Residential broadband subscription demand: an econometric analysis of Australian choice experiment data

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Residential broadband subscription demand: an econometric analysis of Australian choice experiment data

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The recent roll-out of fibre-optic cable suggests that the willingness of households in passed communities to subscribe to networked services is an important issue. This paper studies the determination of the demand for network subscription. Through a discrete choice model the effect of installation and rental price on the likelihood of subscription is analysed. The logit regression is based on choice experiment (stated-preference) subscription data obtained from a national survey of households. Limitations of this preliminary work and suggestions for future research are discussed.

I. INTRODUCTION

The recent and extensive roll-out of fibre-optic cable in Australia has generated much public debate concerned with the likely household demand for network subscription. Very noticeable in this literature is the absence of a sound analytical framework to investigate the demand for network subscription. The work undertaken here envisages choice situations where households choose some combination of networked services. Household network subscription depends on the desire to obtain broadband services.[1] Thus network subscription demand is derived from the demand for networked services. The few studies that recognize this point make no attempt at analysis (BSEG, 1994; BTCE, 1995).[2]

A complication in forecasting the take-up of network subscription is that broadband services are not currently available. As the activity of obtaining information on products usually requires attribute information on a defined set of products the research conducted here is based on recent work in the design of experiments for multiattribute choice behaviour. Experiments generate multiattribute alternatives and place the alternatives in choice sets. The respondent is provided with verbal and written descriptions of certain groups of broadband services. When the respondent shows an interest in one or more services a choice experiment is conducted. The outcome of the experiment is a household network subscription choice.

The econometric model employed here has the advantage that it can be developed in a random utility choice problem context. The structure of the experiment requires a trade-off between installation and rental price is made in selecting an optimal outcome. Accordingly, installation and rental price, income and other household demographic characteristics are linked to subscription through a binomial discrete choice model. This paper presents preliminary empirical results for a simple network subscription model. Estimates are based on a small set of hypothetical choice experiments conducted by the authors. The results are at least illustrative and possibly of some interest *per se*.

[1] Broadband services are defined for the purposes of this paper as those that involve the transmission of video data or a combination of video, text or audio data.
[2] The final report of the Broadband Services Expert Group emphasizes the need for greater understanding of the full range of potential services and the key issues in their delivery. The Communications Futures Project final report, under the auspices of the Bureau of Transport and Communication Economics, provides a diffusion model of broadband network evolution based on parameter values from studies of VCR take-up.

The paper is organized as follows. Details of the specification appear in Section II. Section III provides a brief overview of the experiment and survey procedures. Data description and modifications are discussed therein. In Section IV the estimation procedure is specified. Estimation results are reported in Section V. Section VI contains model predictions and estimated price elasticities. Section VII presents some concluding remarks.

II. SPECIFICATION

McFadden (1974; 1981) uses neoclassical consumer theory to relate the probability of making a choice to a set of behavioural rules reflecting decision-maker preferences. Discussion of the discrete choice theory that corresponds to the logit model is provided by Ben-Akiva and Lerman (1985) and Train (1986). The ith household faces the binary choice of network subscription; $j = 0, 1$ in the set J. Subscription has an installation fee r_1 and $r_o = 0$. Label service rental price p_j, household income as y_i, other observed characteristics of the household and household members as s_i^o, and all unobserved factors as w_i. Suppose the household chooses to subscribe. The maximum utility the household can obtain, given that subscription alternative j is chosen is

$$U_{ij} = U_{ij}(r_j, p_j, y_i, s_i^o, w_i) \tag{1}$$

The ith household chooses to subscribe if and only if:

$$U_{i1}(r_1, p_1, y_i, s_i^o, w_i) > U_{io}(r_0, p_0, y_i, s_i^o, w_i) \tag{2}$$

The probability of household i network subscription is:

$$P_{i1} = \text{Prob}\,[U_{i1}(r_1, p_1, y_i, s_i^o, w_i) > U_{io}(r_0, p_0, y_i, s_i^o, w_i)] \tag{3}$$

To specify these probabilities, recall that factors w_i entering indirect utility are not observed by the researcher. Therefore partitioning indirect utility:

$$U_{ij} = v_{ij}(r_j, p_j, y_i, s_i^o) + e_i \tag{4}$$

where $e_i = e_i(w_i)$ and $v_{ij}(r_j, p_j, y_i, s_i^o)$ is the representative utility of the ith household for subscription alternative j.

If the e_{ij} are distributed each with the extreme value distribution, then the explicit formula for the choice probability is logit in v_{ij}:

$$P_{ij} = \exp\,[v_{ij}(r_j, p_j, y_i, s_i^o)]/\Sigma \exp\,[v_{ik}(r_k, p_k, y_i, s_i^o)] \qquad \text{all } k \text{ in } J \tag{5}$$

III. EXPERIMENTAL DESIGN, SURVEY METHOD AND DATA

Recent studies that apply diffusion models to network subscription, such as St Clair and Madden (1995), can be useful in providing estimates of economy-wide or regional household subscription levels. However, while household expenditure data are used, other important demographic information, such as age, gender and household composition are not linked to these models. As a result little direct information is provided concerning the subscription patterns for these services for subgroups of the covered population. Further, because broadband services are not currently available, model simulations are based on parameter values taken from studies of analogous extant products and services, such as VCRs and payTV. This approach becomes less helpful when considering the take-up of radically new services.

The need for household-based microsimulations to forecast market network subscription is clear. Microeconometric analyses are traditionally based on revealed preference data obtained from surveys asking for actual behaviour. When forecasts of the take-up for new products are required stated-preference data is useful. This is especially the case when new products contain attributes not included in extant products. The stated-preference method employed here generates survey questions designed to mirror the household's market decision by presenting hypothetical but realistic choice contexts.

Section one of the questionnaire provides a description of all the service categories.[3] When the respondent shows no interest in any service the interview is terminated, after the completion of section three of the questionnaire. Section three collects household details. For each service in which the respondent indicates an interest a choice experiment is conducted.[4] The experiment defines discrete broadband subscription alternatives as collections of service attributes. When respondents are not interested in any service, no trade-off is made and so no information is conveyed. Not interested respondents are accordingly identified and excluded from the experiment. Subscription to at least one service and acceptance of an installation fee are necessary for network subscription.[5]

As well as a household subscription variable (*SUBSCRIBE*), two price series are generated by the choice experiment. The variable *INSTALL* is a once-off fee

[3] The service categories employed are entertainment, information and education, transactions and communications.

[4] The authors will provide a copy of the survey questionnaire and ancillary documentation on request.

[5] Respondents have the option of subscribing to any of the mentioned service categories. Services are defined as collections of attributes such as interactivity, ease of use and price. Interactivity can be distributive, selective or communicative. Ease of use concerns the user friendliness and interface characteristics of service. The service may range from very easy to use to not very easy to use. Monthly rental price can take a value in either the low, medium, or high price bands. For example, an entertainment service might be described to a respondent as selective, very easy to use, but high priced. Alternatives are generated by varying attribute levels (see Madden, 1995 for a review of the method). The experiment is conducted three times, that is, each household provides three observations. Details of service category subscription demand are found in Madden and Simpson (1995).

Table 1. *Generated variables*

Variable	Description	Mean
INSTALL	Installation fee	298.80
RENTAL	Charge for average household monthly programme subscription	42.43
INCOME	Pre-tax annual household income (in ten thousands of dollars)	4.36
BCOLLAR	= 1, if the respondent is employed as a tradesperson or trades assistent; = 0, otherwise	0.23
HHLESS35	= 1, if the respondent is aged less than 35 years; = 0, otherwise	0.34
HHMORE55	= 1, if the respondent is aged 55 years or over; = 0, otherwise	0.13
HHSIZE	Number of household members	3.13
IMMIGRANT	= 1, if at least one household member was born in a non-English speaking country; = 0, otherwise	0.12
NAPENS	= 1, if the respondent is a non-aged pensioner; = 0, otherwise	0.04
PTFEM	= 1, if the respondent is female and part-time employed; = 0, otherwise	0.11
RENT	= 1, if tenure is rental; = 0, otherwise	0.31
SEMPHH	= 1, if at least one household member is self-employed; = 0, otherwise	0.17
TECHLIT	= 1, if the respondent uses a computer at work or school, and the household has a computer, multimedia device and a modem; = 0, otherwise	0.07

charged to the household to enable transmissions to be received and sent. *RENTAL* is the charge for average household monthly programme subscription. The level and sequence of the service price is varied within the experiment, while the number of services subscribed is determined by the respondent.

Studies of telecommunications networks that find household characteristics are strong predictors of subscription include Perl (1978; 1983), Brandon (1981), Train *et al.* (1987), Bodnar *et al.* (1988), Taylor and Kridel (1990) and Madden *et al.* (1993).[6] This survey collects both household and household member data. As the unit of analysis is the household, where appropriate, household member data are combined to form household measures. The list of variables developed and included in the econometric model is given in Table 1.

The survey was conducted on the week-ends and evenings of week days during the period 1 April to 9 April 1995. Almost 80% of interviews were undertaken on week-ends between the hours of 10 am and 6 pm. The remainder were conducted on week day evenings between the hours of 4 pm and 8 pm. The survey was distributed to approximately 100 households in each State capital city and Canberra. A further 300 interviews were conducted in provincial centres with population less than 100 000 persons in New South Wales, Victoria and Western Australia.

The survey is conducted by home interview. Cluster probability sampling is used to locate respondents. Given a randomly drawn start point within the sampling area, all households in the sampling frame have an equal chance of being chosen as a start point. Around a start point five households are interviewed.[7] For a total sample size of 1010 households, the survey requires 202 randomly generated start points.[8] Of the households interviewed, 249 (24.7%) had no interest in network subscription while a further 163 (16.1%) respondents failed to provide income information on request. The remaining sample of 598 households provides 1794 cases as the experiment is repeated three times.

IV. ESTIMATION PROCEDURE

This study uses a binary logit model to relate the probability of network subscription to prices, income and other household variables. An observed dichotomous (*SUBSCRIBE*) variable is used to classify households as subscribers (= 1) or nonsubscribers (= 0) to the network.

[6] Infosino (1980) and Alleman *et al.* (1983) consider the relationship between local calling and household characteristics.
[7] The cluster size of five households is based on usual commercial practice. A cluster of five households suggests that the interviewer is given a start point and proceeds in a systematic manner from that start point until five interviews are completed. The interviewer then moves to the next start point.
[8] The start points are randomly generated from local Telecom White Pages directories. A start point is identified as a street corner. The premises on the identified street corner is the first eligible household; the interviewer proceeds along the street to the next premise keeping the left shoulder to the fence line. The results of all door knocks are recorded. In the case of non-response, because of the absence of the main economic decision-maker or unwillingness to take part, the inverviewer moves to the next house. Non-responses are not included in the sample. When non-response is due to absence of the decision-maker, the interviewer returns to the household on the same day. Households not interested in broadband services form part of the sample, however, no choice experiment data is collected. Demographic data from these households are used for sample enumeration purposes.

The model is of the form

$$P_i = F(\beta_1 + \beta_2 x_{i2} + \cdots + \beta_K x_{iK}) = F(x_i'\beta) \tag{6}$$

where

P_i = probability household i subscription
x_i = price and observed household characteristics
β = parameter vector
$F(\cdot)$ = logistic cumulative distribution function.

Model parameters β relate changes in the explanatory variables x_i to changes in the response probability. While the parameter signs indicate the direction of the relationship they are not directly interpretable as marginal changes to the mean value of the dependent variable. This is because of the nonlinear form of the distribution function. Results reported here are transformed so that they can be interpreted in this manner. The logit model is estimated by a two-stage procedure. First, starting values for maximum likelihood estimation are obtained by OLS. Final model parameter estimates are obtained through maximum likelihood estimation.

Table 2. *Estimation results*

Variable	Partial effect	Asymptotic t-statistic
Constant	0.383**	9.35
INSTAL	− 0.0003**	− 5.78
RENTAL	− 0.0004	− 1.24
INCOME	0.007*	1.67
BCOLLAR	− 0.068**	− 3.36
HLESS35	0.038*	1.91
HHMORE55	− 0.056**	− 1.99
HHSIZE	− 0.015**	− 2.13
IMMIGRANT	0.013	0.5
NAPENS	− 0.019	− 0.42
PTFEM	− 0.003	− 0.1
RENT	− 0.014	− 0.66
SEMPHH	0.036	1.19
TECHLIT	0.032	1.05
	Log-likelihood	− 754.246
	R^2	0.337

*significant at 10% level
**significant at 5% level

V. EMPIRICAL RESULTS

Results of the estimated logit regression are shown in Table 2. The model appears to fit well. Homoscedasticity of the error process is supported by a likelihood ratio test ($\chi^2_{\text{calc}} = 25.1$) at the 1% level. Another likelihood ratio test ($\chi^2_{\text{calc}} = 65.6$) rejects the hypothesis that the set of coefficients are not significantly different from zero at the 1% level. The goodness of fit measure, proposed by McElvey and Zavoina (1981) provides an R^2 statistic of 0.337.[9] The model correctly predicts 84.1% (1508 of 1794) of the sample observations. A naive model, which always predicts that interest in subscription is zero, predicts 15.9% (286 of 1794) of the observations correctly.

The marginal effects associated with the parametric estimates are displayed in Table 2. The estimates measure the partial impact of changes in the corresponding variable on the likelihood of household network subscription, all other factors constant. The asymptotic t-statistics indicate whether a particular parameter estimate is statistically different from zero, that is, the variable has an impact on the subscription likelihood.

Table 2 shows that the probability of household subscription is inversely and significantly related to the installation fee, while the monthly recurring price of programme subscription is negatively signed but not significantly different from zero at the 5% level. The estimated coefficient on household income is positive in sign and significantly different from zero at the 10% level. The parameter estimates indicate that subscription is lower when the household head is aged over 55 years and greater when the head is younger (less than 35 years). When the household head is employed in a blue collar occupation subscription likelihood is reduced. Finally, household subscription decreases with the number of household members.

The chi-square statistic is applied to test the joint hypothesis that the set of price and income variables have no impact on the probability that the households will be more or less likely to subscribe. The reported statistic ($\chi^2_{\text{calc}} = 146.1$) clearly rejects the null hypothesis at the 1% level. Finally, parameters are estimated for both metropolitan and provincial subsamples. A likelihood ratio test indicates that the coefficients are not significantly different at the 1% level. This result is not surprising. A test that would be more interesting from a policy perspective involves the comparison of the estimated coefficients from this study with those derived from a survey of rural and remote areas.

VI. MODEL PREDICTIONS AND ESTIMATED PRICE ELASTICITIES

The predictive ability of the model is examined below by comparing the actual and predicted levels of the subscription likelihood for segments of the population. Table 3 shows that the deviations are usually small in absolute value terms while no clear pattern in the prediction error is apparent.

[9]This measure does not correspond to any R^2 measure in the linear regression model.

Table 3. *Predictions by age of household head, household income and household size*

	Level of subscription		
	Observed	Predicted	Deviation
Age of household head			
less than 35 years	86.1	86.5	0.4
more than 55 years	80.0	80.0	0.0
Household income			
less that $20 000	82.2	82.9	0.7
$20 000 to $59 999	83.9	83.3	− 0.6
$60 000 or more	85.7	86.5	0.8
Household size			
single person	88.3	86.1	− 2.2
two through four persons	84.1	84.1	0.0
more that fiver persons	81.5	80.7	− 0.8

Deviation = Predicted − Observed

Table 4. *Network subscription income and price elasticities (by income category)*

	Elasticity		
Income group	Installation price	Rental price	Income
Less than $10 000	− 0.132	− 0.025	0.009
$10 000 to $19 999	− 0.129	− 0.024	0.017
$20 000 to $29 999	− 0.125	− 0.023	0.025
$30 000 to $39 999	− 0.122	− 0.023	0.032
$40 000 to $49 999	− 0.118	− 0.022	0.039
$50 000 to $59 999	− 0.114	− 0.021	0.046
$60 000 to $69 999	− 0.111	− 0.021	0.052
$70 000 to $79 999	− 0.107	− 0.020	0.057
$80 000 and over	− 0.104	− 0.019	0.062

The elasticity is measured at the mean installation fee and rental price

Table 5. *Network subscription price elasticities (by installatioin fee level)*

	Elasticity	
Installation price	Installation price	Rental price
0	0	− 0.013
50	− 0.013	− 0.014
100	− 0.029	− 0.016
150	− 0.047	− 0.017
200	− 0.069	− 0.019
250	− 0.093	− 0.021
300	− 0.121	− 0.022
350	− 0.152	− 0.024
400	− 0.186	− 0.026
450	− 0.222	− 0.028
500	− 0.261	− 0.029
550	− 0.303	− 0.031
600	− 0.346	− 0.032

The elasticity is evaluated at the mean rental price

Table 6. *Network subscription price elasticities (by rental price level)*

	Elasticity	
Rental price	Installation price	Rental price
10	− 0.113	− 0.005
20	− 0.115	− 0.010
30	− 0.117	− 0.015
40	− 0.120	− 0.021
50	− 0.122	− 0.027
60	− 0.124	− 0.033
70	− 0.127	− 0.039
80	− 0.129	− 0.045
90	− 0.132	− 0.052
100	− 0.134	− 0.059
110	− 0.136	− 0.066
120	− 0.139	− 0.073

The elasticity is measured at the mean installation fee.

The results presented in column 1 of Table 4 through Table 6 are consistent with existing empirical evidence that shows the demand for telephone network access demand is own-price inelastic, yet different from zero (Taylor and Kridel, 1990; Taylor, 1994). But this is only part of the story. Table 4 also shows that the elasticity varies inversely with income. The network subscription rental price elasticity, although substantially smaller in magnitude, has a similar pattern. Finally, the network subscription income elasticity, while always inelastic, increases monotonically with income.

Table 5 shows that the network subscription installation price elasticity monotonically increases in magnitude with installation price. This phenomenon is an observed regularity for message toll service where the call price elasticity increases with distance (see de Fontenay and Lee, 1983, p. 210 on this point). Further, the table demonstrates that not only is the demand for network access more sensitive to installation price than to the monthly recurring charge, but that the magnitude of the divergence between the elasticities increases with installation price.

Finally, by comparing Table 5 and Table 6 it is apparent that changes in the network subscription installation price elasticity are more compressed (− 0.113, − 0.139) around the mean of − 0.121 for changes in rental price, than those for changes in the installation fee (0, − 0.346) around the mean. This result is not surprising given the relative magnitudes of the price levels and their corresponding changes.

VII. CONCLUSIONS

The model fitted here shows how empirical analysis of household network subscription demand can be rooted in a model of rational choice behaviour. Experimental subscription choice, rental and installation price data are gathered by a household survey, along with income and other demographic variables. The logit regression model estimated on these data clearly indicates that household income and the installation fee are the principal determinants of take-up. Further, the analysis provides substantive information on how household network subscription responds to changes in installation and rental price. Age and occupation of the household head, together with household size significantly influence the pattern of subscription. The present study offers evidence that well conceived installation fees can augment the take-up of service for these groups.

Many basic questions still remain unanswered. Among these from a policy perspective is the applicability of the estimations to populations in rural and remote areas. Second, the analysis of individual service demands, although estimable through the methods employed here, is outside the ambit of this study. Third, the relationship between household network service subscription and extant products is not analysed here.

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