The Attention Economy:
Measuring the Value of Free Goods on the Internet

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Abstract

The Internet has given rise to an explosion of free information goods, from Wikipedia articles and Facebook photos to Google maps and YouTube videos. What is their value? Traditional approaches based on measuring prices and quantities do not work well for such goods. In this study, we explore a framework to quantify the value of online applications that have very low prices using the insight that even when people do not pay cash, they must still pay "attention," or time, when consuming information goods. Accordingly, we contrast the value of consumer surplus using two different methods, one based on the value of direct market expenditure, and one based on the value of time spent consuming free goods. We provide a generalized model of household consumption and time use and estimate the value of consuming information goods on the Internet that is not measured in the traditional money-based measure of GDP. Our model of the "attention economy" yields an estimate of annual consumer surplus gain around $21 billion between 2003 and 2010 created by free sites on the Internet. This corresponds to about 0.17% of average annual GDP during the relating period. Our data imply that less than 7% of total welfare gain would be measured by approaches that rely solely on the variation in direct dollar expenditures. To identify the remaining 93% of value, one must consider time spent on consumption, as we do in this paper.

Keywords: Consumer surplus, Internet value, Free goods and services, Willingness-to-pay

I. <u>Introduction</u>

How can we measure the value of free goods and services on the Internet like articles in Wikipedia, friend's pictures at Facebook, Google maps, or videos in YouTube? The traditional approach is to estimate a consumer surplus by considering the demand curve implied by direct money expenses: the dollar price and quantity of goods. However, people who already have access to the Internet do not spend any additional money to consume Wikipedia articles, so a money-based "demand curve" is rather uninformative. Nonetheless, they do spend something very valuable: their time and attention. In this study, we consider the time spent on the Internet to quantify the value of recently introduced online applications that provide content, entertainment or knowledge for free.

Wikipedia started in 2001, while Facebook, YouTube, and Google maps were all introduced after the year 2004. In turn, this increase in digital content has corresponded with a doubling in the number of users on the Internet over the past 10 years and a significant increase in the amount of time spent online per user. In 2011, individuals spent about 13.8 hours on the Internet at home each week, which is about 12% of non-sleeping hours. Time spent on the Internet for uses other than work was about 8.4 hours and this is equal to 7.6% of non-sleeping hours. Since year 2003, the proportion of time spent on the Internet for leisure has increased about 36% per year in the average household. Time spent on the Internet necessarily comes at the opportunity cost of time spent consuming other goods. We will use this fact to infer the value of free Internet goods.

Facebook and YouTube, each less than seven years old and each free, are currently the second and third most frequently visited sites on the Internet in the US after Google, which is only slightly older, and also free (Alexa.com 2011). The time share of Facebook, Google sites, and Yahoo sites took each 16%, 11%, and 9% of time spent online (ComScore.com 2011). However, it is difficult to evaluate the value of each free online service since none of these sites charge users for online consumption. Revealed preference suggests that people get significant benefit from spending time on these sites, yet the economic gain from them is not measured well and does not contributed to official GDP or productivity statistics. Calculating the consumer surplus from consuming new goods (see e.g. Bresnahan and Gordon, 1997) and in particular free goods and services with widespread user contributions is a challenging question (see, e.g., Greenstein and McDevitt 2009). In this study, we incorporate the value of time spent in consuming free goods during the leisure hours

Our central research question is: *What is the value of welfare gain from consuming free goods and services on the Internet that is not measured in GDP?*

We develop a framework to quantify the welfare gain from free goods and services on the Internet between 2003 and 2010 by adapting and extending the approach of Goolsbee and Klenow (2006) and applying it to more recent data. We calculate a benchmark for the two conventional approaches to measuring welfare gains, namely, a time-based model and a money-based model. Goolsbee and Klenow estimate the consumer surplus from the Internet in 2005 compare to the state without Internet. In contrast, we focus on the incremental annual change in consumer surplus instead of the total consumer surplus from the Internet. Our approach provides a ready benchmark to annual GDP growth and productivity growth, and eliminates a potential problem of indeterminacy and overestimation created when some individuals have very high estimated values for the utility from Internet use.[1]

Our key findings are as follows: the average incremental welfare gain from the Internet between the years 2003 and 2010 is about $31 billion per year. Of that amount, we estimate that about $21 billion accounts for the consumer surplus from the free goods and services at online. This corresponds to about 0.17% of annual GDP. In contrast, the welfare estimates are significantly lower when we do not account for the time value. The annual incremental welfare gain from direct expenditure of money (i.e. excluding the value of time) between year 2003 and 2010 is only about $1.5 billion, which corresponds to 7% of the estimate from the time-based model.

A number of interesting comparisons can be made with our estimates. First, the time-based measures are much higher – more than an order of magnitude larger – than the money-based measures that are traditionally used for consumer surplus calculations. However, the time-base measured may be a more meaningful metric of welfare. For example, our estimate is broadly consistent with a simple back-of-the-envelope estimate based on the opportunity cost of time. On average, 34% the average person's waking hours is time is spent working. In turn, labor income share accounts for about 60% of GDP. From 2003 to 2010, 3.9% (4.4 hours) of waking hours were spent on the free Internet sites. Thus, the number of hours spent on the Internet is roughly equal to the number of hours used to generate about 7% of GDP. In turn, the annual growth rate of GDP is around 2-3%, so 7% of that figure would be a gain of 0.14-0.18% of GDP each year. This coincides closely with our results of 0.17% annual gain due to free Internet goods.

[1] For instance, when the log-linear utility specification, the utility Internet use for an individual can approach infinity as time spent approaches zero.

Second, both our time-based and money-based estimates provide can be compared to other estimates of other aspects of the Internet's potential value. Varian (2006) presented the annual value of $120 billion for Google's search engine based on the value of time savings to average users. Bughin (2011) estimated about $64 billion of Internet based on a survey where users stated their preferences. While both these paper use very different approaches, they both generate values that are somewhat larger than our estimates. The higher values mainly reflect the fact that they looked at the total value attributable to the Internet each year, not the annual increase in value created by the Internet. On the other hand, Greenstein and McDevitt (2009) found a range of $4.8-$6.7 billion of welfare gain from improved broadband Internet services based on the direct market expenditure data. This is an estimate for seven years of technical improvements and diffusion between 1999-2006, not an annual gain, and thus it is broadly consistent with the value of $1.5 billion from our model that considers only the money-cost of Internet services through 2010.

Third, the annual welfare gain of $21 billion is based on data showing about 36% increase in leisure time spent on the Internet, a 28% increase in Internet household penetration rate, a 33% increase in the expenditure share, and about 2.2% decrease in the time elasticity of substitution parameter since 2003. Each of these trends independently lead to increased welfare from free goods, and this value is augmented further by their interactions. From the comparative statics, we provide a measure to calculate the marginal variation in the welfare gain (measured by equivalent variation) with respect to the marginal change in the time spent on the Internet. We found that the marginal effect on the welfare of a 1% change in time spent is about four times greater than a 1% change in money spent.

The plan for the paper is as follows: In Section II, we briefly discuss related approaches and previous studies measuring the value of new goods and information technology. In Section III, we introduce a generalized model of welfare calculation in the attention economy and then present the framework to measure the welfare gain from Internet based on the time share and money share. In Section IV, we discuss the data, and in Section V, we provide the estimate of consumer surplus from free goods and services on the Internet. Finally, in Section VI, we conclude with a discussion of our results.

II. Literature Review

To what extent is the Internet economy responsible for welfare growth?

It is well known that GDP statistics ignore value of many economic goods. For example, because GDP focused on measurable prices and quantities, it does not reflect the value of most environmental benefits, non-market household production, health or longevity. Not surprisingly, increasing attention has been devoted to the construction of better indicators of social welfare that encompasses recent developments in the analysis of sustainability, happiness and individual well-being, and fair allocation (Fleurbaey 2009). However, there is no integrated indicator that represents both the level of physical economy and the size of recently explosive digital economy. Due to the nature of digital goods, marginal cost of producing an online good is nearly zero. For many of the most important goods and services on the Internet, there is no price per usage other than the monthly cost of general Internet access. For this reason, it is not straightforward to calculate the value of digital goods.

Broadly speaking, there are four approaches to measuring the value of unpriced goods: contingent valuation, conjoint analysis, hedonic price models, and welfare analysis (Smith 1996). Contingent valuation is based on survey responses asking people to report their value for specific hypothetical benefits. Conjoint analysis collects preference or choice data among multi-attribute alternatives, typically using a forced ranking to estimate the relative and absolute marginal willingnesss-to-pay (WTP) for specified changes in the characteristics of goods. Both of the first two approaches are based on stated preferences, which may not reflect actual preferences. In contrast, the following two approaches are based on revealed preference from market transactions. Hedonic price model estimates the value of quality differentials from the regression of price with respect to the unpriced features of products. For instance, even if there are no separate markets for microprocessor speed or disk drive capacity, there are still shadow prices can be inferred by comparing the market prices paid for computers with varying bundles of these characteristics. Finally, welfare analysis is based on the specified economic model measuring the area of consumer surplus under the Hicksian compensated demand curve. Equivalent variation (EV) and compensated variation (CV) infer the welfare gain for consumers due to price changes after adjusting the possible change in the wealth. Because only market prices, not the actual willingness-to-pay, can be observed for most consumers, this typically requires some assumptions about the shape of the demand curve (or utility function) and an extrapolation.

There have been only a few studies that measure the welfare gain from some aspects of Internet. Greenstein and McDevitt (2009) measure the economic value of the diffusion of broadband. They observe $39 billion of total revenue for Internet access providers in 2006 with broadband accounting for $28 billion of this total. In addition, they estimate that about $4.8 to

$6.4 billion of consumer surplus was generated from faster Internet access between the year 1999 and 2006.

Rosston et al (2010) estimated willingness-to-pay of important Internet services characteristics by estimating a random utility model of household preferences for broadband Internet service. They found that the reliability and speed are important service characteristics: 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. As noted above, Bughin (2011) estimated that there was about $64 billion of consumer surplus generated from Internet services based on users self-reported valuations while Varian (2006) found that the annual value for Google's search engine could be as high as $120 billion.

Other studies have sought to measure the welfare gain from IT use in general. For instance, Breshanan, (1986) calculated the derived demand for mainframe computers in financial services and found that most of the benefits from technical advance were not captured by computer manufacturers. Brynjolfsson (1996) estimated $50 to $70 billion annual contribution of IT to consumer welfare by using hardware price and expenditures data through the year 1987. The rapid declines in price and increases in quantity of real IT revealed the underlying demand curve, which in turn could be used to estimated consumer surplus. More recently, Greenwood and Kopecky (2011) measured welfare gain from the price declines in personal computers and found the range of 2% to 3% of consumption expenditure.

While the above approaches seek to use dollars spent in market transactions to make inferences, another approach is to look at time usage. After all, consumers must also "pay" with their finite time budget whenever they consume information goods on the Internet. It was John Maynard Keynes who made prediction on the relationship between usage of leisure hours and productivity. In his 1930 essay, "Economic Possibilities for Our Grandchildren" Keynes predicted that a rise in productivity would result in a large increase in leisure during the next 100 years. Thirty-five years later, Becker (1965), modeled how households combine not only market resources to produce output but also time. Juster and Stafford (1985) emphasize the notion of "process benefits," or the flow of utility that accrues during particular activities, such as work and consumption. They illustrate this idea in a Robinson Crusoe economy where Robinson can divide his time among working, cooking and eating activities. With the assumption that process benefits from activities are separable, the utility can be represented as a sum of utility from time spent in separable activities. More recently, Krueger et al. (2009) sought to value nonmarket time using the wage rate as the shadow price of leisure.

The study that is most directly relevant to ours is Goolsbee and Klenow (2006), hereafter referred to as G&K. They use the time value of leisure to estimate the opportunity cost and value of Internet use. They note that time use data indicates that people spend around 10% of their entire leisure time online. G&K estimated the consumer surplus from Internet use could be over 25% of income based on a log-linear specification for demand or around 3% of income if one assumes a linear demand curve. The large differences reflects the fact that the log-linear demand assumes that marginal utility approaches infinity as time spent approaches zero, while linear demand assumes a much smaller marginal utility for small amounts of internet usage.

The increase in time spent on the Internet likely reflects the introduction of new goods, such as Facebook, which consumers value. However, it is important to note that there is no guarantee that the provision of a broader variety of goods and services will always lead to higher time share on free goods or increase in welfare. A relevant study has done by Liebowitz and Zentner (2011) in the case of television. They found virtually no impact of increased variety brought about by cable and satellite to television viewing. In addition, Penard et al (2011) studied the impact of Internet use on individual well-being. They empirically examined the relationship between Internet and subjective well-being by accounting the detrimental effects of Internet such as addition and social isolation. Using data from a social survey in Luxembourg, they find that Internet use is more influential on life satisfaction than on happiness. They find no evidence that Internet makes users happier when controlling the effect of Internet penetration, GDP per capital, social capital and health. Their results suggest that the digital divide causes dissatisfaction and that the benefits of Internet use maybe stronger for low income and young individuals.

III. Measuring Welfare Gains on the Internet

Consider an individual, *i*, with wage $W(i)$, who receives utility from her consumption of leisure and goods. We differentiate between consumption of digital goods verus all other goods as well as between time spent on consumption versus work versus leisure. Individuals obtain utility from two types of bundles: an Internet good bundle and a composite bundle of all other goods. Consumers choose to work at the expense of hours they could have otherwise spent for leisure or on the Internet. Available time and the wage rate are the constraints that people face. We employ a utility function that accounts for both time and market spending for a good. Consumers seek to maximize their utility, which a weight sum of two main components, Internet goods and all other goods. Furthermore, utility from each type of good takes the form of a Cobb-Douglas style function reflecting a complementarity between the purchases of the goods and the time spent consuming them.

$$Max_{\{I(i),T(i),C(i),L(i)\}}\ U(i) = \theta\left(I(i)^{\alpha_1} T(i)^{1-\alpha_1}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta)\left(C(i)^{\alpha_0} L(i)^{1-\alpha_0}\right)^{\frac{\sigma-1}{\sigma}}$$

$I(i)$ denotes purchased Internet goods and $T(i)$ represents the fraction of total time devoted to the Internet at home. All other purchased goods and services form a composite good $C(i)$. In turn, $L(i)$ is the fraction of time spent on the composite good. Each α_0 and α_1 correspond to the degree of time intensity of composite good and Internet good. The elasticity of substitution of Internet usage, with respect to other goods' consumption for leisure, is represented by the parameter σ.

In the budget constraint, $W(i)$ is the wage, while P_1 and P_0 are the prices of Internet services and the composite good, respectively. F is any fixed fee for subscribing to the Internet in a given period, where P_1 is any marginal cost of using Internet services. In practice, P_1 is zero because Internet costs a flat fee per month for almost all subscribers.

$$P_1 I(i) + F(i) + P_0 C(i) = W(i)(1 - T(i) - L(i))$$

Above utility maximization problem has unique interior solution. By combining the above optimality conditions, we obtain the following equation:

$$\frac{(1-\alpha_1)\left(1-\dfrac{F(i)}{W(i)}\right) - T(i)}{T(i)} = \left[\frac{\left(\dfrac{P_1}{\alpha_1}\right)^{\alpha_1}(1-\alpha_0)^{1-\alpha_0}}{\left(\dfrac{P_0}{\alpha_0}\right)^{\alpha_0}(1-\alpha_1)^{1-\alpha_1}}\right]^{\sigma-1} W(i)^{(\alpha_0-\alpha_1)(\sigma-1)}\left(\frac{1-\theta}{\theta}\right)^{\sigma} \quad (1)$$

Following G&K, the left-hand side of equation (1) can be approximated by $(1-T(i))/T(i)$ and one can estimate σ from the obtained regression coefficient of wage divided by the difference between time intensity of internet goods and composite goods, $(\alpha_0 - \alpha_1)$. The time intensity parameter of $(1-\alpha_1)$ and $(1-\alpha_0)$ can be estimated using the following equation:

$$\alpha_1 = \frac{P_1 I\ /W(1-T-L)}{(P_1 I + WT)/W(1-T-L)}, \quad \alpha_0 = \frac{P_0 C\ /W(1-T-L)}{(P_0 C + WL)/W(1-T-L)}$$

Thus, we can estimate elasticity parameter, σ, from a regression by taking natural logs of equation (1) including other demographic variables.

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$$\ln\left[\frac{1-Internetime(i)}{Internettime(i)}\right] = \beta_0 + \beta_1 \ln(Income(i)) + \beta_3(demographic\ var.) + \varepsilon(i) \qquad (1')$$

<u>Time-use model</u>

Next, we briefly discuss how to measure welfare gain to consumers in 2010 from the free goods and services on the Internet since 2003. One way of measuring welfare gain is based on equivalent variation (EV). Begin by supposing it is the year 2003 and Internet is not available. How much more income would you have to give to a consumer so that her welfare level without Internet is equivalent to the welfare she obtained with Internet? Equivalent variation with and without Internet can be obtained from the conditional difference between expenditure functions. Equation (2) specifies welfare measure of EV as a proportion of wealth. F/W denotes the share of Internet expenditure where T denotes the share of time spending on the Internet for non-work purposes.

$$EV/W = \left[E(P_0, W, u(P_I, F_I, P_0, W \mid Y_I > 0) \mid Y_I = 0) - W\right]/W$$

$$= \left(1 - \frac{T}{(1-F/W)}\right)^{-\frac{1}{\sigma-1}} (1-F/W) - 1 \qquad (2)$$

Note that a drawback of this log-linear type utility function for measuring consumer surplus is a potential overestimation problem because marginal utility is assumed to go to infinity when the Internet usage asymptotically approaches to zero. G&K introduce an alternative measure to avoid potential overestimation. They construct an analog to Hausman's (1997) methodology by linearizing the leisure demand curve. This essentially ignores the entire surplus between the linear demand and the log-linear demand. The area underneath the linear leisure demand curve yields an approximate EV in equation (2). Notice that the denominator is elasticity of leisure demand. T^F stands for the hours spent only on free sites in equation (3).

$$\text{Linear approximation:} \quad EV_L = 0.5 \times \frac{T^F}{\sigma\left(1 - T^F(1-F/W)\right)} \qquad (3)$$

From this linear-demand specification, we develop a framework to compare consumer surplus from Internet. This time-use model estimates the consumer surplus received from both the time share and the expenditure share in dollars. In turn, money model only estimates the consumer surplus from expenditure share on Internet measured in dollars. Welfare gain between year 2003 and 2010 can be calculated as shown in equation (4).

$$Welfare\ \ gain\,|_{2003}^{2010} = \sum_{t=2003}^{2010}(EV_L{}^{t} - EV_L{}^{t-1}) \qquad (4)$$

<u>Money-spending model</u>

We address two methods to estimate consumer surplus based on the expenditure of Internet subscription fee.

One way of calculating consumer surplus is to measure the variation in the share of direct expenditure by assuming a translog utility function, which is one of the least restrictive available (Bresnahan 1986). This method estimates the consumer surplus as the area under the demand curve, which sides equal to the change in prices and the share of Internet expenditure.

Index method: $$0.5\times(s^1 + s^0)\ln(\frac{P_0}{P_1})W_1 \qquad (5)$$

Another way is based on cumulative method (Brynjolfsson 1996) to approximate the increase in Internet users, denoted as ΔQ^t in equation (5) each year. This does not assume any particular functional form for utility or demand but instead makes use of data on intermediate points which may not lie exactly on the estimated demand curve.

Cumulative method: $$\sum(P^t - P^{t-1})\Delta Q^t(W^1 / W^t) \quad for \ \ t = 0,\ldots,1 \qquad (6)$$

While these methods are slightly different, both methods yield essentially similar estimates. We present the welfare gain implied by the money model using Index method in equation (5). By construction, money model does not allow us to calculate the time value of hours spent on free sites. This is a conservative measure that excludes the time value and possible gain higher than the linear slope.

$$Welfare\ \ gain\,|_{2003}^{2010} = 0.5\times\sum_{t=2003}^{2010}\left[(s^{t+1} + s^t)\ln(\frac{P^{t+1}}{P^t})\right]W^{t+1} \qquad (7)$$

In Section V, we estimate welfare gain of Internet based on these two different frameworks, the time-use model and the money-spending model. We also calculate the welfare gain specifically generated from the hours spent on free sites as the value of free goods and services on the Internet.

IV. Data

We collected data from multiple sources. To assess time spent on the Internet, we use the *Consumer Technographics* data of Forrester Research from 2001 to 2011. This is a mail survey conducted annually of more than 40,000 households (on average) and is meant to be nationally representative. The survey includes time usage information on how many hours per week the respondent spends on the Internet for personal reasons and work reasons separately. The data also includes average years of Internet experience, household income level, wealth, education, employment and characteristics of Internet services, as briefly described in Table 1.

Table 1: Summary statistics for year 2010

Total	2003	2004	2005	2006	2007	2008	2009	2010
Observations #	55,037	54,161	61,777	60,978	52,329	55,368	48,412	37,233

Feature	# Obs.	Mean	Median	S.D.	Min	Max
Internet Service Features and Hours Online						
Hours spent on Internet for leisure	36,424	8.39	7	8.87	0	32
Hours spent on Internet for work	36,529	5.68	0.5	9.31	0	32
Internet fee	17,184	20.45	12.5	25.62	0	162
Individual Demographics						
Internet experience (years)	29,715	10.32	11	4.37	1.5	16
Income	37,233	66,045	52,499	51,219	3,749	324,999
Financial asset	28,026	267,529	74,999	1,241,319	0	25,000,000
Full employment	37,233	0.43	0	0.49	0	1
Education	36,194	3.59	3	1.54	1	6
Age	37,233	48.63	48	17.14	18	98
Gender (1: Male, 2: Female)	37,233	1.56	2	0.49	1	2
Marital Status (Married)	37,233	0.52	1	0.49	0	1
Region	37,233	4.99	5	2.49	1	9
Kids (Has kids under 18)	37,233	0.773	1	0.419	0	1

Between the 2006 and 2007 surveys, Forrester substantially changed their methods for determining the number of hours spent on Internet. Among other things, they changed the focus of their sample to “all 18+ households” instead of only “households who access to the Internet more than 3 times”. This is reflected in a large, and we think spurious, drop in the reported level of hours spent on Internet per respondent in 2007 versus 2006. For this reason, we perform our analyses separately for the samples between 2003-2006 and 2007-2010. Individuals in the survey conducted by Forrester are members of NFO mail panel who have been previously chosen to take part in the mail survey. While the sample of respondents in each year changes over time, we were able to construct a set of balanced panels over time by identifying particular users who stayed in the mail survey for four consecutive years.

Figure 1 shows hours spent on Internet for personal purposes in the balanced panels. The left figure summarizes the increasing size of panel data as we shorten the length of years. There are only 79 individuals who remained in the data during all the years from 2004-2010, however, more than 5,400 individuals stayed in the sample for every year from 2007-2010. Figure 1 also shows a shifting pattern of hours as successively younger generations join in the panel in the later years compare to the early years. The right figure depicts a pattern of overlapping panels for individuals who stayed more than four consecutive years. There are 1,049 individuals in the period of 2003-2006 and 2,414 respondents in the period of 2007-2010. Our empirical results are based on these two panel data sets. We present the descriptive statistics of balanced panel data in the Appendix.

Figure 1: Panel data- Hours spent on Internet for leisure

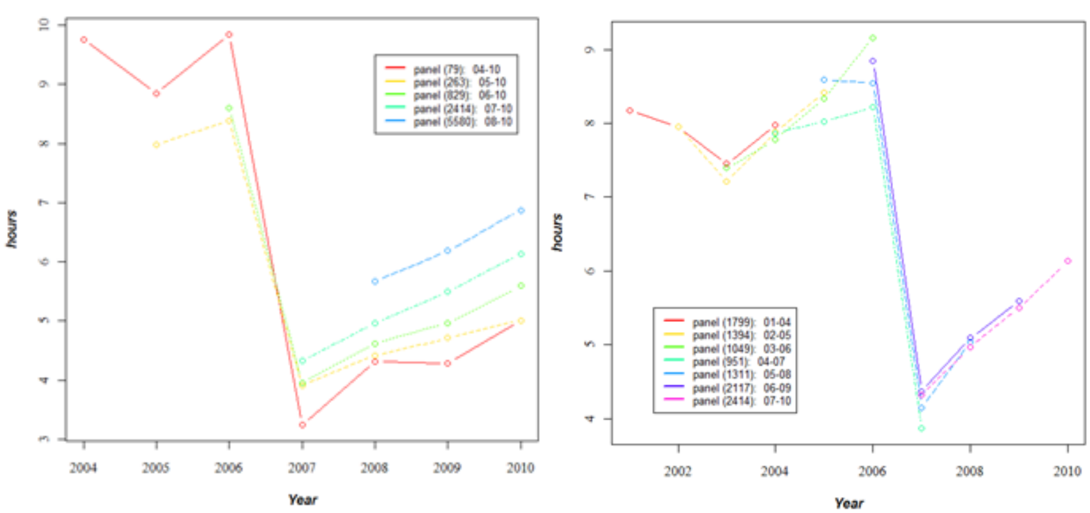

Table 2 presents an overview of change in the share of Internet expenditure and time spending in the panel data. We collected expenditure share of Internet from NIPA table 2.4.5 and Internet penetration rate from the World Bank. In terms of market spending, the expenditure share increased about 57% and the Internet population also increased about 28% between 2003 and 2010. Adjusted expenditure share (in dollars) on the Internet for the average Internet user is about 0.66% in year 2010. This is increase of about 33% compared to the year 2003. In terms of time use, weekly Internet hours spent on leisure increased from 4.3 to 6.1 hours per week which indicates about 42% increase in the non-sleeping hours (assumed to be 16 hours per day, or 112 hours per week) compare to the year 2007.

Table 2: Internet time share, money expenditure share and elasticity of substitution

	Expenditure share (Internet)	Internet adoption (%)	Adj. Expenditure share (F/W)	Hours spent on Internet	Time share (T)
Year 2003	0.00334	61.90%	0.00499	7.392	0.066
Year 2004	0.00345	64.98%	0.00540	7.785	0.069
Year 2005	0.00339	68.21%	0.00498	8.334	0.074
Year 2006	0.00345	69.15%	0.00499	9.163	0.082
% Change	3.29%	11.71%	0%	29.96%	29.96%
Year 2007	0.00393	75.17%	0.00523	4.324	0.039
Year 2008	0.00427	74.15%	0.00576	4.963	0.044
Year 2009	0.00486	78.17%	0.00622	5.497	0.049
Year 2010	0.00525	79.34%	0.00662	6.134	0.055
% Change	33.58%	5.55%	26.58%	41.86%	41.86%
% Average change for two period	18.37%	8.63%	13.29%	35.91%	35.91%

V. Estimation Results

We estimate parameters of equation (1)' and the implied value of elasticity of substitution parameter σ. The data suggests that the elasticity of substitution, σ, between Internet leisure hours and working hours has decreased about 9% compared to year 2003.

$$\ln\left[\frac{1-Internetime(i)}{Internettime(i)}\right] = \beta_0 + \beta_1 \ln(Income(i)) + \beta_3 Internet\_experience(i) + \beta_4 education(i) + \beta_5 gender(i) + \beta_6 Financial\_assets(i) + \beta_7 married(i) + \beta_8 kids(i) + \varepsilon(i)$$

Table 3: Estimation of Elasticity of Substitution

	Coeff.	(S.E.)	Adj. R^2	N	$(\alpha_0 - \alpha_1)$	Implied σ	Moving average σ

Year 2001	0.163	0.008	0.109	50,601	0.365	1.442	
Year 2002	0.162	0.001	0.104	38,488	0.362	1.448	
Year 2003	0.133	0.008	0.107	30,619	0.358	1.370	1.420
Year 2004	0.123	0.009	0.098	27,435	0.359	1.343	1.387
Year 2005	0.139	0.008	0.111	29,708	0.364	1.383	1.365
Year 2006	0.025	0.006	0.069	25,645	0.371	1.068	1.265
Year 2007	0.090	0.011	0.078	25,706	0.337	1.268	1.240
Year 2008	0.110	0.010	0.065	28,510	0.352	1.313	1.217
Year 2009	0.103	0.010	0.112	26,890	0.346	1.298	1.293
Year 2010	0.083	0.011	0.098	19,111	0.356	1.232	1.281

We estimate the consumer surplus (CS) from Internet between 2003 and 2010 by focusing on the incremental change in the welfare created by the Internet annually. Table 4 provides estimates of two different methods, the time-based model from equation (3) and the money-based model from equation (6). In our time-based model, we estimate that the consumer surplus created from the Internet is on average $213 billion which corresponds to about 2.4% of consumption expenditure. Our number is slightly less than G&K who report 2.9% based on year 2005. The incremental welfare gain ranges from $15 to $68 billion. On average, annual gain is about $32.9 billion during 2003-2010.

In contrast, the money model relies on market share of Internet cost as measured in dollars spent. The annual gain from money model is negative when the price increases. While the welfare gain ranges from around -$0.5 to $2 billion, about $11 billion was generated between 2006 and 2007. This reflects a huge price drop of Internet subscription fee mainly due to a pricing change of AOL. Overall, we estimate about $1.5 billion as the annual surplus gain from the money model in equation (6).

The difference between time-based model and money-based model is enormous, averaging over $31 billion per year. Our results suggest that only about 4% of total CS gain from the Internet would be measured by the share of direct dollar expenditure, with the rest of the gain visible only when one considers time use. The result also implies that there is a gain each year equivalent to nearly 0.26% of GDP from the Internet and that this gain would otherwise be unmeasured.

Table 4: Estimation of Consumer Surplus

$Billion	Time model	Yearly gain (Time model)	Yearly gain (Money model)
Year 2003	$185.0 B		
Year 2004	$208.4 B	$23.4 B	$1.00 B

Year 2005	$241.9 B	$33.5 B	$0.73 B
Year 2006	$310.8 B	$68.8 B	$2.04 B
Year 2007	$152.2 B		$11.53 B
Year 2008	$184.8 B	$32.6 B	-$0.55 B
Year 2009	$199.7 B	$15.1 B	-$2.21 B
Year 2010	$224.0B	$24.1 B	-$0.48 B
Yearly CS Gain (2003-2010)		$32.9 B (0.26% of GDP)	$1.47 B (0.01% of GDP)
Yearly value per user		$153/user	$7/user

Table 5 presents a fraction of Internet hours spent only on free sites. This provides our framework to estimate consumer surplus gain from free goods and services between 2003 and 2010. On average, more than two-thirds of time spent online is at so-called free sites (Stranger and Greenstein 2007). If there exists a positive correlation between Internet time spending and the demand for free goods, the share of consumer surplus from free goods might be higher, and conversely, it might be lower if the correlation is negative. For now, we calculate welfare gain from time spent on free sites assuming the minimum portion of time share, which turns out to be about 58% of total gain.

Table 5: Time share in Free Internet sites

	Internet time share (T)	Time spent on free sites (F)
Year 2003-2010	0.059 (6.7hours/week)	0.039 (4.5 hours/week)

Table 6 summarizes our estimates of welfare gain from free goods and services on Internet. Annually, the increase in value due to free online goods is about $21 billion and this corresponds to about $99 every year for individuals according to the time-based model. In contrast, the money model implies that the annual value of free goods on Internet as only $7 per user.[2]

Table 6: Estimation of Annual welfare Gain from Free Goods and Services

ΔCS^{yearly}	Time Model	Money Model
Total yearly gain	$21.2 (billion)	$1.5 (billion)
Yearly gain (/person)	$99	$7

[2] These values are calculated based on the following estimates: the number of average Internet users during 2003 and 2010 is about 215 million, and hours spent of free sites are about 4.5 hours per week.

Monthly (/person)	$8.3	$0.6
Hourly (/person)	$0.01	$0.001
% GDP (% Yearly)	(0.17%)	(0.01%)

How can we understand the origin of welfare gain based on time model? We decompose the welfare gain from hours spent on free sites based on the increase in the Internet adoption rate, increase in hours per Internet users, change in the elasticity of substitution parameter, and the wealth level. Using the data on overall proportion of average hours spent on Internet, we first recover "hours per Internet users" from dividing the average hours by Internet penetration rate. Then we calculated proportion of average hours when assuming each no growth in adoption and no growth in hours per user.

We found that the largest portion of welfare gain originates from increase in the hours per Internet user. Almost 39% of annual welfare gain can be explained by the 24% increase in hours per user during 2003-2010. In turn, the 8.63% increase in adoption rate generates about 16% of the annual welfare gain. The 4% change in time preference measured by elasticity of substitution explains about 9% of the welfare gain. Finally, the increase in wealth, measured by total consumption expenditure also accounts for about 22% of the annual gain.

Table 8: Decomposition of Annual Welfare Gain

Annual CS	Adoption	Hours per user	Preference	Wealth	Sum
21.18	3.43	8.18	1.93	4.70	18.23
100%	16.17%	38.61%	9.11%	22.18%	86.07%

Table 9 provides consumer value created from free Internet sites based on their time share on the Internet. The time share of Facebook, Google sites, and Yahoo sites took each 16%, 11%, and 9% respectively of time spent online (ComScore.com 2011). Using this number, we estimated the time share of other Internet sites, such as Wikipedia based on the percentage of Internet reach and average minutes spent by a user. For instance, the consumer value from Facebook and YouTube is estimated to be about each $5.0 and $2.7 billion.

Table 9: Yearly Consumer value from Free Internet sites

	Reach%	Minutes	Time share	Yearly CS ($Billion)	% GDP
Facebook	0.434	24	16.00%	5.3	0.0362

YouTube	0.330	17	8.62%	2.8	0.0195
Twitter	0.093	7	0.99%	0.3	0.0022
Wikipedia	0.144	4	0.88%	0.3	0.0020
LinkedIn	0.050	7	0.53%	0.2	0.0012
Craigslist	0.015	13	0.30%	0.1	0.0007

In 2011, the total revenue of Facebook is reported as $3.7 billion and total costs were $2.7 billion. This suggests that the marginal value to the consumers per dollar revenue of Facebook was around $1.4 (from the value/revenue ratio) and that the marginal gain in consumer value per dollar expense was around $2.0 (from the value/cost ratio).

VI. Concluding Remarks

The traditional approach to consumer surplus measurement relies on changes in prices measured in money terms. However, when the goods being considered are free or nearly free, the money model may grossly underestimate the value of consumer surplus, since most of the real cost to users is in terms of time, not money. We provide an estimate of consumer surplus gained from free goods and service on the Internet which considers this time component. In particular, we contrast the results using two different methods that emphasize the value of time spent consuming free goods and the value of direct market expenditure, as measured in dollars. Using data on the expenditure share, market price, Internet adoption rate and time spent using the Internet at home, we present an estimate of welfare gain about $21 billion per year from free goods and services. This corresponds to about 0.17% of average GDP during 2003-2010. Our data imply that only 7% of total welfare gain will be measured by approaches that rely solely on the variation in direct dollar expenditures. To identify the remaining 93% of value, one must consider time spent on consumption, as we do in this paper.

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Appendix: Descriptive statistics of balanced panel

Balanced panel : 2003-2006	Year	# Obs.	Mean	Median	S.D.	Min	Max
Internet Service Features and Hours Online							
Hours spent on Internet for leisure	2003	655	7.39	7	6.88	0	28
	2004	646	7.78	7	7.19	0	28
	2005	670	8.33	7	7.56	0	28
	2006	640	9.16	7	8.43	0	28
Hours spent on Internet for work	2003	653	5.54	2.5	8.13	0	28
	2004	646	5.28	2.5	7.87	0	28
	2005	662	6.94	2.5	9.1	0	28
	2006	527	6.14	2.5	8.82	0	28
Individual Demographics							
Age	2003	1,049	56	55	14	21	91
Gender (1: Male, 2: Female)	2003	1,049	1.43	1	0.5	1	2
Income	2003	1,049	60,344	52,500	47,491	3,750	325,000
Financial asset	2003	888	385,318	75,000	1,014,243	12,500	15,000,000
Internet experience (years)	2003	660	4.12	3.5	2.23	0.5	8
Education	2003	1,038	2.92	3	1.3	1	5
Marital Status (Married)	2003	1,021	0.72	1	0.45	0	1
Region	2003	1,049	5.17	5	2.53	1	9
Kids (Has kids under 18)	2003	1,049	1.24	1	0.43	1	2

Balanced panel : 2007-2010	Year	# Obs.	Mean	Median	S.D.	Min	Max
Internet Service Features and Hours Online							
Hours spent on Internet for leisure	2007	2,366	4.32	3	6.66	0	35.5
	2008	2,351	4.96	2.5	7.24	0	32
	2009	2,360	5.50	2.5	7.52	0	32
	2010	2,365	6.13	2.5	8.11	0	32
Hours spent on Internet for work	2007	2,363	3.54	0	7.47	0	35.5
	2008	2,354	3.83	0	7.79	0	32
	2009	2,360	4.09	0	8.01	0	32
	2010	2,356	4.05	0	8.15	0	32
Individual Demographics							
Age	2007	2,414	52.3	52	15.47	18	95
Gender (1: Male, 2: Female)	2007	2,414	1.54	2	0.5	1	2
Income	2007	2,414	58,841	46,250	50,132	3,750	325,000
Financial asset	2007	1,861	316,429	37,500	1,864,883	12,500	25,000,000
Internet experience (years)	2007	1,844	3.46	3.5	1.58	0.5	6.5
Education	2007	2,414	3.55	3	1.89	1	8

Marital Status (Married)	2007	2,414	0.51	1	0.5	0	1
Region	2007	2,414	4.76	5	2.46	1	9
Kids (Has kids under 18)	2007	2,414	1.34	1	0.48	1	2