The Attention Economy: Measuring the Value of Free Digital Services on the Internet

Completed Research Paper

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Abstract

Over the past decade, there has been an explosion of digital services on the Internet, from Google and Wikipedia to Facebook and YouTube. However, the value of these innovations is difficult to quantify, because consumers pay nothing to use them. We develop a new framework to measure the value of free services using the insight that even when people do not pay cash, they must still pay "attention," or time. Using our model, we estimate the increase in consumer surplus created by free internet services to be over $100 billion per year in the U.S. alone. Our analysis implies that most of welfare gain from digital services on the Internet would be overlooked by traditional approaches that rely only on the direct expenditures of money. Considering the time spent on consumption, as we do, makes it possible to assess the full value of these digital innovations.

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

Introduction

Perhaps the most important digital innovation over the past decade is the explosion of services on the Internet. Articles in Wikipedia, friends' pictures on Facebook, maps on Google and videos in YouTube undoubtedly create enormous value for the people who consume them. But how can we quantify the value of these services when so many of them have zero price? The traditional approach is to estimate consumer surplus by considering the demand curve implied by direct money expenses: the dollar price and quantity of goods and services. However, people who already have access to the Internet do not spend any additional money to consume these free services, 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 digital innovations that provide services, content, entertainment or knowledge for free.

Let's start with some basic facts. Wikipedia started in 2001, while Facebook, YouTube, and Google maps were all introduced after the year 2004. In turn, this increase in 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 the U.S. in 2011, individuals spend about 13.8 hours on the Internet at home each week, which is 12% of non-sleeping hours. Time spent on the Internet for uses other than work was about 8.4 hours, or 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 American household. 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 (Alexa.com 2011). Three free sites, Facebook, Google sites, and Yahoo sites accounted for 16%, 11%, and 9% of time spent online, respectively (ComScore.com 2011).

While the consumption of these digital services is enormous, it is difficult to evaluate their value 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 does not contributed to official GDP or productivity statistics. One cannot manage what one doesn't measure. As a result, policymakers, managers and others will be tempted to dismiss or minimize the value of digital innovations that go unpriced, and perhaps underinvest in the people and technologies that make them possible.

Calculating the value of new goods (see e.g. Bresnahan and Gordon, 1997) and in particular free goods and services with widespread user contributions is a challenging question. In this study, we incorporate the value of time spent in consuming free services during the leisure hours. Specifically, every waking hour spent on the Internet necessarily comes at the opportunity cost of time spent consuming other goods and services, or time spent working. We will use this fact to infer the value of free Internet services. We use the opportunity cost of a service -- the amount a person freely gives up in order to get it – to estimate the value of that service.

Thus, our central research question is: *What is the value of welfare gain from the free digital services on the Internet?*

We develop a new framework to quantify the welfare gain from free goods and services on the Internet in recent years since 2007 by extending the time usage data on Internet since 2002. We calculate a benchmark for the two conventional approaches to measuring welfare gains, namely, a time-based model and a money-based model. We build on the insights of Goolsbee and Klenow (2006), hereafter referred to as G&K, in measuring the time value of leisure as well as money value to estimate the value of Internet.

The key contributions of our model can be summarized as follows. First, we develop a model for multiple products of dissimilar characteristics based on the degree of substitutability. For instance, the degree of substitutability among media, e.g., television and internet consumption, might be different from that between other household goods, e.g., internet and food. A CES (constant elasticity of substitution) functional specification of the model enables us to derive distinct estimates for the elasticity of substitution between Internet and television, as well as between the Internet and all other consumption goods. In addition, this utility specification avoids any separability assumption that has typically been assumed in previous studies. For instance, separability would have implied that time spent meeting friends face-to-face would not influence the time spent on the Internet. In contrast, our model accounts for possible interactions among hours spent on multiple activities at online and offline. Overall, we develop a model that is general enough to combine both services which are near-substitutes as well as those that are poor substitutes and in the process, calculate the welfare gain from the Internet as well as from television.

Second, we overcome the over-estimation problem involved in employing log-linear utility function.[1] While the assumption of log-linear utility has many elegant features, a disadvantage is that it assumes that the very first increment of internet use has an infinitely high value.[2] As discussed below, we adapt an approach recently introduced by Greenwood and Kopecky (2010) to overcome this problem.

Third, our model explicitly incorporates new data on the overall quality improvement of Internet since 2002 to estimate annual consumer welfare changes. With this approach, we are able to estimate the annual increase in the welfare gain without changing consumers' preference parameters each year as other cross-sectional model would require (e.g., G&K (2006)). To the best of our knowledge, this is the first approach that has been developed to measure annual welfare gain from free services on the Internet by incorporating not only the opportunity cost of time but also the marginal value of saved time due to the quality improvement.

Our key findings are as follows: the average incremental welfare gain from the Internet between the years 2007 and 2011 is about $159 billion per year. Of that amount, we estimate that about $106 billion accounts for the consumer surplus from the free digital services on the Internet. This corresponds to about 0.74% of annual GDP. In contrast, the welfare estimates are significantly lower when we estimate the welfare gains the traditional way, relying only on money-based expenditures. The best estimate of the annual incremental welfare gain is only about $4.2 billion when we do not consider the value of time. This is less than 1/20th of the estimate derived from our preferred model.

A number of interesting comparisons can be made using 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. In our view, the time-base measures are probably a more meaningful metric of welfare. For example, we can compare our estimate with respect to a simple back-of-the-envelope estimate based on the opportunity cost of time. On average, 34% of the average person's waking hours is time spent working. In turn, labor income share accounts for about 60% of GDP. From 2007 to 2011, 4.9% of waking hours were spent on the free Internet sites based on our estimation. Thus, the number of hours spent on the Internet is roughly equal to the number of hours used to generate about 9% of GDP. In turn, the annual growth rate of GDP is around 2-3%, and 9% of that figure would be a gain of 0.18-0.27% of GDP each year. However, internet usage is growing much faster than overall GDP. Thus, our result of 0.74% of annual gain due to free Internet services strikes us as more reasonable than the 0.03% value that is derived from the purely money-based approach.

Second, our estimate of $106 billion from free Internet services during 2007-2011 is higher than the annual welfare gain of $72 billion from television use during 2007-2011 estimated using the same model. In general, the *level* of welfare from television is about three times higher than that from Internet; however, time spent on the Internet is increasing much more rapidly than time spent on television, so the annual *increase* in the welfare that can be attributed to Internet services is higher.

Third, both our time-based and money-based estimates 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 the consumer surplus from the Internet to be about $64 billion based on a survey where users stated their preferences. While both these papers use very different approaches and are, in fact, measuring somewhat

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[1] Goolsbee and Klenow's (2006) estimate of consumer surplus from Internet using their log-linear utility specification was about 10 times larger than their estimate using a linear utility assumption.

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

different concepts, they both generate values that are in the same general ballpark as our estimates. On the other hand, Greenstein and McDevitt (2009) found a range of \$4.8-\$6.7 billion of welfare gain for seven years of technical improvements and diffusion in broadband Internet services between 1999 and 2006 based on a model using direct market (money) expenditure data. This is much smaller than the estimates we derived when incorporating the value of time, but it is not that far from our own companion model, which relies only on money-costs to estimate the value of the internet. Our money-only model estimated a value of \$4.2 billion for Internet services through 2011.

Fourth, the annual welfare gain of \$106 billion is based on data showing about 21% increase in leisure time spent on the Internet, a 7% increase in leisure hours spent on the television, a 6% increase in Internet penetration rate, a 27% increase in the expenditure share between 2007-2011. From the comparative statics, we provide a calculation of 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. We also are able to disaggregate how each of these increases have affected welfare over this period.

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 the generalized model of welfare calculation in the attention economy and then present the framework to measure the welfare gain from Internet based not only on the money spent on digital services, but also on the time spent on digital services. In Section IV, we discuss the data, and provide the results of consumer surplus from free goods and services on the Internet. In Section V, we compare our results with the welfare gain from television. Finally, in Section VI, we conclude with a discussion of our results.

Literature Review

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

It is well known that GDP statistics ignore the 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 measures the size of both the traditional economy and the rapidly growing digital economy. Due to the nature of digital services, 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 innovations for these services.

Broadly speaking, there are four approaches to measuring the value of unpriced services: 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 services. 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. From equivalent variation (EV) and compensated variation (CV) we can infer the welfare gain for consumers due to price changes after adjusting the possible change in their overall 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. 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, Bresnahan (1986) calculated the derived demand for mainframe computers in financial services and found that most of the benefits from technical advances 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 estimate 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 available time budget whenever they consume information services 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) which we refer 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 as high as 25% of income based on a log-linear specification for demand or around 3% of income if one instead 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.

Recent studies found that the adoption of broadband increases time spent on the Internet. Goldfarb and Prince (2008) found that although high-income were more likely to have adopted the Internet, conditional on adoption, low-income people spend more time online. They examine possible reasons for this pattern such as differences in the amount and opportunity cost of leisure time and differences in the usefulness of online activities. They conclude that the differences in the opportunity cost of leisure time explain this pattern the best. This is consistent with our model's assumption that the opportunity cost of leisure is higher for high income people. Hitt and Tambe (2007) examine how broadband access drives changes in the quantity and diversity of consumption of online content before and after broadband adoption. They found that on average, broadband adoption increases Internet usage by over 1300 minutes per month. They also found that information consumption becomes more evenly distributed within the population, driven in part by post-adoption usage gains of almost 1800 minutes per month among individuals who were in the lowest usage quintile before adopting broadband. More recently, Kolko (2010) focused in assessing how broadband adoption affects Internet usage behavior. Consistent with Hitt and Tambe (2007), he finds that broadband adopters increase their overall Internet usage.[3]

Measuring Welfare Gains on the Internet

We assume that consumers can be described by a utility function is a Constant Elasticity of Substitution (CES) function of three bundles of goods, Internet, television, and all other goods. We choose the CES specification because it is simple and has relatively few parameters.[4]

There are three ways of nesting hours spent on Internet, T_1, hours spent on television, T_2, and consumption of other goods and leisure (C, L), within a CES function, which assume Internet or TV good-composites goods complementarity: $\tilde{u}_1 = \Phi_1(T_1, \Phi_2(CL, T_2))$, $\tilde{u}_2 = \Phi_1(T_2, \Phi_2(CL, T_1))$, and $\tilde{u}_3 = \Phi_1(CL, \Phi_2(T_1, T_2))$. As well known in the literature, the CES functional form imposes symmetry restrictions on substitution elasticities (see e.g., Krusell et al. 2000). For $\tilde{u}_1$, the elasticity of substitution between T_1 and (C, L) is restricted to be the same as that between T_1 and T_2. In the case of $\tilde{u}_2$, the elasticity of substitution between T_2 and (C, L) is restricted to be the same as that between T_1 and T_2. These restrictions, however, are at variance with our intuition that the substitution elasticity between media such as Internet and TV is higher than the substitution elasticity between media and other goods. Moreover, we find that first two specifications are not as consistent with the data.

For $\tilde{u}_3$, the CES function restricts the elasticity of substitution between Internet and other goods to be the same as that between television and other goods while the elasticity of substitution between Internet and television might be higher than that between Internet and other goods. Therefore, we use the third application in our analysis.

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[3] The increase in time spent on the Internet likely reflects the introduction of new services which consumers value, such as Facebook. 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 services 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.

[4] Goolsbee and Klenow (2006) and Greenwood and Kopecky (2011) also used a CES-type utility function. Their research analyzes substitution elasticity between Internet or personal computer and all other goods. However, they both assume a separable utility function. An alternative to the CES form, we considered the more flexible translog function. The translog approach, however, required estimation of far more parameters, which would reduce degrees of freedom in our small sample.

Consider an individual, with wage W, who receives utility from her consumption of leisure and goods. We differentiate between time spent on Internet, television, and all other goods as well as between time spent on consumption versus work versus leisure. Individuals obtain utility from three types of bundles: an Internet bundle, a television bundle, and a composite good bundle of all other goods. In the spirit of G&K (2006), we develop a utility function to account for both time and market spending for a good. An Internet and television bundles are each a highly time-intensive services; individuals spend a significant amount of time without spending any additional money other than subscription fee. In turn, a composite good bundle is less time intensive; people obtain utility from spending both money and leisure time. In addition to deciding how to allocate their leisure, consumers must decide how any hours to devote to paid work, which necessarily comes at the expense of hours they could have otherwise spent for leisure. Available time and the wage rate are the constraints that people face. Consumers seek to maximize their utility, which is a weighted sum of three main components, time spent on Internet, television, and consumption of all other goods.

$$U_{\{I_1,I_2,T_1,T_2,C,L\}}=\left\{\theta_0\left[\theta_1\left(I_1^{\alpha_1}(T_1+\kappa_1)^{1-\alpha_1}\right)^{1-\frac{1}{\sigma_1}}+(1-\theta_1)\left(I_2^{\alpha_2}\cdot(T_2+\kappa_2)^{1-\alpha_2}\right)^{1-\frac{1}{\sigma_1}}\right]^{\left(\frac{\sigma_1}{\sigma_1-1}\right)\cdot\left(1-\frac{1}{\sigma_0}\right)}+(1-\theta_0)\left[C^{\alpha_0}\cdot L^{1-\alpha_0}\right]^{\left(1-\frac{1}{\sigma_0}\right)}\right\}^{\frac{\sigma_0}{\sigma_0-1}}$$

I_1 and I_2 denotes Internet and television goods consumption and T_1 and T_2 represents the fraction of total time devoted to the Internet and television at home. All other purchased goods and services form a composite good C. In turn, L is the fraction of time spent on the composite good. Each α_1, α_2 and α_0 corresponds to the degree of money intensity of Internet, television, and composite goods. The time intensity of each Internet goods, television goods, and composite goods are represented as each $(1-\alpha_1)$, $(1-\alpha_2)$, and $(1-\alpha_0)$. The money intensity parameters, $\alpha_1,\alpha_2,\alpha_0$ can be defined as $\alpha_1=P_1I_1/(P_1I_1+WT_1)$, $\alpha_2=P_2I_2/(P_2I_2+WT_2)$, and $\alpha_0=P_0C\ /(P_0C+WL)$ where P_1,P_2,P_0 denotes price of each good. The elasticity of substitution between Internet and television usage is represented by the parameter σ_1, while the elasticity of substitution between technology goods and all other goods' consumption, is captured by the parameter σ_0.

Note that if the money intensity parameter of Internet and television good, α_1,α_2 are equal to zero, the model reduces to the following utility function. We present our time-based model as follows. The individuals maximize their utility subject to the budget constraint and the non-negativity condition

$$Max_{\{T_1,T_2,C,L\}}\left\{\theta_0\left[\theta_1(T_1+\kappa_1)^{1-\frac{1}{\sigma_1}}+(1-\theta_1)(T_2+\kappa_2)^{1-\frac{1}{\sigma_1}}\right]^{\left(\frac{\sigma_1}{\sigma_1-1}\right)\cdot\left(1-\frac{1}{\sigma_0}\right)}+(1-\theta_0)\left[C^{\alpha_0}\cdot L^{1-\alpha_0}\right]^{\left(1-\frac{1}{\sigma_0}\right)}\right\}^{\frac{\sigma_0}{\sigma_0-1}}$$

$$PC+F=W(1-\frac{T_1}{Q}-T_2-L)$$

$$T_1,T_2,C,L\geq 0.$$

In the budget constraint, W refers to the wage, the opportunity of time spent on Internet, Q represents the quality of Internet. When the quality of Internet increases, then the effective hours spent on Internet decreases. Therefore, Q measures the marginal value of time spent on Internet. P is the price of the composite good, and F is any fixed fee for subscribing to the Internet in a given period, respectively.

Let the utility function to be $U(T_1,T_2,C,L)$ with $\sigma_0,\sigma_1>0$. $U(T_1,T_2,C,L)$ satisfies the standard properties of $U_1(T_1, T_2, C, L) > 0$, $U_{11}(T_1, T_2, C, L) < 0$, $\lim_{T_1, T_2, C, L \to \infty} U_1(T_1, T_2, C, L) = 0$. $U(0, T_2, C, L)$ denotes utility level from Internet when the relative price is equal to or higher than the virtual price represented as $\widetilde{Q}$ below (Hausman 1999; Hicks 1940). By introducing the parameters κ_1, κ_2 in specifying the utility function, we avoid the problem of marginal utility around zero consumption of Internet and television approaching infinity in a log-linear utility function (see Greenwood and Kopecky 2011). Instead, the parameters κ_1, κ_2 shift the curve to the left, so that it intersects the y-axis at a finite level. Additionally, introducing κ_1, κ_2 to the model enables us to achieve a corner solution, as well as interior solution. A corner solution where Internet or TV consumption is equal to zero is utilized in calculating the consumer surplus when the Internet or TV is not available. This correspond to the "virtual price" at which new goods can be introduced and bounds the utility that a consumer gets from their introduction (see e.g. Hicks, 1940).

Since the marginal utility of zero Internet time is bounded below, the solution to the individual's maximization problem could be at a corner where $T_1 = 0$. The solution to the above problem determines the demand functions for the time share of Internet, television and composite good consumption along with the threshold price, Q relative to P. For any given wage level, W, there exists a threshold price $\widetilde{Q}(W)$ such that the optimal time spent on Internet will be zero if $Q \leq \widetilde{Q}(W)$, i.e., relative shadow price for Internet is high where $\widetilde{Q}(W)$ solves for the following equation:

$$\frac{1}{\Gamma} \cdot \frac{1}{(1-\alpha_0)} + \left[\frac{1-\theta_1}{\theta_1} \cdot \frac{1}{\widetilde{Q}} \right]^{\sigma_1} < \frac{1 - F/W + \kappa_2}{\kappa_1}.$$

where $\Gamma = \left[\frac{1-\theta_1}{\theta_1} \frac{1}{\widetilde{Q}} \right]^{\sigma_1[\sigma_0 - 1]} \left[\frac{\theta_1}{1-\alpha_0} \right]^{\sigma_0} \left(\frac{\alpha_0}{1-\alpha_0} \frac{W}{P} \right)^{-\alpha_0 \sigma_0} \left[\frac{\theta_0}{1-\theta_0} \right]^{\sigma_0} \left[\widetilde{Q} \right]^{\sigma_0}$

The demand for time share of Internet is:

$$T_1 = T_1(P, Q, W) = \begin{cases} 0, & \text{if } Q < \widetilde{Q}(W); \\ \dfrac{\Gamma \left[1 + \kappa_2 - \dfrac{F}{W} - \dfrac{\kappa_1}{Q} \right]}{\left[\dfrac{1}{1-\alpha_0} + \dfrac{1}{Q} \cdot \Gamma + \Gamma \cdot \left[\dfrac{1-\theta_1}{\theta_1} \cdot \dfrac{1}{Q} \right]^{\sigma_1} \right]} - \kappa_1, & \text{if } Q \geq \widetilde{Q}(W), \end{cases} \tag{1}$$

$$T_2 = T_2(P, Q, W) = \begin{cases} (see\,below) & \text{if } Q < \widetilde{Q}(W); \\ \left[\dfrac{1-\theta_1}{\theta_1} \dfrac{1}{Q} \right]^{\sigma_1} \cdot \dfrac{\Gamma \left[1 + \kappa_2 - \dfrac{F}{W} - \dfrac{\kappa_1}{Q} \right]}{\left[\dfrac{1}{1-\alpha_0} + \dfrac{1}{Q} \cdot \Gamma + \Gamma \cdot \left[\dfrac{1-\theta_1}{\theta_1} \cdot \dfrac{1}{Q} \right]^{\sigma_1} \right]} - \kappa_2 & \text{if } Q \geq \widetilde{Q}(W), \end{cases} \tag{2}$$

The entire corner solution is characterized by the following one equation with respect to T_2:

$$(1-\alpha_0)\left[1-T_2-\frac{F}{W}\right]=\left[\frac{\theta_0}{1-\theta_0}\frac{1-\theta_1}{1-\alpha_0}\right]^{-\sigma_0}\left[\frac{\alpha_0}{1-\alpha_0}\frac{W}{P}\right]^{\alpha_0(\sigma_0-1)}\left[\theta_1\kappa_1^{\frac{\sigma_1-1}{\sigma_1}}+(1-\theta_1)T_2^{\frac{\sigma_1-1}{\sigma_1}}\right]^{\frac{\sigma_0-\sigma_1}{\sigma_1-1}}\cdot T_2^{\frac{\sigma_0}{\sigma_1}}$$

By numerically solving the above equation with respect to T_2, we derive C, Las a function of T_2. Then the demand for composite consumption bundle is:

$$C=C(P,Q,W)=\begin{cases}\left(\dfrac{\alpha_0}{1-\alpha_0}\cdot\dfrac{W}{P}\right)\cdot L & \mathit{if}\;\; Q<\tilde{Q}(W);\\[2ex] \dfrac{\alpha_0}{1-\alpha_0}\cdot\dfrac{W}{P}\cdot\left\{\dfrac{1+\kappa_2-\dfrac{F}{W}-\dfrac{\kappa_1}{Q}}{\left[\dfrac{1}{1-\alpha_0}+\dfrac{1}{Q}\cdot\Gamma+\Gamma\cdot\left[\dfrac{1-\theta_1}{\theta_1}\cdot\dfrac{1}{Q}\right]^{\sigma_1}\right]}\right\} & \mathit{if}\;\; Q\geq\tilde{Q}(W),\end{cases}\tag{3}$$

and

$$L=L(P,Q,W)=\begin{cases}(1-\alpha_0)\left[1-T_2-\dfrac{F}{W}\right], & \mathit{if}\;\; Q<\tilde{Q}(W);\\[2ex] \dfrac{1+\kappa_2-\dfrac{F}{W}-\dfrac{\kappa_1}{Q}}{\left[\dfrac{1}{1-\alpha_0}+\dfrac{1}{Q}\cdot\Gamma+\Gamma\cdot\left[\dfrac{1-\theta_1}{\theta_1}\cdot\dfrac{1}{Q}\right]^{\sigma_1}\right]}, & \mathit{if}\;\; Q\geq\tilde{Q}(W).\end{cases}\tag{4}$$

Time-Use Model

We briefly discuss how to measure welfare gain to consumers from the free goods and services on the Internet since 2007. One way of measuring welfare gain is based on equivalent variation (EV). Begin by supposing the price of Internet access is so high that it is almost same as if the Internet is not available at all. 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?

First, suppose that Internet had never been invented. This is equivalent to assuming that price of Internet access is prohibitively high or Q, the quality of Internet is extremely low. Let δ_{EV} be the compensation in terms of income to maintain the actual consumption level, $C_{without}$. The maximal utility level a person will get can be written as follows when the Internet does not exist; she will spend her entire time on either work or non-internet leisure such as watching television or consuming other goods.

$$M((1+\delta_{EV})C_{wthout},\infty)=\left\{\theta_0\left[\theta_1\kappa_1^{\frac{\sigma_1-1}{\sigma_1}}+(1-\theta_1)(T_2+\kappa_2)^{\frac{\sigma_1-1}{\sigma_1}}\right]^{\left(\frac{\sigma_1}{\sigma_1-1}\right)\cdot\left(1-\frac{1}{\sigma_0}\right)}+(1-\theta_0)\left(\left\{(1+\delta_{EV})\cdot\left(\frac{\alpha_0}{1-\alpha_0}\right)\cdot\frac{W}{P}\cdot L\right\}^{\alpha_0}\cdot L^{1-\alpha_0}\right)^{1-\frac{1}{\sigma_0}}\right\}^{\frac{\sigma_0}{\sigma_0-1}}$$

The equivalent variation, δ_{EV}, measures the amount such that a consumer would be indifferent between consuming $(1+\delta_{EV})C_{without}$ of the composite good with no Internet when the price of Internet is infinite, and the actually observed consumption bundle of with Internet among wealthy people. Let M specifies the welfare level of $M(C_{with}, Q_{with})$ indicated by the indirect utility function. Equation (5) denotes the equivalent variation implied from the model. Notice that the equivalent variation can be computed given data on total expenditures and prices, and estimates of the six preference parameters, $\theta_1, \theta_0, \kappa_1, \kappa_2$, and σ_1, σ_0.

$$\delta_{EV} = \left\{ \left[\frac{M^{1-\frac{1}{\sigma_0}} - \theta_0 \left[\theta_1 \kappa_1^{\frac{\sigma_1 - 1}{\sigma_1}} + (1-\theta_1)(T_2 + \kappa_2)^{\frac{\sigma_1 - 1}{\sigma_1}} \right]^{\left(\frac{\sigma_1}{\sigma_1 - 1}\right) \cdot \left(1 - \frac{1}{\sigma_0}\right)}}{1-\theta_0} \right]^{\frac{\sigma_0}{\sigma_0 - 1}} \cdot \frac{1}{L} \right\}^{\frac{1}{\alpha_0}} \cdot \frac{P}{W} \cdot \frac{1-\alpha_0}{\alpha_0} - 1 \qquad (5)$$

We calibrate the set of parameters using above equation (1). Then we calculate annual welfare gain using equation (5).

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, the money model only estimates the consumer surplus from expenditure share on Internet measured in dollars. An incremental annual welfare gain, measured as the difference between equivalent variation(EV^t), can be calculated as shown in equation (6).

$$Welfare\ gain\,|_{2007}^{2011} = \sum_{t=2007}^{2011} (EV^t - EV^{t-1}) \qquad (6)$$

Money-spending model

We address two methods to estimate consumer surplus based on the expenditure of Internet subscription fee. One way is based on cumulative method (Brynjolfsson 1996) to approximate the increase in Internet users, denoted as ΔQ^t in equation (7) each year. This makes use of data on intermediate points, which may not lie exactly on the estimated demand curve.

$$\text{Cumulative method: } \sum (P^t - P^{t-1}) \Delta Q^t (W^1 / W^t) \quad for\ \ t = 0, \ldots, 1 \qquad (7)$$

Another 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.

$$\text{Index method: } 0.5 \times (s^1 + s^0) \ln(\frac{P_0}{P_1}) W_1 \qquad (8)$$

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 (8). By construction, the 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.

$$Welfare\ gain\,|_{2007}^{2011} = 0.5 \times \sum_{t=2007}^{2011} \left[(s^{t+1} + s^t) \ln(\frac{P^{t+1}}{P^t}) \right] W^{t+1} \qquad (9)$$

In Section IV, we measure 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. Then we present our analysis starting from as early as year 2007 using the data.

Quantitative analysis

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.

Individuals in the survey conducted by Forrester are members of an 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.

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 consumers" instead of only "Internet users". This is reflected in a large, and we think spurious, drop in the reported level of hours spent on Internet per respondent in 2007 vs. 2006. For this reason, we perform our analyses using balanced panel data during 2007 -2010 which seems to be consistent. There are 2,414 respondents in the period of 2007-2010. We present the descriptive statistics of balanced panel data in the Table1.

Table 1. Panel data- Hours spent on Internet for leisure

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

Figure 1 illustrates monthly hours spent on Internet for leisure. The data from Nielsen Three Screen Report starts as early as 1994 while the data from Forrester research is focused on more recent years. In 2007-2011, non-work purpose Internet usage data obtained from Forrester research and Nielsen Report are similar. We calibrate the set of parameters using the Nielsen data starting from 2002.

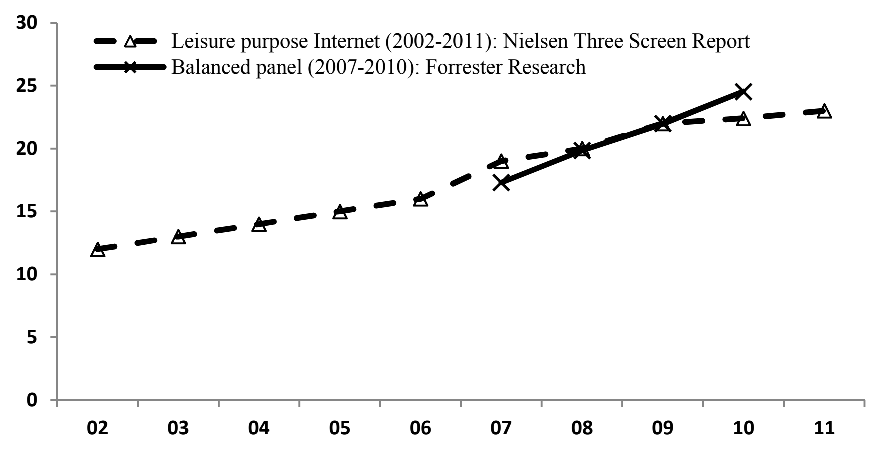

Figure1. Monthly Non-work Purpose Internet hours

Table 2 presents an overview of changes in the share of Internet expenditure and time spending in our panel data. The expenditure share came from from NIPA table 2.4.5 and Internet penetration rate from the World Bank. The expenditure share increased about 36% in dollar terms and the Internet population increased about 6% between 2007 and 2011. Adjusted expenditure share (in dollars) on the Internet for the average Internet user is about 0.66% in year 2011. This is an increase of about 27% compared to the year 2007. Weekly Internet hours spent on leisure increased from 4.8 to 5.8 hours per week which indicates about 21% increase in the non-sleeping hours (assumed to be 16 hours per day, or 112 hours per week) compared to the year 2007. Weekly hours spent in watching television is more than three times higher than hours spent on Internet; however, it has increased only about 7% between 2007-2011.

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	Hours spent on Television
Year 2007	0.0039	75.17%	0.0052	4.75	18.34
Year 2008	0.0043	74.15%	0.0058	5	19.39
Year 2009	0.0049	78.17%	0.0062	5.5	19.74
Year 2010	0.0053	79.34%	0.0066	5.6	18.9
Year 2011		80.02%	0.0066	5.75	19.6
% Change	35.90%	6.45%	26.92%	21.05%	6.87%

We collected total number of websites on the Internet data from a web server survey by Netcraft.com. Figure 2 summarizes annual increase in the total number of hostnames and number of active sites. When the number of informative websites increases, it reduces the costs of searching, communicating and transacting. We use these two measures as proxy of improvement in the supply side of Internet quality and we present the result using the number of active sites which is a more conservative approach for gauging the speed of quality website provision.

Figure 3 summarizes the Internet access Prices Index from NIPA table 2.4.4 and an estimated speed-adjusted price index of Internet. We collected Internet speed data from Net Index by Ookla. The company specializes in broadband testing and web-based network diagnostic applications with certain standards for accuracy, popularity, ease of use and subsequent development of statistical data, collected from more than three million people a day use the software. The download speed measured as MB/second has improved about 18% each year. We combine the NIPA Internet price index with the Ookla data to calculate a new speed-adjusted price index. We then derive the welfare gain using this price index.

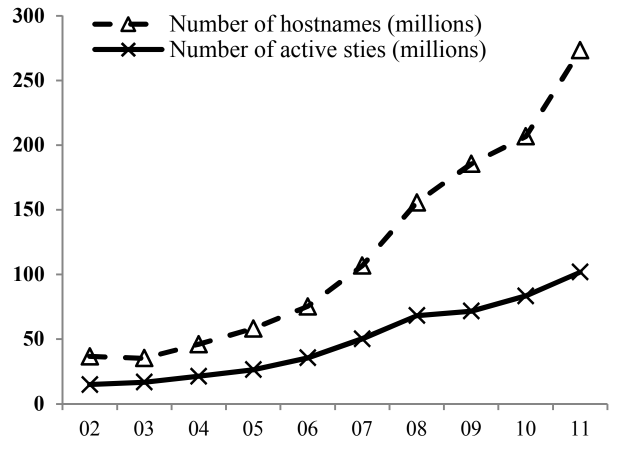

Figure 2. Number of websites on the Internet

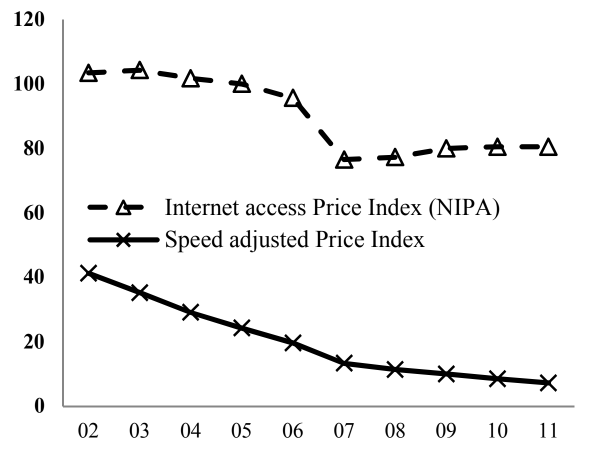

Figure 3. Speed-adjusted Internet Price Index

Calibration Results

Our goal is to compute the welfare gain from Internet to consumers based on the time spent data. In order to compute this, we have to estimate or calibrate six preference parameters: the elasticity of substitution, σ_1, σ_0, the weight on the utility from the time spent on Internet and the bundle of Internet television together, θ_1, θ_0 , and the parameter κ_1, κ_2 , that determines the utility level when the hours spent on Internet and television is zero. Altogether, these parameters specify the utility from Internet, television and other goods.

The predicted proportion of time spent on Internet at year t, $\hat{T}_{1t}$, given the parameter values, can be computed by plugging in the corresponding quality, price and income level, Q_t, P_t, W_t, into the demand functions specified by (1). The preference parameters can be determined by minimizing the sum of the squares of the difference between the time spent on Internet as observed in the data and the time spent as predicted by the model during the period. We estimate the parameters by solving the following equation

$$\underset{\sigma_1,\sigma_2,\theta_1,\theta_2,\kappa_1,\kappa_2}{Min} \sum_{t=2002}^{2011} \left[T_{1t} - \mathrm{T}_{1t}(\sigma_1,\sigma_2,\theta_1,\theta_2,\kappa_1,\kappa_2; W_t, Q_t, P_t) \right]^2 .$$

Table 3. Calibration of parameters							
	σ_1	σ_0	θ_1	θ_0	κ_1	κ_2	R^2
Parameters	1.363	1.145	0.441	0.185	0.001	0.020	0.997

Table 3 summarizes the calibration results. We obtained a value for σ_1 of 1.363, value for σ_0 of 1.145. As we predicted, the elasticity of substitution between Internet and television is much higher than that between Internet and other goods. The weight parameter value of θ_1 is 0.441, and θ_0 is 0.185, which reveals relative importance of Internet bundle. The constant parameter κ_1, κ_2 are estimated as low as 0.001 and 0.020. The calculated R^2 of the prediction for the hours spent on Internet is 0.997.

Table 4 provides estimates of two different methods, the time-based model from equation (6) and the money-based model from equation (9). In our time-based model, we estimate that the consumer surplus created from the Internet is on average $838 billion which corresponds to about 5.8 % of GDP. Our number is higher than G&K who report 2.9% based on the year 2005. On average, the incremental annual gain is about $159 billion during 2007-2011.

In contrast, the money model relies on market share of Internet cost as measured in dollars spent. The annual gain from the money model is negative when the price increases. The Internet access price index from NIPA table 2.4.4 shows slightly increasing trends after 2006. This reflects a huge price drop of Internet subscription fees mainly due to a pricing change of AOL. In turn, the speed adjusted price index consistently decreases over time as shown in Figure 3. The welfare gain based on this speed-adjusted index ranges around $3.4 to $5.1 billion. Overall, we estimate about $4.2 billion as the annual surplus gain from the money model in equation (9).

The difference between time-based model and money-based model is enormous, averaging over $155 billion per year. Our results suggest that only about 4% of total CS gain from the Internet would be revealed by estimates that rely only on the direct dollar expenditure. The full gain is visible only when one considers time use. The result implies that there is a gain each year equivalent to nearly 1.1% of GDP from the Internet. This gain does not appear in the GDP or productivity statistics, but creates real value for consumers.

Table 4. Estimation of Consumer Surplus

$Billion	Time model	Yearly gain (Time model)	Yearly gain (Money model)
Year 2007	$562 B		
Year 2008	$718 B	$156 B	$3.7 B
Year 2009	$676 B	$(41.7) B	$3.4 B
Year 2010	$1,040 B	$364 B	$4.5 B
Year 2011	$1,196 B	$156 B	$5.1 B
Average (2007-2011)	$838 B (5.83% of GDP)	$159 B (1.10% of GDP)	$4.18 B (0.03% of GDP)
Yearly value per user		$740/user	$19/user

We estimate consumer surplus gain from free goods and services based on time spent on free sites. On average, more than two-thirds of time spent online is at so-called free sites (Stranger and Greenstein 2007), and this suggest that a commensurate share of the welfare gain comes from free sites.[5] Table 5 summarizes our estimates of welfare gain from free goods and services on Internet. Annually, the increase in value due to free online services is about $106 billion and this corresponds to about $492 every year for individuals according to the time-based model. In contrast, the money model implies that the yearly value of free services on Internet is only $20 per user.[6] The values from the time based model strikes us as more plausible.

Table 5. Estimation of Annual welfare Gain from Free Goods and Services

ΔCS^{yearly}	Time Model	Money Model
Total yearly gain	$106 (billion)	$4.2 (billion)
Yearly gain (/person)	$492	$20
Monthly (/person)	$41	$1.6
Hourly (/person)	$1.9	$0.07
% GDP (% Yearly)	(0.74%)	(0.03%)

Table 6 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 annual incremental gains in consumer value from Facebook and YouTube are estimated to be about $9.8 and $5.3 billion, respectively.

Table 6. Yearly Consumer value from Free Internet sites

	Reach%	Minutes	Time share	Yearly CS ($Billion)
Facebook	0.434	24	16.00%	16.7
YouTube	0.330	17	8.62%	9.1
Twitter	0.093	7	0.99%	1.1
Wikipedia	0.144	4	0.88%	0.9
LinkedIn	0.050	7	0.53%	0.6
Craigslist	0.015	13	0.30%	0.3

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[5] If there exists a positive correlation between Internet time spending and the demand for free services, the share of consumer surplus from free services might be higher, and conversely, it might be lower if the correlation is negative. For simplicity, we do not consider any correlation.

[6] These values are calculated based on the following estimates: the number of average Internet users during 2007 and 2011 is about 215 million, and hours spent of free sites are about 5.5 hours per week.

In 2011, the total revenue and cost of Facebook is reported as $3.7 billion and $2.7 billion. This results in the marginal value to the consumers per dollar revenue of Facebook to be around $4.5 (from the value/revenue ratio). The marginal gain of consumer value per dollar expense is around $6.2 (from the value/cost ratio). For the case of Google Inc., the total time share of Google takes about 11% which corresponds to $11.7 billion. In 2011, total revenue and cost is equivalent to each $10.6 billion and $3.7 billion. This yields $1.1 of consumer value per dollar of revenue and $3.2 of value per dollar of expense. Wikimedia foundation reports that the total revenue and cost of Wikipedia is each $0.25 billion and $0.18 billion. This generates marginal value of $3.6 per dollar of revenue and $5 per dollar of expense.

Welfare gain from Television

An advantage of our model is that one can estimate the welfare gain from innovations not only in digital services, but for any new goods or technology whose money price is not observable or non-existent, as long as we have the relevant time-use data. One of the most important and comparable leisure goods to the Internet is television. Following the approach that is used for Internet, the welfare gain is computed for the television together with Internet, using time spent on television data from the American Time Use Survey (ATUS).

Figure 4 illustrates the welfare gain from overall Internet, free goods on the Internet, and television. Note that the overall hours spent on television is much higher than that on Internet; on average, consumers spent around 19 hours in a week on television. However, the welfare gap between consumer surplus from Internet and that from television is decreasing over time and nearly close in 2011.

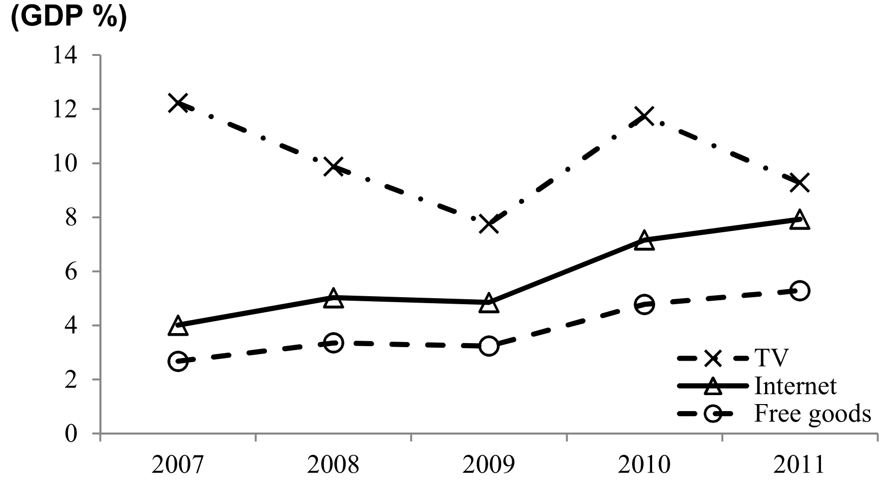

Figure 4. **Consumer surplus (EV) from Internet, Free goods, and Television**

On the other hand, the growth rate of time spent on television is relatively flat compare to the Internet. Consumer surplus from television has declined slightly from about 13% of GDP to less than 10%. Table 7 compares our results for the television, the internet and free sites on the Internet. The equivalent variation from television during 2007-2011 is around 10% of GDP which is nearly twice as high as the value from Internet. However, the *incremental* annual gain from television during the same period is about $72 billion which is only half as much as the incremental annual gain in consumer surplus from digital services on the Internet ($159 Billion) and doesn't even match the $106 billion increase in welfare that free internet services alone provide each year.

Table 7. Comparison of consumer surplus from Television, Internet and Free sites

Year	Television	Annual gain from Television	Internet	Annual gain from Internet	Free sites	Annual gain from free sites
2007	$1,715 B		$562 B		$375 B	
2008	$1,410 B	$(305) B	$718 B	$156 B	$478 B	$104 B
2009	$1,080 B	$(330) B	$676 B	$(41.7) B	$451 B	$(27.8) B
2010	$1,706 B	$615 B	$1,040 B	$364 B	$693 B	$243 B
2011	$1,399 B	$(306) B	$1,196 B	$156 B	$797 B	$104 B
Average (2007-2011)	$1,462 B (10.17% of GDP)	$72B (0.50% of GDP)	$838 B (5.83% of GDP)	$159 B (1.10% of GDP)	$559 B (3.89% of GDP)	$106 B (0.74% of GDP)

Concluding Remarks

Most people have an intuitive sense that digital innovations contribution significantly to our well-being and that these contributions are growing over time as new services are introduced and existing services are enhanced. However, metrics like GDP, or even traditional approaches to consumer surplus, cannot accurately reflect the value of these innovations when the market prices are effectively zero. This is the case for many of the new services available over the Internet, where most of the real cost to users is in terms of time, not money. Making the right decisions about investments in these services, public policy, management, and research agendas, must begin with an accurate assessment of the magnitude and value of these services.

We develop a framework which makes it possible to estimate the consumer surplus created by free services on the Internet, which considers the time component. In particular, we contrast the results using two different methods that emphasize the value of time spent consuming free services 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 estimate that the welfare gain from free goods and services averaged over $100 billion per year during the period 2007-2011. This corresponds to a large fraction of the average annual growth in GDP in those years. In contrast, we find that most of the total welfare gain would be overlooked by approaches that rely only on direct dollar expenditures.

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