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Household Demand for Broadband Internet Service[1]

Final report to the Broadband.gov Task Force
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Executive summary

As part of the Federal Communications Commission ("FCC") National Broadband Report to Congress, we have been asked to conduct a survey to help determine consumer valuations of different aspects of broadband Internet service. This report details our methodology, sample and preliminary results. We do not provide policy recommendations.

This draft report uses data obtained from a nationwide survey during late December 2009 and early January 2010 to estimate household demand for broadband Internet service. The report combines household data, obtained from choices in a real market and an experimental setting, with a discrete-choice model to estimate the marginal willingness-to-pay (WTP) for improvements in eight Internet service characteristics. The first three are standard *features* for all current Internet services and include: cost; connection speed; and the reliability of the connection to the Internet. The remaining five characteristics are new *activitie*s that could be bundled with future Internet services. They include the ability to connect to the Internet wirelessly from outside the home, download and watch high-definition movies, designate certain downloads as high-priority, interact with health specialists, and place free videophone calls over the Internet.

Choice experiments are used to estimate household preferences. Respondents are presented with eight choice scenarios, and in each scenario, must choose between a pair of Internet service alternatives that differ by the levels of their characteristics. The information in these choices is enriched with market data by having respondents indicate whether they would stay with their current (actual) Internet service or switch to the hypothetical service they had just selected. The marginal utility parameters of the representative household's utility function, and WTP, are then estimated from all observed choices.

Knowledge Networks Inc. (KN) administered the online survey. Beginning December 24, 2009, KN obtained responses from a sample of 5,799 experienced Internet users and 472 inexperienced users. The demographics of the sample are relatively similar to those reported by the United States Census Bureau.

Our empirical results show that reliability and speed are important characteristics of Internet service. The representative household is willing to pay about $20 per month for more reliable service and $45-48 for an increase in speed. Willingness-to-pay for speed increases with education, income and online experience, and decreases with age. Rural households value connection speed by about $3 more per month than urban households. Households are also willing to pay an additional $6 so that their Internet service provides the ability to designate downloads as high-priority, about $4 for the ability to interact with health specialists online, about $3 for the ability to download and view full-length movies, and about $5 for the ability to place free phone calls over the Internet and see the person being called.

Using these results, we calculate that a representative household would be willing to pay about $59 per month for a less reliable Internet service with fast speed ("Basic"), about $85 for a reliable Internet service with fast speed and the priority feature ("Premium"), and about $98 for a reliable Internet service with fast speed plus all other activities ("Premium Plus"). An improvement to very fast speed adds about $3 per month to these estimates. In contrast, an inexperienced household with a slow connection would be willing to pay about $31 per month for a Basic Internet service, about $59 per month for a Premium service and $71 for a Premium Plus service.

An interesting finding from our results is that valuations for Internet service increase substantially with experience. The implication is that, if targeted correctly, private or public

programs that educate households about the benefits from broadband (e.g., digital literacy training), expose households to the broadband experience (e.g., public access) or directly support the initial take-up of broadband (e.g., discounted service and/or hookup fees) have potential to increase overall penetration in the United States.

Key words: Broadband, choice experiment, experience, Internet, willingness-to-pay

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1. Introduction

As part of the Federal Communications Commission (FCC) National Broadband Report to Congress, we have been asked to conduct a survey to help determine consumer valuations of different aspects of broadband Internet service. This report details our methodology, sample and empirical results. We do not provide policy recommendations.

Given its enormous potential for improving societal welfare, public policy on broadband deployment and adoption has been one of the most debated aspects of United States telecommunications. Both industry and government have discussed supply-side proposals that would increase the deployment of broadband infrastructure. These include subsidies for universal provision of broadband Internet service provision, providing tax incentives to access providers to build out networks, and the federal funding of appropriate infrastructure initiatives. Several initiatives, contained within the American Recovery and Reinvestment Act of 2009, are "intended to accelerate broadband deployment in unserved, underserved and rural areas and to strategic institutions that are likely to create jobs or provide significant public benefits."[2]

Formal cost-benefit evaluation of these proposals requires, among other things, some understanding of the potential benefits from more widespread access to broadband Internet service. For example, policy makers may want to compare rural household valuations for Internet service to the cost of service provision so they can make a more accurate judgment of the potential subsidy required, or not required, for individual broadband adoption and/or deployment in rural areas. They may also want to use the most recent estimates of valuations to measure the consumer surplus from broadband Internet.[3] The economic construct of

[2] See http://broadband.gov/recovery_act.html.

[3] Goolsbee and Klenow (2006) calculate consumer surplus from the Internet to be several thousand dollars per household at 2005. Greenstein and McDevitt (2009) estimate that broadband deployment (as compared to dial-up access) accounted for about 4.8 to 6.7 billion dollars in new consumer surplus for the entire economy at 2006.

willingness-to-pay (WTP) provides a theory-based, dollar measure of the value consumers place on Internet service, as well as the amount they would be willing to pay for improvements in the individual characteristics that comprise the service. Moreover, because households do not have identical preferences, it is possible to measure how a household's WTP for each Internet service characteristic may vary with observable demographics such as age, education, income, online experience, race and rural location.

This report uses data obtained from a nationwide survey during late December, 2009 and early January, 2010 to estimate household demand for broadband Internet service. The report updates and expands the work of Savage and Waldman (2005, 2009) by combining household data, obtained from choices in a real market and an experimental setting, with a well-specified discrete-choice model to estimate the marginal WTP for improvements in eight Internet service characteristics.

The first three characteristics are standard *features* for all current Internet services and include the:

- price per month for Internet service (*COST*);
- reliability of the connection to the Internet (*RELIABILITY*); and
- time it takes to download and upload information (*SPEED*).

SPEED can be "slow", "fast" or "very fast." Slow has a similar speed to a dial up connection, where downloads from the Internet and uploads to the Internet are slow. It is good for emailing and light web surfing. Fast is similar to a high-speed Internet connection with much faster downloads and uploads. It is great for music, photo sharing and watching some videos. Very fast is similar to a "high end" high-speed Internet connection with blazing fast downloads and

Dutz et. al. (2009) calculate that the net consumer surplus from broadband relative to dial-up increased by about 60 percent from 2005 to 2008, to $31.9 billion.

uploads. It is really great for gaming, watching high-definition movies, and instantly transferring large files.[4] The remaining five characteristics are relatively new *activitie*s that have the potential to be bundled with future Internet services. They include the ability to:

- connect a laptop to the Internet wirelessly while away from home (*MOBILE LAPTOP*);
- download high-definition movies and TV shows (*MOVIE RENTAL*);
- designate some downloads as high-priority so they travel through the Internet at relatively faster speed (*PRIORITY*);
- interact with health specialists online (*TELEHEALTH*); and
- place free phone calls over the Internet and see the person being called (*VIDEOPHONE*).

We use choice experiments to estimate household preferences and their marginal utilities. A carefully designed choice experiment manipulates the characteristics for a series of hypothetical Internet services to obtain the optimal variation in the data needed to estimate the marginal utility parameters precisely.[5] Respondents are presented with eight choice scenarios, and, in each scenario, must choose between a pair of Internet service alternatives that differ by the levels of their characteristics. The information in these choices is enriched with market data by having respondents indicate whether they would stay with their current (actual) Internet service or switch to the hypothetical service they had just selected. The marginal utility

[4] Although we describe a "slow" service in the survey as having a similar speed to a dial-up connection, readers should not assume that slow is in fact dial up. Section 4.3 shows that about eleven percent of our 6,271 survey respondents indicated a slow speed for their home service. By cross referencing these data with pre-recorded data from Knowledge Networks, Inc. for November, 2009, we know that about half of these respondents actually have a dial-up connection at home (Knowledge Networks, Inc., 2009a). The other half have either a cable modem, DSL, satellite or Wifi connection with slow speed.

[5] It is also possible to estimate the marginal utilities for characteristics that are not currently traded in markets or are only available in limited geographical areas. For example, the mobile laptop characteristic is not widely available, while the telehealth characteristic is not bundled into Internet service.

parameters of the representative household's utility function, and WTP, are then estimated from all observed choices.

Our empirical results show that reliability and speed are important characteristics of Internet service. The representative household is willing to pay $20 per month for more reliable service, $45 for an improvement in speed from slow to fast, and $48 for an improvement in speed from slow to very fast. The latter finding indicates that very fast Internet service is not worth much more to households than fast service. Willingness-to-pay for speed increases with education, income and online experience, and decreases with age. Rural households value connection speed by about $3 more per month than urban households. Valuations for speed increase with online experience and with exposure to different connection speeds. For example, households with less than twelve months online experience and with a slow Internet connection are only willing to pay about $16 per month for an improvement in speed from slow to fast. Among other things, inexperienced households are more likely to be older, non-white, female, and have less education and income.

Overall, households are also willing to pay an additional $6 per month so that their Internet service provides the ability to designate downloads as high-priority, $4 for the ability to interact with health specialists online, $5 for the ability to place free phone calls over the Internet and see the person being called, $3 for the ability to download high-definition movies and TV shows. The ability to connect their laptop to the Internet wirelessly outside the home is not valued by respondents.

Using these results, we calculate that a representative household would be willing to pay $59 per month for an Internet service with fast speed ("Basic"), $79 per month for a very reliable Internet service with fast speed ("Reliable"), $85 for a very reliable service with fast speed and the priority feature (“Premium”), and $98 for a very reliable service with fast speed, the priority feature plus all other activities bundled into the service (“Premium Plus”). An improvement to very fast speed adds about $3 per month to these estimates. In contrast, an inexperienced household with a slow connection would be willing to pay $31 per month for a Basic Internet service, $41 for a Reliable service, $59 for a Premium service and $71 for a Premium Plus service.

Willingness-to-pay

	All Users	*Inexperienced with slow connection*
Basic	$59	$31
Reliable	$79	$41
Premium	$85	$59
Premium Plus	$98	$71

An interesting finding from our results is that valuations for Internet service increase substantially with experience. The implication is that, if targeted correctly, private or public programs that educate households about the benefits from broadband (e.g., digital literacy training), expose households to the broadband experience (e.g., public access) or directly support the initial take-up of broadband (e.g., discounted service and/or hookup fees) have potential to increase overall penetration in the United States.

The report is organized as follows. Section 2 reviews previous studies. Section 3 describes the random utility model of Internet service choice and the econometric method used to estimate the model and calculate WTP. The experimental design, survey questionnaire and data are described in Section 4. Section 5 presents the results from estimating WTP and compares the responses from different segments of the population, and Section 6 concludes.

2. Literature Review

It is difficult to estimate demand for broadband service, and more importantly for specific characteristics of broadband service with data currently available. For example, while there is information about subscription rates to Internet access, pricing and plan choice are not generally available publicly. As a result, it would be difficult to implement the discrete choice methods of Berry et. al. (1995). Moreover, even if these data were available, there is insufficient variation in product characteristics to identify important marginal utility parameters of interest. For example, Internet access service plans are typically structured so that more reliability is bundled with more speed so that it is impossible to separate the willingness-to-pay for these two characteristics.

Previous studies have typically used demographic variables to explain the demand for broadband Internet service ("Digital Divide Studies") or have collected market and/or experimental data from household surveys to explain how price and non-price characteristics affect demand ("Price and Non-Price Characteristics"). A selection of studies from these two approaches is provided below.[6] A caveat is that given the rapidly changing characteristics of the marketplace for Internet services even well-done studies relying on historical data may not provide a sufficiently accurate picture for current policy decisions.[7]

2.1 Digital Divide Studies

Several studies have examined the potential for a digital divide in both the deployment and use of high-bandwidth Internet infrastructure in the United States. Pew Internet and

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[6] See Hauge and Prieger (2009) for a more complete list of previous studies of the demand for Internet service.

[7] Specifically, home broadband Internet penetration increased from well under ten percent in 2000 to about 30 percent in 2005 and over 60 percent in 2009 (See Pew Internet and American Life Internet Surveys, 2000-2009). Moreover, services like YouTube did not exist a few years ago.

American Life provide results from periodic surveys of large numbers of households that provide a timeline for studying the characteristics of adoption at any point in time. For example, Horrigan (2009) provides survey results that show that broadband Internet service was adopted by 63 percent of households as of 2009, and that adoption rates differed by income, age and education.

Gabe and Abel (2002) adopt a supply-side approach and count the number of telephone lines with integrated services digital network (ISDN) capability in each United States state from 1996 to 2000. They find considerably more ISDN infrastructure in urban areas and suggest that rural demand for broadband services is generally insufficient to attract new investments in advanced telecom infrastructure.

Prieger (2003) estimates a reduced-form model that relates the decision by a broadband carrier to enter geographic markets to expected demand, costs and entry by other firms. Using FCC zip-code data for 2000, he finds little evidence of unequal broadband availability based on income or on black or Hispanic concentration. He also finds that rural location decreases availability; market size, education and commuting distance increase availability.

Fairlie (2004) uses household data from the August 2000 Current Population Survey to examine racial differences in the demand for Internet service. He models the household's decision to purchase Internet service as a function of race and various demographic characteristics. His model estimates suggest that racial differences in education, income and occupation contribute substantially to the black/white and Hispanic/white divide in home Internet service. Fairlie also finds a negative correlation between rural location and the likelihood of subscribing to Internet services.

Using Forrester data from 18,439 United States households at 2001, Goldfarb and Prince (2008) show that while income and education correlate positively with Internet adoption, they are negatively related with hours spent online. They argue that with fixed connection and near-zero usage fees, low-income people spend more time online due to their lower opportunity costs of time. They suggest that if given the opportunity to go online, Americans without access would likely use the Internet to engage in many of the activities policymakers have stated as the goals of Internet access subsidies.

Prieger and Hu (2008) examine the racial gap in Internet demand in states served by Ameritech at 2000. Because they have incomplete data on the availability and characteristics of all options, they model the probability that at least one household in the census block subscribes to digital subscriber line (DSL) service. They find that race matters independently of income, education and location, in the demand for DSL, and that rural locations have lower demand. Service quality, measured by distance from the central office, has the largest marginal effect on demand and omitting this variable leads to under-estimates of the DSL gap for Hispanics. Prieger and Hu conclude that the lack of options and competition in promotional prices may play a role in creating some dimensions of the digital divide.

In summary, the existing "Digital Divide Studies" have typically used aggregated data and reduced-form model specifications to estimate the effects of income, education, race and location on Internet penetration rates. They do not measure the direct impacts of prices and other quality characteristics on Internet demand and, as such, provide little information on the value households place on different Internet services and individual service characteristics.[8]

[8] Prieger and Hu (2008) indirectly account for quality by measuring household's distance from the central office.

2.2 Price and Non-Price Characteristics

Several other studies use survey and/or experimental data to examine how price and non-price characteristics affect the choice of Internet service. Goolsbee (2006) uses stated preference data from a 1999 survey of about 100,000 consumers to estimate the probability of choosing cable modem Internet service. After controlling for individual demographics, model results show an increase in the likelihood of cable modem service for people with lower prices. The elasticity of demand for cable Internet with respect to price ranges from -2.8 to -3.5.

Hausman et. al. (2001) estimate a reduced-form model that relates the price of broadband to dial-up price, presence of RoadRunner service, and demand and cost variables. Model results cannot reject the hypothesis that dial-up prices do not constrain broadband prices, and they conclude that broadband Internet is a separate relevant market for competitive analysis. However, the finding of zero cross-price elasticity should be qualified to some extent as they do not control for variation in the quality-adjusted prices of Internet service.

Using a sample of 5,255 households in 2000, Rappoport et. al. (2002) estimate a nested logit model where the first branch considers the choice between dial-up and broadband, and given broadband, the second branch considers the choice between cable modem and DSL. Model estimates provide own price elasticities for cable and DSL of –0.587 and –1.462, respectively, and also suggest that dial-up service is not a substitute for broadband users. However, cross-price elasticities of 0.618 and 0.766, respectively, indicate that cable and DSL are strong substitutes for one another.

Dutz et. al. (2009) employ market data from Forrester for over 30,000 households and a similar methodology to Rappoport et. al. (2002) to estimate elasticities of Internet demand. They find that dial-up Internet is not a strong substitute for broadband and that the own-price elasticity of broadband declined from -1.53 in 2005 to -0.69 in 2008. Dutz et. al. argue that their own-price elasticity finding indicates that “broadband is progressively being perceived by those who are using it as a household necessity.” They also calculate that the net consumer surplus from broadband relative to dial-up service increased by about 60 percent from 2005 to 2008, to $31.9 billion.

Varian (2002) uses experimental data to estimate how much people are willing to pay for speed. During 1998 and 1999, 70 users at UC Berkeley were able to choose various bandwidths from 8 to 128 kbps through a degraded integrated services digital network line. Varian estimates reduced-form demand for bandwidth with own-price elasticities ranging from -1.3 to -3.1. Cross-price elasticities are generally positive and indicate that one-step lower bandwidths are perceived as substitutes for chosen bandwidth. A regression of time costs on demographics shows that users are not willing to pay very much for bandwidth. Unless new applications and content are forthcoming, or broadband prices fall, Varian suggests there may not be a large surge in broadband demand in the near future.

Savage and Waldman (2005) use survey data, obtained from choices in both a real market and an experimental setting, to estimate a random utility model of Internet service choice. They find that consumers are willing to pay up to $16.54 for more reliable service, $11.37 for a substantive improvement in speed and $5.07 for “always on” functionality. Savage and Waldman (2009) extend their analysis by focusing on preference heterogeneity between urban and rural households.[9] They find that rural and urban households have similar valuations for an improvement in bandwidth; about $8 to $25 per month for low- and high-

[9] Several other studies use a hedonic pricing model to measure the implicit price of bandwidth and various contract features, such as hourly limits and length of contract (Stranger and Greenstein, 2008; Williams, 2008). While informative, both studies use relatively old data and they do not measure how the implicit price of bandwidth may vary across different households and/or different bandwidth thresholds.

ability households, respectively.[10] However, an increase in ability translates into a \$3.07 increase in WTP for bandwidth per month for urban households compared to \$1.15 for rural consumers.

Estimates from the price and non-price determinants of Internet demand described above are based on survey and/or experimental data that was obtained prior to 2003. Furthermore, these studies do not consider some of the new features that are relevant for current and future Internet services. This report uses the methodology described by Savage and Waldman (2005, 2009), and survey data obtained during December, 2009 and January, 2010 to estimate the WTP for improvements in *SPEED*, *RELIABILITY*, and *MOBILE LAPTOP*, and for the inclusion of *MOVIE RENTAL*, *PRIORITY*, *TELEHEALTH* and *VIDEOPHONE* into one's Internet service.

3. Estimating Willingness-To-Pay

3.1 Empirical Model

The random utility model is used to estimate marginal utilities and calculate WTP. Survey respondents are assumed to maximize their household's utility of the Internet service option A or B conditional on all other consumption and time allocation decisions. A linear approximation to the household conditional utility function is:

$$U^* = \beta_1 COST + \beta_2 SPEED + \beta_3 RELIABILITY + \beta_4 MOBILE\ LAPTOP$$

$$+ \beta_5 MOVIE\ RENTAL + \beta_6 PRIORITY + \beta_7 TELEHEALTH + \beta_8 VIDEOHONE + \varepsilon \quad (1)$$

[10] Savage and Waldman (2004, 2009) employ two measures of technical ability. The first is specific to the Internet task as it measures the relationship between Internet experience, i.e., the number of years the respondent has been using the Internet to go online, and the productivity of the individual when using the Internet. The second measure is more general in that it captures the relationship between education, i.e., the number of years of schooling, and the productivity of the individual when using the Internet.

where U^* is utility, β_1 is the marginal disutility of *COST*, β_2 and β_3 are the marginal utilities for the Internet service features *SPEED* and *RELIABILITY*, β_4 through β_8 are the marginal utilities for the Internet service activities *MOBILE LAPTOP*, *MOVIE RENTAL*, *PRIORITY*, *TELEHEALTH* and *VIDEOPHONE*, and ε is a random disturbance. *COST* is the price per month for home Internet service. *SPEED* is the time it takes to upload and download information to and from the Internet . *RELIABILITY* is the reliability of the connection to the Internet. *MOBILE LAPTOP* is the ability to connect your laptop to the Internet wirelessly while away from home. *MOVIE RENTAL* is the ability to download high-definition movies and TV shows. *PRIORITY* is the ability to designate some downloads as high-priority so they travel through the Internet at relatively faster speed. *TELEHEALTH* is the ability to interact with health specialists online. *VIDEOPHONE* is the ability to place free phone calls over the Internet and see the person being called.

The marginal utilities have the usual partial derivative interpretation - the change in utility from a one-unit increase in the level of the feature or activity. *SPEED* and *RELIABILITY* are standard features of all current Internet services; they cannot be unbundled. Given that "more is better", our *a priori* expectation for these two features is $\beta_2, \beta_3 > 0$. For example, an estimate of $\beta_2 = 0.2$ indicates that a one unit improvement in *SPEED*, measured by a discrete improvement from "Slow = 1" to "Fast = 2", increases utility by 0.2 for the representative household. *COST* is also a standard service feature, however, a higher cost of service provides less satisfaction so $\beta_1 < 0$. In contrast to the features *COST*, *SPEED* and *RELIABILITY*, the activities *MOBILE LAPTOP*, *MOVIE RENTAL*, *PRIORITY*, *TELEHEALTH* and *VIDEOPHONE* are not widely available in Internet services and/or can be unbundled. The signs and magnitudes of the marginal utilities for these hypothetical features, β_4 through β_8, within a bundled Internet service are an empirical question.

Since the estimates of marginal utility (such as an increase in utility of 0.2 as described above) do not have a readily understandable metric, it is convenient to convert these changes into dollar terms. This is done by employing the economic construct of willingness-to-pay. For example, the WTP for a one unit increase in *SPEED* (*i.e.*, the discrete improvement from "Slow" to "Fast") is defined as how much more the Internet service would have to be priced to make the consumer just indifferent between the old (cheaper but slower) service and the new (more expensive but faster) service:

$$\beta_1 COST + \beta_2 SPEED + \beta_3 RELIABILITY + \beta_4 MOBILE\ LAPTOP$$

$$+ \beta_5 MOVIE\ RENTAL + \beta_6 PRIORITY + \beta_7 TELEHEALTH + \beta_8 VIDEOHONE$$

$$=$$

$$\beta_1 (COST + WTP) + \beta_2 (SPEED + 1) + \beta_3 RELIABILITY + \beta_4 MOBILE\ LAPTOP$$

$$+ \beta_5 MOVIE\ RENTAL + \beta_6 PRIORITY + \beta_7 TELEHEALTH + \beta_8 VIDEOHONE \qquad (2)$$

Solving algebraically for WTP in equation 2 gives the required change in cost to offset an increase of β_2 in utility:

$$WTP(Speed) = -\beta_2/\beta_1 \qquad (3)$$

For example, estimates of $\beta_2 = 0.2$ and $\beta_1 = -0.01$ indicate that the WTP for an improvement in connection speed from "Slow" to "Fast" is \$20 (= -0.2/0.01). Note that the model specification in equation 1 implies that the representative household would also be willing to pay the same amount (\$20) for an improvement in speed from "Fast" to "Very Fast" as it would to move from "Slow" to "Fast." This constraint is relaxed during econometric estimation so that the marginal utility for an improvement in speed from "Fast" to "Very Fast" can be different from the marginal utility for an improvement in speed from "Slow" to "Fast."

This approach to estimating consumer valuations is used for all other features and Internet activities. The WTP for *MOBILE LAPTOP*, *MOVIE RENTAL*, *PRIORITY*, *TELEHEALTH* and *VIDEOPHONE* is the negative of the ratio of its marginal utility to the marginal disutility of *COST*. In summary, the WTP construct provides a theory-driven, intuitive (dollar) measure of the value consumers place on Internet service and the specific features and activities that comprise the service.

Households may not have identical preferences. Preferences towards speed, for example, may differ because of observable demographic characteristics, or may be idiosyncratic. It is possible to estimate differences in the marginal utility of specific service features to different households by interacting those features with demographic variables. For instance, suppose households in urban and rural locations value speed differently. A specification of utility that captures this difference is:

$$U^{*} = \beta_1 COST + (\beta_2 + \eta RURAL) \times \beta_2 SPEED + \beta_3 RELIABILITY + \beta_4 MOBILE\ LAPTOP$$
$$+ \beta_5 MOVIE\ RENTAL + \beta_6 PRIORITY + \beta_7 TELEHEALTH + \beta_8 VIDEOHONE + \varepsilon \quad (4)$$

where η is an additional parameter to be estimated, and *RURAL* is a dummy variable that is equal to one when the respondent is in a rural location, and zero otherwise. When location is not important ($\eta = 0$), the WTP for a one-unit improvement in connection speed is $-\beta_2/\beta_1$. When location is important ($\eta \neq 0$), the WTP for a one-unit improvement in connection speed in a rural location is:

$$WTP(Speed) = -\frac{(\beta_2 + \eta)}{\beta_1} \quad (5)$$

Equation 5 provides a concrete illustration of how WTP estimates will inform the design of government programs to promote broadband Internet service in under-served areas. For example, policy makers can use equation 5 to compare rural valuations for broadband to the cost of service provision, and then make a more accurate judgment of the potential subsidy required or, not required, for individual broadband adoption and/or infrastructure deployment in rural areas.

The specification in equation 4 constrains the parameters of the other characteristics (*RELIABILITY*, *MOBILE LAPTOP*, etc.) to be the same for both rural and urban households. To relax this constraint, we estimate the WTP for speed for rural and urban households on separate subsamples of the data. We have this ability because of the large number of respondents answering our survey questionnaire.

3.2 Estimation Method

The hypothetical utility of each service option U^* is not observed. What is known is which option has the highest utility. For instance, when a respondent chooses Internet service A over B and then the status quo (SQ) over A, it is assumed that $U_A^* > U_B^*$ and $U_{SQ}^* > U_A^*$. For this kind of dichotomous choice data, a suitable method of estimation is maximum likelihood (i.e., a form of bivariate probit) where the probability of the outcome for each respondent-choice occasion is written as a function of the data and the parameters. Appendix A provides a detailed description of the method used to estimate the random utility model.

Since the WTP estimates are nonlinear functions of the structural parameters from the random utility model, their exact standard errors for the purpose of hypothesis testing are unknown. We use a linear approximation to the variance, sometimes known as the "delta method," to obtain standard errors for the WTP estimates. Appendix B, provided as an attachment to this report, describes the delta method for estimating the standard error of WTP measures from discrete choice experiments.

4. Data

4.1 Experimental Design

The WTP for Internet service is estimated with data from an online survey questionnaire employing repeated discrete choice experiments. Each respondent answers four choice questions from two sequential choice tasks. In each choice question a pair of hypothetical Internet service alternatives, A and B, is presented. Respondents indicate their preference for choice alternative A or B. The alternatives differ by the levels of the three Internet features, *COST*, *SPEED* and *RELIABILITY*, and *one* of the five Internet activities, *MOBILE LAPTOP*, *MOVIE RENTAL*, *PRIORITY*, *TELEHEALTH* or *VIDEOPHONE*.[11] Each respondent is randomly assigned one of the following survey versions:

1) Priority-Telehealth;
2) Telehealth-Mobile Laptop;
3) Mobile Laptop-Videophone;
4) Videophone-Movie Rental; or
5) Movie Rental-Priority.

In each version, the first activity corresponds to the first choice task and the second activity corresponds to the second choice task. For example, the "Priority-Telehealth" version contains

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[11] We want to estimate the WTP for five Internet activities but not to overload the cognitive task for respondents by asking them to evaluate an Internet service with three features, *COST*, *SPEED* and *RELIABILITY*, and five activities, *MOBILE LAPTOP*, *MOVIE RENTAL*, *PRIORITY*, *TELEHEALTH* and *VIDEOPHONE*. Therefore, we constrain the choice task to three features and a single activity with the single activity randomly assigned across all respondents.

four choice questions where alternatives A and B differ by the levels of *COST*, *SPEED*, *RELIABILITY,* and *PRIORITY*, followed by four choice questions where A and B differ by the levels of *COST*, *SPEED*, *RELIABILITY,* and *TELEHEALTH*.

We used the marketing programs from various Internet service providers, a pilot study and two focus groups to test and refine our descriptions of the service characteristics for choice alternatives A and B. The pilot hard-copy version of the survey was given to 71 undergraduate students at the University of Colorado on October 30, 2009. The same day we held the first focus group, with a hard-copy survey, in the seminar room of the Economics building at the University of Colorado at Boulder. Five individuals: a barber, mail clerk, restaurant owner, secretary, and advanced graduate student simultaneously took the survey and then discussed its presentation and content with Savage and Waldman in a group setting. The second focus group, with an online survey, was facilitated by RRC Associates in Boulder on November 19. The group consisted of five diverse individuals with respect to age, gender, and Internet experience, who completed the survey sequentially in the presence of a professional facilitator.

Table 1 describes the levels of the characteristics that comprise Internet service A and B. *COST* is the dollar amount the household pays per month for home Internet service. *SPEED* is the time it takes to receive (download) and send (upload) information from the home computer. *RELIABILITY* is the reliability of home's connection to the Internet. Very reliable Internet service is rarely disrupted by service outages, that is, the service may go down once or twice a year due to severe weather. With less reliable Internet service the household will experience more outages, perhaps once or twice a month for no particular reason. The *MOBILE LAPTOP* feature allows the household to use its Internet service to connect laptop(s) to the Internet wirelessly while away from home. The *MOVIE RENTAL* feature allows the household to use its Internet service to regularly download high definition movies and TV shows from the Internet, and watch them on a computer or TV (saving the cost of a trip to the video store). The *PRIORITY* feature allows the household to designate some of its downloads as high priority so they travel through the Internet at a much faster speed than low-priority downloads. The *TELEHEALTH* feature allows the household to use its Internet service to go online for remote diagnosis, treatment, monitoring and consultations, saving a trip to the health specialist. The *VIDEOPHONE* feature allows the household to use its Internet service to place free phone calls over the Internet and see the person that is being called.

Measures developed by Zwerina et. al. (1996) are used to generate an efficient non-linear optimal design for the levels of the characteristics that comprise the Internet service choice. A fractional factorial design creates 24 paired descriptions of Internet service, A and B, that are grouped into three sets of eight choice questions that are randomly distributed across all respondents. In addition, the information in these A-B choices is enriched with market data by having respondents indicate whether they would stay with their current (actual) Internet service, the "status quo," or switch to the hypothetical service they had just selected, or if they would adopt the service selected if they did not already have service. The parameters of the representative individual's utility function, and WTP, are then estimated from the observed choices.

The research methodology has several important characteristics. First, the experimental approach exogenously determines the levels of the characteristics of each Internet service offered and avoids collinearity problems by offering non-existing alternatives. For example, the values for the service reliability and connection speed characteristics change independently in the hypothetical alternatives as opposed to market data where they often move together perfectly. By asking eight choice questions, we are able to generalize the model by identifying an additional variance parameter, increase parameter estimation precision and reduce sampling costs by obtaining more information on preferences for each respondent.[12] The use of revealed-preference information on each respondent's status quo alternative, chosen in the market for Internet service, into our experimental design helps alleviate any biases in the hypothetical choice setting.[13]

Second, the choice data are used to estimate parameters of the representative household's utility function. This has the advantage that from estimates of these structural parameters, we can construct estimates of the value of *any* variant of current and future Internet services, and any potential characteristic of these services. For example, Athey and Stern (2002) and Savage and Waldman (2009) show that various online health and medicine activities have the potential to improve societal welfare through improved communication and reduced transport costs.[14] Because we include the telehealth activity in our hypothetical Internet service options, we can estimate consumer valuation for online health services. That is, it is not necessary to design separate health plan choice experiments where consumers choose between different health plans with and without an online health feature. Furthermore, because we know the geographical location of respondents, and the deployment of broadband, it is possible to use the WTP construct described in equation 5 to estimate consumer valuations for telehealth in remote and underserved locations.

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[12] This information also facilitates the fitting of more sophisticated models with random parameters.

[13] It is possible that market data may introduce an endogeneity problem concerning the positive correlation between market price and quality characteristics observed by the household but not the econometrician. Using a similar experimental design, Savage and Waldman (2009) show that there is minimal correlation between prices and unobserved error differences in the utility function.

[14] The benefits of these activities have been raised in the health and communications literatures, and in discussions with the members of the Broadband.gov Task Force as part of the National Broadband Plan (See, for example, http://www.broadband.gov/broadband_advantages.html.).

Finally, as an alternative to choice questions, we could employ payment-card questions that simply ask respondents what they would be willing to pay for various Internet services, or what they would pay for specific characteristics. However, the literatures on marketing, transportation choice, and environmental economics, show that the quality of these data relative to choice questions and the resulting valuations have proven inferior. Specifically, individuals tend to over- or under-estimate their values when they do not face a clear comparison. However, we employ two payment card questions in the survey questionnaire to break up the two choice tasks and to provide a secondary source of data for future analysis and methodological comparison.

4.2 Survey

Knowledge Networks Inc. (KN) administered the household survey online. There are five versions of the survey, which are identical except for the Internet activity being evaluated and the levels of the features for the Internet services in the choice task. The questionnaire begins with a cognitive buildup section that asks respondents ten questions about their use of the Internet and their current Internet service in terms of the characteristics described in Table 1.[15] Respondents who are not entirely sure what the description of a characteristic means are provided with a prompt screen with additional information. For example, the additional description for *SPEED* is:

> "This is the time it takes to receive (download) and send (upload) information from your home computer. Speed can be slow (similar to travelling on a San Francisco cable car at 5 mph), fast (similar to travelling on an AMTRAK train at 100 mph, or, 20x faster than Slow) or very fast (similar to travelling on the 'bullet train' at 300 mph or, 60x faster than Slow)."

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[15] The descriptions of the "Internet Service Features" as they appear in the survey are provided in Appendix C.

Here, the added advantage of the online survey is that only those unsure of their home connection speed will click on the hyperlink and take the time to read the enhanced description, thus reducing potential survey fatigue.

Cognitive buildup is followed by the first choice task where each respondent is presented with four questions that describe a pair of Internet service options A and B that differ by *COST*, *SPEED*, *RELIABILITY* and activity *X* (*MOBILE LAPTOP*, *MOVIE RENTAL*, *PRIORITY*, *TELEHEALTH* or *VIDEOPHONE*).[16] Respondents indicate their preferred choice and then indicate whether they would switch from their home service to the hypothetical service they chose in the A-B choice question (See Figure 1 for a choice question example). Respondents complete the first choice task by indicating in a payment card question how much they would be willing to pay for the service described by levels of *SPEED*, *RELIABILITY* and *X*. In the second choice task, each respondent is presented with four questions that describe A and B by the levels of *COST*, *SPEED*, *RELIABILITY* and activity $Y \neq X$.[17] Respondents complete the second choice task with a second payment card question for a service described by levels of *SPEED*, *RELIABILITY* and *Y*.

KN panel members are drawn by random digit dialing of listed and unlisted telephone households, with a success rate of about 45 to 50 percent. For incentive, panel members are rewarded with points for participating in surveys, which can be converted to cash or other rewards. An advantage of using KN is that it obtains high completion rates and the majority of the sample data are collected in less than two weeks. KN also provides detailed demographic

[16] Carson et. al. (1994) review a range of choice experiments and find that respondents are typically asked to evaluate eight choice questions. Savage and Waldman (2008) find there is some fatigue for online respondents in answering eight choice questions when compared to mail respondents. To remedy this, we have reduced the cognitive burden in this survey in two ways: by decreasing the number of features to be compared from five to four; and by splitting the choice questions into two choice tasks with a different fourth activity feature. The respondent is given a break between the first and second choice task with a payment card question.

[17] To account for the possibility of order effects that could confound the analysis, the order of the eight A-B choices questions in the two choice tasks is randomly assigned across all respondents.

data for each respondent. Because these demographics are previously recorded, the length of the field survey is shortened to under 12 minutes (on average) and ensures higher quality responses from the respondents.

We want to estimate the marginal utilities and WTP for a subsample of experienced users, as well as for a subsample of inexperienced users to provide some indication of valuations for households that are not connected to the Internet. Based on recruitment information, KN knows if a household previously had Internet service, and the type of service, dial-up, cable modem, DSL, etc. We use this information to oversample new recruits to the panel, that is, those with less than twelve months of panel experience *and* who did not have Internet service prior to recruitment ("inexperienced"). There are about 800 panel members that fulfill this criteria.

During the week of December 21, 2009, KN contacted a gross sample of experienced panel members and a gross sample of inexperienced panel members informing them about the Internet service choice experiment. The survey was fielded on December 24, 2009 and by January 18, 2010, 6,271 respondents from all 50 states and the District of Columbia had completed survey questionnaires. 5,799 respondents are experienced and the remaining 472 respondents are inexperienced.[18]

Table 2 presents a selection of demographics for KN's panel members, the full sample, the subsample of experienced respondents, the subsample of inexperienced respondents and the United States population (Knowledge Networks, Inc., 2009b; United States Census Bureau, 2009). The demographics for the full sample are relatively similar to those reported by the Census Bureau. Both the full sample and the experienced subsample differ from the population

[18] The panel tenure in months for sample respondents ranged from 1 to 121 with a mean of 37.72 and standard deviation of 27.14. See Dennis (2009) for a description of the within-panel survey sampling methodology.

in education, income and employment. The inexperienced subsample also differs from the population with respect to several demographic characteristics. Table 3 presents summary statistics for the full sample, and Table 4 reports the estimates from a probit regression of *INEXPERIENCED* (equals one if the respondent has less than twelve months of panel experience *and* who did not have Internet service prior to recruitment) on selected demographic and regional variables The results show that an inexperienced respondent is more likely to be older, non-white, female, unmarried and with less education and household income.

4.3 Current Internet Service and Use

Table 5 presents summary statistics describing the home Internet service for respondents and their use of the Internet. The top panel shows that most respondents have high-speed Internet service. 22.1 percent indicated that they have “Very Fast” speed, 67.2 percent have “Fast” speed and 10.7 percent have “Slow” speed. About 76 percent indicated that they bundled their Internet service with other services such as phone, TV and/or some “other” telecommunications service, 19 percent to do not bundle their Internet service and about five percent were not sure. The average price for stand-alone Internet service, or the Internet portion of bundled service, is $39.15 per month. The average price per month for slow, fast and very fast Internet services are $25, $39.54 and $44.07, respectively. Over 87 percent of respondents indicated that their home Internet service was “very reliable.” The bottom panel shows that most inexperienced respondents have slow service, do not bundle their Internet connection with other services, and pay an average price of $16.89 per month. [19]

[19] Table 5 shows that 46.4 percent of inexperienced users say that they buy bundled services. This may be a lower-bound estimate as it is possible that many of these new users also get phone service with their DSL service but do not think of it as bundled. This was an issue with Point Topic data in 2003 when people did not think of DSL as being bundled with phone service even though it was frequently impossible to buy DSL without phone service.

About 73 percent of inexperienced respondents indicated that their home Internet service was "very reliable."

About ten percent of all respondents have been using the Internet for less than six months, about 18 percent have been using the Internet for six months to one year, and about 22 percent have been using the Internet for over one year. On average, respondents use their home Internet service to go online for a total of about 16 hours per week. Broadband users are more active. Respondents with "Fast" and "Very Fast" connections spent about 15 and 19 hours online per week, respectively, compared to users with a "Slow" Internet connection, who spent about 10 hours online per week.

Internet activity data are obtained by asking respondents "How often do you use your home Internet service to do each of the following Internet activities: email and instant messaging (IM); use search engines (e.g., Google); play online games; sit on a bench in a public park and connect your laptop computer to the Internet wirelessly; download full-length high-definition movies and TV shows to view on your PC; place telephone calls and see the person you are calling ("Videophone"); and interact with your health care specialists ("Telehealth")." Table 6 shows Internet activity for the most extreme response, "many times a week." Email and IM, using search engines and playing games are frequent activities for all Internet users. As expected, broadband users are more active on the Internet than users with a slow connection. The percentage of broadband Internet users answering "many times a week" is higher for all seven Internet activities.

Table 7 summarizes household responses to questions about activities that are not widely available in Internet services. Four percent of survey respondents indicated that they had the ability to prioritize traffic with their home Internet service, with over 70 percent of these being served by AT&T, Comcast Communications, Cox Communications or Time Warner Cable. Interestingly, each of these four companies have had trials of alternative usage-based pricing and prioritized traffic service plans over the past two years. For example, Cox Communications tested a service that gives priority to time-sensitive Internet traffic during peak demand times in Arkansas and Kansas.[20] About seven percent of respondents have interacted with their health specialists through their home Internet service. Just under five percent indicated that they used a mobile laptop feature with their home Internet service.[21] About 18 percent of respondents indicated that they have used a videophone feature to place phone calls and see the person they calling, through their internet service, and about 17 percent have used online movie rental services such as Netflix, Blockbuster.com and iTunes to download and watch high-definition movies and TV shows.

After completing the survey, 358 respondents provided additional comments on the individual questions, choice experiments and methodology. 250 respondents had comments on the Internet features, *COST*, *SPEED* and *RELIABILITY*. 28 percent indicated that reliability was the most important characteristic for their home Internet service, 26 percent indicated that monthly cost was the most important characteristic and 14 percent indicated that speed was the most important characteristic. 27 percent indicated that speed and reliability were equally the most important characteristics. There were also 196 comments on the Internet activities, *MOBILE LAPTOP*, *PRIORITY*, *TELEHEALTH*, *VIDEOPHONE* and *MOVIE RENTAL*. In 87 percent of the comments, respondents indicated that they did not want to pay for these Internet

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[20] For example, see http://www.allbusiness.com/media-telecommunications/telecommunications/11845135-1.html, http://www.lightreading.com/document.asp?doc_id=175121&site=cdn, and http://www.dslreports.com/shownews/Checking-Out-the-Time-Warner-Bandwidth-Usage-Meter-101278.

[21] For example, Qwest offer their “Mobile Laptop Data Plan” for $79.99 per month. See http://www.qwest.com/residential/products/wireless/mbb.html.

activities. There were two main reasons: 1) they did not want the service(s); or 2) they already use the service(s) with their current Internet service provider for free.

4.4 Choice Questions

The distributions of answers to the choice questions show that in 54 percent of the A-B choice occasions, respondents chose Internet service alternative A over B. In the follow up questions, respondents chose to stay with their actual (status quo) service over the hypothetical alternative, A or B, in about 68 percent of the choice occasions. There is an equal distribution of A and B choices when respondents chose to switch from their actual (status quo) home service to the hypothetical service. There are no discernable trends over the eight choice questions.

5. Results

About 350 cases from the sample cannot be used because the respondents provided incomplete information about the characteristics of their home (status quo) Internet service. As a result, there are at most 5,921 usable cases with information on at least some of the eight A-B choices and the follow-up status quo versus A or B question. Since each pair of binary choices (A vs. B, and A or B vs. SQ) for each choice occasion represents information on preferences, the starting maximum sample size for econometric estimation is effectively n = 5,921 x 8 = 47,368. In models where respondent demographic data are used to measure preference heterogeneity the sample size is reduced as made necessary by missing values for demographic variables.

Note that the coding of the categorical variable *SPEED* in equation 1 is linear, which implies that the marginal utility for *SPEED* is the same when moving from “Slow” to “Fast” and when moving from "Fast" to "Very Fast." We relax this restriction during the econometric estimation below by replacing *SPEED* (= 1, 2, 3) with a pair of dichotomous variables, *FAST SPEED* (equals one when *SPEED* equals "Fast" and zero otherwise) and *VERY FAST SPEED* (equals one when *SPEED* equals "Very fast" and zero otherwise). The estimated parameter on *FAST SPEED* measures the change in utility from moving from slow to fast connection speed and the estimated parameter on *VERY FAST SPEED* measures the change in utility from moving from slow to very fast connection speed.

5.1 Baseline Results

Equation 14 of Appendix A describes the likelihood function for the bivariate probit model used to estimate the household's utility function. Table 8 reports maximum likelihood estimates of the baseline model without preference heterogeneity for the full sample of 47,368 observations.[22] Marginal utility parameters (MU), asymptotic t-statistics for the marginal utilities (*t*), WTP calculations and standard errors for the WTP calculations are presented in column two through column five.[23] The estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives estimate, $\lambda = 0.94$, implies that the error in the utility function for the SQ questions has about the same variance than the error from the A-B questions. The interpretation is that

[22] Because consumers may have heterogeneous preferences for unmeasured aspects of Internet alternatives we estimate utility with a constant to capture differences in tastes between the status quo and hypothetical services. We also estimated an alternative specification of utility where individual specific constants were randomly distributed across households. The results, not reported, are similar to those in Table 8.
[23] Our WTP calculations are reported the conventional way, in dollars and cents. The standard errors of WTP are calculated using the delta method – see Appendix B.

respondents seem to have the same consistency in choice when comparing a hypothetical choice to a real alternative than when comparing two hypothetical choices.[24]

The data fit the baseline model well as judged by the statistical significance of most parameter estimates. The estimated coefficient on *MOBILE LAPTOP* is relatively small and not significantly different from zero. As such, the choice data provide no evidence that households value the ability to connect their laptop to the Internet wirelessly while away from home. This estimate may arise from the fact that many people have the ability to connect away from home via a Smartphone and interpret the question as having an exclusive bundle of services.

The marginal utility parameter for *COST* is negative and statistically significant at the one percent level. The marginal utility parameters for *FAST SPEED*, *VERY FAST SPEED*, *RELIABILITY*, *PRIORITY*, *TELEHEALTH*, *VIDEOPHONE* and *MOVIE RENTAL* are positively signed and are also significant at the one percent level. The estimated signs for these service characteristics imply that the representative household's relative utility increases when cost is decreased, speed is increased and service is improved from less reliable to very reliable. Relative utility is also higher for a service that allows the household to designate some downloads as high-priority, interact with health specialists online, place free phone calls over the Internet and see the person being called, and download movies and TV shows, etc. Reliability and speed are important characteristics of Internet service with consumers willing to pay $19.88 per month for more reliable service, $45.10 for an improvement in speed from slow to fast, and $48.12 for an improvement in speed from slow to very fast.

[24] The parameter λ is generally estimated to be close to, or greater than, one in all models in Table 8 through Table 18. We report its estimate and the corresponding test statistic, but do not discuss it further.

Households also value the *PRIORITY* feature and to a lesser extent, the *TELEHEALTH, VIDEOPHONE* and *MOVIE RENTAL* activities. The results show that households would be willing to pay an additional $6.37 per month so that their Internet service provides the ability to designate downloads as high-priority, $4.39 for the ability to interact with health specialists online, $5.06 for the ability to place free phone calls over the Internet and see the person being called, and $3.29 for the ability to download movies and TV shows.

The marginal utility estimates for *FAST SPEED* and *VERY FAST SPEED* in Table 8 indicate that households value an improvement in connection speed from slow to very fast (i.e., WTP = $48.12) only slightly more than an improvement from slow to fast (i.e., WTP = $45.10). In other words, very fast service is worth approximately $3 more than fast service. An explanation for this finding is that the typical household in the sample is involved in Internet activities and applications at home that do not require blazing fast download and upload speeds. When we split the sample by household's existing connection speed, we observe in Table 9 that households with slow speed are willing to pay about $16 per month for an improvement to fast and that they place no premium on very fast speed. Households with a fast Internet connection value that speed at about $39, relative to slow speed, and also place no premium on very fast speed. Households with very fast Internet connection value fast speed at about $55 per month and value very fast speed at about $63 per month. Willingness-to-pay for reliability of service also increases with household's existing connection speed. Households with slow speed are willing to pay about $11 per month for an improvement in service reliability and households with fast and very fast speeds are willing to pay about $19 and $25, respectively.

Additional insight into the demand for broadband Internet is obtained by estimating utility for subsamples of respondents that differ in their ownership of technology. Using pre-recorded data from KN for November, 2009, we are able to distinguish between respondents who own and do not own a Smartphone, own or do not own a webcam device, and respondents who pay a fee to view and/or download digital movies and TV shows ("Download digital video") and respondents who do not do so (Knowledge Networks, Inc., 2009a).[25] Estimates of utility for these subsamples are provided in Table 10 through Table 12. Overall, we observe that households that use these technologies have higher valuations for service reliability and connection speed and they also place a premium on very fast speed relative to fast speed. For example, as reported in Table 10, respondents who download digital video are willing to pay $28.79 per month for more reliable service compared to about $20 for respondents who do not download digital video. Moreover, respondents who download digital video are also willing to pay $62.99 and $70.21 per month for fast and very fast speeds, while respondents who do not are willing to pay about $41 for fast or very fast speeds. Another interesting observation is that respondents who own a Smartphone do not value the bundling of the mobile laptop characteristic into their Internet service relative to respondents who do not own a Smartphone (see Table 11). Similarly, respondents who own a webcam do not value the videophone characteristic (see Table 12) and respondents who download digital video do not value the movie rental characteristic (see Table 10).

[25] Knowledge Networks, Inc. (2009a) defines a Smartphone as a cellular phone that allows you to access email and browse the Internet. Many of these cellular phones feature an operating system that allows you to use personal computer (PC) like applications, such as Excel or PowerPoint.

5.2 Heterogeneous Preferences

Because they do not have identical preferences, it is possible that individual household's WTP for Internet service varies with observable demographics such as age, education, income, race, rural location, as well as Internet experience.[26]

Carey (1991) and Madden et. al. (1997) find that younger persons have been more open to learning about new technologies such as video cassette recorders, PCs and broadband, and as such, may have higher valuations. Table 13 reports estimates of the model for subsamples of respondents aged from 18 to 34 years, 35 to 58 years and respondents aged 59 to 91 years. Younger households, aged 18 to 34 years, value speed and the ability to interact with health specialists online relatively more than older households. Willingness to pay for reliability of service decreases slightly with age, with the 59 to 91 years of age group having the lowest value for reliability of $19.48 per month. This oldest age group also values the ability to place free phone calls over the Internet and see the person being called and the ability to download movies and TV shows. None of the three separate age groups value the ability to connect their laptop to the Internet wirelessly while away from home as part of the home Internet service.

Savage and Waldman (2009) describe a theoretical model of consumer choice that predicts that Internet ability will increase the demand for bandwidth. This possibility is examined in Table 14 which reports estimates for a subsample of respondents with a college education and a subsample with no college education. Willingness-to-pay for speed increases with years of education with college educated respondents willing to pay $45 per month for fast speed compared to $38 for respondents without a college education. Willingness to pay for reliability and telehealth decreases with education, while both the college and non-college

[26] The likelihood ratio test statistics for Table 13 through Table 18, not reported, are large and reject the hypothesis that the estimated marginal utilities are equal across different subsamples.

educated groups do not value the ability to connect their laptops to the Internet wirelessly while away from home.

Table 15 reports estimates for a subsample of low income respondents (i.e., annual household income less is than $25,000), a subsample of middle income respondents (i.e., annual household income is more than $25,000, but less than $75,000) and a subsample of high income respondents (i.e., annual household income is $75,000 or more). Low- and middle-income households have similar valuations for broadband, about $37-$39 to go from slow to fast speed. Willingness to pay for speed is higher for high-income households – about $8-$10 per month when compared to low- and middle-income households – however, none of these groups place a premium on very fast speed. Willingness to pay for reliability increases with household income.[27]

Estimates of utility for subsamples of white and non-white respondents are reported in Table 16. The estimated willingness-to-pay for speed and reliability are reasonably similar across these groups. Like most of the previous results, white and non-white households do not value a very fast Internet service more than a fast Internet service, nor do they do not value the ability to connect their laptops to the Internet wirelessly while away from home.

Forman et. al. (2003) suggest that the Internet substitutes for the benefits that accrue in an urbanized environment and that rural residents may be willing to pay more for faster Internet access. To examine variation in Internet service valuations by location, we use population and area data from Geolytics, Inc. (2010) and an approximation to the "rural region" definition

[27] We also used Census Bureau definitions to construct a "below poverty level" income group from data on the number of occupants per household and annual household income. The results, not reported, are qualitatively similar to those reported for the low-income group in Table 15. Furthermore, we also estimated subsamples of no college/low income versus no college/high income and subsamples for college/low income versus college/high income. The results, not reported, suggest that college education is not as important as income. High income respondents are willing to pay about 34 percent more for a improvement from slow to fast speed, regardless of whether or not they have a college education.

from the U.S. Census Bureau, i.e., respondent resides in a zip code with population density less than 1,000 persons per square miles, to measure each respondent's urban/rural location.[28] The mean population density for the rural subsample is 305 persons per square mile and the mean density for the urban subsample is 6,170 persons per square mile. Maximum likelihood estimates of the model for the urban and rural subsamples are reported in Table 17. The WTP estimates are qualitatively similar to those reported for the full sample in Table 8. Rural consumers are willing to pay $20.64 per month for more reliable service, about $44 for fast speed and about $8 for the ability to prioritize traffic. Urban households are willing to pay about $20 per month for more reliable service, about $40 for fast speed and about $7 for the ability to prioritize traffic. For both rural and urban households, there is very little difference in valuations for fast and very fast speeds, and neither group values the ability to connect their laptops to the Internet wirelessly while away from home.

5.3 Inexperienced Households

Dutz et. al. (2009) and Savage and Waldman (2004, 2009) show that experience, measured by the number of years online and by exposure to faster Internet connections, is an important determinant of household valuations for broadband. Table 18 presents estimates of the marginal utilities and WTP for a subsample of inexperienced Internet users with slow connection speed and a subsample of inexperienced Internet users with a high-speed connection (i.e., fast or very fast speed). Because they are from relatively small samples, these estimates

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[28] For Census 2000, the Census Bureau delineated urbanized area (UA) and urban cluster (UC) boundaries to encompass densely settled territory, which consists of core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile. The Census Bureau's classification of "rural" consists of all territory, population, and housing units located outside of UAs and UCs (See http://www.census.gov/geo/www/ua/ua_2k.html). Due to data constraints we are unable to classify a household as urban or rural according to the strict definition of the Census Bureau and, instead, use an approximation to its definition.

should be interpreted somewhat cautiously. Nevertheless, the estimates are similar to those reported in Table 8, where we split the full sample by household's existing connection speed. Inexperienced households with slow speed are willing to pay about $16-$17 per month for an improvement from slow to fast speed but they do not value an improvement from fast to very fast speed. Inexperienced households with a high-speed connection are willing to pay about $26-$27 per month for an improvement from slow to fast speed and value the improvement from fast to very fast at 70 cents.

Willingness-to-pay for characteristics ($ per month)

	All Respondents	*Inexperienced with Slow Connection*	*Inexperienced with High-Speed Connection*
Fast Speed	$45.10	$16.74	$26.38
Very Fast Speed	$48.12	$15.91	$27.08
Reliability	$19.88	$10.06	$3.11
Priority	$6.37	$17.89	$6.53
Telehealth	$4.39	($0.27)	$19.88
Mobile Laptop	$0.01	$1.19	($14.61)
Videophone	$5.06	$5.72	$21.26
Movie Rental	$3.29	$12.31	($9.26)

A comparison of the estimates in Table 8 and Table 18 shows that inexperienced Internet users have relatively lower valuations for speed. One interpretation is that inexperienced users are less aware of the full range of economic, entertainment, information and social benefits that the World Wide Web has to offer. Inexperienced users may also have less technical ability when using high-technology goods and service. As such, they are relatively less productive when using the Internet to produce household income and/or savings in time. Interestingly, Table 4 shows that inexperienced Internet users are more likely to be older, non-white, female, unmarried and with less education and household income.

5.4 Valuations for Internet Service

The estimates in Table 8 and Table 18 can be used to calculate household's total valuations for high speed Internet services that are comprised of different characteristics. For this calculation, we first construct four hypothetical Internet services from the characteristics described in Table 1. Because the valuation of very fast speed is, generally, not significantly higher than the valuation of fast speed, the four examples have fast speed only. "Basic" Internet service has fast speed and less reliable service. "Reliable" Internet service has fast speed and very reliable service. "Premium" service has fast speed, very reliable service and the ability to designate some downloads s as high priority. "Premium Plus" service has fast speed, very reliable service plus all other activities bundled into the service. We then assume that the household valuation for a less reliable, slow speed service with no other special activities is $14 per month.[29] We next multiply the WTP estimates from Table 8 by the level for each characteristic and sum these individual characteristic valuations for each Internet service.[30] Adding the base valuation for dial-up service of $14 gives the total valuation for each of the four Internet services for the representative household. These valuations, provided in Table 19, suggest that the representative household would be willing to pay $59 per month for a "Basic" service, $79 for a "Reliable" service, $85 for a "Premium" service and $98 for a "Premium Plus" service. Table 20 shows that an inexperienced household with a slow connection would be willing to pay $31 per month for a Basic service, $41 for a Reliable service, $59 for a Premium service and $71 for a Premium Plus service.

[29] We obtained this estimate from the mid point of range of subscription prices for dial-up Internet service listed on CostHelper.com (http://www.costhelper.com/cost/computers/internet-access.html). Since these are the actual prices charged by Internet service providers, they provide a lower-bound estimate of customer valuations for dial-up service.

[30] When the marginal utilities for Internet activities are imprecisely estimated, we value the individual characteristics at zero in the total valuation calculation.

6. Conclusions

We used choice experiments to estimate household preferences for Internet service. Respondents were presented with eight choice scenarios, and in each scenario, chose between a pair of Internet service alternatives that differed by the levels of their characteristics. The information in these choices was enriched with market data by having respondents indicate whether they would stay with their current (actual) Internet service or switch to the hypothetical service they had just selected. The marginal utility parameters of the representative household's utility function, and WTP, were then estimated from all the observed choices.

Our empirical results show that reliability and speed are important characteristics of Internet service. The representative household is willing to pay $20 per month for more reliable service, $45 for an improvement in speed from slow to fast, and $48 for an improvement in speed from slow to very fast. The latter finding indicates that very fast Internet service is not worth much more to households than fast service. Willingness-to-pay for speed increases with education, income and online experience, and decreases with age. Rural households value connection speed by about $3 more per month than urban households. Households are also willing to pay an additional $6 so that their Internet service provides the ability to designate downloads as high-priority, $4 for the ability to interact with health specialists online, about $3 for the ability to download and view full-length movies, and $5 for the ability to place free phone calls over the Internet and see the person being called.

Using these results, we calculate that a representative household would be willing to pay about $59 per month for a less reliable Internet service with fast speed ("Basic"), about $85 for a reliable Internet service with fast speed and the priority feature ("Premium"), and about $98 for a reliable Internet service with fast speed plus all other activities ("Premium Plus"). An improvement to very fast speed adds about $3 per month to these estimates. In contrast, an inexperienced household with a slow connection would be willing to pay about $31 per month for a Basic Internet service, about $59 per month for a Premium service and $71 for a Premium Plus service.

An interesting finding from our results is that valuations for Internet increase substantially with experience. The implication is that, if targeted correctly, private or public programs that educate households about the benefits from broadband (e.g., digital literacy training), expose households to the broadband experience (e.g., public access) or directly support the initial take-up of broadband (e.g., discounted service and/or hookup fees) have potential to increase overall penetration in the United States (see Ackerberg et al, 2009).

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Appendix A: Estimating the Random Utility Model

For easier explanation of the econometric method used to estimate the random utility model, let the utility for Internet service alternatives described by equation (1), including the SQ, be:

$$U_{ij}^{k_{ij}} = \beta' x_{ij}^{k_{ij}} + \varepsilon_{ij}^{k_{ij}}, \quad i = 1, \ldots, n, \quad j = 1, \ldots, J, \quad k_{ij} = 1, 2, \tag{6}$$

where $U_{ij}^{k_{ij}}$ is utility of alternative k_{ij} chosen by individual i during occasion j,

x′ = [COST, SPEED, RELIABILITY, MOBILE LAPTOP, MOVIE RENTAL, PRIORITY, TELEHEATH, VIDEOPHONE] is a vector of service characteristics, β = (β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8]′ is a vector of marginal utilities, and $\varepsilon_{ij}^{k_{ij}}$ are disturbances in the evaluation of utility. Disturbances are assumed to be independent and identically distributed mean zero normal random variables, uncorrelated with x_{ij} and with constant variance σ_ε^2.

Individuals maximize utility at each choice occasion. For instance, the probability of choosing alternative 1 (or A) is:

$$\begin{aligned} P_{ij}^1 &= P(\beta' x_{ij}^1 + \varepsilon_{ij}^1 > \beta' x_{ij}^2 + \varepsilon_{ij}^2) \\ &= P(\varepsilon_{ij}^2 - \varepsilon_{ij}^1 < -\beta'(x_{ij}^2 - x_{ij}^1)) \\ &= \Phi(-\beta'(x_{ij}^2 - x_{ij}^1)/\sqrt{2\sigma_\varepsilon}) \end{aligned} \tag{7}$$

and similarly for alternative 2 (or, B), where $\sqrt{2\sigma_\varepsilon}$ is the standard deviation of $\varepsilon_{ij}^2 - \varepsilon_{ij}^1$, and Φ is the univariate standard normal cumulative distribution function. The unit of observation is an i, j pair so that the likelihood is the product of the *Jn* probabilities like equation 7:

$$L(k_{ij}, i = 1,\ldots, n, j = 1,\ldots, J \mid x_{ij}^1, x_{ij}^2; \beta, \sigma_\varepsilon) = \prod_{i=1}^{n} \prod_{j=1}^{J} P_{ij}^{k_{ij}} \tag{8}$$

After choosing k_{ij}, individual households answer a question stating whether alternative k_{ij} would be chosen over the SQ. Let the SQ be indicated by 0. There are now four kinds of observations:[31]

$$Z_{ij}^1 = \begin{cases} 0 & \text{choose alternative 1} \\ 1 & \text{choose alternative 2} \end{cases} \qquad Z_{ij}^2 = \begin{cases} 0 & \text{choose 1 or 2 over SQ} \\ 1 & \text{choose SQ over 1 or 2} \end{cases} \tag{9}$$

Utility for the SQ is:

$$U_i^0 = \beta' x_i^0 + \varepsilon_i^0 \tag{10}$$

where x^0 is a vector of characteristics for the household's current Internet service, and ε_i^0 are disturbances assumed to be independent and identically distributed mean zero normal random variables with variance σ_0^2, assumed uncorrelated with $\varepsilon_{ij}^{k_{ij}}$.

The probability of choosing alternative k_{ij} over alternative 3 - k_{ij}, and then choosing alternative k_{ij} over the SQ ($Z_{ij}^2 = 0$) is:

$$\begin{aligned} P_{ij} &= P(U_{ij}^{k_{ij}} > U_{ij}^{3-k_{ij}}, U_{ij}^{k_{ij}} > U_{ij}^0) \\ &= P(\varepsilon_{ij}^{3-k_{ij}} - \varepsilon_{ij}^{k_{ij}} < -\beta'(x_{ij}^{3-k_{ij}} - x_{ij}^{k_{ij}}), \varepsilon_i^0 - \varepsilon_{ij}^{k_{ij}} < -\beta'(x_i^0 - x_{ij}^{k_{ij}})) \\ &= \Phi_2(-\beta'(x_{ij}^{3-k_{ij}} - x_{ij}^{k_{ij}})/\sqrt{2\sigma_\varepsilon}, -\beta'(x_i^0 - x_{ij}^{k_{ij}})/\sqrt{\sigma_0^2 + \sigma_\varepsilon^2}; \rho) \end{aligned} \tag{11}$$

where $\rho = \dfrac{\sigma_\varepsilon^2}{\sqrt{2\sigma_\varepsilon^2(\sigma_0^2 + \sigma_\varepsilon^2)}} = \dfrac{\sigma_\varepsilon}{\sqrt{2(\sigma_0^2 + \sigma_\varepsilon^2)}}$ is the correlation between $\varepsilon_{ij}^{3-k_{ij}} - \varepsilon_{ij}^{k_{ij}}$ and $\varepsilon_i^0 - \varepsilon_{ij}^{k_{ij}}$,

and Φ_2 is the standard bivariate normal distribution function. Similarly, for ($Z_{ij}^2 = 1$) the probability of choosing alternative k_{ij} over alternative 3 - k_{ij}, and then choosing the SQ over alternative k_{ij} is obtained by utilizing the symmetry of the normal distribution.

[31] When the SQ is chosen over 1 or 2, a complete ranking of the three alternatives has been determined. When 1 or 2 is chosen over the SQ, all that is known is that 1 or 2 is the most preferred alternative.

For estimation, a normalization is required. Let $\sigma_\varepsilon = 1/\sqrt{2}$. By defining $\lambda = \sqrt{\sigma_0^2 + \sigma_\varepsilon^2} = \sqrt{\sigma_0^2 + 1/2}$, equation (11) can be written as:

$$\begin{aligned} P_{ij} &= P(U_{ij}^{k_{ij}} > U_{ij}^{3-k_{ij}}, U_{ij}^{k_{ij}} > U_{ij}^{0}) \\ &= \Phi_2(-\beta'(x_{ij}^{3-k_{ij}} - x_{ij}^{k_{ij}}), -\beta'(x_j^0 - x_{ij}^{k_{ij}})/\lambda; -1/2\lambda) \end{aligned} \tag{12}$$

and similarly for $Z_{ij}^2 = 1$.[32]

Let $x_{ij}^{rp} = (x_{ij}^r - x_{ij}^p)$, r, p = 0, 1. The probabilities of the four data types are:

$$P(Z_{ij}^1 = 0, Z_{ij}^2 = 0) = \Phi_2(-\beta' x_{ij}^{21}, -\beta' x_{ij}^{01}/\lambda; 1/2\lambda)$$

$$P(Z_{ij}^1 = 0, Z_{ij}^2 = 1) = \Phi_2(-\beta' x_{ij}^{21}, \beta' x_{ij}^{01}/\lambda; -1/2\lambda) \tag{13}$$

$$P(Z_{ij}^1 = 1, Z_{ij}^2 = 0) = \Phi_2(\beta' x_{ij}^{21}, -\beta' x_{ij}^{02}/\lambda; 1/2\lambda)$$

$$P(Z_{ij}^1 = 0, Z_{ij}^2 = 1) = \Phi_2(\beta' x_{ij}^{21}, \beta' x_{ij}^{02}/\lambda; -1/2\lambda)$$

The unit of observation is an i, j pair so that the likelihood is the product of the *Jn* probabilities:

$$L(Z_{ij}^1, Z_{ij}^2, i = 1,\ldots,n, j = 1,\ldots,J \mid x_{ij}^1, x_{ij}^2, x_i^0; \beta, \lambda) = \prod_{i=1}^{n} \prod_{j=1}^{J} P(Z_{ij}^1, Z_{ij}^2) \tag{14}$$

[32] Note when λ = 1, $\sigma_\varepsilon^2 = \sigma_0^2$ and the two questions (A versus B; A or B versus the SQ) have equal weight in the likelihood. When λ < 1, the second question contains more information as there is more variability in the errors for the first question ($\sigma_\varepsilon^2 > \sigma_0^2$), and conversely.

Appendix C: Survey Questions: Internet Service Features

Q5. Some Internet service providers offer deals when you bundle Internet service with a traditional or cellular phone and/or TV into an "all-in-one" service plan with a single monthly bill. What kind of service do you have at home?

- ❍ Not sure
- ❍ Internet only
- ❍ Internet and phone
- ❍ Internet and TV
- ❍ Internet, phone and TV
- ❍ Other (please specify: ___________________________)

SHOW Q6 IF Q5 = "INTERNET ONLY" OR REFUSED.

Q6. Your Internet service has a monthly *cost*. How much does your household pay per month for the Internet service at your home?

$ ___________ per month

[OR, FOR EXAMPLE] SHOW Q13 & Q14 IF Q5 = "OTHER.".

Q13. Your bundle of services has a monthly *cost*. How much does your household pay per month for the bundle of services at your home?

$ ___________ per month

Q14. How much does your household pay per month for the Internet portion of your bundle of services?

$ ___________ per month

Q15. *Speed* describes the time it takes to receive (download) and send (upload) information from your home computer. Table 1 shows three common speeds.

Table 1. Speed of receiving and sending information over the Internet

Speed	*Description*
Slow	Similar to dial up. Downloads from the Internet and uploads to the Internet are slow. It is good for emailing and light web surfing.
Fast	Much faster downloads and uploads. It is great for music, photo sharing, and watching some videos.
Very Fast	Blazing fast downloads and uploads. It is really great for gaming, watching high-definition movies, and instantly transferring large files.

Consider the speed of the Internet service you have at home. Using Table 1 above as a guide, please indicate the level of speed for your service.

❍ Very fast ❍ Fast ❍ Slow

Q16. Very *reliable* Internet service is rarely disrupted by service outages, that is, your service may go down once or twice a year due to severe weather. With *less reliable* Internet service you will experience more outages, perhaps once or twice a month for no particular reason.

How reliable is your Internet service?

❍ Very reliable ❍ Less reliable

Q17. The Internet is like a freeway. When traffic is light, all vehicles travel at the maximum speed. Some lanes are reserved for priority traffic such as buses and emergency vehicles. During peak times, most vehicles must slow down. However, the priority traffic can travel at the maximum speed.

An Internet *priority* feature allows you to designate some of your Internet downloads as high priority. During peak periods, your high-priority downloads will travel through the Internet at a much faster speed than low-priority downloads (e.g., an interactive gaming activity could be given priority over a software update, or vice versa).

Does your Internet service have a priority feature (note: this is not PowerBoost)?

❍ Yes ❍ No ❍ Not sure

[Hyperlink to <u>PowerBoost</u>: "In contrast, a <u>PowerBoost</u> feature provides a temporary 10 second burst of connection speed when you are downloading large files."]

Q17. You may be able to use your Internet service to interact with your health specialists. For example, the "*Telehealth*" feature allows you to go online for remote diagnosis, treatment, monitoring and consultations, saving you a trip to your health specialists.

Have you ever interacted with your health care specialists through *your* Internet service?

❍ Yes ❍ No

Q17. Many Internet services have a free wireless home network feature that allows you to connect your laptop computer to the Internet wirelessly within your home. Some Internet services also have a *mobile laptop* feature where you pay an extra monthly fee to connect your laptop to the Internet wirelessly while away from your home.

Does your Internet service have a mobile laptop feature (note: this is not Wifi)?

❍ Yes ❍ No

[HYPERLINK TO WIFI: "IN CONTRAST, WIFI OFTEN PROVIDES THE PUBLIC WITH A FREE, WIRELESS CONNECTION TO THE INTERNET AT WIFI HOTSPOTS OPERATED BY AIRPORTS, HOTELS, RESTAURANTS AND COFFEE SHOPS."]

SHOW Q17B IF Q17 = "YES".

Q17b. How much extra does your household pay per month for your mobile laptop feature?

$ __________ per month

Q17. Some software applications such as Skype provide a "*videophone*" feature that allows you to place free phone calls over the Internet and see the person you are calling.

Have you used a videophone feature to place free phone calls and see the person you are calling, through *your* Internet service?

❍ Yes ❍ No

Q17. Some *movie rental* services such as Netflix, Blockbuster.com and iTunes allow you to download and watch high-definition movies and TV shows, saving the cost of a trip to the video store.

Do you use these or similar services to download and watch high-definition movies and TV shows?

❍ Yes ❍ No

SHOW Q17B IF Q17 = "YES".

Q17b. How much does your household pay per month for your *online* movie rental service?

$ __________ per month

Tables and Figures

Table 1. Internet Service Characteristics

Characteristic	Levels
COST	The amount the household pays per month for home Internet service (ranging from $5 to $90 per month in increments of $5).
SPEED	Slow: Similar to dial up. Downloads from the Internet and uploads to the Internet are slow. It is good for emailing and light web surfing. Fast: Much faster downloads and uploads. It is great for music, photo sharing and watching some videos. Very fast: Blazing fast downloads and uploads. It is really great for gaming, watching high-definition movies, and instantly transferring large files.
RELIABILITY	Very reliable Internet service is rarely disrupted by service outages, that is, your service may go down once or twice a year due to severe weather. With less reliable Internet service you will experience more outages, perhaps once or twice a month for no particular reason.
MOBILE LAPTOP	Yes, I can use my Internet service to connect my laptop to the Internet wirelessly while away from my home. No, I cannot use my Internet service to connect my laptop to the Internet wirelessly while away from my home.
MOVIE RENTAL	Yes, I can use my Internet service to download and watch high-definition movies and TV shows. No, I cannot use my Internet service to download high-definition movies and TV shows.
PRIORITY	Yes, I can use my Internet service to designate some of my downloads as high priority. No, I cannot use my Internet service to designate some of my downloads as high priority.
TELEHEALTH	Yes, I can interact with my health care specialists through my Internet service. No, I cannot interact with my health care specialists through my Internet service.
VIDEOPHONE	Yes, I can place free calls through my Internet service and see the person I am calling. No, I cannot place calls through my Internet service.

Table 2. Demographic Distributions (%)

	Census	KN panel	KN sample		
			Full sample	Experienced	Inexperienced
Region					
Northeast	18.5	18.7	18.8	19.3	13.6
Midwest	21.9	22.3	23.6	23.3	28.0
South	36.5	35.5	34.5	34.2	38.6
West	23.1	23.5	23.1	23.3	19.9
Age					
18-24 years	12.6	10.4	11.4	12.0	4.2
25-34 years	17.8	17.7	18.0	18.4	13.6
35-44 years	18.1	19.1	20.9	21.2	16.9
45-54 years	19.6	18.9	18.5	17.7	28.0
55-64 years	15.3	18.3	17.0	16.5	22.9
65 years or over	16.7	15.7	14.2	14.2	14.2
Race					
Non-white	18.8	20.5	22.7	20.9	44.5
White	81.2	79.5	77.3	79.1	55.5
Gender					
Female	51.7	52.7	51.5	50.5	64.4
Male	48.3	47.3	48.5	49.5	35.6
Marital status					
Married	55.5	53.4	58.7	60.7	33.9
Not married	44.5	46.6	41.3	39.3	66.1
Education					
< High school	14.2	13.1	7.7	6.8	18.2
High school	30.9	29.9	25.4	25.3	27.3
Some college	27.8	28.9	32.6	31.9	40.9
Bachelors degree or higher	27.1	28.0	34.3	36.0	13.6
Household income					
< $10,000	5.9	6.6	3.4	2.3	16.5
$10,000-$24,999	15.6	16.2	10.0	8.5	28.2
$25,000-$49,999	26.5	26.5	23.0	22.3	31.4
$50,000-$74,999	19.7	20.2	22.7	23.4	15.2
> $75,000-	32.3	30.5	40.9	43.5	8.7
Employment					
In labor force	67.6	67.4	61.4	61.6	43.0
Not in labor force	32.4	32.6	38.6	38.4	57.0

SOURCE. United States Census Bureau (2009); Knowledge Networks, Inc. (2009b).

Table 3. Summary Statistics for KN Full Sample

Demographic	Description	Obs	Mean	s.d.	Min	Max
INEXPERIENCED	1 if the respondent has less than twelve months of panel experience *and* who did not have Internet service prior to recruitment; 0 otherwise.	6,271	0.075	0.264	0	1
AGE	1 if 18-24 years; 2 if 25-34; 3 if 35-44; 4 if 45-54; 5 if 55-64; 6 if 65-74; 7 if 75 years or over.	6,270	3.578	1.639	1	7
RACE	1 if white; 0 otherwise.	6,271	0.773	0.419	0	1
GENDER	1 if female; 0 if male.	6,271	0.515	0.500	0	1
MARITAL STATUS	1 if married; 0 otherwise.	6,271	0.587	0.492	0	1
EDUCATION	1 if less than high school; 2 if high school; 3 if some college; 4 if bachelors degree or more.	6,271	2.935	0.949	1	4
HOUSEHOLD INCOME	1 if less than $10,000; 2 if $10,000-$24,999; 3 if 25,000-$49,999; 4 if $50,000-$74,999; 5 if $75,000 or more.	6,271	3.878	1.153	1	5
EMPLOYMENT	1 if in work force; 0 otherwise.	6,271	0.614	0.487	0	1
NORTHEAST	1 if respondent resides in the Northeast census region; 0 otherwise.	6,271	0.188	0.391	0	1
MIDWEST	1 if respondent resides in the Midwest census region; 0 otherwise.	6,271	0.236	0.425	0	1
SOUTH	1 if respondent resides in the South census region; 0 otherwise.	6,271	0.345	0.475	0	1
WEST	1 if respondent resides in the West census region; 0 otherwise.	6,271	0.231	0.421	0	1

NOTES. Obs is number of observations. s.d. is standard deviation. Min is minimum value. Max is maximum value.

Table 4. Probit Estimates of Inexperienced Internet Users

	Coef.	|z|	P>|z|	dF/dx
AGE	0.129	7.92	0.000	-0.011
RACE	-0.531	9.22	0.000	0.061
GENDER	0.189	3.45	0.001	-0.017
MARITAL STATUS	-0.318	5.40	0.000	0.030
EDUCATION	-0.101	3.58	0.000	0.009
HOUSEHOLD INCOME	-0.356	14.46	0.000	0.032
EMPLOYMENT	-0.015	0.26	0.796	0.001
NORTHEAST	-0.090	1.00	0.317	0.008
MIDWEST	0.249	3.12	0.002	-0.025
SOUTH	0.067	0.92	0.355	-0.006
CONSTANT	0.261	1.64	0.101	
Likelihood	-1340.07			
Observations	6,270			

NOTES. "Inexperienced" are new recruits to the panel, that is, those with less than twelve months of panel experience *and* who did not have Internet service prior to recruitment. Coef. is the estimated coefficient for the independent variables in the probit model. z is the z value. P>|z| is the probability of getting an extreme value of the test statistic. dF/dx is the effect of a marginal change in the independent variable on the probability of being an experienced Internet user.

Table 5. Summary Statistics for Internet Service Features and Hours Online

Feature/Hours online	Obs	Mean	s.d.	Min	Max
All Internet users					
SPEED	6,260	2.114	0.561	1	3
COST ($ per month)	5,925	39.15	23.17	0	250
RELIABILITY	6,261	0.872	0.334	0	1
BUNDLE	6,271	0.764	0.425	0	1
HOURS ONLINE PER WEEK	6,250	15.58	15.15	0	168
Inexperienced Internet users					
SPEED	466	1.412	0.606	1	3
COST ($ per month)	374	16.89	24.39	0	145
RELIABILITY	472	0.725	0.447	0	1
BUNDLE	472	0.464	0.499	0	1
HOURS ONLINE PER WEEK	465	9.64	14.44	0	140

NOTES. SPEED = 1 when service is slow, SPEED = 2 when service is fast and SPEED = 3 when service is very fast. RELIABLITY = 0 when service is less reliable and RELIABLE = 1 when service is very reliable. BUNDLE = 1 when Internet service is bundled with other telecommunication services. Obs is number of observations. s.d. is standard deviation. Min is minimum value. Max is maximum value.

Table 6. Frequency of Internet Activity – "Many Times a Week."

Internet activity	All	Slow	High speed
Email and instant messaging	71.4 %	68.5 %	79.7 %
Search engines (e.g., Google)	37.8 %	29.5 %	60.8 %
Play online games	24.0 %	18.0 %	24.7 %
Connect your laptop to the Internet wirelessly	0.88 %	0.45 %	0.88 %
Download movies to view on your PC	2.85 %	0.89 %	3.09 %
Place telephone calls and see the person you are calling	1.78 %	0.45 %	1.64 %
Interact with your health care specialists	0.58 %	0 %	0.65 %

NOTES. Cells are percent of respondents using the activity "many times a week." All is all Internet users. Slow is Internet users with slow service. High speed is Internet users with fast or very fast service.

Table 7. Summary Statistics for Internet Service Activities

Activity	Question	Obs.	Yes	Percent
PRIORITY	Does your Internet service have a priority feature (note: this is not PowerBoost)?	2,514	105	4.177
TELEHEALTH	Have you ever interacted with your health care specialists through your Internet service?	2,517	175	6.953
MOBILE LAPTOP	Does your Internet service have a mobile laptop feature (note: this is not Wifi)?	2,494	123	4.932
VIDEOPHONE	Have you used a videophone feature to place free phone calls and see the person you are calling, through your Internet service?	2,496	456	18.23
MOVIE RENTAL	Do you use movie rental services such as Netflix, Blockbuster.com and iTunes, to download and watch high-definition movies and TV shows?	2,493	424	16.98

NOTES. Obs is the number of respondents who answered the question. Yes is the number of respondents who answered yes. Percent is the percentage of respondents that answered yes.

Table 8. Baseline Estimates of Utility

	5,921 respondents			
	MU	t	WTP	s.e.
COST	-0.021	66.58		
FAST SPEED	0.945	67.32	$45.10	$0.48
VERY FAST SPEED	1.009	60.75	$48.12	$0.54
RELIABILITY	0.417	40.89	$19.88	$0.42
PRIORITY	0.134	7.636	$6.37	$0.84
TELEHEALTH	0.092	6.583	$4.39	$0.67
MOBILE LAPTOP	0.000	0.018	$0.01	$0.55
VIDEOPHONE	0.106	8.976	$5.06	$0.56
MOVIE RENTAL	0.069	6.173	$3.29	$0.53
CONSTANT	0.816	66.911		
λ	0.940	33.042		
Likelihood	-1.082			
Observations	47,368			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 9. Baseline Estimates of Utility by Existing Internet Connection Speed

	Slow speed (568 respondents)				Fast speed (4,028 respondents)				Very fast speed (1,325 respondents)			
	MU	t	WTP	s.e.	MU	t	WTP	s.e.	MU	t	WTP	s.e.
COST	-0.029	27.31			-0.022	56.75			-0.018	27.00		
FAST SPEED	0.475	10.73	$16.35	$1.37	0.881	50.66	$39.49	$0.57	0.983	31.31	$55.14	$1.62
VERY FAST SPEED	0.436	8.453	$15.02	$1.65	0.846	41.67	$37.89	$0.65	1.129	29.91	$63.32	$1.95
RELIABILITY	0.313	9.308	$10.78	$1.10	0.421	32.95	$18.87	$0.51	0.447	19.31	$25.05	$1.13
PRIORITY	0.289	3.903	$9.93	$2.55	0.172	7.554	$7.69	$1.02	0.180	4.368	$10.08	$2.31
TELEHEALTH	0.085	1.462	$2.91	$1.99	0.111	6.026	$4.99	$0.83	0.130	3.853	$7.30	$1.89
MOBILE LAPTOP	0.060	1.294	$2.05	$1.59	0.010	0.679	$0.47	$0.69	0.067	2.466	$3.78	$1.53
VIDEOPHONE	0.126	2.429	$4.34	$1.79	0.129	8.241	$5.76	$0.70	0.178	6.198	$9.97	$1.61
MOVIE RENTAL	0.441	8.452	$15.18	$1.83	0.121	7.999	$5.41	$0.68	0.005	0.177	$0.26	$1.47
CONSTANT	0.087	2.307			0.944	51.72			1.403	23.61	1.403	23.61
λ	1.717	18.71			1.226	32.02			1.369	15.14		
Likelihood	-1.155				-1.089				-1.030			
Observations	4,544				32,224				10,600			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 10. Baseline Estimates of Utility by Download Digital Video

	Download digital video (291 respondents)				Do not download digital video (4,371 respondents)			
	MU	t	WTP	s.e.	MU	t	WTP	s.e.
COST	-0.016	11.37			-0.022	56.73		
FAST SPEED	0.968	13.14	$61.99	$3.61	0.875	51.56	$40.64	$0.57
VERY FAST SPEED	1.096	12.36	$70.21	$4.13	0.872	43.96	$40.48	$0.64
RELIABILITY	0.449	9.631	$28.79	$2.43	0.441	35.53	$20.46	$0.50
PRIORITY	0.091	1.224	$5.82	$4.76	0.152	6.924	$7.07	$1.02
TELEHEALTH	0.116	2.566	$7.46	$2.91	0.128	6.840	$5.93	$0.87
MOBILE LAPTOP	-0.149	-3.500	($9.53)	$2.69	0.023	1.545	$1.07	$0.69
VIDEOPHONE	0.016	0.350	$1.05	$3.00	0.100	6.555	$4.63	$0.71
MOVIE RENTAL	-0.181	-3.441	($11.58)	$3.31	0.084	5.701	$3.92	$0.69
CONSTANT	0.693	10.48			1.001	50.34		
λ	0.959	5.795			1.332	32.29		
Likelihood	-1.119				-1.105			
Observations	2,328				34,960			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 11. Baseline Estimates of Utility by Smartphone Ownership

	Own Smartphone (1,881 respondents)				Do not own Smartphone (3,001 respondents)			
	MU	t	WTP	s.e.	MU	t	WTP	s.e.
COST	-0.019	32.17			-0.022	49.07		
FAST SPEED	0.878	32.70	$46.99	$1.02	0.903	44.77	$40.20	$0.68
VERY FAST SPEED	0.899	28.77	$48.13	$1.11	0.881	37.09	$39.18	$0.76
RELIABILITY	0.444	23.96	$23.77	$0.83	0.428	28.15	$19.03	$0.60
PRIORITY	0.109	3.570	$5.83	$1.63	0.171	6.208	$7.63	$1.23
TELEHEALTH	0.106	4.420	$5.68	$1.28	0.120	5.204	$5.36	$1.03
MOBILE LAPTOP	-0.082	-4.175	($4.41)	$1.05	0.053	2.812	$2.38	$0.85
VIDEOPHONE	0.036	1.712	$1.92	$1.12	0.154	8.083	$6.87	$0.85
MOVIE RENTAL	-0.015	-0.778	($0.81)	$1.04	0.093	4.914	$4.15	$0.84
CONSTANT	0.779	31.33			1.026	42.67		
λ	1.032	16.76			1.446	29.76		
Likelihood	-1.121				-1.094			
Observations	?				24,008			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 12. Baseline Estimates of Utility by Webcam Ownership

	Own Webcam (1,749 respondents)				Do not own Webcam (3,817 respondents)			
	MU	t	WTP	s.e.	MU	t	WTP	s.e.
COST	-0.018	30.41			-0.023	55.31		
FAST SPEED	0.878	32.04	$49.30	$1.14	0.871	48.56	$38.71	$0.58
VERY FAST SPEED	0.907	28.26	$50.89	$1.22	0.855	40.71	$37.99	$0.66
RELIABILITY	0.445	23.05	$24.99	$0.90	0.428	32.23	$19.03	$0.52
PRIORITY	0.124	3.997	$6.98	$1.75	0.163	6.667	$7.22	$1.08
TELEHEALTH	0.107	4.297	$6.00	$1.40	0.108	5.292	$4.78	$0.90
MOBILE LAPTOP	-0.027	-1.350	($1.52)	$1.13	0.039	2.284	$1.71	$0.75
VIDEOPHONE	0.022	1.104	$1.23	$1.11	0.201	10.73	$8.92	$0.83
MOVIE RENTAL	0.004	0.201	$0.22	$1.11	0.119	7.076	$5.30	
CONSTANT	0.839	29.808			0.979	47.90		
λ	1.085	16.68			1.356	32.41		
Likelihood	-1.124				-1.096			
Observations	13,992				30,536			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 13. Estimates of Utility by Age

	18 – 34 years (1,769 respondents)				35 – 58 years (2,723 respondents)				59 – 91 years (1,425 respondents)			
	MU	t	WTP	s.e.	MU	t	WTP	s.e.	MU	t	WTP	s.e.
COST	-0.021	-35.216			-0.021	-43.421			-0.021	-31.304		
FAST SPEED	1.000	35.795	$47.65	$1.02	0.885	41.119	$41.72	$0.74	0.681	24.565	$33.11	$1.04
VERY FAST SPEED	1.067	32.613	$50.82	$1.11	0.891	35.572	$42.03	$0.82	0.564	17.455	$27.39	$1.30
RELIABILITY	0.459	23.949	$21.86	$0.78	0.424	27.004	$20.02	$0.65	0.401	18.228	$19.48	$0.95
PRIORITY	0.093	2.807	$4.44	$1.58	0.158	5.707	$7.45	$1.31	0.251	6.044	$12.22	$2.03
TELEHEALTH	0.180	6.469	$8.60	$1.33	0.114	4.995	$5.38	$1.08	0.049	1.498	$2.37	$1.58
MOBILE LAPTOP	0.029	1.336	$1.38	$1.03	-0.023	-1.205	($1.06)	$0.88	-0.013	-0.446	($0.63)	$1.41
VIDEOPHONE	0.055	2.426	$2.61	$1.08	0.081	4.220	$3.84	$0.91	0.190	6.468	$9.25	$1.43
MOVIE RENTAL	-0.015	-0.721	($0.73)	$1.01	0.021	1.195	$1.01	$0.85	0.259	8.239	$12.59	$1.53
CONSTANT	0.853	29.604			0.904	38.297			1.020	28.173		
λ	1.241	19.401			1.245	24.197			1.420	19.602		
Likelihood	-1.105				-1.108				-1.020			
Observations	14,152				21,784				11,432			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 14. Baseline Estimates of Utility by Education

	No college (3,837 respondents)				College (2,084 respondents)			
	MU	t	WTP	s.e.	MU	t	WTP	s.e.
COST	-0.020	49.07			-0.023	-41.04		
FAST SPEED	0.768	43.58	$38.68	$0.65	1.032	40.38	$45.17	$0.86
VERY FAST SPEED	0.755	36.55	$38.02	$0.75	1.032	34.56	$45.18	$0.91
RELIABILITY	0.418	31.77	$21.05	$0.58	0.443	24.68	$19.40	$0.69
PRIORITY	0.147	6.189	$7.41	$1.20	0.168	5.269	$7.36	$1.40
TELEHEALTH	0.124	6.415	$6.22	$0.97	0.103	3.906	$4.50	$1.15
MOBILE LAPTOP	0.017	1.086	$0.88	$0.81	-0.037	-1.741	($1.61)	$0.92
VIDEOPHONE	0.103	6.211	$5.18	$0.83	0.096	4.431	$4.19	$0.94
MOVIE RENTAL	0.072	4.653	$3.63	$0.78	0.010	0.461	$0.42	$0.92
CONSTANT	0.949	44.17			0.914	35.88		
λ	1.303	28.09			1.274	24.05		
Likelihood	-1.119				-1.088			
Observations	30,696				16,672			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 15. Estimates of Utility by Income

	Low income < $25,000 (751 respondents)				$25,000 ≤ Middle income < $75,000 (3,245 respondents)				$75,000 ≤ High income (1,925 respondents)			
	MU	t	WTP	s.e.	MU	t	WTP	s.e.	MU	t	WTP	s.e.
COST	-0.020	22.01			-0.021	48.43			-0.021	36.28		
FAST SPEED	0.754	18.74	$37.00	$1.50	0.838	43.03	$39.02	$0.66	0.965	36.75	$46.90	$0.97
VERY FAST SPEED	0.733	15.57	$35.96	$1.74	0.830	36.34	$38.63	$0.76	0.986	32.27	$47.91	$1.03
RELIABILITY	0.363	12.12	$17.83	$1.33	0.412	28.54	$19.18	$0.59	0.486	26.39	$23.61	$0.75
PRIORITY	0.255	4.450	$12.51	$2.83	0.188	7.190	$8.74	$1.22	0.078	2.488	$3.81	$1.53
TELEHEALTH	0.106	2.118	$5.21	$2.46	0.095	4.536	$4.41	$0.97	0.105	4.001	$5.11	$1.28
MOBILE LAPTOP	0.030	0.773	$1.46	$1.89	0.021	1.213	$1.00	$0.83	-0.043	-2.046	($2.08)	$1.02
VIDEOPHONE	0.055	1.329	$2.69	$2.02	0.110	6.104	$5.10	$0.84	0.099	4.580	$4.79	$1.05
MOVIE RENTAL	0.107	2.955	$5.24	$1.77	0.069	4.002	$3.23	$0.81	0.025	1.198	$1.20	$1.00
CONSTANT	1.000	18.18			0.946	42.42			0.855	33.23		
λ	1.512	13.35			1.342	28.50			1.135	19.32		
Likelihood	-1.126				-1.107				-1.100			
Observations	6,008				25,960				15,400			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 16. Baseline Estimates of Utility by Race

	White (4,612 respondents)				Non white (1,309 respondents)			
	MU	T	WTP	s.e	MU	T	WTP	s.e.
COST	-0.022	59.03			-0.018	24.91		
FAST SPEED	0.876	53.07	$39.93	$0.55	0.685	22.35	$38.85	$1.24
VERY FAST SPEED	0.865	44.65	$39.43	$0.62	0.699	19.38	$39.62	$1.45
RELIABILITY	0.435	35.77	$19.86	$0.49	0.401	17.61	$22.71	$1.11
PRIORITY	0.167	7.444	$7.60	$1.02	0.148	3.823	$8.41	$2.20
TELEHEALTH	0.149	8.026	$6.80	$0.85	0.027	0.887	$1.54	$1.74
MOBILE LAPTOP	0.018	1.169	$0.81	$0.69	-0.022	-0.875	($1.25)	$1.43
VIDEOPHONE	0.143	9.222	$6.54	$0.71	0.020	0.738	$1.11	$1.51
MOVIE RENTAL	0.094	6.285	$4.29	$0.68	-0.004	-0.146	($0.21)	$1.42
CONSTANT	1.059	52.54			0.854	23.06		
λ	1.430	35.21			1.235	13.99		
Likelihood	-1.100				-1.151			
Observations	36,896				10,472			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 17. Baseline Estimates of Utility by Location

	Urban location (2,956 respondents)				Rural location (2,747 respondents)			
	MU	t	WTP	s.e.	MU	t	WTP	s.e.
COST	-0.020	43.82			-0.022	44.86		
FAST SPEED	0.822	40.60	$40.80	$0.73	0.944	43.82	$43.55	$0.75
VERY FAST SPEED	0.805	34.01	$39.96	$0.83	0.954	37.76	$44.03	$0.82
RELIABILITY	0.407	27.19	$20.17	$0.65	0.447	28.83	$20.64	$0.62
PRIORITY	0.145	5.538	$7.18	$1.30	0.173	6.173	$7.98	$1.29
TELEHEALTH	0.099	4.785	$4.91	$1.03	0.126	5.356	$5.81	$1.08
MOBILE LAPTOP	-0.015	0.887	($0.77)	$0.87	0.006	0.306	$0.27	$0.87
VIDEOPHONE	0.095	5.380	$4.73	$0.88	0.094	4.724	$4.32	$0.91
MOVIE RENTAL	0.061	3.563	$3.02	$0.85	0.052	2.843	$2.41	$0.85
CONSTANT	0.915	38.79			0.888	39.16		
λ	1.207	23.72			1.300	26.51		
Likelihood	-1.109				-1.105			
Observations	23,648				21,992			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood.

Table 18. Baseline Estimates of Inexperienced by Speed of Internet Connection

	Slow (231 respondents)				High speed (140 respondents)			
	MU	t	WTP	s.e.	MU	t	WTP	s.e.
COST	-0.033	17.47			-0.015	-8.228		
FAST SPEED	0.559	6.795	$16.74	$2.18	0.400	4.924	$26.38	$4.71
VERY FAST SPEED	0.531	5.610	$15.91	$2.57	0.410	4.247	$27.08	$5.60
RELIABILITY	0.336	5.941	$10.06	$1.59	0.047	0.728	$3.11	$4.26
PRIORITY	0.597	4.783	$17.89	$3.81	0.099	0.776	$6.53	$8.42
TELEHEALTH	-0.009	0.088	($0.27)	$3.09	0.301	3.467	$19.88	$5.88
MOBILE LAPTOP	0.040	0.540	$1.19	$2.21	-0.221	-2.873	($14.61)	$4.98
VIDEOPHONE	0.191	1.897	$5.72	$3.00	0.322	3.806	$21.26	$5.84
MOVIE RENTAL	0.411	4.848	$12.31	$2.56	-0.140	-1.840	($9.26)	$5.02
CONSTANT	0.224	2.335			1.066	8.502		
λ	2.096	10.73			1.300	26.51		
Likelihood	-1.086				1.152	4.199		
Observations	1,848				1,120			

NOTES. MU is estimate of marginal utility. t is t ratio for MU estimate. WTP is estimate of willingness to pay. s.e. is standard error of WTP estimate. λ is the estimate of the ratio of the standard deviation of the errors in evaluating the status quo alternative to the errors in evaluating the hypothetical alternatives. Likelihood is mean log likelihood. Slow is Internet users with slow service. High speed is Internet users with fast or very fast service.

Table 19. Estimated Valuation for Internet Service for All Respondents ($ per month)

Characteristics	**Basic**	**Reliable**	**Premium**	**Premium Plus**
Speed	Fast	Fast	Fast	Fast
Reliability	Less reliable	Very reliable	Very reliable	Very reliable
Priority	No	No	Yes	Yes
Telehealth	No	No	No	Yes
Mobile laptop	No	No	No	Yes
Videophone	No	No	No	Yes
Movie rental	No	No	No	Yes
Total valuation	$59.10	$78.98	$85.35	$98.09

Table 20. Estimated Valuation for Internet Service for Inexperienced Users with Slow Internet Connection ($ per month)

Characteristics	**Basic**	**Reliable**	**Premium**	**Premium Plus**
Speed	Fast	Fast	Fast	Fast
Reliability	Less reliable	Very reliable	Very reliable	Very reliable
Priority	No	No	Yes	Yes
Telehealth	No	No	No	Yes
Mobile laptop	No	No	No	Yes
Videophone	No	No	No	Yes
Movie rental	No	No	No	Yes
Total valuation	$30.74	$40.80	$58.69	$71.00

Figure 1. Choice Question Example

1. Consider the following two Internet service options, A and B. For this first question, we highlight the differences in the levels of the features in red. For some features, there may be no difference

   Click here to review a summary of the levels of all the features.
   To see the description of an individual feature, place your cursor over that feature

	Option A	**Option B**
Cost	$25 per month	$45 per month
Speed	Fast	Slow
Reliability	Less reliable	Very reliable
Priority	No	Yes
	Option A is less expensive and faster	*Option B is more reliable and has the Telehealth feature*
Select the option you prefer	○ I prefer option A	◉ I prefer option B

2. Since you currently have Internet service at home, we also ask if you would actually switch to the Internet service, A or B, you have chosen. Please indicate "Yes" when your choice of A or B is preferred to your service at home, or "No" when your choice of A or B is not preferred to your service at home.

   Click here to review a summary of the levels of all the features.
   To see the description of an individual feature, place your cursor over that feature.

	Your Home Service	Option B
Cost	$25.99 per month	$45 per month
Speed	Fast	Slow
Reliability	Very reliable	Very reliable
Priority	No	Yes
Select the option you prefer	◉ I would stay with my home service	○ I prefer option B

Investigator Profiles

Gregory L. Rosston is Deputy Director of the Stanford Institute for Economic Policy Research and Deputy Director of the Public Policy program at Stanford University and has served as Deputy Chief Economist at the Federal Communications Commission. Dr. Rosston received his Ph.D. in Economics from Stanford University in 1994. He has written extensively on the application of economics to telecommunications issues and is the co-editor of two books relating to telecommunications and is associate editor of Information, Economics and Policy.

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Appendix A
Structural economic and econometric model

The Demand for Internet Access

The conventional labor-leisure choice model is extended to include the benefits from Internet access. The consumer is assumed to maximize a utility function of consumption and leisure, subject to a monetary budget constraint that includes the household production input *Internet bandwidth*, and subject to a time budget constraint that includes the household production input *time online*. Both inputs are used to produce reductions in essential time, defined as the non-remunerated time lost when participating in the labor market, plus time doing fundamental living activities such as banking, bill-paying, maintaining health, shopping, etc.

Essential time is represented by the household production function $\overline{T}(h, b, t; a)$, where h is the number of hours worked, b is Internet bandwidth, t is time spent online, and a is an efficiency parameter that reflects the technical ability of the individual. The function $\overline{T}$ is convex in b and t, and b and t are assumed to be complements in production so that increasing b will raise the marginal productivity of t. Similarly, a augments the productivity of b and t, decreasing essential time for a given input level. As such, $\overline{T}_b$, $\overline{T}_t$, $\overline{T}_a$, $\overline{T}_{bt}, \overline{T}_{ba}, \overline{T}_{ta} < 0$ and $\overline{T}_{bb}, \overline{T}_{tt} > 0$, where subscripts indicate partial derivatives. Some of the time costs of work may be fixed. Others, including commuting time, costs associated with the stress of work, the preparation and recovery period, and training and child care costs, may be linear or concave functions of the number of hours worked (Heim and Meyer, 2004). Essential time is concave in h so that $\overline{T}_h > 0$ and $\overline{T}_{hh} < 0$.

The consumer's maximization problem is:

$$\begin{aligned} &\max_{h,b,t} \quad U(c,\, L) \\ &s.t. \quad c = y + wh - p_b b - p_t t \\ &\qquad\;\; L = T - h - t - \overline{T}(h, b, t; a) \end{aligned} \tag{A1}$$

where U is utility, c is consumption, L is leisure, y is non-wage income, w is the wage rate, p_b is the per-unit price of bandwidth, p_t is the per-unit price of time online, and T is total time available.

Structural Econometric Models and Likelihoods

The individual's utility of an Internet service is assumed to be a function of the attributes of the service and a random error (known to the individual but not the researcher). This is the *Random Utility Model* (RUM) as it is applied in environmental economics, transportation research, health economics, and marketing.

It is assumed that respondents maximize their household's conditional utility of the service option (conditional on all other consumption and time allocation decisions):

$$U_{ij}^{k_{ij}} = \boldsymbol{\beta}'\boldsymbol{x}_{ij}^{k_{ij}} + \epsilon_{ij}^{k_{ij}} \;\; , \, i = 1, \ldots, n; \; j = 1, \ldots J, \; k_{ij} = 1, 2 \qquad \text{(A2)}$$

where $U_{ij}^{k_{ij}}$ is the utility of alternative k_{ij} chosen by individual i during occasion j.[1] The vector $\boldsymbol{x}_{ij}$ contains the observed attributes of the alternatives. It is assumed that the $\epsilon_{ij}^{k_{ij}}$ are independent, and identically distributed mean zero normal random variables, uncorrelated with $\boldsymbol{x}_{ij}$, with constant unknown variance σ_{ϵ}^{2}.[2] The probability of choosing alternative 1, for example, is:

$$\begin{aligned} P_{ij}^{1} &= P(U^1 > U^2) \qquad \text{(A3)} \\ &= P(\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{1} + \epsilon_{ij}^{1} > \boldsymbol{\beta}'\boldsymbol{x}_{ij}^{2} + \epsilon_{ij}^{2}) \\ &= P\Big(\epsilon_{ij}^{2} - \epsilon_{ij}^{1} < \, -\boldsymbol{\beta}'(\boldsymbol{x}_{ij}^{2} - \boldsymbol{x}_{ij}^{1})\Big) \\ &= \Phi\Big[-\boldsymbol{\beta}'(\boldsymbol{x}_{ij}^{2} - \boldsymbol{x}_{ij}^{1})/\sqrt{2}\sigma_{\epsilon}\Big] \end{aligned}$$

and similarly for alternative 2, where $\sqrt{2}\sigma_{\epsilon}$ is the standard deviation of $\epsilon_{ij}^{2} - \epsilon_{ij}^{1}$ and $\Phi(\,\cdot\,)$ is the univariate standard normal cumulative distribution function. Note that equation A2 comprises the usual probit model for dichotomous choice under the assumption the individual knows the random component and maximizes utility. The parameter vector $\boldsymbol{\beta}$ is identified only up to the scale factor $\sqrt{2}\sigma_{\epsilon}$, and σ_{ϵ} is not identified, since only the sign and not the scale of the dependent variable (the utility difference) is observed. If the J observations for each respondent are simply "stacked" to produce a data set with Jn observations, the unit of observation is an i, j pair and the likelihood is the product of the Jn probabilities like equation A2:

$$L(k_{ij}, \, i = 1, \ldots, n, \; j = 1, \ldots, J \,|\, \boldsymbol{x}_{ij}^{1}, \boldsymbol{x}_{ij}^{2}; \boldsymbol{\beta}, \sigma_{\epsilon}) = \prod_{i=1}^{n}\prod_{j=1}^{J} P_{ij}^{k_{ij}}. \qquad \text{(A4)}$$

Incorporating the Status Quo Question

After choosing k_{ij}, individuals answer a question stating whether alternative k_{ij} would be chosen over the status quo. Let the status quo be indicated by 0. There are now four kinds of observations. Let the binary variable Z_{ij}^{1} indicate the choice of alternative 1 or 2

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[1]This notation, especially the use of k_{ij} to indicate either a 1 or a 2, is a bit cumbersome at first, but will make precise many of the concepts below.

[2]We allow for correlation of errors for an individual when it comes to choices involving the status quo–see section 3.2. For the hypothetical choices, there is no question of correlation since the effective errors that enter the likelihood are the *difference* in the two errors for any choice occasion, and the attribute sets are randomly assigned to choice "A" or choice "B". That is, the relevant distribution theory for forming the likelihood is based on $\epsilon_{i1}^{1} - \epsilon_{i1}^{2}$, for example (person i, first choice occasion–see equation A7). In addition, any additive systematic component of the error is then eliminated. This is similar to the arguments of Heckman and Robb (1985) in their evaluation of social interventions.

for individual i on occasion j, and let the binary variable Z_{ij}^2 indicate the chosen alternative or the status quo. These are defined by:

$$Z_{ij}^1 = \begin{cases} 0 & \text{choose 1} \\ 1 & \text{choose 2} \end{cases} \qquad Z_{ij}^2 = \begin{cases} 0 & \text{choose 1 or 2 over status quo} \\ 1 & \text{choose status quo over 1 or 2} \end{cases} \tag{A5}$$

Note that there is an information asymmetry here: when the status quo is chosen over 1 or 2 ($Z_{ij}^2 = 1$), a complete ranking of the three alternatives has been determined; when 1 or 2 is chosen over the status quo ($Z_{ij}^2 = 0$), all that is known is that 1 or 2 is the most preferred alternative.

Utility for the status quo, U_i^0 under the model assumption (equation A1) is given by:

$$U_i^0 = \boldsymbol{\beta}' \boldsymbol{x}_i^0 + \epsilon_i^0 \ , \tag{A6}$$

where ϵ_i^0 are disturbances and $\boldsymbol{x}^0$ are the attributes of the individual's current Internet access. The attributes of the status quo vary over individuals, but not over choice occasions, and the utility of the status quo is evaluated only once by each individual (U_i^0 and ϵ_i^0 are subscripted with i only). The ϵ_i^0 are assumed to be independent, identically distributed normal random variables with zero expectation and variance σ_0^2, uncorrelated with $\epsilon_{ij}^{k_{ij}}$.

The probability of choosing alternative k_{ij} $(1, 2)$ over alternative $3 - k_{ij}$ $(2, 1)$ and then choosing alternative k_{ij} over the status quo ($Z_{ij}^2 = 0$) is the bivariate probability:

$$\begin{aligned} & P(U_{ij}^{k_{ij}} > U_{ij}^{3-k_{ij}}, U_{ij}^{k_{ij}} > U_i^0) \\ & = P\Big(\epsilon_{ij}^{3-k_{ij}} - \epsilon_{ij}^{k_{ij}} < -\boldsymbol{\beta}'(\boldsymbol{x}_{ij}^{3-k_{ij}} - \boldsymbol{x}_{ij}^{k_{ij}}), \epsilon_i^0 - \epsilon_{ij}^{k_{ij}} < -\boldsymbol{\beta}'(\boldsymbol{x}^0 - \boldsymbol{x}_{ij}^{k_{ij}})\Big) \\ & = \Phi_2\Big[-\boldsymbol{\beta}'(\boldsymbol{x}_{ij}^{3-k_{ij}} - \boldsymbol{x}_{ij}^{k_{ij}})/\sqrt{2}\sigma_\epsilon, \ -\boldsymbol{\beta}'(\boldsymbol{x}^0 - \boldsymbol{x}_{ij}^{k_{ij}})/\sqrt{\sigma_0^2 + \sigma_\epsilon^2}; \ \rho\Big] \end{aligned} \tag{A7}$$

where ρ is the correlation between $\epsilon_{ij}^{3-k_{ij}} - \epsilon_{ij}^{k_{ij}}$ and $\epsilon_i^0 - \epsilon_{ij}^{k_{ij}}$,

$$\rho = \frac{\sigma_\epsilon^2}{\sqrt{2\sigma_\epsilon^2(\sigma_0^2 + \sigma_\epsilon^2)}} = \frac{\sigma_\epsilon}{\sqrt{2(\sigma_0^2 + \sigma_\epsilon^2)}}, \tag{A8}$$

and Φ_2 is the standard bivariate normal cumulative distribution function. Similarly, the probability of choosing alternative k_{ij} over alternative $3 - k_{ij}$ and then choosing the status quo over alternative k_{ij} ($Z_{ij}^2 = 1$) is:

$$\begin{aligned} & P(U_{ij}^{k_{ij}} > U_{ij}^{3-k_{ij}}, U_{ij}^{k_{ij}} < U_i^0) \\ & = P\Big(\epsilon_{ij}^{3-k_{ij}} - \epsilon_{ij}^{k_{ij}} < -\boldsymbol{\beta}'(\boldsymbol{x}_{ij}^{3-k_{ij}} - \boldsymbol{x}_{ij}^{k_{ij}}), \epsilon_i^0 - \epsilon_{ij}^{k_{ij}} > -\boldsymbol{\beta}'(\boldsymbol{x}^0 - \boldsymbol{x}_{ij}^{k_{ij}})\Big) \\ & = \Phi_2\Big[-\boldsymbol{\beta}'(\boldsymbol{x}_{ij}^{3-k_{ij}} - \boldsymbol{x}_{ij}^{k_{ij}})/\sqrt{2}\sigma_\epsilon, \boldsymbol{\beta}'(\boldsymbol{x}^0 - \boldsymbol{x}_{ij}^{k_{ij}})/\sqrt{\sigma_0^2 + \sigma_\epsilon^2}; \ -\rho\Big] \end{aligned} \tag{A9}$$

where the symmetry of the normal distribution has been utilized.

One normalization is required: let $\sigma_\epsilon = 1/\sqrt{2}$. Define $\lambda^2 = \sigma_0^2/\sigma_\epsilon^2 = 2\sigma_0^2$. Then equation A8 can be written as:

$$P(U_{ij}^{k_{ij}} > U_{ij}^{3-k_{ij}}, U_{ij}^{k_{ij}} < U_i^0) = \tag{A8$'$}$$
$$\Phi_2\Big[-\boldsymbol{\beta}'(\boldsymbol{x}_{ij}^{3-k_{ij}} - \boldsymbol{x}_{ij}^{k_{ij}}), \frac{\boldsymbol{\beta}'(\boldsymbol{x}^0 - \boldsymbol{x}_{ij}^{k_{ij}})}{\sqrt{(1+\lambda^2)/2}}; -\frac{1}{\sqrt{2(1+\lambda^2)}}\Big]$$

and similarly for equation A6. The additional parameter to be estimated is λ. When $\lambda = 1$, $\sigma_\epsilon^2 = \sigma_0^2$ and the A versus B question and the question comparing A or B to the status quo have equal weight in the likelihood. When $\lambda < 1$ the question relating to the status quo contains more information, as there is more variability in the errors for the A *vs.* B question ($\sigma_\epsilon^2 > \sigma_0^2$), and conversely. Let $\boldsymbol{x}_{ij}^{rp} = (\boldsymbol{x}_{ij}^r - \boldsymbol{x}_{ij}^p)$ for $r,\ p = 0, 1$. Then the probabilities of the four data types are:

$$P(Z_{ij}^1 = 0, Z_{ij}^2 = 0) = \Phi_2\Big[-\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{21}, -\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{01}/\lambda; \frac{1}{2\lambda}\Big] \tag{A10}$$
$$P(Z_{ij}^1 = 0, Z_{ij}^2 = 1) = \Phi_2\Big[-\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{21}, \boldsymbol{\beta}'\boldsymbol{x}_{ij}^{01}/\lambda; -\frac{1}{2\lambda}\Big]$$
$$P(Z_{ij}^1 = 1, Z_{ij}^2 = 0) = \Phi_2\Big[\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{21}, -\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{02}/\lambda; \frac{1}{2\lambda}\Big]$$
$$P(Z_{ij}^1 = 1, Z_{ij}^2 = 1) = \Phi_2\Big[\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{21}, \boldsymbol{\beta}'\boldsymbol{x}_{ij}^{02}/\lambda; -\frac{1}{2\lambda}\Big]$$

The likelihood is the product of these Jn probabilities:

$$L(Z_{ij}^1, Z_{ij}^2,\ i = 1, \ldots, n,\ j = 1, \ldots, J | \boldsymbol{x}_{ij}^1, \boldsymbol{x}_{ij}^2, \boldsymbol{x}^0; \boldsymbol{\beta}, \lambda) = \prod_{i=1}^{n}\prod_{j=1}^{J} P(Z_{ij}^1, Z_{ij}^2) \tag{A11}$$

which, upon substitution of equations 9 can be written

$$L(Z_{ij}^1, Z_{ij}^2,\ i = 1, \ldots, n,\ j = 1, \ldots, J | \boldsymbol{x}_{ij}^1, \boldsymbol{x}_{ij}^2, \boldsymbol{x}^0; \boldsymbol{\beta}, \lambda) = \tag{A12}$$
$$\prod_{i=1}^{n}\prod_{j=1}^{J}\Phi_2\Big\{(-1)^{1-Z_{ij}^1}\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{21}, (-1)^{1-Z_{ij}^2}\Big[(1 - Z_{ij}^1)\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{01} + Z_{ij}^1\boldsymbol{\beta}'\boldsymbol{x}_{ij}^{02}\Big]/\lambda; (-1)^{Z_{ij}^2}\frac{1}{\lambda}\Big\}$$

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Appendix B
Estimating the standard error of WTP measures from discrete choice experiments

Ignoring interactions, the utility model for Internet access choice is

$$U_{ij}^* = \beta_p p_{ij} + \boldsymbol{X}_{ij}'\boldsymbol{\beta}_a + \beta_s b_{ij} + \epsilon_{ij},\ i = 1, \ldots, n;\ j = 1, \ldots, 8. \quad \text{(B1)}$$

where p_{ij} is price, b_{ij} is bandwidth, and $\boldsymbol{\beta}_a$ is a $K \times 1$ vector of attributes of the service other than price and bandwidth. The estimates of WTP for these attributes are $\widehat{\boldsymbol{\beta}}_a/\widehat{\beta}_p$ and the estimated WTP for bandwidth is $\widehat{w}_b = \widehat{\beta}_s/\widehat{\beta}_p$.

Since the estimates of willingness-to-pay are nonlinear function of parameter estimates, their exact standard errors are unknown. While it would be possible to bootstrap the distribution of these estimators, since the normally distributed estimator of β_p is the denominator, the simulation would not converge to anything useful (see Kling and Sexton, 1990; Morey and Waldman, 1994). Instead, we use a linear approximation to the variance (sometimes known as the "delta method"). This approximation for elasticities has been examined in Krinsky and Robb (1986).

Define the $(K+1) \times 1$ vector

$$\widehat{\boldsymbol{w}} = (\ \widehat{\boldsymbol{\beta}}_a \vdots\ \widehat{\beta}_s)/\widehat{\beta}_p\ . \quad \text{(B2)}$$

Define the $(K+2) \times 1$ vector of parameter estimates $\widehat{\boldsymbol{\theta}} = \left(\widehat{\beta}_p \vdots \widehat{\boldsymbol{\beta}}_a' \vdots \widehat{\beta}_s\right)'$. Let $\widehat{\boldsymbol{\Sigma}}$ be the estimated variance-covariance matrix of $\widehat{\boldsymbol{\theta}}$. The linear approximation to the variance of $\widehat{\boldsymbol{w}}$ is

$$\widehat{V}(\widehat{\boldsymbol{w}}) \approx \left[\frac{\partial \boldsymbol{w}}{\partial \boldsymbol{\theta}}\right]' \widehat{\boldsymbol{\Sigma}} \left[\frac{\partial \boldsymbol{w}}{\partial \boldsymbol{\theta}}\right] \quad \text{(B3)}$$

where the derivatives are evaluated at the parameter estimates. The square root of the diagonal elements of $\widehat{V}(\widehat{\boldsymbol{w}})$ are the estimated standard errors of the estimates of WTP. These derivatives are

$$\frac{\partial \widehat{\boldsymbol{w}}}{\partial \widehat{\boldsymbol{\theta}}} = \begin{pmatrix} -\frac{\widehat{\beta}_{a_1}}{\widehat{\beta}_p^2} & \frac{1}{\widehat{\beta}_p} & 0 & 0 & \ldots & 0 \\ -\frac{\widehat{\beta}_{a_2}}{\widehat{\beta}_p^2} & 0 & \frac{1}{\widehat{\beta}_p} & 0 & \ldots & 0 \\ \vdots & \vdots & & \vdots & & \vdots \\ -\frac{\widehat{\beta}_{a_K}}{\widehat{\beta}_p^2} & 0 & 0 & 0 & \ldots & 0 \\ -\frac{\widehat{\beta}_s}{\widehat{\beta}_p^2} & 0 & 0 & 0 & \ldots & \frac{1}{\widehat{\beta}_p} \end{pmatrix} \quad \text{(B4)}$$

Focusing on bandwidth, the estimated variance of the WTP for bandwidth from equation B2 is

$$V(\widehat{w}_s) = \Big(\frac{\widehat{\beta}_s^2}{\widehat{\beta}_p^4}\Big)\widehat{\sigma}_{pp} + 2\Big(\frac{\widehat{\beta}_s}{\widehat{\beta}_p^3}\Big)\widehat{\sigma}_{ps} + \frac{1}{\widehat{\beta}_p^2}\widehat{\sigma}_{ss}$$

The utility model for access, with interactions, is

$$U_{ij}^* = \beta_p p_{ij} + \boldsymbol{X}_{ij}'\boldsymbol{\beta} + (\beta_s + \boldsymbol{a_i'\delta})b_{ij} + \epsilon_{ij},\ i = 1, \ldots, n;\ j = 1, \ldots, 8, \qquad \text{(B5)}$$

where $\boldsymbol{a}_i$ is a vector of L demographic variables for individual i and the elements of $\boldsymbol{\delta}$ are additional parameters to be estimated. The estimate of WTP for bandwidth from this model is

$$\widehat{w}_s = (\widehat{\beta}_s + \overline{\boldsymbol{a}}_{\boldsymbol{i}}'\widehat{\boldsymbol{\delta}})/\widehat{\beta}_p \qquad \text{(B6)}$$

where the vector of individual-specific demographic variables is evaluated at their means. Define $\widehat{\boldsymbol{\phi}} = \left(\widehat{\beta}_p \vdots \widehat{\beta}_s \vdots \widehat{\boldsymbol{\delta}}'\right)'$, and define $V\left(\widehat{\boldsymbol{\phi}}\right) = \boldsymbol{\Sigma}^*$. The variance of $\widehat{w}_s$ is

$$\widehat{V}(\widehat{w}_s) \approx \left[\frac{\partial \widehat{w}_s}{\partial \boldsymbol{\phi}}\right]' \widehat{\boldsymbol{\Sigma}}^* \left[\frac{\partial \widehat{w}_s}{\partial \boldsymbol{\phi}}\right] \qquad \text{(B7)}$$

where

$$\frac{\partial \widehat{w}_s}{\partial \boldsymbol{\phi}} = \begin{pmatrix} -\frac{\widehat{\beta}_s + \overline{\boldsymbol{a}}_{\boldsymbol{i}}'\widehat{\boldsymbol{\delta}}}{\widehat{\beta}_p^2} & \frac{1}{\widehat{\beta}_p} & \frac{a_1}{\widehat{\beta}_p} & \frac{a_2}{\widehat{\beta}_p} & \cdots & \frac{a_L}{\widehat{\beta}_p} \end{pmatrix}' . \qquad \text{(B8)}$$

Reference:

Kling, C., and R. Sexton (1990). "Bootstrapping in Applied Welfare Analysis." *American Journal of Agricultural Economics* 72: p.

Krinsky, I., and A. Robb (1986). "On Approximating the Statistical Properties of Elasticities." *Review of Economics and Statistics* 68(4): p. 715-19.

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Appendix C
Details on the study design: within subjects

The likelihood as it is written in equation A12 does not take into consideration the fact that the formation of that part of the likelihood involving the comparison of the chosen alternative to the status quo involves the error difference $\epsilon_i^0 - \epsilon_{ij}^{k_{ij}}$, where $k_{ij} = 1$ or 2 (depending upon the choice), and from choice occasion to choice occasion these error differences are correlated. This correlation is induced by the common occurrence of ϵ_i^0, since respondents need evaluate their utility of the status quo only once. This point is generally missed in conjoint analysis. An econometric innovation of this study is to treat the person, and not the person-choice occasion, as the unit of observation, so that we may explicitly model this correlation. The likelihood is now written

$$L(Z_{ij}^1, Z_{ij}^2,\ i = 1, \ldots, n,\ j = 1, \ldots, J | \boldsymbol{x}_{ij}^1, \boldsymbol{x}_{ij}^2, \boldsymbol{x}^0; \boldsymbol{\beta}, \lambda) = \prod_{i=1}^{n} P(Z_{i1}^1, Z_{i1}^2, Z_{i2}^1, Z_{i2}^2, \ldots, Z_{iJ}^1, Z_{iJ}^2)\ . \tag{C1}$$

The probability in equation C1 would appear to be computationally intractable, as it involves a 16-fold $(2 \times J = 8)$ integration of the multivariate normal density function. Fortunately, this is not the case, as the correlation between $\epsilon_i^0 - \epsilon_{ij}^1$ and $\epsilon_i^0 - \epsilon_{ij}^2$, for example, is a result of the common occurrence of ϵ_i^0. This means that we can follow a familiar conditioning argument to express the probability in equation C1 as the integral of the product of eight bivariate probabilities, integrated against the univariate normal density (see Waldman, 1985). But the cost of this generality is in programming and computer time, as the likelihood must be maximized by simulation or with quadrature methods. We used Hermite polynomial quadrature (Abramowitz and Stegun, 1964, p. 890).

References

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