \sigma_{mobile,Smob} \frac{\varphi(G_{mobile})\Phi(G^*_{NCC})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})}$$

$$\ln\frac{P}{P_2} = a_0 + a_1\ln\frac{P_1}{P_2} + a_3\ln\frac{P_3}{P_2} + \frac{1}{2}b_{11}\left(\ln\frac{P_1}{P_2}\right)^2 + \frac{1}{2}b_{13}\left(\ln\frac{P_1}{P_2}\right)\left(\ln\frac{P_3}{P_2}\right) + \frac{1}{2}b_{33}\left(\ln\frac{P_3}{P_2}\right)^2$$
$$+ \sigma_{NCC,P} \frac{\varphi(G_{NCC})\Phi(G^*_{mobile})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})} + \sigma_{mobile,P} \frac{\varphi(G_{mobile})\Phi(G^*_{NCC})}{\Phi_2(G_{NCC}, G_{mobile}; \sigma_{NCC,mobile})}$$

Tables & Figures

Table 1 Previous Studies on Telephone Demand

Articles	Period	Model	Area/Service	Elasticity		
				Price	Cross Price	Income
Nakamura & Jitsuzumi (2006)	1997-1999	AIDS. SUR	Tokyo Metropolitan Area/NTT Tokyo Metropolitan Area/NCC Tokyo Metropolitan Area/Mobile	-0.89 -4.08 -0.18	NTT-NCC: 0.66, 4.26 NTT-Mob: 0.23, 0.33 NCC-Mob: -0.18, -0.29	1.04 0.71 1.00
Nakamura (2004)	1998-1999	AIDS, 3SLS	Japan/Fixed-Fixed [FF] Japan/Fixed-Mobile [FM] Japan/Mobile-Mobile [MM]	-0.69 -0.03 -1.87	FF-FM: -0.006, -0.004 FF-MM: 1.81, 0.70 MM-FM: 0.03, 0.06	1.02 0.98 1.03
Nakamura (2002)	1996-1998	Fixed & Random Effect	Japan/NTT inter-prefecture Japan/NCC inter-prefecture	-0.19～-0.66 -0.22～-1.40	NTT-NCC: 0.25～1.05 NTT-NCC: 0.36～0.56	0.26～0.85 0.62～0.63
Kawamura, Jitsuzumi, & Ando (2000)	1998-1999	AIDS, SUR	Tokyo Metropolitan Area/NTT Tokyo Metropolitan Area/NCC Tokyo Metropolitan Area/Mobile	-0.73～-0.75 -0.98～-0.99 -1.34～-1.37	NTT-NCC: 0.10～0.49 NTT-Mob: 0.50～0.53 NCC-Mob: 1.39～1.89	1.05～1.06 0.60～0.72 1.0041～1.0044
Okada & Hatta (1999)	1992-1996	Maximum Likelihood	Japan/Fixed phone Japan/Mobile Phone	-1.41 -3.96	0.87 0.28	0.59 0.67
Rappoport & Taylor (1997)	1994.4-1994.5	OLS	U.S./Inter LATA U.S./Inter LATA Inter State U.S./Total Inter LATA	-0.44～-0.70 -0.42～-0.70 -0.35～-0.50	N/A	N/A
Kawamura (1996)	1989-1994	Fixed & Random Effect, Weighted LS, Censored Regression	Japan/NTT inter-prefecture Japan/NCC inter-prefecture	-1.67～-1.81 -1.16～-1.17	N/A	1.29～ 2.99 1.19～1.30
Munoz (1996)	1985-1989	Fixed & Random Effect	Spain	-0.13	N/A	0.46
Mitomo & Ota (1994)	1990	OLS	Tokyo Metropolitan Area/NTT inter-MA	-1.87 or -0.88	N/A	0.1994
Yamazaki, Imagawa, & Mitomo (1993)	1990	2step OLS	Japan/NTT inter-MA	-1.56 (Tokyo MA)	N/A	N/A
Shiba & Nakatsuma (1993)	1953-1990	OLS, ML, Cocran Orchit	Japan/ NTT	approx. -1.0～ approx. -0.2	N/A	approx. 0.55～ approx. 0.85
Appelbe et al. (1992)	1979Q1-1988Q4	AR1, Fixed & Random Effect	Canada/Domestic Long Distance/Peak-hours Canada/Domestic Long Distance/Non-peak	-0.26～-0.65 -0.40～-0.83	N/A	N/A N/A
Lang & Lundgren (1991)	1988	Nonlinear Leased Square	Sweden	-0.013～-0.016	N/A	
Appelbe et al. (1990)	1975Q1-1983Q3	AR1, Fixed & Random Effect	Canada/Domestic Long Distance/Peak-hours Canada/Domestic Long Distance/Non-peak	-0.24～-0.54 -0.45～-0.89	N/A	0.56～1.38 0.72～1.29
Larson et al. (1990)	1983	AR1, 2step LS	U.S./Domestic Inter-City	-0.75	N/A	0.54
Appelbe et al. (1988)	1977Q1-1986Q4	AR1, Fixed & Random Effect	Canada/Domestic Long Distance/Peak-hours Canada/Domestic Long Distance/Non-peak Canada/Canada-US Long Distance/Peak-hours Canada/Canada-US Long Distance/Non-Peak	-0.21～-0.73 -0.39～-0.75 -0.43～-0.49 -0.45～-0.53	N/A	0.33～0.95 0.23～0.79 0.12～0.74 0.17～0.54

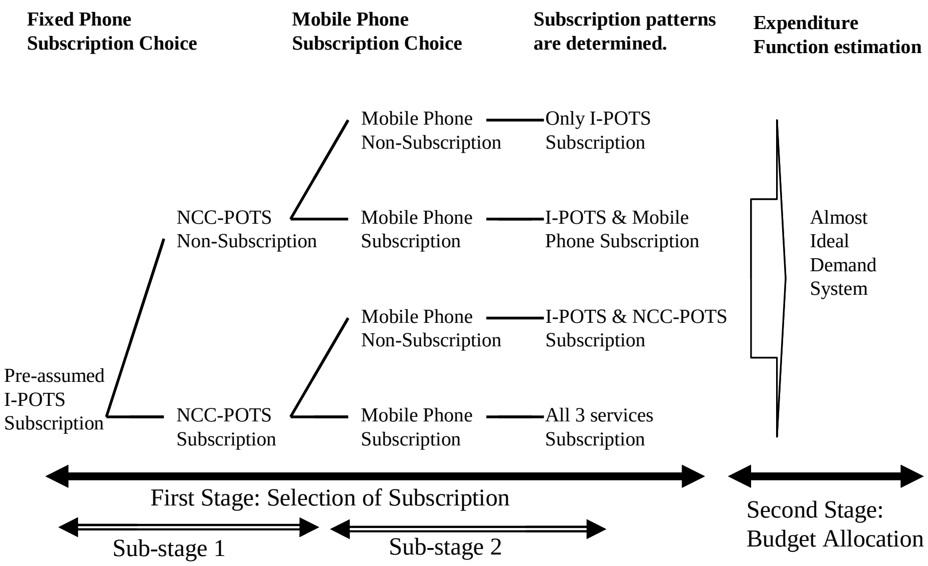

Figure 1: Assumed decision-making mechanism

Table 2 Survey Specifications

Survey	No. 1	No. 2	No. 3	No. 4
Timing	Feb. 1998	Jan. 1999	Jan. 2000	Jan. 2001
Survey area	Tokyo, Kanagawa, Chiba, Saitama, Gunma, Tochigi, and Ibaraki. Isolated islands are not included.			
Dispatch and recovery	Mailing			
Sampling method	Stratified multistage random sampling method using the basic register of residents			
# of sheets dispatched	2,300	11,800	12,000	12,000
# of sheets recovered	1,006	2,061	1,168*	1,033
Collection rate	43.7%	17.5%	9.73%	8.61%

Note*: Monitoring research was simultaneously conducted due to an extremely low initial collection rate.

Table 3 Descriptive Statistics of Respondents

Survey (Year)	Total	No. 1 (1998)	No. 2 (1999)	No. 3 (2000)	No. 4 (2001)
# of Respondents	5,367	1,006	2,060	1,168	1,033
		19.1%	39.1%	22.2%	19.6%
Spending (yen)					
Total Expenditures for Telephone Service	14,635.71	12,380.63	14,819.52	14,816.12	16,251.09
S.D.	22,116.43	10,562.31	26,991.62	18,166.26	20,980.28
N	4,375	774	1949	893	759
(for I-POTS)	7,464.84	7,213.05	7,542.43	7,798.67	7,170.80
(for NCC-POTS)	1,562.68	1,326.78	1,914.70	1,225.46	1,322.20
(for mobile phone service)	5,914.59	4,073.27	5,349.93	6,534.32	8,286.30
Ownership/Subscription Ratio of IT					
Personal Computer	55.4%	37.2%	56.8%	57.5%	67.4%
Word Processor	44.2%	49.6%	43.8%	44.4%	39.3%
Facsimile	48.1%	35.9%	51.2%	47.9%	54.0%
PC network	35.2%	16.0%	34.6%	39.4%	47.2%
Internet	50.5%	20.0%	52.6%	52.6%	67.7%
Other Features					
Annual Income before Tax (in thousand yen)	8,448.18	9,040.04	8,502.92	8,059.54	8,266.35
S.D.	7,531.94	10,184.87	7,042.92	5,947.02	7,331.07
N	4,946	865	1,957	1,126	998
Annual Income after Tax (,000yen)	6,349.73	6,672.39	6,424.09	6,094.46	6,224.50
S.D.	4,979.83	6,178.81	4,741.13	4,518.94	4,799.28
N	4,689	795	1,863	1,082	949
Annual Savings (,000yen)	1,154.90	1,276.11	1,147.47	1,099.62	1,130.64
S.D.	1,695.12	2,457.62	1,555.45	1,486.67	1,362.24
N	4,705	799	1,872	1,083	951
# of Household Members	2.92	3.15	2.93	2.81	2.79
S.D.	1.43	1.49	1.38	1.45	1.40
N	5,267	1,006	2,060	1,168	1,033
(male)	1.46	1.59	1.43	1.42	1.42
(female)	1.46	1.56	1.50	1.39	1.37
(self-employed)	0.22	0.25	0.19	0.21	0.22
(employed, full-time)	1.03	1.09	1.05	0.98	0.96
(employed, part-time)	0.16	0.16	0.16	0.16	0.17
(unemployed, excluding students)	0.73	0.77	0.70	0.74	0.72
(elementary school age or younger children)	0.43	0.42	0.47	0.39	0.38
(junior high school students)	0.10	0.11	0.10	0.11	0.08
(senior high school students)	0.10	0.10	0.09	0.12	0.10
(college, university students)	0.13	0.14	0.14	0.10	0.13
Average Age of Household Members	38.79	39.92	37.29	39.70	39.67
S.D.	15.11	14.86	14.55	15.28	15.99
N	5,151	945	2,029	1,157	1,020
# of Family Members who Live Remotely	0.23	0.14	0.17	1.57	0.22
S.D.	0.67	0.47	0.60	0.95	0.71
N	3,913	880	1,953	130	950
Prefectures					
Tokyo	1,644	287	712	364	330
Share	32.2%	28.5%	34.6%	31.2%	31.9%
Kanagawa	1,133	219	501	245	209
Share	22.2%	21.8%	24.3%	21.0%	20.2%
Saitama	862	179	337	192	176
Share	16.9%	17.8%	16.4%	16.4%	17.0%
Chiba	755	151	288	181	159
Share	14.8%	15.0%	14.0%	15.5%	15.4%
Ibaraki	303	55	89	90	79
Share	5.9%	5.5%	4.3%	7.7%	7.6%
Tochigi	209	58	62	52	40
Share	4.1%	5.8%	3.0%	4.5%	3.9%
Gunma	204	57	71	44	40
Share	4.0%	5.7%	3.4%	3.8%	3.9%

Table 4 Descriptive Statistics for Subscription Patterns

Subscription Pattern	1	2	3	4
# of Respondents	1,119	888	1,619	1,484
Share	21.9%	17.4%	31.7%	29.0%
Survey (Year)				
No. 1 (1997)	35.2%	18.0%	25.2%	21.6%
No. 2 (1998)	16.8%	24.0%	24.6%	34.7%
No. 3 (1998)	21.7%	11.7%	39.4%	27.2%
No. 4 (2001)	19.1%	9.8%	43.9%	27.1%
Spending (yen)				
Total Expenditures for Telephone Service	6,389.48	8,174.00	18,465.95	20,635.54
S.D.	15,533.80	8,680.19	17,708.42	31,157.32
N	834	837	1,206	1,370
(for I-POTS)	6,664.66	5,645.14	9,316.56	7,833.13
(for NCC-POTS)	0.00	2,631.83	0.00	3,368.13
(for mobile phone service)	0.00	0.00	9,707.51	9,545.08
Ownership/Subscription Ratio of IT				
Personal Computer	34.6%	53.0%	60.0%	69.1%
Word Processor	36.0%	41.7%	48.7%	49.0%
Facsimile	26.9%	49.6%	47.3%	65.1%
PC network	23.7%	34.1%	36.3%	40.2%
Internet	32.5%	48.8%	50.4%	59.8%
Other Features				
Annual Income before Tax (in thousand yen)	7,353.61	7,863.12	9,210.15	9,002.54
S.D.	6,993.70	8,656.40	8,193.13	6,425.41
N	1,032	843	1,518	1,411
Annual Income after Tax (in thousand yen)	5,543.82	6,036.42	6,818.45	6,804.37
S.D.	4,066.87	4,927.70	5,715.99	4,790.50
N	969	802	1,434	1,348
Annual Savings (in thousand yen)	1,191.12	1,063.44	1,178.92	1,200.99
S.D.	2,170.00	1,123.87	1,612.59	1,741.21
N	958	806	1,449	1,356
# of Household Members	2.53	2.77	3.12	3.13
S.D.	1.44	1.32	1.44	1.37
N	1,119	888	1,619	1,484
(male)	1.25	1.35	1.58	1.56
(female)	1.28	1.42	1.54	1.57
(self-employed)	0.18	0.13	0.27	0.24
(employed, full-time)	0.75	0.85	1.20	1.15
(employed, part-time)	0.11	0.15	0.19	0.18
(unemployed, excluding students)	0.86	0.81	0.68	0.66
(elementary school age or younger children)	0.36	0.55	0.38	0.48
(junior high school students)	0.09	0.11	0.10	0.10
(senior high school students)	0.06	0.08	0.12	0.13
(college, university students)	0.06	0.08	0.15	0.18
Average Age of Household Members	46.64	39.46	37.63	34.49
S.D.	18.09	17.08	12.74	11.55
N	1,056	866	1,604	1,472
# of Family Members who Live Remotely	0.23	0.23	0.21	0.21
S.D.	0.71	0.71	0.59	0.62
N	782	717	1,151	1,155
Prefectures				
Tokyo	32.6%	34.7%	29.0%	33.8%
Kanagawa	20.4%	25.6%	21.1%	22.7%
Saitama	16.2%	16.8%	17.2%	17.0%
Chiba	14.8%	14.1%	14.8%	15.2%
Ibaraki	5.8%	3.6%	8.2%	5.0%
Tochigi	4.6%	2.6%	5.1%	3.6%
Gunma	5.6%	2.7%	4.7%	2.8%

Table 5　Estimated Parameters for NCC-POTS Subscription Function

The number of observations = 3722

variable	estimate	stndard error	p-value
Dprice_NCC	-0.0836	0.0149	(0.000)
Single_m	-0.2326	0.0680	(0.001)
Single_f	-0.1299	0.0830	(0.117)
Remote	0.0217	0.0698	(0.756)
fax	0.4881	0.0434	(0.000)
SelfEmp	-0.2480	0.0610	(0.000)
hhAge	0.0001	0.0001	(0.265)
constant	-0.2565	0.0318	(0.000)

Note: *hhAge* = the age of the householder
Single_m = 1 if the household is a bachelor (male) residence, 0 otherwise.
Single_f = 1 if the household is a bachelor (female) residence, 0 otherwise.
Remote = 1 if some family members live in remote locations, 0 otherwise
Fax = 1 if the household has a facsimile machine, 0 otherwise.
SelfEmp = 1 if the householder is self-employed, 0 otherwise.

Table 6　Estimated Parameters for the Mobile Subscribing Function

The number of observations = 1702

variable	estimate	stndard error	p-value
CRate_NOT	0.0326	0.0041	(0.000)
CRate_SUB	-0.0197	0.0016	(0.000)
student	0.4341	0.1047	(0.000)
$\sigma_{NCC,mobile}$	0.0006	0.0003	(0.076)
constant	-0.7447	0.3878	(0.055)

Note: *student* = 1 if there is any high school or college student in the household, 0 otherwise.

Table 7　Estimated Parameters for the Expenditure Function

The number of observations = 907

parameter	estimate	standard error	p-value
a_0	0.0027	0.0022	(0.218)
a_1	0.4091	0.0233	(0.000)
a_3	0.3706	0.0067	(0.000)
b_{11}	-0.0405	0.1136	(0.721)
b_{13}	-0.0719	0.0263	(0.006)
b_{33}	0.0728	0.0239	(0.002)
c_1	-0.0081	0.0051	(0.111)
c_3	0.0076	0.0024	(0.002)
$\sigma_{NCC,SI\text{-}POTS}$	0.0518	0.0182	(0.004)
$\sigma_{NCC,Smob}$	-0.0834	0.0189	(0.000)
$\sigma_{NCC,P}$	-0.0022	0.0042	(0.595)
$\sigma_{mobile,SI\text{-}POTS}$	-0.0518	0.0182	(0.004)
$\sigma_{mobile,Smob}$	0.0834	0.0190	(0.000)
$\sigma_{mobile,P}$	0.0022	0.0042	(0.596)

Table 8 Estimated Uncompensated Price Elasticity

		quantity		
		I-POTS	NCC-POTS	Mobile Phone
price	I-POTS	-1.0978	0.2999	-0.1807
	NCC-POTS	0.4816	-1.4794	-0.0046
	Mobile Phone	-0.1943	-0.0065	-0.8188

Table 9 Estimated Compensated Price Elasticity

		quantity		
		I-POTS	NCC-POS	Mobile Phone
price	I-POTS	-0.7249	0.5280	0.1970
	NCC-POTS	0.8635	-1.2458	0.3823
	Mobile Phone	0.1942	0.2311	-0.4253

Table 10 Simulation Results for Equivalent Variation of Unequal Price Declines

I-POTS Calling Rate	Mobile Phone Calling Rate	NCC-POTS Calling Rate	Equivalent Variation (Yen/US$ in parenthesis)
100%	100%	100%	0 (0.00)
100%	80%	100%	1474 (12.49)
100%	60%	100%	3489 (29.57)
100%	100%	80%	844 (7.15)
100%	80%	80%	2401 (20.35)
100%	60%	80%	4530 (38.39)
100%	100%	60%	2145 (18.18)
100%	80%	60%	3829 (32.45)
100%	60%	60%	6133 (51.97)
80%	100%	100%	1318 (11.17)
80%	80%	100%	2983 (25.28)
80%	60%	100%	5273 (44.69)
80%	100%	80%	2133 (18.08)
80%	80%	80%	3881 (32.89)
80%	60%	80%	6286 (53.27)
80%	100%	60%	3397 (28.79)
80%	80%	60%	5274 (44.70)
80%	60%	60%	7857 (66.59)
60%	100%	100%	3231 (27.38)
60%	80%	100%	5180 (43.90)
60%	60%	100%	7880 (66.8)
60%	100%	80%	3996 (33.87)
60%	80%	80%	6027 (51.07)
60%	60%	80%	8841 (74.9)
60%	100%	60%	5197 (44.05)
60%	80%	60%	7357 (62.35)
60%	60%	60%	10350 (87.72)