NBER WORKING PAPER SERIES

VALUING CONSUMER PRODUCTS BY THE TIME SPENT USING THEM: AN APPLICATION TO THE INTERNET

Austan Goolsbee
Peter J. Klenow

Working Paper 11995
http://www.nber.org/papers/w11995

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
January 2006

This paper was prepared for the AEA Session on "The Roots of Innovation", Boston, Massachusetts, January 8, 2006. We wish to thank Kevin Murphy, Amil Petrin and Joel Waldfogel for helpful comments and Romans Pancs for superb research assistance. Goolsbee also thanks the National Science Foundation for support. The views expressed herein are those of the author(s) and do not necessarily reflect the views of the National Bureau of Economic Research.

Valuing Consumer Products by the Time Spent Using Them: An Application to the Internet
Austan Goolsbee and Peter J. Klenow
NBER Working Paper No. 11995
January 2006
JEL No. D6, L0

ABSTRACT

For some goods, the main cost of buying the product is not the price but rather the time it takes to use them. Only about 0.2% of consumer spending in the U.S., for example, went for Internet access in 2004 yet time use data indicates that people spend around 10% of their entire leisure time going online. For such goods, estimating price elasticities with expenditure data can be difficult, and, therefore, estimated welfare gains highly uncertain. We show that for time-intensive goods like the Internet, a simple model in which both expenditure and time contribute to consumption can be used to estimate the consumer gains from a good using just the data on time use and the opportunity cost of people's time (i.e., the wage). The theory predicts that higher wage internet subscribers should spend less time online (for non-work reasons) and the degree to which that is true identifies the elasticity of demand. Based on expenditure and time use data and our elasticity estimate, we calculate that consumer surplus from the Internet may be around 2% of full-income, or several thousand dollars per user. This is an order of magnitude larger than what one obtains from a back-of-the-envelope calculation using data from expenditures.

Austan Goolsbee
Graduate School of Business
University of Chicago
5807 S. Woodlawn Ave
Chicago, IL 60637
and NBER
goolsbee@chicagogsb.edu

Peter J. Klenow
Department of Economics
579 Serra Mall
Stanford University
Stanford, CA 94305-6072
and NBER
klenow@stanford.edu

I. Introduction

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.[1] 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 highly uncertain.[2]

In this paper we show that thinking about that distinction can open up new avenues for estimating welfare. We will focus on the particular case of residential use of the Internet as our example 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 (Greenstein and Downes, 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.

---

[1] Recent examples include Hausman (1999), Petrin (2002a), Nevo (2003), Goolsbee and Petrin (2004) and papers in Bresnahan and Gordon (1997).

[2] The distinction between expenditure and consumption was first analyzed in Becker (1965) but has had little impact on the analysis of consumer innovations. Petrin (2002b), which uses data on utilization to improve conventional estimates of consumer welfare, is an exception. Aguiar and Hurst (2005) show the importance of distinguishing Consumption from Expenditure for understanding behavior over the lifecycle.

The model will let the utility function for a good include consumption in the form of direct expenditures as well as in the form of time. The results suggest that consumer gains from the Internet (as of January 2005) are quite high, perhaps more than a thousand dollars 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

(1.1) $$\theta\left(C_I^{\alpha_I} L_I^{1-\alpha_I}\right)^{1-1/\sigma} + (1-\theta)\left(C_O^{\alpha_O} L_O^{1-\alpha_O}\right)^{1-1/\sigma},$$

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, and L_O is the fraction of time spent on the composite. 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, whereas P_I is any marginal cost of using Internet services. In practice, this is essentially zero (because 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

$$Y_I = \frac{W - F_I}{\lambda_I (1+\Gamma)} \quad \text{and} \quad Y_O = \frac{W - F_I}{\lambda_O (1+1/\Gamma)} \quad \text{where} \quad \Gamma = \left(\frac{\lambda_I}{\lambda_O}\right)^{\sigma-1}\left(\frac{1-\theta}{\theta}\right)^{\sigma}.$$

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 0 and all consumption is the composite. Expenditure functions with and without the Internet are

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

$$E(P_O, W, u \mid Y_I = 0) = \lambda_O \left(\frac{u}{1-\theta}\right)^{\frac{\sigma}{\sigma-1}}.$$

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

$$\begin{aligned} EV &= E\big(P_O, W, u(P_I, F_I, P_O, W \mid Y_I > 0) \mid Y_I = 0\big) - W \\ &= W\left[(1+1/\Gamma)^{1/(\sigma-1)}(1 - F_I/W) - 1\right] \end{aligned} \qquad (1.2)$$

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, though, would then require variation in prices. 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

$$\text{(1.3)} \qquad \frac{(1-\alpha_I)(1-F_I/W)-L_I}{L_I} = AW^{(\alpha_O-\alpha_I)(\sigma-1)}\left(\frac{1-\theta}{\theta}\right)^{\sigma}$$

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 costs a flat subscription rate so the relevant case is $\alpha_I = 0$ and $F_I > 0$. Moreover, the fixed cost itself is typically very small relative to full income (0.2% or less), so that $F_I/W \approx 0$. As a result, the left-hand-side of (1.3) is approximately equal to $(1-L_I)/L_I$. Taking natural logs of (1.3) yields

$$\text{(1.4)} \qquad \ln\left[\frac{1-L_I}{L_I}\right] \approx \ln(A)+(\alpha_O-\alpha_I)(\sigma-1)\ln(W)+\sigma\ln\left(\frac{1-\theta}{\theta}\right).$$

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 below that

$(\alpha_O - \alpha_I)$ is approximately -0.62 so we can directly translate the coefficient from a regression like (1.4) 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 (1.1). Below we will discuss how this variation might affect our parameter estimate.

II. Data

To assess time spent on the Internet, we use the 2005 *Consumer Technographics* data of Forrester Research. This was a mail survey conducted in early of 2005 of more than 60,000 households and is meant to be nationally representative. More detail about the Forrester data can be found in Goolsbee and Klenow (2002). The survey includes demographic and socio-economic information as well as information on how many hours per week the respondent spends on the Internet for personal reasons (i.e., not for work). The answers are grouped (e.g., 0 hours, 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% of non-sleep time (assuming 8 hours of sleep per day).

Only 0.21% 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% of people that are not online in our data, typical consumption of a subscriber would be around 0.33%.[3] The time share is some 30 times larger than the expenditure share so the Internet would is an extremely time-intensive type of consumption.

[3] Adding computer hardware and software, including video games, the expenditure share is 1.3%.

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 of the Internet of 1.[4] To compute welfare in our model, we will also use the fact that consumer spending on Internet access relative to full income (wage income plus the value of leisure time) is .0012, so that the share of non-sleep time spent online is .069, the share devoted to other leisure is .574 and the rest, .357, goes to work.

In Table 1 we estimate equation (1.4) 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.

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

In row three, we tried including a variety of demographic variables which might correlate with Internet usage, such as a dummy for whether the respondent has children, for whether they are single, as well as dummies for educational attainment, gender and

---

[4] This is derived from $\alpha_x = P_x C_x / (P_x C_x + WL_x)$, dividing numerator and denominator by income, $W(1- L_I - L_O)$, and plugging an expenditure share of .0033 for the Internet and .9966 for the composite and using 7.7 hours per week for the Internet, 40 hours for work and the rest of non-sleep time to the composite good.

race. The implied σ barely changes. In row four, 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.

In the fifth row, 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 non-wage 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 a fixed cost of getting access for the first time, 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.[5] In practice, we are not especially concerned with selection because our estimate of σ does not vary much when we confine the sample to people with a college degree that are younger than 50 years old as in the sixth row of Table 1. The unconditional probability of having Internet access among this group is almost 95%, 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 α_I =0), the equivalent variation in (1.2) is

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

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=-.5*(expenditure share)/(elasticity of demand). With an expenditure share of 0.3% and an estimated price elasticity of -.27 or -1.49, this would be 0.1% to 0.6% of income, or only \$50 to \$290 at the median income in the sample. If estimating the price elasticity has problems, however, because of the lack of variation in prices and the small share of prices in the total cost, this estimate should be viewed with caution.

[5] We tried doing the correction using a dummy variable for whether the person uses a computer at work and 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.

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, of course, generate a much larger total gain since the utility from the first units of consumption are 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 $\sigma\left(1-L_I(1-F_I/W)\right)$.

Table 2 gives the surplus, relative to full income, under various values of σ. The Table shows that linearization would yield surplus of 2% to 3% of full income, and with log-linear demand substantially larger.[6] 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 the wage then the time component will be reduced and the welfare gains as well.[7] The second is that 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

[6] One reason to be wary of the log demand model is that it predicts that virtually all households would subscribe to the Internet given the low price of doing so. In the data, some 37% of people were not online.
[7] If people value their time at some constant fraction of their wage, this would not affect the estimates of σ which since they were in logs.

multinomial setting where people can choose between different uses of their time when estimating the demand curve for the Internet.[8]

V. Conclusion

Consumption of every good arguably involves both expenditures and time. The total 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 liable to be 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 which differ in their time-intensity.

[8] 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.

Table 1: Regressions of $\ln\left[\frac{1-L_I}{L_I}\right]$ **on** $\ln W$

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

Notes: The dependent variable is the log ratio of non-Internet time to Internet time as described in the text. Standard errors are in parentheses. Each regression includes the additional variables listed in the first column and described in the text.

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%

Notes: Authors' computation using the model in the paper and the data as described in the text. Full income is total income plus the value of leisure time (where the opportunity cost is defined as the wage)

References

Aguiar, Mark and Erik Hurst (2005), "Consumption Versus Expenditure," *Journal of Political Economy*, October, 113(5), 919-948.

Becker, Gary (1965), "A Theory of the Allocation of Time," *Economic Journal*, 75 (299): 493-508.

Bresnahan, Timothy and Roger Gordon, eds (1997), *The Economics of New Goods*. University of Chicago Press (Chicago, IL).

Downes, Tom and Shane Greenstein (2002), "Universal Access and Local Internet Markets in the US," *Research Policy*, 31 (7): 1035-1052.

Goolsbee, Austan and Peter J. Klenow (2002), "Evidence on Learning and Network Externalities in the Diffusion of Home Computers," *Journal of Law and Economics*, October 2002, Vol XLV (2, part 1), 317-344.

Goolsbee, Austan and Amil Petrin (2004), "The Consumer Gains from Direct Broadcast Satellites and the Competition with Cable TV," *Econometrica*, vol. 72, no. 2: 351-381.

Hausman, Jerry (1999), "Cellular Telephone, New Products and the CPI," *Journal of Business and Economic Statistics;* 17(2): 188-94, April.

Nevo, Aviv (2003), "New Products, Quality Changes and Welfare Measures from Estimated Demand Systems," *The Review of Economics and Statistics*, 21(1), 43-52.

Petrin, Amil (2002a), "Quantifying the Benefits of New Products: The Case of the Minivan," *Journal of Political Economy*, 110:705-729.

Petrin, Amil (2002b), "Improving Demand and Welfare Estimates with Utilization Data," manuscript, University of Chicago, GSB, November.

Rappoport, Paul, Donald Kridel, Lester Taylor, Kevin Duffy-Deno, and James Allemen (2003), "Residential Demand for Access to the Internet," Chapter 5 in the International Handbook of Telecommunications Economics, Volume II, ed. G. Madden, Edward Elgar.