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Australian Residential Telecommunications Consumption and Substitution Patterns

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Abstract. Better telecommunications pricing decisions are able to be made when more complete information concerning relationships among services is available. This study analyses residential fixed-line and mobile telephony, and Internet access and usage demands in an encompassing framework. The discrete-continuous framework allows for service interaction within and between service portfolios. Model estimation is based on the examination of data collected from a country-wide survey of Australian households. In particular, observed service portfolios (household consumption patterns at prevailing access prices and estimated average service usage prices), income and demographic characteristic data are collected. These data also allow the modelling to potentially identify market segments based on income and other household characteristics.

Key words: service subscription and usage, substitution patterns, telecommunications pricing.

JEL Classifications: D12, L11, L69.

I. Introduction

Competition, deregulation and new services, made available by the convergence of computers, wireless, cable and the Internet with conventional wire-line telephony, has identified modelling requirements not traditionally addressed by telecommunications demand analyses (Taylor, 2002). In particular, as Taylor argues, while the interdependence of access and usage remains fundamental – the treatment of access needs to be more comprehensive to include fixed-line and mobile telephony, and the Internet within an encompassing framework. This approach enables the identification of any substitution or complementary relations among services. Whether services are complements or substitutes matters in the designing of revenue

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enhancing service bundles.[1] Such assessments require price and income elasticity estimates for alternatives within and between bundles. For example, Sung and Lee (2002) and Rodini et al. (2003) only examine substitution between fixed-line and mobile telephony, i.e., relationships among fixed-line telephony and Internet service, and mobile telephony and the Internet, are not considered.

Adding further to the difficulties faced by applied demand analysts is that it is no longer feasible to organize comprehensive industry-wide data bases by service, e.g., of the type undertaken by Gatto et al. (1988). Accordingly, this paper uses Australian household survey data to analyse residential (subscription and usage) demand relationships for fixed-line and mobile telephony, and the Internet. Furthermore, relationships among the services are empirically examined both within, and between, service portfolios. Observed household telecommunication service portfolios (household consumption patterns at prevailing access prices and estimated average service usage prices), income and demographic characteristic data are collected. These data allow the modelling to potentially identify market segments based on income and household characteristics. In particular, the paper estimates a discrete–continuous econometric demand system. The discrete–continuous approach recognises that telecommunications service demands are comprised of interdependent choice among portfolios containing alternative service combinations, viz., fixed-line telephony, mobile telephony and the Internet, together with related vectors of conditional continuous usage demands.

The paper is organised as follows. Section II presents a selective review of fixed-line and mobile telephony, and Internet demand studies. The intention of the review is to provide a basis from which to identify non-economic determinants of residential telecommunications demand and also to obtain a consensus as to reasonable usage and access elasticity magnitudes. The literature has tended to follow industry service innovation, i.e., the literature is, more or less, written in the chronological order of fixed-line telephony access, fixed-line telephony access-usage, mobile telephony access, fixed-line and mobile telephony access substitution and Internet access. The literature review follows this chronology and is restricted to recent analyses. Section III specifies household telecommunications mode subscription choice and service usage demand models, while Section IV discusses related econometric estimation procedures. Next, Section V provides an outline of the survey design. Preliminary descriptive data analysis is contained therein. Section VI defines variables, and presents the econometr-

[1] Additionally, Brynjolfsson and Bakos (1999) argue that identification of submarkets by observable consumer characteristics enhances both consumer welfare and firm revenue.

ric model parameter and elasticity estimates. A synthesis on the results is provided in Section VII. Section VIII concludes.

II. Received Telecommunications Demand Analysis

Taylor and Kridel (1990) analyse the impact of fixed-line subscription price rises on US calling plan substitution. Measured rate plans offer a lower access price, while usage sensitive pricing ensures poor households retain their subscription. Train et al. (1987) consider fixed-line plan subscription when price and calling patterns change. Calling patterns are defined by call numbers, duration, distance and time (time of day and day of week). Households are shown to be insensitive to small plan price differentials, but are more responsive when differentials increase. Typically calling pattern adjustments, and not plan switches, result from price changes. Table I, shows own-price elasticity estimates are elastic for Budget and Standard plans.

Madden et al. (1993) model Australian consumer responsiveness to price changes. A pricing experiment provides data on call price and line rental,

Table I. Fixed-line telephony studies

Study	Focus and findings
Taylor and Kridel (1990)	
Access elasticity	Income: 0.04; Access price: −0.029
Focus	Access price impact on universal fixed-line telephony subscription
Price response	Substitute from flat-rate to measured plans and not reduce subscription
Characteristics	Age, employment, household ownership and size, location, race
Train et al. (1987)	
Access elasticity	Budget: −1.06; Standard: −1.38; Local flat rate: −0.46
Focus	Fixed-line calling portfolio choice by telephone subscribers
Price response	Elasticity increase with price. Change calling pattern rather than plan
Characteristics	n.a.
Madden et al. (1993)	
Access elasticity	−0.003 to −0.001
Focus	Subscription response to tariff. Calling portfolio choice by subscribers
Price response	Day for night substitution within distance bands
Characteristics	Age, children, household ownership and size

call duration and network subscription. Calling bands are defined by distance and time. Fixed-line subscription depends on subscription and call price, viz., consumer surplus from network use relative to line rental. Own-price line rental probability estimates are inelastic and small in magnitude. Per-minute call price elasticity estimates increase with distance. Income elasticity estimates suggest households prefer Day for Night or Economy (off-peak) calling. Cross-price elasticity estimates indicate Day and Night are not local calling substitutes, whereas temporal substitution occurs for 30–100 km calling.

Rodini et al. (2003) examine substitution among primary fixed-line and mobile telephony, and for second fixed-line and mobile telephony. Services are treated as combinations of attributes that vary by time and region. Further, calling plan choice is assumed conditional on expected use. Second fixed-line and mobile telephony subscription is modelled separately. Own-price access elasticity estimates for monthly subscription are −0.60 and −0.43 for fixed-line and mobile telephony, respectively. Estimated cross-price elasticity for fixed-line subscription price on mobile subscription is 0.18 (for 2000) and 0.13 (for 2001), and suggest fixed-line telephony is a substitute for mobile telephony. Own-price access elasticity values for second fixed-line subscription (from −0.69 to −0.65), are more elastic than for the primary fixed-line. This result is consistent with the view that the primary fixed-line is considered a necessity. Rodini et al. also find that fixed-line and mobile telephony markets are defined by age, education, household size, income and martial status. Additionally, computer and facsimile ownership, Internet subscription and working at home increase mobile telephone subscription (Table II).

Madden et al. (2002) model the derived demand for broadband access for entertainment. Respondents select among service offerings that vary by service attributes and price. Choice sets are structured to ensure respondents trade attributes and price when making choices. Estimation indicates own-price access elasticity for mobile telephony is close to that reported by Rodini et al. (2003). Model estimates also indicate a 10% decrease in

Table II. Mobile telephony studies

Study	Focus and findings
Rodini et al. (2003)	
Access elasticity	Mobile: −0.43; Second fixed-line: −0.69
Focus	Fixed-line and mobile telephony substitution
Price response	Moderate substitution between fixed-line and mobile telephone
Characteristics	Age, education, employment, household size, intensity of use, married, race

Table III. Internet access studies

Study	Focus and findings
Madden et al. (2002)	
Access elasticity	−0.69 to −0.59
Focus	Broadband service bundle subscription
Price response	Subscription falls with rental price rise. Switch service than not subscribe
Characteristics	Age, employment, children, location, gender
Rappoport et al. (2003)	
Access elasticity	Dial-up: −0.37 to −0.23; ADSL: −1.46 to −1.36; Cable: −0.90 to −0.59
Focus	Internet access with available infrastructure, viz., dial-up, ADSL or cable
Price response	Substitute from dial-up to cable. ADSL and cable are close substitutes
Characteristics	Age, education, gender, household size

household affordability for a service bundle results in a 1.47% increase in the probability of choosing another service bundle and a 0.19% increase in the probability of not subscribing – suggesting that households are more likely to substitute between services than not subscribe in response to a price rise. Finally, Rappoport et al. (2003) consider US Internet subscription. When broadband is not available, choice is restricted to narrowband Internet or no subscription. Where broadband is available, there is a choice of ADSL, cable, dial-up or no subscription. Table III, shows own-price dial-up access is inelastic, while the own-price broadband access elasticity is unit elastic. Cross-price elasticity estimates indicate that broadband is a substitute for dial-up, but dial-up does not substitute for broadband. Not surprisingly, ADSL and cable are substitutes.

III. Model Specification

Train et al. (1987) define a portfolio as a particular level of consumption of telephone service, where the portfolio contains the number and duration of fixed-line calls to discrete destinations by time of day. The customer is seen as choosing a portfolio and tariff pair from an exhaustive set of possible combinations. The focus of this study is broader and characterises household telecommunications consumption patterns for several services, viz., fixed-line and mobile telephony, and the Internet. Within this framework, following Train (1986), the discrete subscription (access) demand equations are treated as jointly determined with service usage. Household

telecommunications usage is estimated by service type, e.g., for fixed-line telephony no break down by distance, duration, time of date or day of week is attempted. To begin, based on observed subscription, households are allocated to the mutually exclusive and exhaustive groups: Portfolio A (fixed-line subscription only); Portfolio B (fixed-line and Internet subscription); Portfolio C (fixed-line and mobile telephony subscription); and Portfolio D (fixed-line and mobile telephony, and Internet subscription). The portfolios, depicted in Figure 1, suggest that fixed communications services are enhanced through mobility, and that communications and information services are distinct. However, this dichotomy will become less apparent with the increased penetration and development of 3G and WiFi markets.

Discrete-continuous models recognise that household i indirect utility depends on prices, income and service attributes, and is conditioned by household demographic characteristics. As this utility is not observed by the analyst it is treated as a random variable. To make the model operational, for household i and portfolio j, utility is partitioned into deterministic (V) and stochastic (ε) components

$$U_{ij} = V_{ij} + \varepsilon_{ij}. \tag{1}$$

Following Train, (1) is specified as,

$$U_{ij} = ln((\alpha^i + \sum_k \beta_k^i p_{jk} + \theta(y_i - r_j) + \psi f(z_i, s) + \varepsilon_{ij}) e^{-\theta_{p_j}}), \tag{2}$$

where f is a vector-valued function of observed characteristics of alternative portfolio j and the household, e_i is a function of unobserved factors, α^i, β_k^i and θ are scalar parameters, ψ is a vector of parameters. The price associated with the usage of service k in portfolio j chosen by household i is denoted by p_{jk}. Household i's income is net of the rental price of portfolio j and is denoted $(y_i - r_j)$.

Since household i selects the portfolio that yields greatest utility, the probability that household i selects portfolio j is,

$$P_{ij} = \Pr(V_{ij} + \varepsilon_{ij} > V_{il} + \epsilon_{il}), \quad l \neq j. \tag{3}$$

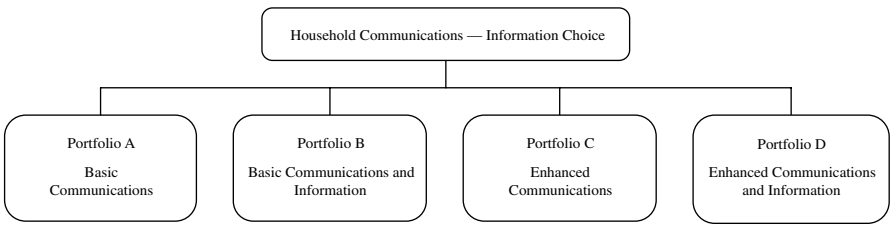

Figure 1. Observed household subscription.

With errors distributed extreme value the conditional probability of portfolio j is

$$P_{ij} = \frac{e^{\alpha^i + \sum_k \beta^i p_{jk} + \theta(y_i - r_j) + \psi f(z_i, s)}}{\sum_{l \in J} e^{\alpha^i + \sum_k \beta^i p_{jk} + \theta(y_i - r_j) + \psi f(z_i, s)}}. \tag{4}$$

For an observed portfolio, the corresponding system of continuous demand functions contained in portfolio j implied by (2) is,

$$x_{ijk} = \alpha^i - \beta^i_k/\theta + \sum_k \beta^i_k p_{jk} + \theta(y_i - r_j) + \psi f(z_i, s) + \varepsilon_{ijk} \tag{5}$$

where x_{ijk} is the quantity of service k used in portfolio j.

IV. Econometric Procedures

Discrete subscription choice is modelled as multinomial logit (MNL) and relates the service portfolio subscription probability (4) to prices, income and household variables. System (5) is the set of telecommunications service demands corresponding to household subscription. The systems are estimated simultaneously by portfolio. Consistent estimation requires two-stage estimation to correct for any bias induced through endogeneity and by sample selection. Endogeneity arises from the observed choice, represented by binary variables contained in **d** and prices in **p** being correlated with the error terms in $\boldsymbol{\varepsilon}$. Following Train, instrumental variables for **d** and **p** are generated by

$$\mathbf{d} = \hat{\mathbf{P}}\mathbf{a}_1 + \mathbf{w}\mathbf{b}_1 + \mathbf{u}_1 \tag{6}$$

and

$$\mathbf{p} = \tilde{\mathbf{P}}\mathbf{a}_2 + \mathbf{w}\mathbf{b}_2 + \mathbf{u}_2 \tag{7}$$

where $\hat{\mathbf{P}}$ contains the estimated choice probabilities, while $\tilde{\mathbf{P}}$ is the price-weighted matrix of choice probabilities, **w** is a matrix of exogenous variables, $\mathbf{u}_1$ and $\mathbf{u}_2$ are error terms, and **a**, **b** are vectors of parameters to be estimated. The predicted values of (6) and (7) replace **d** and **p** in (5).

Sample selection bias occurs when a household's predicted service portfolio is different to the observed choice. The difference is caused by the presence of unobserved factors that induce the household to select a portfolio different to the choice predicted by the subscription model. Unbiased parameters are estimated by augmenting the usage demand equations with the selectivity correction term:

$$E(\varepsilon_{ij}) = \sum_{l \neq j}^{J} \frac{\sigma\sqrt{6R_{jl}}}{\pi} \left(\frac{P_{il} \ln P_{il}}{1 - P_{il}} + \ln P_{ij} \right) \tag{8}$$

where $E(\varepsilon_{ij})$ is the expected error, σ is the standard deviation of the population error and R_{jl} is the correlation coefficient between portfolio j and portfolio l. Augmenting the usage demand equations with selectivity correction terms result in the following equations for simultaneously estimation by Zellner's SUR estimator,

$$x_{ijk} = (\alpha^i - \beta^i_k/\theta) + \alpha_{jk}\hat{d}_j + \sum_k \beta^i_{jk}\hat{p}_{ijk} + \theta_{ijk}(y_i - r_j) + \psi_{ijk}z_{ij} + \sum_{l \neq j} \gamma_{lj}C_{lj} + \varepsilon_{ijk} \quad (9)$$

where $j, l =$ A, B, C, D, and $k =$ F, I, M.

V. Sampling Frame and Questionnaire Design

Liberalisation of the Australian telecommunications industry was managed through a competition phase between incumbent Telstra and entrant Optus (1992–1997), followed by open competition post-1997. According to the OECD (2003), 89 active licensees supply fixed PSTN service. Telstra's wholesale share of the fixed-line market is 94.1%, including basic access lines resold by its competitors. Its main challenger is Optus, whose market share is only 5.9%. A further four offer digital mobile telephony – Optus, Orange, Telstra and Vodafone provide terrestrial mobile telecommunications service. Optus, Iridium Satellite, Telstra and Vodafone collectively provide 100% national coverage. Terrestrial networks span 13% of Australia's geographic area (ACCC, 2003). Despite continued growth in Internet subscription to about 5.2 million at March 2004, the growth in the number of ISPs fell from 767 in June 2000 to 694 in March 2004.

A profile of Australian household telecommunications usage is generated in August 2003 through a telephone survey. The sampling frame consists of an exogenously stratified sample of 1456 respondent households. Within strata, choice-based sampling ensures 100 respondent households are surveyed from Australian State and Territory capital cities plus the populous coastal areas of the Gold Coast (Queensland), Newcastle and Wollongong (New South Wales). A further 350 respondents from rural and remote regions in the States and the Northern Territory are surveyed. Also, six pilot survey responses are included in the sample. Respondent households are asked to supply information concerning their subscription, estimated monthly expenditure and usage of fixed-line and mobile telephony, and Internet-delivered services. Services contained in a household portfolio can be obtained from a single carrier or from several carriers. Information relating to home technology, network quality, and household and main income earner demographics are also sought.

The questionnaire is comprised of a 19-page A4 document, and a maximum 37 responses are sought. In particular, (a) three questions ask household location and two questions identify local remoteness (proximity to community access points); (b) five questions concern subscribed services and household communication lines; (c) three questions elicit household usage by service; (d) another question identifies initial reasons for subscription; (e) four questions concern the timing and duration of service usage; (f) three questions identify the purpose for usage; three questions obtain billing amount estimates; and (g) three questions record the quality of telecommunications service received. Finally, (h) seventeen questions elicit information concerning household characteristics and those of the main income earner. Household characteristics include aspects of resident profile (persons; persons by gender; persons by adult and child), household mobility (tenure at residence), economic position (income) and household location (metropolitan or rural). Details of the main income earner profile sought include age, education, ethnicity, gender, occupation and employment status and mode.

Of 1456 survey respondents, 265 (18%) subscribe to Portfolio A, 167 (12%) to Portfolio B, 312 (21%) to Portfolio C and 708 (49%) to Portfolio D.[2] Pairwise household income comparisons indicate that Portfolio D subscribers earn 62% more income than other respondent households. Conversely, Portfolio A subscribers receive half the income of the 555 households not subscribing to Portfolio D. Portfolio D and Portfolio B subscribers have similar household incomes. The household income received by Portfolio B subscribers is 50% higher than for households subscribing to Portfolio C. Furthermore, Portfolio D subscriber households have more female residents, while their main income earners are mostly younger, self-employed and possess a post-graduate qualification. Portfolio C subscriber households are smaller in size with fewer children, have relatively fewer university student and university qualified residents. Finally, the main income earners of Portfolio C subscribing households are less likely to be self-employed, males, in a skilled or a professional occupation relative to those subscribing to Portfolio B.

VI. Variables and Estimation

Variables used to estimate the MNL subscription and service usage models are presented in Table IV.

[2] Four households indicate no fixed-line telephony subscription. Two households subscribe to mobile telephony only, another subscribes to the Internet and mobile telephony, and while yet another subscribes only to the Internet.

Table IV. Variables

Variable	Definition
Economic	
Fixed-line	Price per average duration fixed-line telephone call
Internet	Price per average duration Internet session
Mobile	Price per average duration mobile telephone call
Income	Monthly household income less portfolio subscription price
Family	
Mature	= 1, if over two persons and main income earner aged over 50 years; = 0, otherwise
Young	= 1, if age of main income earner is less than 30 years; = 0, otherwise
Household	
Country	= 1, if house in rural area; = 0 otherwise
East City	= 1, if house in Brisbane, Canberra, Melbourne or Sydney; = 0, otherwise
Non-English	= 1, if language spoken in household is not English; = 0, otherwise
Children	Persons aged less than 15 years
Persons	Persons reside in household
Degree	Persons with pass degree
Tenure	Years at current address
Main income earner	
Age	Age of the main income earner
Female	= 1, if main income earner is female; = 0, otherwise
Postgraduate	= 1, if main income earner has postgraduate qualification; = 0, otherwise
Pension	= 1, if main household income is from social security payment; = 0, otherwise
Self-employ	= 1, if main income earner is self-employed; = 0, otherwise
Skilled	= 1, if main income earner occupation is Associate Professional, Defence Force Personnel, Manager, Professional, Public Servant or Tradesperson; = 0, otherwise

Fixed-line and mobile telephony and Internet usage prices are calculated as the average expenditure per call or session, respectively. For example, average fixed-line usage price is net (of service rental price) monthly expenditure divided by monthly calls. Table V lists monthly telecommunications service rental prices used in this calculation. Additionally, household income is monthly gross income less the rental price of the portfolio. Demographic variables are arranged by family, household and main income earner profile.

Table V. Monthly service rental price

Variable	Rental price	Source
Fixed-line	A$19.90	ACCC, (2002)
Internet	A$25.35	ITU, (2002)
Mobile	A$10.00	ITU, (2003)

1. Subscription model results

Since the subscription choice model is non-linear in its arguments, marginal effects are calculated and presented in Table VI. Coefficients estimates for own- and cross-partial price effects are negative and positive, respectively. Further, positive parameter estimates for income, other than for fixed-line telephony, indicate that telecommunications services are viewed as normal goods. By contrast, an increase in household income has a negative impact on the probability of basic or fixed-line telephony subscription, i.e., it is considered an inferior good. This means that service migration from fixed-line telephony occurs with a rise in household income. Table VI also suggest households are more likely to subscribe to fixed-line only service when the primary source of household income is from a pension and many persons reside in the household. Fixed-line usage price does not affect any portfolio subscription probability. Table VI also shows a rise in Internet and mobile usage price increases the probability of selecting Portfolio A, viz., mobile telephony and Internet services are viewed as substitutes for fixed-line telephony. Other factors that reduce the Portfolio A selection probability are residence in an Eastern mainland capital city and many resident children. Finally, Portfolio A subscription is less likely when a main income earner is a postgraduate student.

Higher mobile usage price and household income increase the Portfolio B subscription probability, i.e., mobile telephony is considered a substitute for the portfolio and a normal good. The subscription probability is also higher for households with children, degree qualified adults and a self-employed or pensioner main income earner. The Portfolio C (fixed-line and mobile telephony) subscription probability increases with the Internet usage price, but declines with the own mobile telephony usage price. Non-English speaking households have a higher probability of selecting mobile telephony to the exclusion of Internet service. Households with degree qualified persons are less willing to subscribe to Portfolio C, as are households with a self-employed main income earner. Finally, household subscription declines with main income earner age.

Portfolio D subscription (fixed-line and mobile telephony, and Internet service) falls with own mobile and Internet usage prices, and increases with household income. Households with more than two residents that are not children

Table VI. MNL subscription model

Variable	Portfolio			
	A	B	C	D
Constant	−0.19089*	−0.29208	0.21849	0.26448
	(0.05950)	(0.06356)	(0.08751)	(0.11460)
Economic				
Fixed-line	−0.00038	0.00339	−0.00003	−0.00297
	(0.00296)	(0.00223)	(0.00511)	(0.00645)
Internet	0.02212*	0.01204	0.04370*	−0.07786*
	(0.00938)	(0.01160)	(0.01574)	(0.02499)
Mobile	0.03037*	0.03085*	−0.02129*	−0.03992*
	(0.00462)	(0.00443)	(0.00665)	(0.00838)
Income	−0.00003*	0.00001*	−0.00001	0.00004*
	(0.00001)	(0.00000)	(0.00007)	(0.00001)
Family				
Mature	−0.14494*	−0.20713*	0.07824	0.27383*
	(0.05048)	(0.09304)	(0.06834)	(0.09607)
Young	−0.02164	−0.05352	0.05250	0.02266
	(0.04510)	(0.04731)	(0.05421)	(0.07457)
Household				
Country	0.00452	0.03366	0.02139	−0.05957
	(0.02111)	(0.02461)	(0.03505)	(0.04390)
East City	−0.04664*	0.02168	−0.00321	0.02817
	(0.02363)	(0.02435)	(0.03358)	(0.04204)
Non-English	0.06712	0.01286	0.13219*	−0.21217*
	(0.04887)	(0.05392)	(0.07677)	(0.10146)
Children	−0.02984*	0.02527*	−0.02410	0.02867
	(0.01299)	(0.01207)	(0.02527)	(0.02368)
Persons	0.00755*	−0.01654	−0.02512	0.03411
	(0.00377)	(0.01056)	(0.01850)	(0.01617)
Degree	0.00778	0.03506*	−0.10863*	0.06580*
	(0.01662)	(0.01397)	(0.02700)	(0.02838)
Tenure	0.00102	0.00128	0.00218*	−0.00447*
	(0.00072)	(0.00097)	(0.00133)	(0.00177)
Main income earner				
Age	0.00122	−0.00064	−0.00286*	0.00228
	(0.00075)	(0.00087)	(0.00125)	(0.00169)
Female	−0.01213	−0.03781	0.05008	−0.00013
	(0.02096)	(0.02545)	(0.03164)	(0.04064)
Postgraduate	−0.09649*	−0.03659	0.05778	0.07530
	(0.04461)	(0.03388)	(0.05230)	(0.06164)

Table VI. Continued

Variable	Portfolio			
	A	B	C	D
Pension	0.06769*	0.06927*	0.04474	−0.18171*
	(0.02679)	(0.03066)	(0.04031)	(0.05262)
Self-employ	0.02869	0.06535*	−0.16463*	0.07059
	(0.02894)	(0.02597)	(0.04882)	(0.05195)
Skilled	−0.03808	0.03680	−0.03127	0.03256
	(0.02318)	(0.02651)	(0.03299)	(0.04197)

Note: Standard errors are in parentheses.
*Statistically significant at 5%.

and a main income earner aged more than 50 years increase the Portfolio D subscription probability. More residents also increase the subscription probability, especially when they are degree qualified. Pensioner main income earners negatively impact on household subscription to Portfolio D.

Usage price and income subscription probability elasticity estimates are provided for portfolios contained in the MNL subscription model in Table VII and Table VIII, respectively. All portfolios, except Portfolio A (fixed-line only), contain several services. Accordingly, a portfolio may have more than one own-price elasticity. Consider, e.g., Row 1 of Table VII. As fixed-line service is contained in all portfolios, (bolded) own-price usage elasticity

Table VII. MNL model price elasticity estimates

Usage	Portfolio			
	A	B	C	D
Fixed-line	**−0.01**	**0.05**	**0.00**	**−0.01**
Internet	0.38*	**0.20**	0.36*	**−0.24***
Mobile	1.07*	1.03*	**−0.36***	**−0.26***

Note: Elasticity calculated at sample means.
*Statistically significant at 5%.
Bold is own-price elasticity.

Table VIII. MNL model income elasticity estimates

Usage	Portfolio			
	A	B	C	D
Income	−1.15*	0.26*	−0.25*	0.25*

Note: Elasticity calculated at sample means.
*Statistically significant at 5%.

estimates appear in each row (portfolio) of the table. Interestingly, a percent increase in the fixed-line usage price does not impact on any portfolio subscription probability.

For Portfolio B, neither fixed-line nor Internet usage price affects household subscription to that portfolio. Household Portfolio C (fixed-line and mobile telephony service) subscription falls when the mobile usage price increases, however, the effect is inelastic. For Portfolio D, both mobile telephony and Internet usage own-price elasticity estimates are negative and inelastic. Table VII also contains cross-price subscription elasticity estimates. Column 1 indicates a percent increase in mobile or Internet usage price increases the likelihood of Portfolio A (fixed-line) subscription. The mobile usage price effect is elastic with a percent rise in price implying an increase in fixed-line subscription of 1.07%. Increased mobile telephone usage price has a similar effect on Portfolio B selection. Finally, Portfolio C subscription probability increases in response to a rise in the Internet usage price. Again, this impact is inelastic.

Household income (net of service subscription price) subscription probability elasticity estimates are listed in Table VIII. Elasticity estimates are positive and inelastic for Portfolio B and Portfolio D. Interestingly, Internet service is included in both portfolios. The corresponding elasticity estimates for Portfolio A and Portfolio C are negative. Fixed-line telephone service is common to both portfolios, and in particular, the fixed-line only portfolio (Portfolio A) is elastic.

2. Usage model results

Table IX contains partial coefficient estimates for fixed-line usage demand by portfolio, while Table X presents partial effects for Internet and mobile telephony usage demand (B, C and D only). First, it is important to note with regard to the correlation of household portfolio choice and associated usage demands that the selectivity correction terms vary in significance by service and portfolio.[3] In particular, the fixed-line selectivity correction coefficients are significant for Portfolio A and Portfolio B. This result validates employing the maintained discrete-continuous framework

[3] Correlation among household portfolio subscription choice dummy variables and random error terms in the calling demand equations arises when unobserved factors influence household subscription and usage demands. That is, disturbance term expectations in the usage demand equations are not zero for each observation. This problem is addressed by including a selectivity correction variable in the usage demand equations to force disturbance expectation to zero. Subscription choice and usage demand is interdependent when the estimated coefficient on the selectivity correction variable is different from zero. The structure of the subscription choice and usage demand models independence is observed by examining the pattern of significance for correction variables through the usage demand systems.

Table IX. Fixed-line usage demand model estimates

Variable	Portfolio			
	A	B	C	D
Constant		−0.08395	3.34440	1.29480
		(4.8590)	(6.5710)	(2.5080)
Economic				
Fixed-line	−3.17340*	−3.14540*	−3.14100*	−3.13140*
	(0.94820)	(0.9473)	(0.9588)	(0.9569)
Internet	3.37200	3.27090	2.30720	2.71730
	(2.87000)	(2.8710)	(2.9060)	(2.8960)
Mobile	−0.07372	−0.13876	−0.10694	−0.12313
	(1.08800)	(1.0810)	(1.1500)	(1.1440)
Income	0.00302*	0.00338*	0.00384*	0.00372*
	(0.00103)	(0.0010)	(0.0010)	(0.0010)
Family				
Mature	−5.80140	−6.08200	−3.71620	−3.97040
	(13.55000)	(13.5500)	(13.6800)	(13.6800)
Young	30.21600*	29.94100*	30.39400*	30.45700*
	(11.78000)	(11.7900)	(11.8800)	(11.8500)
Household				
Country	11.64600	11.88400	10.95600	11.19400
	(7.72400)	(7.7200)	(7.8130)	(7.8000)
East City	7.11020	7.75420	8.38130	8.31000
	(7.43400)	(7.4120)	(7.5150)	(7.4930)
Non-English	−18.92500	−19.42300	−22.43600	−21.37900
	(17.08000)	(17.0600)	(17.2800)	(17.2100)
Children	11.86300*	12.34500*	13.36800*	13.23600*
	(2.92200)	(2.8960)	(2.9160)	(2.9010)
Persons	0.56406	0.33173	0.66618	0.47063
	(0.90980)	(0.9268)	(0.9589)	(0.9178)
Degree	4.66830	4.78890	6.75980	6.25680
	(4.90500)	(4.9010)	(5.0260)	(4.9100)
Tenure	0.71534*	0.71770*	0.64639*	0.66660*
	(0.28960)	(0.2895)	(0.2922)	(0.2918)
Main income earner				
Age	0.89075*	0.86627*	0.97020*	0.94934*
	(0.19090)	(0.1931)	(0.1927)	(0.1922)
Female	5.32860	5.15090	4.80770	4.96640
	(7.10900)	(7.1100)	(7.2080)	(7.1710)
Postgraduate	0.03923	0.77683	1.24810	1.25130
	(10.53000)	(10.4900)	(10.6100)	(10.5900)

Table IX. Continued

Variable	Portfolio			
	A	B	C	D
Pension	−14.73300	−14.79900	−17.64100*	−16.97600*
	(9.13100)	(9.1320)	(9.1910)	(9.2260)
Self-employ	43.45900*	43.56700*	46.23400*	45.53100*
	(8.86200)	(8.8520)	(9.0650)	(8.9050)
Skilled	2.12600	2.75730	4.17730	3.98510
	(7.34900)	(7.3110)	(7.4100)	(7.3830)
Selectivity correction				
	0.92729	0.03746	−2.24090	−2.11550
	(3.42100)	(1.8060)	(4.7950)	(4.3150)
	9.12730*	10.05200*	4.61600	5.30390
	(5.32300)	(4.9780)	(5.7490)	(5.7890)
	−11.14400*	−11.16900*	−1.31710	−2.32760
	(4.71800)	(4.7840)	(1.7680)	(2.3310)

Note: Standard error in parentheses.
*Statistically significant at 5%.

for fixed-line telephony subscription-usage. Further, the estimated coefficients for fixed-line price (negative) and income (positive) are consistent with consumer theory. Fixed-line usage, for all portfolios, is unaffected by Internet or mobile usage price changes. Interestingly, the number of children, residential tenure, and age and self-employment of the main income earner are associated with increased fixed-line usage in all portfolios.

Table X also supports the maintained discrete-continuous specification for mobile and Internet. Own-price effects are positive while income effects are negative. The results also suggest that mobile telephony is a substitute for Internet usage in both Portfolio B and Portfolio D. Not surprisingly, Internet is not viewed as a substitute for mobile telephony. Further, for Internet usage, demand is greater with more children and persons with a degree residing in the household. For the main income earner, demand is less for a household with a female main income earner and those with postgraduate qualifications, while demand increases with age, and skilled self-employment of the main income earner. Distinct patterns appear for mobile usage demand. In particular, younger persons are more intense users, while child numbers and self-employment by the main income earner matter.

Table XI contains own-price usage demand elasticity estimates corresponding to the portfolios contained in the MNL model. Namely, as Portfolio A contains fixed-line service only, there is a single fixed-line usage demand equation estimated, and Column 1 of Table XI lists the

Table X. Internet and mobile usage demand model estimates

Variable	Internet Session Demand		Mobile Call Demand	
	B	D	C	D
Constant	−45.57900	−9.56480	28.99600	12.07000
	(23.5800)	(5.3320)	(31.9500)	(13.5900)
Economic				
Fixed-line	0.08018	0.08590	0.33128	0.28275
	(0.2972)	(0.3032)	(0.8221)	(0.8220)
Internet	−6.31670*	−6.53400*	1.28610	−0.19678
	(0.9282)	(0.9490)	(2.5410)	(2.5390)
Mobile	0.88862*	0.89908*	−7.15500*	−7.23300*
	(0.4351)	(0.4696)	(1.1760)	(1.1990)
Income	0.00128*	0.00142*	0.00627*	0.00674*
	(0.0003)	(0.0003)	(0.0011)	(0.0010)
Family				
Mature	−5.19590	−4.35070	8.75470	10.08900
	(4.4530)	(4.5380)	(11.5700)	(11.7300)
Young	3.55920	3.77670	53.53500*	52.68200*
	(4.0340)	(4.0930)	(10.3800)	(10.3000)
Household				
Country	−2.23140	−2.51250	−6.57900	−7.56850
	(2.5180)	(2.5640)	(6.8210)	(6.8340)
East City	0.19523	0.42035	5.12610	5.23820
	(2.4610)	(2.5100)	(6.8900)	(6.8680)
Non-English	−1.14100	−1.92040	3.97440	−0.11802
	(5.3490)	(5.4470)	(14.7800)	(14.5800)
Children	3.53540*	3.89330*	4.66040*	5.17370*
	(0.9373)	(0.9414)	(2.7380)	(2.6990)
Persons	−0.45739	−0.40038	−0.34247	0.41246
	(0.3015)	(0.2916)	(0.9590)	(0.7924)
Degree	8.15320*	8.74300*	−0.27824	1.99570
	(1.6650)	(1.6880)	(4.8390)	(4.3570)
Tenure	−0.08490	−0.10536	−0.21794	−0.29610
	(0.0909)	(0.0924)	(0.2456)	(0.2464)
Main income earner				
Age	0.35838*	0.39218*	−0.08796	−0.02953
	(0.0663)	(0.0657)	(0.2112)	(0.2122)
Female	−4.64600*	−4.71930*	9.10200	8.30750
	(2.3210)	(2.3660)	(6.2280)	(6.1160)
Postgraduate	−8.02470*	−7.83290*	3.25040	2.92820
	(3.4580)	(3.5220)	(9.0080)	(8.9680)

Table X. Continued

Variable	Internet Session Demand		Mobile Call Demand	
	B	D	C	D
Pension	2.90710	2.04260	−4.17160	−6.73370
	(3.0090)	(3.0710)	(8.1010)	(8.3570)
Self-employ	12.95000*	13.74200*	27.08900*	30.23000*
	(2.9860)	(3.0390)	(8.3500)	(7.6910)
Skilled	5.44050*	5.93650*	8.05280	8.56450
	(2.3870)	(2.4320)	(6.7900)	(6.7360)
Selectivity correction				
	27.07100*	26.21100*	−57.96000*	−57.80300*
	(6.0840)	(6.3680)	(23.6400)	(23.5800)
	−22.97200*	2.14220	53.79100*	51.18100*
	(6.2920)	(2.9440)	(24.4100)	(24.9700)
	−4.53780*	−27.97700*	−0.02462	2.06220
	(2.1090)	(6.1500)	(2.0330)	(3.3130)

Note: Standard error in parentheses.
*Statistically significant at 5%.

corresponding own-price elasticity estimate. Conversely, as Portfolio D includes fixed-line and mobile telephony, and Internet service, Column 4 of Table XI reports own-price usage elasticity estimates for these services. Clearly, two elasticity estimates are reported for Portfolio B and Portfolio C, respectively, in Column 2 and Column 3 of the table. All usage own-price elasticity estimates reported in Table XI are negative and inelastic. Fixed-line usage demands are the smallest in absolute magnitude with values close to zero. A percent usage price rise is typically associated with a fall in monthly call numbers of approximately 0.05%. While Internet usage demand is inelastic, it is ten-fold that for fixed-line usage, viz., a percent increase in average Internet usage price reduces household monthly activity by about 0.5%. The reported elasticity estimates for household monthly mobile usage are near one in absolute value, with a percent increase in the average Internet usage price results in an approximate 0.85% reduction in monthly mobile calling.

Table XII reports cross-price usage elasticity estimates. Inspection reveals that cross-price effects are generally less important in household usage decisions than for portfolio choice, with only three cross-price usage elasticity estimates significant, and these are relatively small in magnitude. Namely, Table XII indicates a percent rise in the average monthly Internet session price results in a 0.04% increase in monthly fixed-line calling in Portfolio C. Further, a percent increase in the average mobile telephony usage charge

Table XI. Usage demand model own-price elasticity estimates

Usage	Portfolio			
	A	B	C	D
Fixed-line	−0.06*	−0.06*	−0.05*	−0.05*
Internet		−0.48*		−0.50*
Mobile			−0.84*	−0.85*

Note: Elasticity calculated at sample mean.
*Statistically significant at 5%.

Table XII. Usage demand model cross-price elasticity estimates

Usage	Portfolio			
	A	B	C	D
Fixed-line calling				
Internet	0.06	0.06	0.04*	0.05
Mobile	−0.00	−0.00	−0.00	−0.00
Internet session				
Fixed-line		0.00		0.00
Mobile		0.14*		0.14*
Mobile calling				
Fixed-line			0.02	0.01
Internet			0.07	−0.01

Note: Elasticity calculated at sample means.
*Statistically significant at 5%.

corresponds to an average monthly Internet activity rise of 0.14% for Portfolio B and Portfolio D.

Table XIII contains household income (net of service subscription price) usage demand elasticity estimates. Namely, as Portfolio A contains fixed-line service only, and Column 1 of Table XIII lists the corresponding income elasticity estimate. As Portfolio D includes fixed-line and mobile telephony and Internet service, Column 4 of Table XIII reports income usage elasticity estimates for the services. Two elasticity estimates are reported for Portfolio B and Portfolio C. All usage demand income elasticity estimates are positively signed and inelastic. Fixed-line call demand household income elasticity estimates are similar in magnitude with a percent increase in household income resulting in increase average usage of approximately 0.15%. The corresponding elasticity estimates for Internet service are approximately 0.25%. For mobile telephony calling, the income elasticity is close to one in value at about 0.88%.

Table XIII. Usage demand model income elasticity estimates

Usage	Portfolio			
	A	B	C	D
Fixed-line	0.10*	0.15*	0.16*	0.16*
Internet		0.22*		0.25*
Mobile			0.82*	0.88*

Note: Elasticity calculated at sample means.
*Statistically significant at 5%.

VII. Synthesis of the Results

Table XIV and Table XV provide an overview of income and price effects for the subscription model and usage model, respectively. Table XIV indicates that income is an important factor determining household portfolio choice, with higher household income leading to an increased likelihood of subscription to more than basic communications (fixed-line) service. That is, households earning a relatively low income, such as those depending on pensions as a primary income source, tend to subscribe only to fixed-line telephony. By contrast, high income households subscribe to the complete set of available services, viz., fixed-line and mobile telephony and Internet service (Portfolio D). Furthermore, price elasticity estimates are inelastic and small in magnitude – in fact zero for fixed-line access. More interest lie in the cross-price elasticity estimates both in terms of sign and magnitude. In particular, mobile usage price elasticity estimates are elastic for Portfolio

Table XIV. Overview of subscription model income and price effects

Variable	Portfolio			
	A	B	C	D
Income	Inferior good	No effect	Normal good	Normal good
Fixed-line Price	No own effect	No own effect	No own effect	No own effect
Mobile Price	**Substitute good**	**Substitute good**	Negative own effect	Negative own effect
Internet Price	Substitute good	No own effect	Substitute good	Negative own effect

Note: Bold is elastic.

Table XV. Overview of usage model income and price effects

Variable	Portfolio			
	A	B	C	D
Fixed-line				
Income	Normal good	Normal good	Normal good	Normal good
Fixed-line Price	Negative own effect	Negative own effect	Negative own effect	Negative own effect
Mobile Price	No cross effect	No cross effect	No cross effect	No cross effect
Internet Price	No cross effect	No cross effect	No cross effect	No cross effect
Mobile				
Income			Normal good	Normal good
Fixed-line Price			No cross effect	No cross effect
Mobile Price			Negative own effect	Negative own effect
Internet Price			No cross effect	No cross effect
Internet				
Income		Normal good		Normal good
Fixed-line Price		No cross effect		No cross effect
Mobile Price		Substitute good		Substitute good
Internet Price		Negative own effect		Negative own effect

A and Portfolio B, viz., should average mobile usage prices not be kept low through competition or regulatory oversight then the potential for this segment of the residential market to grow would be prematurely stifled. The same argument is true, but of smaller impact, for Internet prices for Portfolio A and Portfolio C.

Table XV also shows that income is an important determinant of household usage. Usage for all services is greater with higher household income. However, the estimated elasticity magnitudes are greater for mobile calling. Usage price elasticity estimates are generally smaller than those for income

in corresponding subscription and usage demand models. Usage demand equation own-price elasticity estimates clearly indicate consistent negative impacts on calling. Basic or fixed-line calling is least affected. Internet and mobile usage are clearly the more elastic, with mobile telephony usage near elastic. This result bears some importance for the pricing of emerging 3G data-orientated services. Pricing is critical to their ultimate success.

VIII. Conclusions

In conclusion, several study findings have important consequences for the effective bundling of service offerings by carrier. In particular, fixed-line telephony subscription is perceived as an inferior service by respondent households. Also, demand for Internet and mobile telephony subscription rises with income. Moreover, fixed-line telephone usage price rises have no impact on fixed-line subscription or usage. Additionally, Internet and mobile telephony usage price falls reduce low-income (Portfolio A) household subscription and promote the transition of Portfolio A subscribers to portfolios containing enhanced (mobile telephony and Internet) service. A complex implication of these findings is that telecommunication carriers should focus on enhanced service pricing, as this behaviour offers an opportunity to expand the household subscriber network beyond its current reach and into the emerging 3G data services market. Additionally, profiling household telecommunications behaviour using pricing scenarios is helpful for bundling of services. Bundling scenarios are readily obtainable from simulation models based on data and models from this study.

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