

**Household Demand for Wireless Telephony:
An Empirical Analysis**

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I. Introduction

This paper looks at the demand for wireless access to the Internet. In particular, the focus is on the demand for wireless Internet services that would be accessible via a cell phone or a personal digital assistant (PDA) device.¹ The study uses information obtained from an omnibus consumer survey where respondents were asked a number of questions on their use, preference and their “willingness to pay” for technology-based products and services including wireless access to the Internet². This paper builds on our previous studies of the demand for broadband access using models of willingness to pay³. In a study of the demand for broadband access [Rappoport *et al.* (2003c)], the authors focused on the construction of price elasticities for broadband access using a generally overlooked procedure suggested by Cramer (1969). That procedure was modified and used in this study. Price elasticities for wireless Internet access were obtained that ranged from an order of -0.45 for a fixed price of \$20 to slightly over -1.6 for a fixed price of \$60.

The format of the paper is as follows. The next section (II) begins with a short comparison of the relationship between age and income on the penetration rates for mobile (cellular) telephony service phones, any Internet access, broadband Internet Access and purchasing a mobile telephony Internet ready phone. Section III provides a description of the access/usage framework that guides the analysis. In Section IV, price elasticities for wireless Internet access are calculated from kernel-smoothed cumulative distributions of willingness-to-pay (WTP). Conclusions are given in Section V.

II. Descriptive Analysis

The data used in this analysis comes from an omnibus survey. The sample used consisted of 12,000 respondents who responded to the survey during the second quarter of 2003. The survey, CENTRISSM tracks over 75 communications, entertainment and technology areas on a daily basis, at the household level. The CENTRISSM survey is a random digit dialing (RDD) telephone survey administered by the Marketing Systems Group. The survey is capable of providing projections of key entertainment, consumer electronic and communication variables to all census geographies.

Is the demand for wireless Internet access best viewed as the union of the demand for Internet access or more specifically the demand for broadband Internet access and the demand for mobile (cellular) telephony services? Are the underlying demographics similar? The following charts provide some evidence that the demographic drivers of the demand for broadband access and the demand for wireless access to the Internet are similar?

¹ Wireless WIFI Internet packages for accessing the Internet in designated “hot spots” are not included in this study

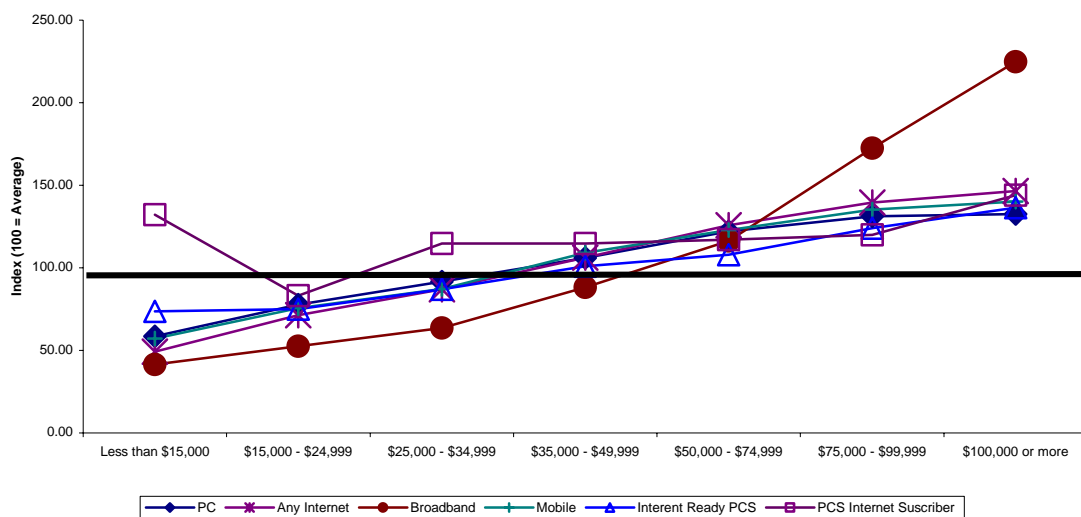
² www.m-s-g.com and www.centris.com

³ In view of the novelty of the Internet phenomenon, it is hardly surprising that the literature on Internet demand is small. Existing studies include several by the present authors [Rappoport, Taylor, Kridel, and Serad (1998), Rappoport, Taylor, and Kridel (1999, 2002a, 2002b 2003c), and Rappoport *et al.* (2003), as well as papers by Hausman, Sidak, and Singer (2001), Andersson and Myrvold (2002), and Varian (2002).

Chart 1 displays the relationship between the level of income and the penetration rates for mobile (cellular) service phones, any Internet access, broadband Internet access and wireless Internet access. All series are normalized at their means and expressed in terms of an index where a value of 100 is the average across all income groups. A value of 150 would imply that the group in question had a 50% higher penetration rate than the overall average penetration rate.

Not surprisingly, any Internet and broadband Internet service display a strong positive correlation with income. All services have above higher penetration rates for income greater than \$50,000.

Chart 1: Index of Product Use as a Function of Income



The penetration rates as a function of age are presented in Chart 2. As expected, penetration rates are a declining function of age. Wireless Internet access is highest in the 21-30 age group, a pointed already noted by wireless providers.

Chart 3 explores the relationship between level of education and the penetration rates of these products and services.

The higher the level of education, the more likely a household will have any of the above services.

A comparison across these products suggests that the same demographics can be used to segment the market potential. Broadband access stands out in this comparison. Table 1 displays the index for three demographic segments for six products and services. With the exception of age, the index for broadband is consistently higher than for any Internet, mobile (cellular) telephony service, Internet ready mobile service phones or mobile service Internet subscription.

Chart 2: Index of Product Penetration as a Function of Age

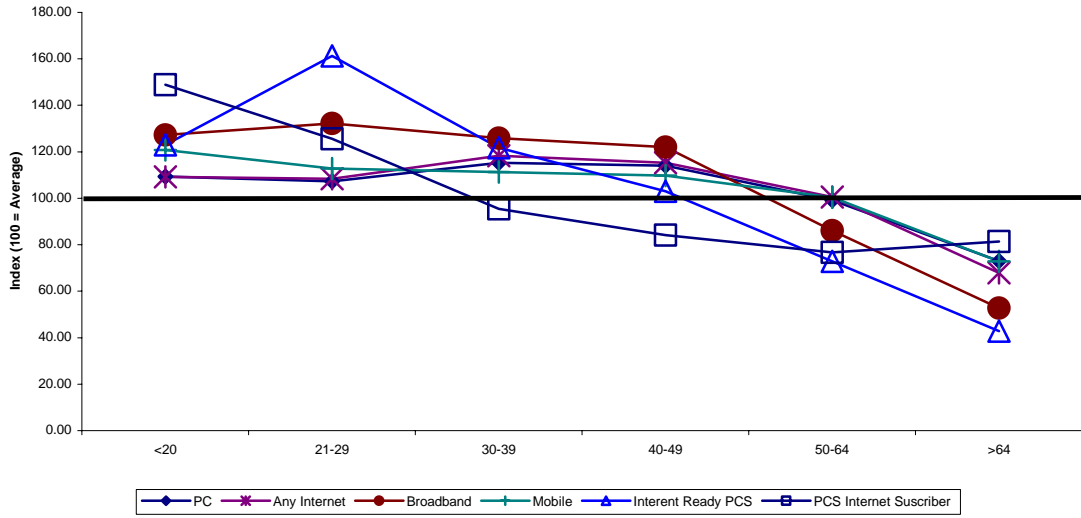


Chart 3: Index of Penetration Rates for Selected Products by Level of Education

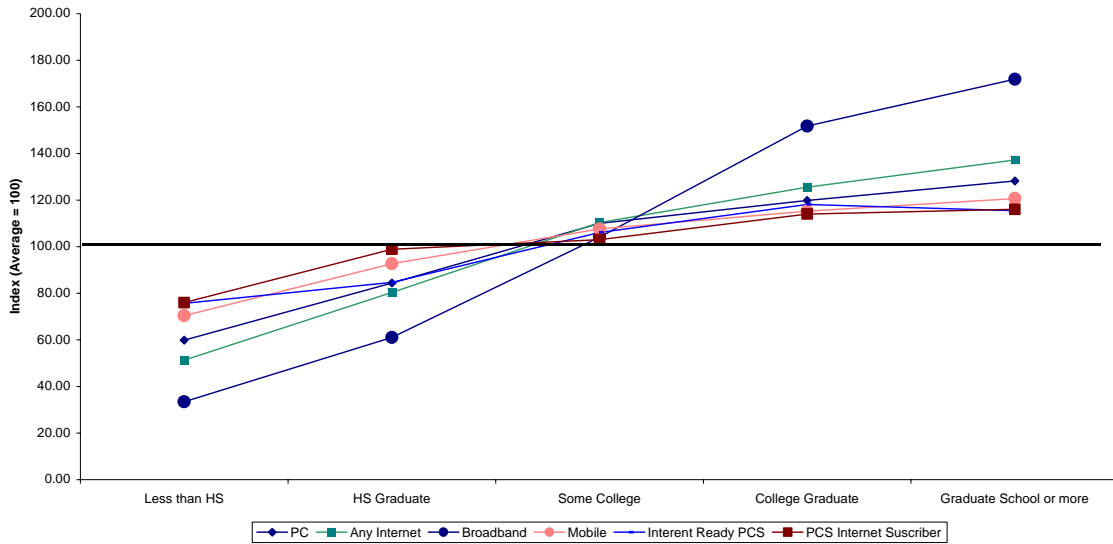


Table 1: Broadband Compared with other Products

	<i>PC</i>	<i>Any Internet</i>	<i>Broadband</i>	<i>Mobile</i>	<i>Internet Ready mobile</i>	<i>Mobile Internet Subscriber</i>
College Graduate	120	126	152	115	118	114
High Income	133	146	225	140	136	144
Age 21-29	107	108	132	113	161	148

The relationship between the use of wireless Internet access and other variables can be assessed by comparing the conditional probability of having wireless Internet access given another factor to the unconditional probability of having wireless access to the Internet. For example, this comparison of probabilities can be used to look at the relative importance of broadband access as a *prima facie* cause of a household obtaining wireless access to the Internet (WI). If $P(WI|Broadband) > P(WI)$ than one could suggest that broadband was a cause of wireless Internet, if broadband was purchased prior to wireless Internet access (which is almost certainly the case for households in this sample). Dividing the conditional probability by the unconditional probability yields an index where a value greater than one indicates that the explanatory variable led to a higher penetration rate as compared to the unconditional penetration rate. Table 2 displays a set of these indices.

Table 2: Conditional Probability of Wireless Internet Access Given Presence of other Factors

X	P(WI X)
Broadband	1.54
Any Internet	1.33
1 Cell Phone	0.78
2 Cell Phones	1.33
3 Cell Phones	1.89
1 Land Line Phone	0.88
2 Land Line Phones	1.23
3 Land Line Phones	1.46
Subscribe to Digital Cable	1.16
Household Recently Moved	1.23

The largest non-demographic factor associated with the subscription of wireless Internet access, aside from pricing considerations, is having broadband access. Nor does it appear to matter whether that broadband access is provided via cable modem or DSL.

Table 3 provides estimated penetration rates for wireless Internet access by wireless company.

Table 3: Share of Wireless Internet Subscribers by Wireless Company

Company	Penetration Rate
Sprint	39.2
Verizon	25.8
AT&T	18.4
Cingular	8.7
T-Mobile	4.8
Other	3.1

Source: www.centris.com

III. Modeling Framework

We begin with usual access/usage framework for determining the demand for access to a network, whereby the demand for access is determined by the size of the consumer surplus from usage of the network in relation to the price of access.⁴ Accordingly, let q denote usage, and let $q(p,y)$ denote the demand for usage, conditional on a price of usage, p , and other variables (income, education, etc.), y . The consumer surplus (CS) from usage will then be given by

$$CS = \int_p^{\infty} q(z, y) dz \quad (1)$$

Let π denote the price of access. Access will then be demanded if

$$CS \geq \pi, \quad (2)$$

or equivalently (in logarithms) if

$$\ln CS \geq \ln \pi. \quad (3)$$

Alleman (1976 and 1977) and Perl (1983) were among the first to apply this framework empirically, doing so by assuming a demand function of the form:⁵

$$CS = \int_p^{\infty} A e^{-\alpha z} y^{\beta} e^u dz \quad (4)$$

where y denotes income (or other variables) and u is a random error term with distribution $g(u)$. Consumer's surplus, CS, will then be given by

$$CS = \frac{A e^{-\alpha p} y^{\beta} e^u}{\alpha} \quad (5)$$

With net benefits from usage and the price of access expressed in logarithms, the condition for demanding access to the telephone network accordingly becomes:

$$P(\ln CS \geq \ln \pi) \quad (6)$$

⁴ See Chapter 2 of Taylor (1994).

⁵ Since its introduction by Perl in 1978 in an earlier version of his 1983 paper, this function has been used extensively in the analysis of telecommunications access demand (see, e.g., Kridel (1988) and Taylor and Kridel (1990)). The great attraction of this demand function is its nonlinearity in income and an ability to handle both zero and non-zero usage prices.

$$= P(u \geq \ln \pi - a + \alpha p - \beta \ln y), \quad (6a)$$

where $a = \ln(A/\alpha)$. The final step is to specify a probability law for consumer surplus, which, in view of the last line in equation (6), can be reduced to the specification for the distribution of u in the demand function for usage. An assumption that u is distributed normally leads to a standard probit model, while an assumption that u is logistic leads to a logit model.

The standard procedure for estimating access demand can thus be seen in terms of obtaining information on the consumer surplus from usage by estimating a demand function, and then integrating beneath this demand function. In the present context, however, our procedure is essentially the reverse, for what we have by way of information are statements on the part of respondents in a survey as to the *most* that they would be willing-to-pay for wireless Internet access. This “*most*” accordingly represents (at least in principle) the maximum price at which the respondent would purchase that type of access. Thus, for any particular price of access, π^* , say, access will be demanded for WTP’s that are this value or greater, while access will not be demanded for WTP’s that are less than this value. Hence, implicit in the *distribution* of WTP’s is an aggregate demand function (or more specifically, *penetration function*) for wireless Internet access. In particular, this function will be given by

$$\begin{aligned} D(\pi) &= \text{proportion of WTP's that are} \\ &\quad \text{greater than or equal to } \pi \\ &= P(\text{WTP} \geq \pi) \quad (7) \\ &= 1 - \text{CDF}(\pi), \end{aligned}$$

where $\text{CDF}(\pi)$ denotes the cumulative distribution function of the WTP’s. Once CDF’s of WTP’s are constructed, price elasticities can be obtained (without intervention of the demand function) via the formula (or an empirical approximation thereof):

$$\text{Elasticity } (\pi) = \frac{d \ln \text{CDF}(\pi)}{d \ln \pi} \quad (8)$$

IV. Modeling Willingness-to-Pay for Wireless Internet Access

As noted, information on willingness-to-pay for wireless Internet access was collected in an omnibus national survey of about 12,000 households for the second quarter, 2003 by the Marketing Systems Group (MSG) of Philadelphia. The omnibus survey, Centris, is a

continuous random telephone survey. Each of the participants in the survey was asked one (but not both) of the following two questions regarding their willingness-to-pay for wireless access to the Internet:

- (a). What is the most you would be willing to pay on a monthly basis for wireless access to the Internet ?
- (b). What is the highest monthly price at which you would consider purchasing wireless access to the Internet?

Calculation of Price Elasticities

As has been noted, an attractive feature of CDF's of willingnesses-to-pay is that they can be interpreted as penetration functions, from which it is possible to obtain price elasticities in line with expression (8) above. Three procedures come to mind as to how these elasticities might be constructed. The most straightforward procedure would be to define the elasticities as simple arc elasticities between selected adjacent values on the empirical CDF's. Unfortunately, however, because of the 'pileups' of responses around WTP values divisible by 5 (e.g. 35, 40, 45 etc), the elasticities that would emerge from this procedure would be highly unstable, and accordingly of little practical use. A second procedure would be to derive the elasticities on the presumption [*a la* Cramer (1969)] that the WTP's are distributed according to the log-normal distribution.⁶ This second procedure was our initial focus, but had to be abandoned when it became apparent that the assumption that the WTP's follow a log-normal distribution is empirically not justified. Finally, a third way, which is the one that we have employed, is to construct the elasticities from a non-parametric approximation to the empirical CDF's.

To approximate the CDF we estimate kernel density functions (using the unit normal density function as the kernel weighting factor) as approximations to the empirical frequency distributions of the WTP's, and then use the empirical approximation to calculate elasticities at various points on these functions.

Wireless Internet Elasticities are displayed in Table 4.

Table 4. Wireless Interent Elasticities

Price	Elasticity
\$70	-2.13
\$60	-1.84
\$50	-1.58
\$40	-1.22
\$30	-0.83
\$20	-0.45

⁶ See Cramer (1969) pp. 40-45 for this discussion of lognormal demand curves

V. Conclusions

This paper has analyzed the demand for wireless access to the Internet using information on willingness-to-pay that was collected in 2003 in an omnibus survey of some 12,000 households. A theoretical framework has been utilized that identifies willingness-to-pay with consumer surplus from usage. The results of this research suggest that the demand for wireless access to the Internet is elastic over the range of prices currently charged by wireless service providers. The determinants of demand are consistent with the determinants of the demand for Internet access and for broadband access. The descriptive analysis suggests that age and income are clearly important in the decision to purchase wireless Internet services. Non demographic variables that are correlated to this decision include indicators of current Internet use, presence of a mobile phone and presence of a personal computer.

This study did not examine the WTP under conditions where customers pay on a usage basis (number of messages, number of bytes transferred). The low penetration rates for wireless Internet access suggest that plans that price on a usage basis have not been readily accepted by consumers. In addition, this study examined WTP for wireless access to the Internet, not for the WTP for combined voice and data access. Indeed, as wireless providers map out future plans, there is some recognition that consumers are looking for a fixed price plan that incorporates both voice and data. Finally, by modifying a generally overlooked procedure suggested by Cramer (1969), it has been possible to obtain non-parametric price elasticities for wireless Internet access from the frequency distributions of the willingnesses-to-pay. The elasticities obtained range from a low value of -.15 to a high value of -2.13. These estimated elasticities are in line with previous studies of the demand for broadband access.

Since these elasticities are constructed from information elicited directly from households, and thus entail the use of contingent-valuation (CV) data, the seriousness (in light of the longstanding controversy surrounding the use of such data) with which our elasticities are to be taken might be open to question.⁷ However, in our view, the values that we have obtained are indeed plausible and warrant serious consideration. Added credence for our results, it seems to us, is provided by the fact that, with wireless Internet access, we are dealing with products (or services) with which respondents are already familiar (and in many instances the respondents already demand), unlike in circumstances (such as in the valuation of a unique natural resource or the absence of a horrific accident) in which there is no generally meaningful market-based valuation can be devised.

⁷ The critical literature on contingent valuation methods is large. See the NOAA Panel Report (1993), Smith (1993), Portnoy (1994), Hanneman (1994), Diamond and Hausman (1994), and McFadden (1994). On the other hand, particularly successful uses of CV data would seem to include Hammitt (1986) and Kridel (1988).

In closing, we would like to say that we feel that the findings of this paper are more suggestive of what is possible to do with willingness-to-pay data of this type. While it is encouraging that, in view of the fact that the question eliciting willingness-to-pay was posed in two different forms, we did not find any apparent “framing” differences, this does not mean that “framing” problems in exercises such as this one are absent. All considered, however, we believe that the results of this paper show that demand analysis involving contingent-valuation data in circumstances in which the products or services are familiar and well-defined is an approach to be encouraged.

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