

Valuing Consumer Products by the Time Spent Using Them: An Application to the Internet

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Recent years have witnessed a surge in studies using micro data on consumer demand to estimate the welfare gains that new goods bring to consumers.² These papers typically estimate demand curves for a product and use them to impute the consumer surplus generated from the good. For some goods, however, like watching television or using the Internet (for fun), direct expenses are miniscule and the main cost of consumption is the amount of leisure time spent using the product. For such goods, estimating the price elasticity from expenditures can be quite difficult and, thus, welfare calculations are highly uncertain.³

We show that thinking about that distinction can open new avenues for estimating welfare. We will focus on the particular case of residential use of the Internet, because it has many of the relevant features: low marginal costs (zero for people paying a fixed fee per month), almost no cross-sectional variation in prices (Tom Downes and Shane Greenstein, 2002), a very small share of spending, and time costs making

up the vast majority of the cost of consuming the product.

We show that, by relating the time consumers spend on a good to the opportunity cost of their time in a simple utility model, we can estimate the demand curve and compute the consumer surplus from Internet access in a way that is distinctly different from a conventional calculation based on observed price and expenditure data.

The model will let the utility function for a good include consumption in the form of direct expenditures and in the form of time. The results suggest that consumer gains from the Internet (as of January 2005) are quite high, perhaps more than \$3,000 per year for the median person. This contrasts sharply with the back-of-the-envelope calculation one might make using standard data, which would put the value at less than \$100.

I. Model

To account for both time and market spending for a good, we specify utility of the form

$$(1) \quad \theta(C_I^\alpha L_I^{1-\alpha})^{1-1/\sigma} + (1-\theta)(C_O^\alpha L_O^{1-\alpha})^{1-1/\sigma}$$

where C_I denotes purchased Internet services and L_I the fraction of time devoted to enjoying the Internet (not work related). For simplicity, all other purchased goods and services form a composite C_O ; L_O is the fraction of time spent on the composite; and θ scales the importance of the Internet bundle compared to the composite bundle.

Consumers maximize utility subject to the budget constraint

$$P_I C_I + F_I + P_O C_O = W(1 - L_I - L_O)$$

where W is the wage and P_I and P_O are the prices of Internet services and the composite good, respectively. F_I is any fixed fee for subscribing to the Internet in a given period,

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² Recent examples include Jerry Hausman (1999), Amil Petrin (2002b), Aviv Nevo (2003), Goolsbee and Petrin (2004), and Timothy Bresnahan and Robert J. Gordon (1997).

³ The distinction between expenditure and consumption was first analyzed in Gary S. Becker (1965) but has had little impact on the analysis of consumer innovations. Petrin (2002a), who uses data on utilization to improve conventional estimates of consumer welfare, is an exception. Mark Aguiar and Erik Hurst (2005) show the importance of distinguishing consumption from expenditure for understanding behavior over the life cycle.

whereas P_I is any marginal cost of using Internet services. In practice, this is essentially zero (because the Internet costs a flat fee per month).

For good j , call the combined Cobb-Douglas consumption Y_j and the weighted averages of the price of market goods and the value of time (i.e., the wage) λ_j . Then

$$\lambda_j = \left(\frac{P_j}{\alpha_j}\right)^{\alpha_j} \left(\frac{W}{1 - \alpha_j}\right)^{1 - \alpha_j}$$

and the optimal choices for people with Internet access are

$$Y_I = \frac{W - F_I}{\lambda_I(1 + \Gamma)} \quad \text{and} \quad Y_O = \frac{W - F_I}{\lambda_O(1 + 1/\Gamma)}$$

where

$$\Gamma = \left(\frac{\lambda_I}{\lambda_O}\right)^{\sigma-1} \left(\frac{1 - \theta}{\theta}\right)^\sigma$$

These break down into

$$C_j = \frac{\alpha_j \lambda_j Y_j}{P_j} \quad \text{and} \quad L_j = \frac{(1 - \alpha_j) \lambda_j Y_j}{W}$$

for good j (either Internet, I , or composite, O).

When the Internet is not available, C_I and L_I (and thus Y_I) are zero and all consumption is the composite. Expenditure functions with and without the Internet are

$$\begin{aligned} E(P_O, P_I, F_I, W, u | Y_I > 0) &= F_I + \frac{\lambda_O}{(1 + 1/\Gamma)^{1/(\sigma-1)}} \left(\frac{u}{1 - \theta}\right)^{\frac{\sigma}{\sigma-1}} \quad \text{and} \\ E(P_O, W, u | Y_I = 0) &= \lambda_O \left(\frac{u}{1 - \theta}\right)^{\frac{\sigma}{\sigma-1}} \end{aligned}$$

Consumer surplus from the Internet, measured as an equivalent variation, will then be:

$$\begin{aligned} (2) \quad EV &= E(P_O, W, \\ &u(P_I, F_I, P_O, W | Y_I > 0) | Y_I = 0) \\ &- W = W[(1 + 1/\Gamma)^{1/(\sigma-1)}(1 - F_I/W) - 1]. \end{aligned}$$

As expected, the surplus depends on σ , the elasticity of substitution between the Internet bundle and the bundle of other goods and services. This is very similar to a conventional demand analysis. To identify the sensitivity of demand to price would then require variation in prices. Paul Rappoport et al. (2003) argue there is enough variation to estimate the elasticity of demand and put it at -0.27 for dial-up access and -1.49 for broadband access. The true elasticity σ , however, would be dramatically larger since the access fees make up only a small part of the full cost of using the Internet (because of the time component).

An alternative to using Internet service provider fees is to use variation in the opportunity cost of time to estimate the elasticity σ . The theory above predicts that, as wages rise, people should use the Internet less. How quickly use declines will indicate σ . Since wages vary a great deal across individuals, this also gives us a chance to identify the elasticity in a way that is very difficult using only purchase prices.

Using the optimal allocations implies that

$$\begin{aligned} (3) \quad \Gamma &= \frac{(1 - \alpha_I)(1 - F_I/W) - L_I}{L_I} \\ &= A W^{(\alpha_O - \alpha_I)(\sigma-1)} \left(\frac{1 - \theta}{\theta}\right)^\sigma \end{aligned}$$

where

$$A = \left[\frac{(P_I/\alpha_I)^{\alpha_I} (1 - \alpha_O)^{1 - \alpha_O}}{(P_O/\alpha_O)^{\alpha_O} (1 - \alpha_I)^{1 - \alpha_I}} \right]^{(\sigma-1)}$$

The Internet has a flat subscription rate, so the relevant case is $\alpha_I = 0$ and $F_I > 0$. Moreover, the fixed cost is typically very small, relative to full income (0.2 percent or less), so that $F_I/W \approx 0$. As a result, the left-hand side of (3) is approximately equal to $(1 - L_I)/L_I$. Taking natural logs of (3) yields

$$\begin{aligned} (4) \quad \ln \left[\frac{1 - L_I}{L_I} \right] &\approx \ln(A) \\ &+ (\alpha_O - \alpha_I)(\sigma - 1) \ln(W) + \sigma \ln \left(\frac{1 - \theta}{\theta} \right). \end{aligned}$$

TABLE 1—REGRESSIONS OF $\ln[(1 - L_I)/L_I]$ ON $\ln W$

	Coeff.	S.E.	R^2	N	Implied σ
Basic regression	0.121	(0.021)	0.005	43,699	1.32
Internet for work (rather than leisure)	-0.480	(0.066)	0.042	43,362	N/A
Adding demographic controls	0.137	(0.015)	0.023	38,996	1.36
Adding Internet at work, yrs. of access	0.239	(0.017)	0.071	42,558	1.62
Adding nonwage income	0.113	(0.015)	0.026	30,693	1.30
Those with college and <50 yrs. old	0.176	(0.035)	0.008	8,414	1.46

The left-hand side is (the log of) time spent on non-Internet pursuits relative to time spent on the Internet. $\ln(A)$ is constant across individuals and we will illustrate that $(\alpha_O - \alpha_I)$ is approximately -0.62 , so we can directly translate the coefficient from a regression like (4) into an estimate of σ . We envision that the error term in this regression arises from individual variation in the preference for the Internet good relative to the composite, θ , from (1).

II. Data

To assess time spent on the Internet, we use the 2005 *Consumer Technographics* data from Forrester Research. This was a mail survey conducted in early 2005 including more than 60,000 households; it is meant to be nationally representative. More detail about the Forrester data is in Goolsbee and Klenow (2002). The survey includes demographic and socioeconomic information, as well as information on how many hours per week the respondent spends on the Internet for personal reasons. The answers are grouped (e.g., 1–4 hours, 4–8 hours, and so on), and we take the smallest number for each category, though this proved inconsequential. The average subscriber spends about 7.7 hours per week on the Internet for personal reasons, or 6.9 percent of their time (assuming 8 hours of sleep per day).

Only 0.21 percent of consumption spending went for Internet service providers in 2004 (from Table 2.4.5U of the NIPA accounts). Scaling this up to account for the 37 percent of people not on-line in our data, typical spending of a subscriber is around 0.33 percent.⁴ The time share is some 30 times

⁴ Adding computer hardware and software, including video games, the expenditure share is 1.3 percent.

larger than the expenditure share, so the Internet is an extremely time-intensive type of consumption.

Using the equations above, we can get a plausible value for the time intensity of the composite good: one minus the ratio of direct expenditures on the good to direct plus time expenditures (i.e., wage \times leisure time spent). By this measure, the time intensity of the composite would be 0.38 versus a time intensity for the Internet of 1.⁵ To compute welfare in our model, we also use the fact that consumer spending on Internet access, relative to full income (wage income plus the value of leisure time), is 0.0012, so that the share of time spent on-line is 0.069, the share devoted to other leisure is 0.574, and the rest, 0.357, goes to work.

In Table 1, we estimate equation (4) and the implied value of σ . The positive coefficients confirm that those with higher incomes report spending less time on the Internet. This result may seem surprising, given that Internet subscription is concentrated among higher-income people (something our model can produce if $F_I > 0$ and σ is not too high). But *conditional* on subscribing, the higher the value of one's time, the less one uses the Internet. The coefficient of 0.12 in the first row corresponds to a σ of 1.3.

We tried the same regression using time spent on the Internet for *work-related* reasons, which is somewhat outside the control of the consumer and should not, necessarily, show the pattern

⁵ This is derived from $\alpha_x = P_x C_x / (P_x C_x + W L_x)$, dividing numerator and denominator by income, $W(1 - L_I - L_O)$, and plugging an expenditure share of 0.0033 for the Internet and 0.9966 for the composite, and using 7.7 hours per week for the Internet, 40 hours for work, and the rest of nonsleep time to the composite good.

of our model. The results indicate that while higher-income people use the Internet less for leisure, this is not true for work.

We tried including a variety of demographic variables which might correlate with Internet usage, such as a dummy for whether the respondent has children, whether respondents are single, for educational attainment, gender, and race. The implied σ barely changes. In the fourth row, we add controls for time spent on the Internet for work-related reasons and dummies for how many years the individual has had access to the Internet. These variables are positively related to personal use of the Internet—the more time spent working on the Internet and the more years one has had Internet access, the more time one spends on the Internet for personal reasons. But inclusion of these controls does not reduce the relationship of personal Internet usage and the value of time. The coefficient is actually twice as large as in the baseline case but the implied σ is 1.6 versus 1.3.

We allow for income to affect demand for the Internet, independent of the opportunity cost of time (e.g., if Internet content caters to high-income people), by including dummies for the total value of assets owned as an indicator of nonwage income. Again, σ barely changes. We will use these demand estimates to calculate surplus from the Internet. Since we conditioned on subscribers, though, there may be a selection problem in the estimates; usage of the Internet falls with income but the probability of having Internet access rises with income. While this could be caused by the existence of the fixed cost of getting initial access, there is also likely to be considerable heterogeneity across people in their taste for technology. In future work, we hope to ground the sign-up and usage decision in one larger framework. The problem we face here is the absence of factors correlated with whether a person signs up for Internet access but unrelated to the amount of time spent using the Internet conditional on access. It is difficult, therefore, to do a Heckman-type selection correction.⁶ In practice, we are not especially concerned with selection because our estimate of σ

⁶ We tried doing the correction using a dummy variable for whether the person uses a computer at work, and we obtained a very similar σ . Since Internet use at work is probably correlated with the preference for the Internet elsewhere, this doesn't really solve the problem.

does not vary much when we confine the sample to people with a college degree who are younger than 50, as shown in the sixth row of Table 1. The unconditional probability of having Internet access among this group is almost 95 percent, so selection is not especially relevant for them.

IV. Welfare

Assuming Internet subscription is at a flat rate with no marginal cost (so $F_I > 0$ and $\alpha_I = 0$), the equivalent variation in (2) is

$$\begin{aligned} EV/W &= (1 + 1/\Gamma)^{1/(\sigma-1)}(1 - F_I/W) - 1 \\ &= \left(1 - \frac{L_I}{(1 - F_I/W)}\right)^{-1/(\sigma-1)} (1 - F_I/W) - 1. \end{aligned}$$

Each of the variables in the formula can be measured in the data.

As a comparison, take the standard “triangle” approach to approximating demand described in Hausman (1999). Here, one linearizes the demand curve and estimates the welfare (as a share of income) as $CS = -0.5 * (\text{expenditure share}) / (\text{elasticity of demand})$. With an expenditure share of 0.3 percent and an estimated price elasticity of -0.27 or -1.49 , this would be 0.1 percent to 0.6 percent of income, or \$50 to \$290 at the median income in the sample. If estimating the price elasticity has problems because of the lack of variation in prices and the small share of prices in the total cost, however, this estimate should be viewed with caution.

Our approach uses the estimates of σ from above and the model to compute the welfare gain. Doing this with the log demand curve will generate a much larger total gain since the utility from the first units of consumption is so high. To limit the importance of that, we can also construct an analogue to Hausman's methodology by linearizing the “leisure demand curve” instead of the goods demand curve. The area underneath the linear, leisure demand curve yields an EV as a share of full income of approximately $0.5 * L_I / \eta$, where the elasticity of leisure demand, η , is $\sigma(1 - L_I(1 - F_I/W))$.

Table 2 gives the surplus, relative to full income, under various values of σ . The Table shows that linearization would yield surplus of

TABLE 2—CONSUMER SURPLUS FROM INTERNET ACCESS
CALCULATED FROM TIME-USE DATA
(As a % of full income)

σ	Linear demand	Log demand
1.3	2.9%	26.8%
1.6	2.3%	12.5%
2	1.9%	7.3%

2 percent to 3 percent of full income, and with log-linear demand substantially larger.⁷ At the median, full income in the sample (actual income plus the value of leisure time), surplus would be \$2,500 to \$3,800 in the linear case.

Thus, we are able to get estimates of the welfare gain from the product using only data on time use. We add two important caveats, however. First, we are valuing leisure time at the wage. If people value their time less than wages then the time component and welfare gains will be reduced.⁸ Second, our simple model, with only a composite alternative, assumes there are no closer, time-intensive substitutes. Television would be a potential counter example. If television and the Internet are very close substitutes, then our surplus estimate is too large. This same issue arises with conventional demand curve analysis, and argues that future work should consider a multinomial setting where people can choose between different uses of their time when estimating the demand curve for the Internet.⁹

V. Conclusion

Consumption of every good arguably involves both expenditures and time. The total

⁷ One reason to be wary of the log-demand model is that it predicts virtually all households would subscribe to the Internet given the low price of doing so. In the data, some 37 percent of people were not online.

⁸ If people value their time at some constant fraction of their wage, this would not affect the estimates of σ , since they were in logs.

⁹ Such a program is well beyond the scope of this paper, but we did check whether Internet usage varied systematically with the price of cable television in an area (which changes the relative price of television) using the data in Goolsbee and Petrin (2004). We found no relationship. As a first pass, this may suggest the two activities are not such close substitutes.

cost of some goods, like the Internet, are primarily comprised of time costs rather than monetary costs. In such cases, estimating conventional price elasticities can be hard and welfare gains from the products highly uncertain. Using data on the time spent using the Internet and a simple model of utility, we show that for time-intensive goods, one can get a direct estimate of the welfare gains from consumer products using only the time-use data.

Although Internet use illustrates our point nicely, our simple model may overstate the gains from its availability by treating all other leisure pursuits as equally substitutable with Internet use. Some activities are much closer substitutes than others—for example, reading a newspaper or watching TV. Still, given a set of goods and their substitutability, taking into account the time intensity of the Internet can amplify its importance. And, as we have done, one can use variation in the value of time across individuals to estimate the substitutability between goods that differ in their time intensity. Such a method could be useful for future research in many other areas.

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