Improving Demand and Welfare Estimates with Utilization Data

AMIL PETRIN
Graduate School of Business
University of Chicago
and NBER
November 20, 2002

Abstract

The value of a durable is reflected in the adoption decision and in how much the durable is used once adopted. This paper shows how product utilization rates can account for otherwise unobserved taste heterogeneity. Improved estimators obtain if, after conditioning on the observed, taste-related variables (usually demographics and product characteristics), utilization rates have explanatory power for what remains of durable demand variation. Utilization corrections are a consistency issue if unobserved taste heterogeneity does not enter the demand equation linearly, because these taste errors do not average out in the welfare calculation. The empirical application uses data from the telecommunications industry: market-level observations on the adoption of cable television and on the average amount of cable television watched. For the linear, log-linear, log-log, and logit demand models, the null of consistent welfare estimates without utilization data is rejected. Median welfare increases between 60% and 90%. For some infra-marginal markets, welfare is understated by several magnitudes.

*Thanks to Austan Goolsbee, Tom Holmes, Kevin Murphy, Peter Reiss, Matthew White, the University of Chicago and the 2002 Society for Economic Dynamics for helpful suggestions. Financial support from the Center for the Study of Industrial Organization and from the National Bureau of Economic Research is greatly appreciated.
Correspondence to: National Bureau of Economic Research, 1050 Massachusetts Ave., Cambridge, MA, 02139. email: amil.petrin@gsb.uchicago.edu.

1 Introduction

Durable good expenditures make up more than 30% of consumption in the United States.[1] The value of a durable is reflected in the adoption decision and in how much the durable is used once adopted. This paper shows how product utilization rates can account for otherwise unobserved taste heterogeneity when estimating demand and/or welfare. Improved estimators obtain if, after conditioning on the observed, taste-related variables (usually demographics and product characteristics), utilization rates have explanatory power for what remains of durable demand variation.[2] When they do, including utilization as an additional regressor improves the fit of the demand equation, conferring benefits to demand and welfare estimators.

Utilization corrections are a consistency issue if unobserved taste heterogeneity does not enter the demand equation linearly, because these taste errors do not average out in the welfare calculation. As Hausman and Newey (1995) note, ignoring unobserved taste heterogeneity is "consistent with current practice in applied econometrics, and is difficult to improve without more information about the residual."[3] The role of utilization data is precisely to provide this information; if observed, it can be used to condition out some of the unobserved taste heterogeneity that would otherwise be attributed to measurement error (and not conditioned on in the welfare calculation).

The empirical application in this paper uses data from the telecommunications industry. Many policy questions arise in this industry regarding the effects of mergers (AOL/Time-Warner in 2000, ATT/Comcast in 2001, and Echostar-DirecTV in 2001), new product introductions (Satellite dish, DSL and cable modem internet access), regulation of cable franchise monopolies (price deregulation, promotion of entry), programming, and other related issues. The application here uses variability in the amount of television watched

[1] Economic Report of the President, 2002.

[2] There are many examples from the demand literature of durable good demands for which demographics explain only a small part variability in the adoption decision.

[3] They precede this remark with "one can ignore the residual if it is all measurement error but not if it contains individual heterogeneity."

– a measure of otherwise unobserved taste heterogeneity – to improve demand estimates for the adoption of cable television. The reason for doing so is straightforward; two individuals that look the same "demographically" may differ quite substantially in their unobserved tastes for television, and amount of television viewing may reflect this otherwise unobserved difference.

Research on demand estimation has recognized the simultaneity of a durable's adoption and utilization since the introduction of discrete/continuous models by Hausman (1979), Dubin and McFadden (1984), Hanemann (1984), and Mannering and Winston (1985). They describe related choices made by consumers that have both discrete (the adoption) and continuous (the use) aspects to them. One example is the choice of television-viewing medium (e.g. cable) and the amount of television watched conditional on this choice. market-level Other examples include the purchase of a car and the mileage it is driven, and the adoption of household appliances (like air conditioners or heaters) and the use of electricity or gas to power them.[4] In every case the discrete and the continuous choice are determined simultaneously by some underlying factors that are similar and some that may differ.

The approach in this paper also exploits the simultaneous determination of demand and usage. However, the purpose here is different from previous works. They are concerned with finding a functional form for indirect utility that has a closed-form solution for demand via Roy's identity, or with controlling for the endogeneity of the adoption decision when estimating the demand for use. Here utilization rates are included in the durable's demand equation to directly control for unobserved tastes. The correction is particularly helpful when many infra-marginal consumers remain after conditioning on the set of observed variables at one's disposal.

This idea extends immediately to any pair (or more) of consumer choices that reflect common underlying tastes. For example, whether cable television is adopted may be affected by the same underlying taste that determines whether a large television is purchased. If both decisions are observed, methods outlined in this paper are available for improving estimators.

[4]See also Goldberg (1998), Hendel(1999), and Dube(2001).

In the application improved estimates obtain because television viewing has, conditional on other observables, significant explanatory power in the demand for cable television. For the linear, log-linear, log-log, and logit demand models, the null of consistent welfare estimates without utilization data is rejected. Median welfare increases between 60% and 90% with utilization in the demand equation. For some infra-marginal markets, welfare is understated by several magnitudes. When measurement error is introduced into the data, improvements in standard errors the equivalent of a tripling in sample size obtain from adding the utilization regressor.

Sections 2-4 of the paper explore the econometrics behind the consistency and efficiency issues. Section 5 contains the application. Section 6 concludes.

2 Demand and Utilization

The "reduced form" demand equation does not condition on utilization and is given by

$$Q = \gamma_Z Z_R + \gamma_P P + \eta, \tag{1}$$

where Q is quantity demanded, Z_R is a vector of the observed product and household characteristics (and interactions), γ_Z is the vector of associated parameters, γ_P is the price coefficient, P is the durable adoption cost, and η is the reduced form error, reflecting both unobserved (by the econometrician) demographics, idiosyncratic household tastes (that may be reflected in utilization rates), and errors of measurement.[5]

For goods that have a utilization aspect to them, the amount demanded of the good is determined simultaneously with the decision of how much the good will be used. The simultaneity of the decisions does not imply either one "causes" the other. Instead, both decisions are caused by underlying observed and unobserved "tastes" and cost factors. Usually, in the reduced form from

[5] More generally, to allow demographics to rotate the demand curve (in addition to shifting it) the price coefficient could be written as $\gamma_P(Z)$, the scalar value output of a multivariate function of consumer demographics and parameters.

(1), the researcher implicitly accounts for the fact that utilization enters the demand equation by including the underlying factors that affect use directly in Z_R (like the price of usage), or by assuming that the factors that enter the use equation are a subset of the factors entering the discrete demand equation.

The structural equation for demand is given by

$$Q = \theta_Q Z_Q + \theta_{Q,P} P + \theta_{Q,U} U + \epsilon_Q, \tag{2}$$

where Z_Q is the vector of relevant observed product and household characteristics (and interactions) after conditioning on usage U, θ_Q is the vector of associated parameters, $\theta_{Q,P}$ is the sensitivity of demand to price *conditional* on use U, $\theta_{Q,U}$ gives the change in quantity demand if utilization increases one unit, and ϵ_Q reflects both unobserved demographics, idiosyncratic household tastes, and errors of measurement.[6]

The structural equation for utilization is given by

$$U = \theta_U Z_U + \theta_{U,Q} Q + \theta_{U,P_U} P_U + \epsilon_U, \tag{3}$$

where θ_U is a vector of parameters that relates exogenous factors Z_U to use, $\theta_{U,Q}$ is the increase in use due to a one unit increase in demand, θ_{U,P_U} relates the amount of use undertaken to its unit price,[7] and ϵ_U represents unobserved factors affecting use.[8]

[6] Generally, subscripts of the form (A, B) denote a coefficient from the structural equation with the left-hand side variable given by A (that is, with A's coefficient normalized to one) and a right-hand side endogenous variable given by B.

[7] In the electricity demand and appliance choice models, the price of utilization is the price per hour of electricity times the amount of electricity per hour the appliance uses. In the vehicle demand literature, the price of use is the miles per dollar the vehicle obtains. In the application later use is amount of television watched. The price of an hour of use is the opportunity cost of that hour for the individual.

[8] Economists have a long history of estimating equations similar to (3). The parameters of interest are usually (the equivalent of) $\theta_{U,P}$ or $\theta_{U,Q}$, and the econometric discussion revolves around the fact that the demand decision (for appliances say) is endogenous (see Dubin and McFadden (1984)). A common solution is to plug-in a predicted probability $\hat{Q}$ for Q, usually estimated from a reduced form equation where only exogenous variables are used to estimate $\hat{Q}$. Alternatively, one can instrument for Q with predicted probabilities $\hat{Q}$ that are constructed only from exogenous variables.

When usage is not included in the demand equation, the reduced form from (1) is estimated. In terms of the structural parameters this equation is given by

$$Q = \frac{1}{1 - \theta_{Q,U} * \theta_{U,Q}} * \left[\theta_Q Z_Q + \theta_{Q,P} P + \theta_{Q,U} \theta_U Z_U + \theta_{Q,U} \theta_{U,P_U} P_U + \theta_{Q,U} \epsilon_U + \epsilon_Q\right]. \quad (4)$$

The coefficient on price (for example) from the reduced form equation is a function of structural parameters given by

$$\gamma_P = \frac{1}{1 - \theta_{Q,U} * \theta_{U,Q}} * \theta_{Q,P}. \quad (5)$$

These reduced form parameters are the statistics of interest for many questions because they *do not* condition on usage.[9]

If only Z_Q are included in the reduced form (i.e. $Z_R = Z_Q$), the error η from (1) in terms of (4) is given by

$$\frac{1}{1 - \theta_{Q,U} * \theta_{U,Q}} * \left[\theta_{Q,U} \theta_{U-Q} Z_{U-Q} + \theta_{Q,U} \epsilon_U + \epsilon_Q\right], \quad (6)$$

where Z_{U-Q} are demographics/characteristics in U but not in Q. Thus, if only Z_Q are included in the reduced form, the part of U not controlled for in this case is

$$\frac{1}{1 - \theta_{Q,U} * \theta_{U,Q}} * \left[\theta_{Q,U} \theta_{U-Q} Z_{U-Q} + \theta_{Q,U} \epsilon_U\right]. \quad (7)$$

Generally, if this term is not zero, welfare estimates will be biased and inconsistent, as is now shown.[10]

3 Welfare

The literature on demand and welfare estimation is largely dominated by four functional forms: linear, log-linear, log-log, and logit (or logit-like discrete

[9] The reduced form parameters and their standard errors are easily reconstructed from the structural estimates using either the delta method or an easier-to-compute alternative suggested in the Appendix.

[10] If any of the elements of Z_{U-Q} are correlated with Z_R or P, demand estimates will also be biased and inconsistent.

choice models). In each case the reduced form $Q^R(\cdot)$ and structural equation $Q^S(\cdot)$ are given as

$$Q^R = Q^R(P, Z_R, \eta; \theta)$$

and

$$Q^S = Q^S(P, Z_Q, U, \epsilon_Q; \theta)$$

respectively. As mentioned earlier, in the reduced form Z_R may contain observables that do not enter the structural demand equation directly but do enter the reduced form via the utilization equation when U is not conditioned on (e.g. P_U).

Except for the case of the logit model, $Q^R(\cdot)$ and $Q^S(\cdot)$ are evaluated with η and ϵ_Q respectively set to zero. This is the standard approach in the applied literature. Effectively, it assumes all of remaining error in both cases is not unobserved taste heterogeneity.

For the structural equation, the change in welfare for any (Z_Q, U) pair that occurs when price increases from P_0 to P_1 is

$$\int_{P_0}^{P_1} Q^S(v; Z_Q, U, 0, \theta)\, dv \tag{8}$$

where, for simplicity, income effects are ignored.[11] Summing over the distribution of (Z_Q, U) pairs yields one measure of aggregate welfare:

$$\int_{Z_Q,U} \int_{P_0}^{P_1} Q^S(v, Z_Q, U, 0; \theta)\, p(Z_Q, U) dv \;\, dZ_Q\, dU, \tag{9}$$

where $p(Z_Q, U)$ is the weight applied to each (Z_Q, U) pair. Similarly, aggregate welfare when the reduced form is used is given by

$$\int_{Z_R} \int_{P_0}^{P_1} Q^R(v, Z_R, 0; \theta)\, p(Z_R)\, dv\, dZ_R. \tag{10}$$

The difference between these aggregate welfare numbers arises from what is set to zero when the integration takes place. In the structural equation

[11] They can be added back to the framework at a cost to exposition.

everything but ϵ_Q is conditioned on when integrating. In the reduced form, if (for example) $Z_R = Z_Q$, then

$$\frac{1}{1-\theta_{Q,U} * \theta_{U,Q}} * [\theta_{Q,U}\theta_{U-Q}Z_{U-Q} + \epsilon_U]$$

is *not* conditioned on; instead, it is assumed to be zero. Since the demand equation with levels as the dependent variable is the relevant equation for calculating welfare and this term does not generally enter the levels equation linearly, not conditioning on it results in inconsistent welfare estimates. Simply put, this term does not generally average out in the levels equation.

To see this for log-log demands, aggregate welfare using the structural equation is

$$\int_{Z_Q,U} \frac{exp(\theta_Q Z_Q + \theta_{Q,U}U)}{1+\theta_{Q,P}} * (P_1^{1+\theta_{Q,P}} - P_0^{1+\theta_{Q,P}})\, p(Z_Q,U)\, dZ_Q\, dU, \qquad (11)$$

whereas the reduced form yields the integral

$$\int_{Z_R} \frac{exp(\gamma_Z Z_R)}{1+\gamma_P} * (P_1^{1+\gamma_P} - P_0^{1+\gamma_P})\, p(Z_R)\, dZ_R. \qquad (12)$$

Since U enters the levels demand equation non-linearly (via $exp(\theta_{Q,U}U)$), it will not average out if it is left out of the integration used to obtain welfare.

One alternative to the log-log, log-linear, and linear approximations to demand is to take the other extreme viewpoint on the error, assuming it is all unobserved taste heterogeneity. This approach is usually advocated from within characteristics-based frameworks originating with Lancaster and McFadden. In these frameworks, decisions are modeled as directly determined from the latent variable "utility", a function of underlying tastes parameters and observed and unobserved product characteristics. Deviations between observed and predicted outcomes are explained entirely by differences in unobserved utility (or unobserved taste heterogeneity). Thus, in these frameworks, *all* of the error is compensated in the welfare calculation. From a practitioner's standpoint, one might view results from both approaches, when taken together, as providing a loose bound on the true change in welfare. Here the most popular form of these characteristics-based models, the logit demand model, is added to provide an alternative along these lines. Using this model is also useful because it explicitly recognizes that the dependent variable only varies between zero and one.[12]

4 Model Results

Two general results obtain when the structural equations are considered. First, consistency problems for demand and welfare estimates can arise when the utilization equation is ignored. Second, even if consistency is not a problem for demand and welfare estimates, the utilization information can improve the precision of demand estimates (like price elasticities). Both of these results are a simple consequence of the fact that demand and utilization are joint decisions and thus contain information on each other.

Result 1 *If (Z_U, P_U) contains elements that are not contained in Z_R but are correlated with elements in Z_R or P, estimates of the reduced form demand equation are biased and inconsistent.*

It is apparent from the reduced form equation (4) that any relevant variable excluded from the equation enters η as an omitted variable. If this omitted variable is correlated with any included regressor, it will lead to inconsistent parameter estimates. This result is the principle motivation for applied researchers attempts to include all possible explanatory variables from the (structural) usage and demand equation directly in the reduced form demand equation. Thus, one advantage of focusing explicitly on the full system of equations is that it can make omitted variables problems more apparent.

Result 2 *If (Z_U, P_U) contains elements that are not contained in Z_R, welfare estimates obtained from the reduced form demand equations are generally inconsistent, even if the omitted variables are not correlated with Z_R and/or P.*

[12] The logit demand model also has a very simple closed-form solution for welfare.

By definition, any explanatory variable that affects tastes shifts or rotates the demand curve. Any change typically changes the area under the demand curve.[13] Result 2 obtains because some of the variation in demand associated with (Z_U, P_U) should be accounted for in the welfare measure but is mistakenly attributed to measurement error. As Hausman and Newey (1995) note, the applied literature typically has chosen to ignore the residual, treating it entirely as measurement error, because this approach is "difficult to improve without more information about the residual." The role of utilization data is *precisely* to provide this kind of additional information on unobserved heterogeneity.

Result 3 *When the errors ϵ_U and ϵ_Q that enter the demand and utilization equations contain a taste component, welfare estimates that ignore this unobserved taste component are inconsistent.*

This result is the trivial extension of the previous result; unobserved tastes, whether they obtain from omitted demographics or difficult to quantify idiosyncratic tastes, must be accounted for when welfare is computed. If two individuals that look the same "demographically" differ substantially in their unobserved tastes, utilization data can help to more accurately recover the area under the true demand curve for each individual.

Result 4 *More precise estimates of demand and welfare may obtain from recognizing exclusion restrictions implied by the structural equations and correlation of errors across the structural equations.*

Imprecise estimates of the reduced form parameter from (5) can effectively frustrate policy analysis related to demand and welfare estimates.[14] More precise estimates of these reduced form statistics may be available if, in the structural equations, there exist exclusion restrictions and/or correlation among

[13] One exception is the case of linear demands and mean zero measurement error, where unobserved taste heterogeneity averages out in the aggregate.

[14] This problem can arise when observed price variation is limited, or when price is endogenous and the correlation of price and its instrument are low.

errors. If the structural parameters can be estimated with more precision, reduced form estimates constructed using, for example, (5), may be more precise than those statistics obtained from the reduced form regression.

5 Application: Cable Demand and TV Use

The application uses data on television viewing to improve the fit of the demand curve for cable television. The basis of demand estimation begins with the (reduced form) regression of market-level shares on prices, average consumer demographics in the market, and product characteristics of the available goods. The structural equation adds the market-level average of weekly hours watched of television to the reduced form equation. Estimates of demand and welfare are compared across the linear, log-linear, log-log, and logit demand models.

5.1 Data

The definition of goods in this market follows that in Goolsbee and Petrin (2001), with the overall set of goods approximated by the four main choices: antenna only, expanded basic cable, expanded basic cable plus some premium television (like the a la carte movie channel Home Box Office), and satellite dish. The focus of this paper will be on demand for expanded basic cable, which includes the local channels available via "antenna only" like ABC, NBC, CBS, Fox, and PBS, plus additional channels like ESPN (a sports channel), TNT (primarily movies), and others, with an average cable franchise providing 62 channels on expanded basic. Premium channels are available a la carte if and only if expanded basic cable has been adopted. Finally, satellite dish is a multi-channel video option like cable that has a relatively small market share of 11% in 2001.

The basis of estimation will be data on market-level shares and demographics along with the cable characteristics of expanded basic that households face in their cable franchise market.[15] This market-level data typifies the kind most often available to practitioners. Average demographics and market shares for expanded basic come from Forrester Technographics, 2001, a household-level survey which is meant to be nationally representative.[16] To minimize sampling error problems in market share estimates from less populated areas, the analysis is restricted to 265 cable franchise markets for which at least 30 respondents exist. For these markets, 70% subscribe to either expanded basic or expanded basic plus premium cable, which compares closely to the 68% reported as the aggregate cable share in Federal Communications Commission 01-389, the 2001 annual report on the status of competition in multichannel video markets. Table 1 reports summary statistics for all of the aggregates used in the analysis.

The exercise here will focus on estimating demand for expanded basic for two reasons. First, with an average market share of 47%, it is the most popular of the four choices. Second, any one premium option rarely costs more than $10 per month, providing an upper bound on expanded basic welfare estimates that is not imposed during the estimation.

The utilization variable is derived from a Forrester survey question which asks *individuals* whether they (not the household) watch 0, 1-2, 3-5, 6-10, 11-15, or 16+ hours of television a week. Averaging these responses across households in every market (evaluating each bin except the largest at the midpoint) yields the variable television viewing hours (tvhours). This estimate is a lower bound on household television viewing because the top-coded bin is evaluated at 17 hours and the data is only reported for one individual in the household.[17] Except for the variables "all adults work" and "free time", which are excluded from the demand equation conditional on utilization, all of the other variables listed in Table 1 enter the cable adoption equation.

[15] Each cable franchise is considered its own market, and almost all consumers in 2001 have one and only one cable company in their market.

[16] More details about it can be found in Goolsbee and Petrin (2001).

[17] The exact underlining and question is "How may hours per week do you spend watching TV?".

Table 1

Summary Statistics: Market Shares and Household Averages

Variable	Mean	Std. Dev.
Expanded Basic*	0.47	0.11
Expanded Basic + Premium*	0.23	0.10
Television Watched (Hrs. Weekly)	8.07	0.81
Free Time (Hrs. Weekly)	20.17	2.04
All adults work*	0.29	0.08
Married*	0.69	0.10
Household Size	2.61	1.23
Household Income	$56.0K	$10.5K
Household Assets	$220.8K	$92.5K
Observations	265	

Source: Forrester Technographics, 2001.
* designates a share variable.

Since television viewing is endogenous, an exclusion restriction is necessary to consistently identify its effect on adoption decisions. The excluded variables are constructed from survey answers to the questions "How many hours of free time (time which excludes work, chores, errands) do you have per week, including weekend hours?" and "Do all adults in the household work full time?" Thus, the identification assumption is that these variables, which affect the amount of time available to watch television, only affect cable television adoption decisions through their effect on television viewing. In the data television viewing across markets increases with increases in free time, and decreases with increases in the fraction of households that have both adults working.

Table 2 summarizes the prices and characteristics of cable companies used to estimate demands. Consumer preferences can be affected by the channel capacity of a cable system, the price of expanded basic for the system, the price of expanded basic plus premium, the number of premium channels available, and the number of over the air channels available in the market area. The Factbook also provides the local franchise tax as a percent of revenue paid by the cable company to the local community.

Table 2

Summary Statistics: Television Markets

Variable	Mean	Std. Dev.
Monthly Expanded Basic Price	$27.17	$5.68
Monthly HBO Price	$11.44	$1.38
Channel Capacity	66.13	22.46
Premium Channels	5.56	1.45
Over-Air Channels	10.91	4.39
City Fixed Fee (percent)	4.29	1.14
Observations	265	

Source: Warren Publishing Television and Cable Factbook, 2001.

Since prices for antenna and satellite dish do not vary across markets, only the prices of expanded basic and expanded basic plus some premium enter the demand equation.[18] There is substantial price variation for the monthly cost of expanded basic around the mean price of $27.10, ranging from a minimum of $15 to a maximum of $45. In the data respondents only answer whether they have consumed some premium television. Expanded basic price plus the price of the most popular premium channel, Home Box Office (HBO), is used as the premium price proxy; consumers are paying at least this much to consume the most popular premium television option.

One concern when estimating a demand curve using this variation directly is the potential for price endogeneity.[19] Three instruments for the two endogenous prices are used. The first is the local franchise tax paid by the cable com-

[18]This presents no problems for estimating cable demands, but does pose problems for satellite demand estimates (see Goolsbee and Petrin (2001)).

[19]If there are some characteristics of the local cable franchise that are known by both the consumers and the suppliers and if cable prices respond to these factors, the price elasticity

pany to the local community. This is a percent of gross revenue that varies by market and is reported in Warren Publishing (2001). It is positively correlated with prices. It is also not correlated with any of the observed characteristics, suggesting it may be uncorrelated with any unobserved characteristics that lead to price endogeneity problems (like customer service).

The last two instruments follow Hausman (1997) and Crawford (2001), averaging over the prices of the cable companies with the same multiple system operators (MSOs) but operating in different markets. These average prices reflect common cost side factors like programming costs shared by companies owned by the same MSO.[20] These instruments should exclude some of the idiosyncratic features of demand in each market that are correlated with prices in the market (like service).

5.2 Demand Results

Table 3 presents demand estimates for the linear probability model. The explanatory variables that enter the demand equation include channel capacity of the system, the number of premium channels available, the number of over-the-air channels, and market-level averages of household size, an indicator for marital status, and four indicator variables for five income groups and six indicator variables for seven wealth groups. To account for differences in sampling error, each market-level observation is weighted by the number of households observed in that market from the Forrester data.

The first column contains the OLS results without television hours entering the regression (i.e. the reduced form equation). Both price coefficients are very close to zero, which is consistent with the existence of unobserved characteristics like service that are positively correlated with price. The point

will typically be biased toward zero. For example, a cable system with the same observables but with relatively good service will tend to be more desirable and have higher prices, making it seem as though consumer demand does not respond to high prices. Goolsbee and Petrin (2001) show this problem is a pronounced one for cable markets.

[20]Larger MSOs with the ability to reach more advertising markets typically receive lower programming prices.

Table 3

Expanded Basic Demand Estimates

Dependent Variable: Expanded Basic Market Share

	OLS Coefficient (Std. Error)	2SLS Coefficient (Std. Error)	2SLS Coefficient (Std. Error)
expanded basic price	-0.005	-0.031	-0.023
	(0.006)	(0.018)	(0.018)
premium price	0.006	0.035	0.024
	(0.004)	(0.017)	(0.018)
tvhours			0.053
			(0.026)
channel capacity	-0.0002	-0.0001	-0.0001
	(0.0002)	(0.0003)	(0.0003)
premium channels	-0.016	-0.014	-0.016
	(0.004)	(0.005)	(0.004)
over the air channels	-0.003	-0.002	-0.003
	(0.001)	(0.001)	(0.002)
household size	-0.105	-0.100	-0.023
	(0.037)	(0.041)	(0.056)
married	0.568	0.573	0.473
	(0.104)	(0.114)	(0.122)
constant	-0.313	-0.232	-0.540
	(0.286)	(0.289)	(0.324)
Root MSError	0.100	0.105	0.103
Observations	265	265	265

Note: All regressions include extensive controls for income and wealth, including four indicator variables for five income groups and six indicator variables for seven wealth groups. All of the income indicators and four of the six wealth indicators enter with t-statistics of at least one; six are greater than two. Income is negatively correlated with cable adoption conditional on wealth and wealth is positively correlated with cable adoption conditional on income.

estimates imply an elasticity of -0.33 for expanded basic cable, suggesting either an omitted variables problem or many cable monopolists pricing on the very inelastic part of the demand curve.

Column two presents the two stage least squares (2SLS) results for the no-utilization (reduced form) equation. The instruments for price are the market franchise tax and the average prices of same-MSO-but-different-market cable franchises (for both expanded basic and expanded basic plus premium). Both price coefficients increase by a factor of six. At the new point estimates, the aggregate elasticity for expanded basic cable is -1.75, comparable to previous expanded basic cable estimates found in the literature from Hazlett and Spitzer (1997), U.S. General Accounting Office (2000), or Crawford (2000). Over-the-air channels and premium channels enter with the expected sign; increases in each are likely to increase antenna only and expanded basic plus premium shares respectively at the expense of expanded basic shares. There is one overidentification restriction that can be tested, and the validity of instruments/model is not rejected at the usual levels of significance (p-value=0.36). Finally, while the difference between the OLS and 2SLS estimates of the price coefficient is 0.026 – large in economic terms – a Hausman test for a significant difference cannot reject the null of no difference (p-value=0.17).

Column three contains the 2SLS results conditional on utilization, with amount of free time and whether both adults work as instruments for the endogenous regressor tvhours. The unconditional price elasticity of demand implied by these conditional estimates is -2.1, similar to that obtained without utilization. The coefficient on market television viewing is significant at 5%, rejecting the demand specification without utilization. Conditional on expanded basic and expanded basic plus premium prices, a one hour increase in market television viewing (approximately one standard deviation) leads to an increase in the market share of expanded basic equal to 5.3%, on the base share of 47%.

Table 4 compares point estimates and standard errors, implied elasticities, and p-values for two overidentification tests, one for each equation. For every functional form television hours is significant at the 5% level. All of the esti-

Table 4

TVhours and Cable Elasticity Estimates, and Two Overidentification Tests

Method	TVhours Estimate (Std. Error)	Implied Cable Price Elasticity	P-Value for Over-ID Test 1	P-Value for Over-ID Test 2
Linear	0.53 (0.26)	-2.10	0.36	0.80
Logit	0.22 (0.11)	-2.26	0.33	0.79
Log	0.13 (0.06)	-2.38	0.25	0.78
Log-Log	0.13 (0.06)	-2.02	0.22	0.78

mates imply an elasticity close to 2. In column three Test 1 asks whether the two overidentification restrictions for the cable demand equation can reject the specification. The lowest p-value is 0.22, so no rejection of the null of correct specification/valid instruments obtains at any meaningful level of significance. The second overidentification test in column four asks if the tvhours equation is well-specified. Again, no rejection obtains at any meaningful level of significance. The welfare implications of these estimates are considered next.

5.3 Welfare

The average welfare change is equal to the average amount of household surplus in each market for expanded basic subscribers. Alternatively, for adopters of expanded basic, it is the average difference in the reservation price minus the existing price of expanded basic in a market, where a household's reservation price is defined as the price at which it substitutes to one of the other television products: expanded basic plus premium, satellite dish, or antenna only.

Cable monopolies' bundling of expanded basic with premium implies a specification test that has power to uncover overstatements of welfare, like those that often arise when one extrapolates the surplus measure to regions outside the observed price variation. For the surplus question the price change of expanded basic increases to ∞ with all other product prices held constant. Since expanded basic is bundled with premium in the expanded basic plus premium choice, surplus for expanded basic cannot, in theory, exceed the price for the a la carte premium channel; no rational consumer would purchase expanded basic when they could get expanded basic *plus* premium for a lower price. This is not imposed during the estimation of welfare.

Monthly welfare estimates for the linear specification with the tvhours regressor are reported in Figure 1. The distribution of welfare for each of four television viewing groups is shown: lowest use, low-mid use, mid-high use, and high use. Not one market has an average surplus estimate that exceeds the price of HBO in the market, suggesting the linear specification is a reasonable one. The economic significance of including television viewing in the cable demand equation is apparent; as viewing increases, the distribution of surplus shifts to the right, from a mean of \$4.05 per month for the low use group to a mean of \$5.88 per month for the high use group. These differences are statistically significant. Thus, the answer to any question related to the *distribution* of welfare or to infra-marginal markets improves with utilization data.

Two methods to compute surplus without utilization data are explored. First, the implied price coefficient for the reduced form equation is computed using the estimates from the utilization specification. Second, the reduced form equation is estimated directly. Welfare estimates did not differ appreciably between these two approaches, and the former is reported.

Figure 2 plots the distribution of percentage increases in surplus associated with using utilization relative to not using it. The median percentage increase in the linear case is 61.8% relative to no use data, with the 10th and 90th percentiles 29% and 121% respectively. Conditional on four use groups, the largest percentage increases are associated with the highest use markets, with the low use group averaging a 15% increase and the high use group averaging a 70% increase. In this application, use plays an important role in the welfare estimates.

Table 5 summarizes results for all of the functional forms under considera-

Figure 1: Average Monthly Surplus: Expanded Basic Adopters

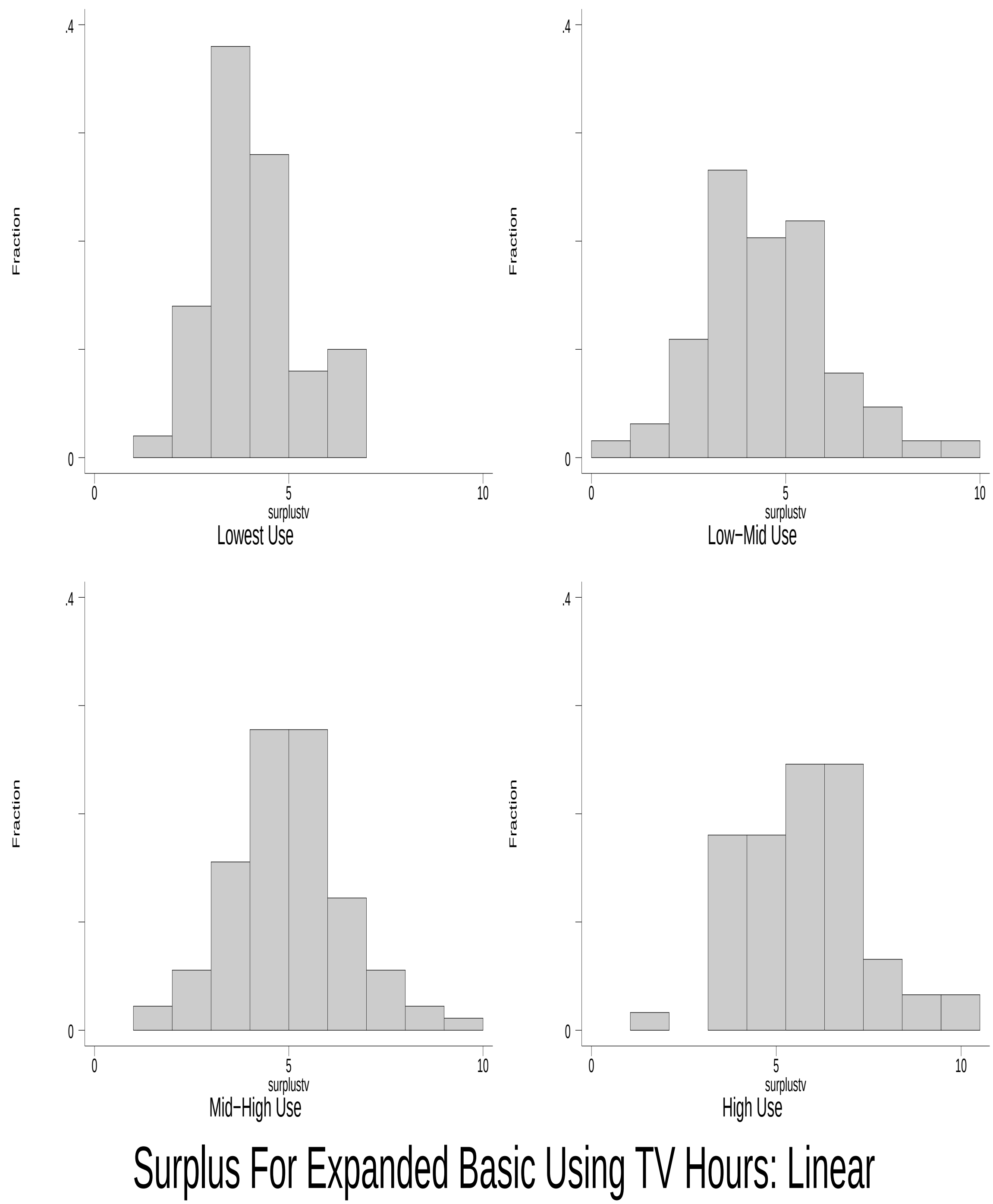
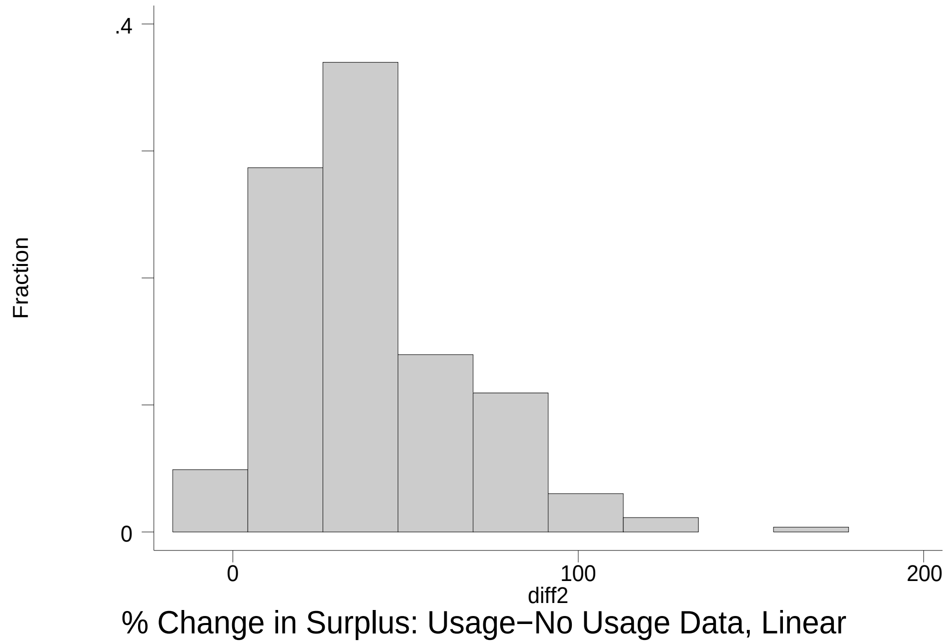


Figure 2: Surplus Increases With Use Data



tion. The table has estimates for median surplus, the percent of markets failing the welfare specification test, and the median percentage welfare increases relative to not incorporating use data (and standard deviation). The top part of the table contains results for price increases to the reservation price. Welfare estimates for the same specifications but for price increases only up to \$44 a month, the largest price observed in the data for expanded basic, are reported in the lower half of Table 5. These numbers provide a lower bound on welfare that does not suffer from the extrapolating outside the region of observed price variation.

Median monthly surplus estimates vary across the estimators from \$4.79 for the linear case to \$6.39 for the logit case to \$53.65 for the log-log case. Welfare estimates using log-log demands exceed the price of HBO in *every* market, suggesting that functional form outside the region of observed price variation is driving these numbers. The log-linear specification also suffers from this phenomenon (less dramatically at 18% of markets failing the test).

Ignoring the log-log case, welfare estimates increase between 60% and 90% over the no use case.

Table 5

Median Surplus and Percentage Increases in Surplus (Use-NoUse)/Use for Price Increases to...

...Estimated Reservation Prices:				
Method	Median Surplus	% Surplus $> P_{HBO}$	Median % Increase	Std. Error % Increase
Linear	\$4.79	0.0%	61.8%	36.6%
Log-Linear	\$9.84	18.8%	87.6%	24.1%
Logit	\$6.39	1.1%	60.2%	24.9%
Log-Log	\$53.65	100.0%	484.9%	74.9%

...\$44, the Maximum Expanded Basic Price:				
Method	Median Surplus	% Surplus $> P_{HBO}$	Median Increase %	Std. Error Increase %
Linear	\$4.25	0.0%	31.6%	64.4%
Log-Linear	\$5.36	0.3%	17.6%	16.0%
Logit	\$4.72	0.0%	20.0%	19.1%
Log-Log	\$5.65	0.3%	18.3%	18.0%

When the analysis is restricted to price variation observed in the data the surplus numbers across specifications are very similar, ranging from the minimum linear case of \$4.25 to the maximum log-log case of \$5.65. Only one market of the 265 fails the specification test, and only for the log-linear and log-log case. Even for this more modest price increase, median percentage increases range from 17% to 31%. Overall, the use data plays an important role in the welfare estimates, and the results suggest that households are realizing at least \$5 per month in surplus with their expanded basic choice, with the higher use households receiving more surplus.

6 Conclusions

This paper shows how product utilization rates can account for otherwise unobserved taste heterogeneity when estimating demand and/or welfare. Improved estimators obtain if, after conditioning on the observed, taste-related variables (usually demographics and product characteristics), utilization rates have explanatory power for what remains of durable demand variation. When they do, including utilization as an additional regressor improves the fit of the demand equation, conferring benefits to demand and welfare estimators.

Utilization corrections are a consistency issue if unobserved taste heterogeneity does not enter the demand equation linearly, because these taste errors do not average out in the welfare calculation. As Hausman and Newey (1995) note, ignoring unobserved taste heterogeneity is "consistent with current practice in applied econometrics, and is difficult to improve without more information about the residual." The role of utilization data is precisely to provide this information; if observed, it can be used to condition out some of the unobserved taste heterogeneity that would otherwise be attributed to measurement error (and not conditioned on in the welfare calculation).

The empirical application in this paper uses data from the telecommunications industry. Variability in the amount of television watched – a measure of otherwise unobserved taste heterogeneity – is used to improve demand estimates for the adoption of cable television. Improved estimates obtain because television viewing has, conditional on other observables, significant explanatory power in the demand for cable television. For the linear, log-linear, log-log, and logit demand models, the null of consistent welfare estimates without utilization data is rejected. Median welfare increases between 60% and 90% with utilization in the demand equation. For some infra-marginal markets, welfare is understated by several magnitudes.

This idea extends immediately to any pair (or more) of consumer choices that reflect common underlying tastes. For example, whether cable television is adopted may be affected by the same underlying taste that determines whether a large television is purchased. If both decisions are observed, methods outlined in this paper are available for improving estimators.

References

Crawford, G. (2000): "The Impact of the 1992 Cable Act on Household Demand and Welfare," *RAND Journal of Economics*, 31(3), 422–449.

Crawford, G. (2001): "The Discriminatory Incentives to Bundle: The Case of Cable Television," Working Paper.

Dubin, J. A., and D. L. McFadden (1984): "An Econometric Analysis of Residential Electric Appliance Holdings and Consumption," *Econometrica*, 52(2), 345–62.

Goldberg, P. (1998): "The Effects of the Corporate Average Fuel Efficiency Standards in the U.S.," *Journal of Industrial Economics*, 46(1), 1–33.

Goolsbee, A., and A. Petrin (2001): "The Consumer Gains from Direct Broadcast Satellites and the Compeitition with Cable Television," *NBER Working Paper 8317*.

Hanemann, W. M. (1984): "Discrete/Continuous Models of Consumer Demand," *Econometrica*, 52(3), 541–62.

Hausman, J. (1979): "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," *The Bell Journal of Economics*, 10(1), 33–54.

——— (1997): "Valuation of New Goods Under Perfect and Imperfect Competition," in *The Economics of New Goods*, ed. by R. Gordon, and T. Bresnahan. Chicago: University of Chicago Press, chap. 5, pp. 209–237.

Hausman, J. A., and W. K. Newey (1995): "Nonparametric Estimation of Exact Consumers Surplus and Deadweight Loss," *Econometrica*, 63(6), 1445–76.

Hazlett, T., and M. Spitzer (1997): *Public Policy Toward Cable Television*. The MIT Press and the AEI Press (Cambridge, Massachusetts and Washington, D.C.).

Mannering, F., and C. Winston (1985): "A Dynamic Empirical Analysis of Household Vehicle Ownership and Utilization," *RAND Journal of Economics*, 16(2), 215–236.

U.S. General Accounting Office (2000): "The Effect of Compeitition from Satellite Providers on Cable Rates," *Report to Congressional Requesters*, (GAO/RCED-00-164).

Warren Publishing (2001): *Warren Publishing Television and Cable Factbook*. Warren Publishing Inc (Washington, D.C.).