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The Broadband Bonus:
Accounting for Broadband Internet's Impact on U.S. GDP

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Not for quotation. Comments welcome.

Abstract

What is the economic value created by the increased use of broadband? We provide a set of benchmark estimates that suggest broadband created approximately 15 billion dollars of economic value between 1999 and 2006. Depending on the estimate, it reaches approximately $8.3 to $10.6 billion of additional revenue between 1999 and 2006, and between $6.7 and $4.8 billion in consumer surplus, on a base of total revenue that is approximately $20 to $22 billion. That is, broadband generates new additional revenue between 40% and 50% of measured GDP, while consumer surplus (which is not measured) is between 31% and 47% of the new revenue created. The study also raises questions about the construction of the price index for Internet access. The index would have to decline by 1.6% to 2.4% per year to account for the benefit of this widespread upgrade.

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1. Introduction

In September 2001, approximately 45 million US households accessed the Internet through a dial-up connection, while only 10 million used a broadband connection.[2] By March, 2006, a sharply contrasting picture emerged: Approximately 47 million households (and growing) had broadband, while 34 million (and declining) used dial-up.[3] The economic determinants behind this trend are straightforward: Dial-up became available first and diffused to more than half of US households. Broadband emerged later as a higher quality alternative, albeit a more expensive alternative that was available in only a few places and from a limited set of providers, if any. The service became more readily available over time, and, as that happened, many households paid to upgrade their dial-up Internet with broadband.

The upgrade to broadband motivates a seemingly straightforward question: What is the economic value created through the replacement of dial-up access with broadband? No researcher has calculated a benchmark answer to this question. This is unfortunate since this market is worth tens of billions of dollars and considered to be an important infrastructure. Moreover, a rendering of numerical estimates would illustrate the importance of missing data and/or unrecognized assumptions in the models underlying policy discussion. The goal of this study is to provide that benchmark in the spirit of Johnson's quote, who states, "That, sir, is the good of counting. It brings every thing to a certainty, which before floated in the mind indefinitely."[4]

[2] The source for these statistics is NTIA (2004).
[3] See Horrigan (2007) at http://www.pewinternet.org/.
[4] From *Boswell's Life of Johnson*.

There are two conventional alternative approaches for understanding the value created by a new good. One conventional approach focuses on the value created by the creation of new gross domestic product (GDP). The other conventional approach focuses on the creation of new consumer surplus. Neither is better than the other; each measures something conceptually different. The open question in this case concerns the size of each, and the sensitivity of estimates to different assumptions about the processes underlying diffusion of broadband.

Making benchmark estimates requires accurate data on prices and quantities for household use of the Internet. One of the novelties of this paper is to assemble many publicly available sources of data. After doing that we do not perform estimation in the usual sense. Instead, we perform an accounting and calibration exercise that relies on comparatively straightforward models and methods, while remaining consistent with the available data. That exercise exposes the importance of specific assumptions for inferences about the economic gains from broadband. It also focuses attention on areas that require improvement in order to estimate a benchmark answer with more precision.

Our main theme should not be a surprise: the economic gain from broadband is much larger than what is actually measured by government statistics. Our primary contribution is to estimate the plausible range of the size of the measured and unmeasured gains. We find that broadband created approximately $15 billion dollars of additional value. We show that this reaches approximately $8.3 and $10.6 billion of additional revenue between 1999 and 2006, and between $6.7 and $4.8 billion in consumer surplus, on a base of total revenue between $20 and $22 billion. That is, broadband generates

new additional revenue between 40% and 50% of measured GDP, while consumer surplus (which is not measured) is between 31% and 47% of the newly created revenue.

A third way to measure economic progress is as an equivalent decline in prices. We also perform this exercise. It highlights one major measurement problem: the CPI for household Internet access in the US is quite easy to misinterpret (for reasons explained in the text). We recalculate the index in light of the standard suggestion to value a new good's price change as the decline from its reservation value. We show price indices would have to decline 1.6% to 2.4% per year to account for the benefit generated from upgrading to broadband, which it currently does not do.

This paper is motivated by long standing policy interest in deployment of the "last mile," i.e., the supply of services to deliver data between the national data grid and end-users. National policy for this part of infrastructure has tended to follow market events, and, accordingly, it changed as the commercial Internet emerged over the early to mid-1990s.[5] At first, most federal policy sought to subsidize the deployment of dial-up technologies to less-served areas and users, but another line of policies emerged later and attempted to alter the incentives of private actors to deploy broadband technologies.[6] During this build-out, the only measurement issues to receive much attention were the low availability of broadband, which motivated the aforementioned changes to policies.

[5] Then US national policy focused on deploying technologies that allowed for higher data-transfer rates over telephone lines, such as ISDN. ISDN stands for Integrated Service Date Networks, and supported bandwidth speeds of 128k.

[6] For example, the e-rate program was a provision of the 1996 Telecommunication Act and sought to subsidize the cost of deploying dial-up access for hard-to-serve areas. Later, changes to access and interconnection policies altered investment incentives for incumbent local exchange providers. Later still, the FCC reclassified broadband investment outside the range of procedures used to review common carriers. For overview, see Neuchterlein and Weiser (2005) and Greenstein (2008).

There also were attempts to rank the US deployment in comparison to deployment in other countries.[7] The latter especially gets attention because the US was the earliest country to use the Internet, but has gradually fallen in its ranking. We overlap with one of the core concerns of these exercises by highlighting the importance of measuring non-price aspects of service, such as bandwidth improvements. We depart from this literature by raising issues related to measuring GDP, consumer surplus, and upgrade biases in price indices.[8]

Our plan is as follows: We first provide a brief overview of the history of the measurement of Internet access in the US to familiarize readers with the timing and size of the market. We then consider the history of the price index for Internet access for the last decade. Following that, we discuss the data we collect and perform our simulations of the value created by the diffusion of broadband. Finally, we conclude and offer an assessment of future directions for policy discussions.

2. Internet deployment policy and gaps in measurement

To familiarize readers with this technology and market, we provide a picture of deployment, adoption, and revenue generation for broadband. All these data tell a similar story. The diffusion of dial-up coincided with the initial use of the Internet in most households. The diffusion of broadband came a few years later and, most commonly,

[7] See http://www.oecd.org/document/54/0,3343,en_2649_33703_38690102_1_1_1_1,00.html, e.g., OECD Broadband Portal. For an interpretation, see Atkinson et al (2008).

[8] The paper closest to us is Flamm, Friedlander, Horrigan, and Lehr (2007), which also raises concerns about measurement for policy making. We share the same core motivation, to end the silence about these issues. Flamm et al focuses on other aspects of the topic, such as measuring productivity and assembling new data to accommodate novel on-line economic behavior.

involved an upgrade of the bandwidth for access services to many households.[9]

For all intents and purposes, broadband service is delivered to households primarily in two forms: over cable lines or over telephone lines. The former involved a gradual upgrade to cable plant in many locales, depending on the generation of cable system.[10] The latter involved upgrades to telephone switches and lines to make it feasible to deliver a service called Digital Subscriber Line (DSL). Both of these usually supported higher bandwidth to the household than from it (typically called Asymmetric Digital Subscriber Line (ADSL) in the latter case). Some cable firms built out their facilities to deliver these services in the late 1990s, and many – especially telephone companies – waited until the early to mid 2000s.

Broadband has several appealing features that users experience in heterogeneous ways. In comparison to dial-up service, broadband provides users with as faster Internet access and better on-line applications. Broadband services are also "always on," and users perceive that as a more convenient service.[11] Broadband also may allow users to

[9] No agency is responsible for making data from disparate sources consistent with each other at any point in time or over time, so it is surprising that there are so few discrepancies in the publically available data. The most noticeable discrepancy comes recently, when the Pew and FCC data do not imply the same market shares among broadband and cable. There are also issues with the yearly estimates of broadband revenue from the Census. These issues will be reviewed in the study where relevant.

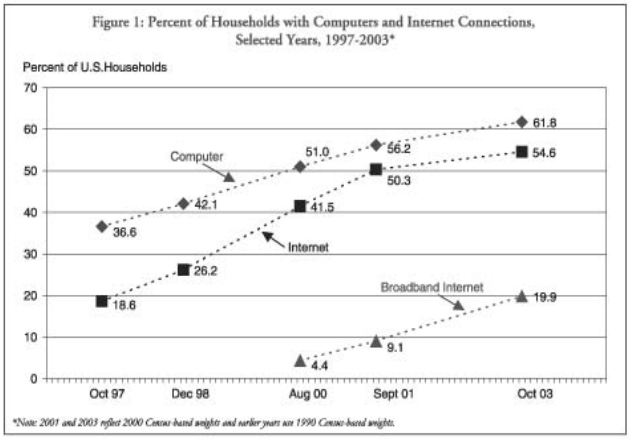
[10] In many areas households also had access to direct supply of high-speed lines, such as T-1 lines. This was prohibitively expensive for almost all users except businesses, and even then, it was mostly used by businesses in dense urban areas, where the fiber was cheaper to lay. Fiber to the home has recently become cheaper, and may become a viable option sometime in the future. During the 1990s most cable companies sold access to the line directly to users, but made arrangements with other firms, such as Roadrunner or @home, to handle traffic, routing, management and other facets of the user experience. Some of these arrangements changed after 2001, either due to managerial preferences, as when @home lost its contract, or due to regulatory mandates to give users choice over another ISP, as occurred after the AOL/Time Warner merger. See Rosston (2007).

[11] Surveys show that a maximum rate of 14,400 kilobytes per second and 28,800k bps were predominant in the mid 1990s for dial-up modems. The typical bandwidth in the late 1990s was 43K to 51K (typically), with a maximum of 56K. DSL and cable achieved much higher maximum bandwidths, typically somewhere in the neighborhood of a maximum rate of 750K to 3M bps, depending on the user choices and

avoid an additional phone line for supporting dial-up. That said, many factors shape the quality of a user's experience, such as the capacity of lines, the number of users in the neighborhood in a cable system, the locality of system in the national grid, and the time of day for performing activities. In brief, generalizations are hard to make beyond the obvious: broadband gives the user a better experience than dial-up access.[12]

2. A. Diffusion and Measurement

All available data suggest that the Internet first diffused to most households as dial-up service, and only later did households moved to broadband service. These happened in sequence because broadband was not widely available in the 1990s and the early 2000s. In addition, user demand for high-bandwidth applications has increased as households have become familiar with high-bandwidth Internet applications (such as music downloading). Firms also have rolled out new services as more users have broadband, generating additional adoption.



vendor configuration.

[12] Download speed may not reach their advertised maxima. In cable networks, for example, congestion issues were possible during peak hours. In DSL networks, the quality of service could decline significantly for users far away from the central switch. The results are difficult to measure with precision.

This is one interpretation of Figure 1, which provides a summary of the Federal government's efforts to collect data about the adoption of the Internet.[13] The first questions about broadband use appear in 2000 and show a growth in adoption, peaking at close to 20% of households in 2003, when all these surveys were discontinued.[14] Recent data about household use, collected by Pew Internet and American Life Project, show that the diffusion continued in the anticipated direction, accelerating somewhat.[15] Notably, adoption reaches over 47% of households by 2006. We will discuss this data in more detail below.

Table 1, Residential Broadband Deployment, 1000s of households

Year	1999	2000	2001	2002	2003	2004	2005	2006
DSL	291.8	1594.9	3616.0	5529.2	8909.0	13119.3	17371.1	20143.3
Cable	1402.4	3294.5	7050.7	11342.5	16416.4	21270.2	24690.0	27720.4
Satellite	50.2	102.4	195.0	257.0	341.9	422.6	529.4	1839.4

Source: Federal Communications Commission.[16]

Table 1 provides a summary of another set of efforts by the Federal Communications Commission (FCC) to measure deployment of broadband lines, information which the FCC collects from surveys of firms.[17] It tells the same story as Figure 1, but from the vendor-side of the market; vendors were increasingly deploying broadband, presumably to meet growing household demand.

[13] The first government surveys of household Internet adoption date back to 1997. These came from additional questions in the CPS Supplement, which had added questions about household use of personal computers in 1995. See NTIA (1995). These were continued with surveys in 1997, 1998, 2000, 2001, and 2003. See NTIA (2004).
[14] The descriptive results were published in reports authored by staff at the NTIA. See NTIA (2004).
[15] See http://www.pewinternet.org/.
[16] See http://www.fcc.gov/wcb/iatd/comp.html, Broadband reports, Table 3.
[17] It has never asked about deployment of dial-up. It also has never asked about the prices of broadband.

There are no estimates of revenue for household broadband services, but we can place a bound on an estimate with revenue for the combination of household and business revenue. The Census estimates revenues for broadband and publishes these in its Annual Service Survey. Table 2 provides a summary of these reports, to which we have made considerable adjustments to correct for related measurement issues. (See appendix).[18] We expect somewhere between 60% and 80% of the revenue in Table 2 is from households, depending on the year and access mode.[19]

Table 2, Adjusted Revenue for Access Market, $M Dollar

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
Dial-up	5499	8966	12345	13751	14093	14173	14081	12240	10983
DSL		228	1245	2822	4316	6954	10240	12034	15066
Cable modem	138	274	903	2600	4117	7372	9435	11139	13156
Wireless							668	1140	.

Source: Census Annual Survey. See Appendix for adjustments.

The growth in revenues in Table 2 – from $5.5B in 1998 to $39B in 2006 – is quite astonishing for an entirely new market, especially one that did not start growing quickly until after 1995. These levels of revenue are also astonishing in light of what they represent: namely, access fees generated most of the revenue during the first decade of the Internet. The typical household spends more than three-quarters of its time online at

[18] The adjustments are for changes in sampling frame; Census does not return to historical estimates and review the sampling frame of prior estimates to make it consistent over time.

[19] Our estimates below suggest household revenue for the Internet overall makes up 70% to 75% of the total revenue. The FCC broadband deployment report puts the number of broadband lines to households at roughly two-third of the total number of lines deployed. See Table 13, High Speed Services for Internet Access, http://www.fcc.gov/wcb/iatd/comp.html. Note that Table 1 and 2 are not comparable, since Table 1 is for households only, which Table 2 is for households and business.

free or advertising-supported sites.[20] Although subscription-based services and advertising services have started growing in the last few years, the amount spent on access fees far exceed advertising revenue. Advertising revenue is growing at a more rapid pace than subscription fees today and may exceed access revenue soon, but not as of this writing.[21]

2. B. Measuring Prices

The consumer price index (CPI) for Internet access is officially called "Internet Services and electronic information providers," which the BLS began compiling in December,1997, after approximately 20% of US households had adopted the commercial Internet.[22] Table 3 displays a monthly quote from the price index, taken the last month of each year, and normalized to 100 for the year in which the index began.

Table 3. US Internet access price index.

Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Index	100.0	103.3	96.0	95.7	100.3	99.6	97.6	97.2	94.5	77.2	73.1

Source: Bureau of Labor Statistics, http://data.bls.gov.

The series has a distinct pattern: It indicates that the official price index for Internet access in the US went mildly down and up during the five years of dot-com

[20] See, e.g., Goldfarb (2004).

[21] In the 2006 Annual Service Survey, Web Search Portals, NAICS 518112, generated $6.3B in advertising in 2006, out of a total revenue of $9.1B. This is up from $4.5B and $3.3B in advertising revenue in 2005 and 2004. In addition, Internet Publishers, NAICS 516, generated $2.6B in revenue in 2006, up from $2.3B and $1.8B in 2004 and 2005. That is still far less than the $39B in access revenue.

[22] Entry into the provision of dial-up Internet services began to explode in 1995 and 1996. The potential appeal of selling access to the World Wide Web induced most of the entry in 1995 and 1996. See Downes and Greenstein (2002). Stranger and Greenstein (2007) estimate a quality adjusted price index for access between 1993 and 1999 and find that most of the dramatic price decline came in 1995.

boom and bust, between December, 1997, and December, 2002. [23] It then declined five percent over the next three years, between December, 2002, and December, 2005 – again, a rather mild decline for a downturn. Then, in late 2006, it declined more than eighteen percent from its base—that is, (94.5 – 77.2)/94.2 = .183. We note that the drop continued (illustrated with the quote from 12/07). It settled at a 23 percent decline from its base in January, 2007 — that is, (94.5 – 73.4)/94.5 — and stayed there for the year. Also, looking closely at the monthly data (also not shown), a mild downward trend began in the fall of 2006, with the big drops occurring in October, November and December.[24] The timing matters for reasons we will explain momentarily.

This pattern differs from many closely related categories, which is somewhat puzzling at first glance. Specifically, during the period from December, 1997, to December, 2005, official price indices for the US demonstrated the following patterns: computer software and accessories declined 42 percent; personal computers and peripheral equipment declined 88 percent; telephone hardware and calculators and related consumer items declined 55 percent; and wireless telephone services declined 35 percent.

These comparisons might lead one to conclude that, until recently, prices declined for everything except Internet access, which experienced its decline relatively later. In fact, that conclusion would be wrong, as the late timing of the price decline resulted from an unusual mix of standard index construction procedures and market events. More to the point, the index is not very informative about changes in the price of broadband.

[23] With only a few exceptions, the index does not change very much month to month or year to year, so we could have taken a sample of another month and gotten a similar picture.
[24] The index in July 2006 is 97.3, and 94.7 and 93.1 the next two months. It then drops to 87.0 in October, 81.1 in November and 77.2 in December, settling at 73.4 in January 2007.

Specifically, in the fall of 2006, AOL announced a dramatic change to its pricing: It was moving to advertising-supported service in response to losing customers to broadband. We see the index behave in ways consistent with AOL's announced price change. By the fall of 2006, the trade press conjectured that AOL's service went to less than a quarter of the households in the US using the Internet.[25] And, when one vendor makes up approximately 25 percent of an index and it announces a 100 percent decline in price, it is tautological that the index must decline by 25 percent. That is nearly what we observe: a 23% decline in price in a very short period.

To be clear, this is merely "informed" speculation, since we have not examined the confidential BLS data. It is theoretically possible that other prices are moving downward and upward at the same time.[26] To bolster our contention that AOL's price change is primarily responsible for the observed trends, we note that this was not the first time that AOL's pricing decisions had moved the index dramatically over a short period of time. In the summer of 1999, when its market share was much larger, AOL attempted to give price breaks to former CompuServe users after AOL merged with CompuServe (as part of an attempt to move them to AOL email addresses and other services). That price break appeared to have moved the index down for three months – in May through July. The effect lasted only as long as AOL's promotion, as the index subsequently

[25] The 23% market share for the index is a plausible number. The last expenditure survey was in 2005, but due to lags the 2006 index uses the survey from 2003. Source: BLS web site. In 2003 dial-up's revenue share of household use of the Internet was approximately 53 - 55%. See Table 3. If AOL's market share was 60% of dial-up, then 26 - 27% decline is the result. For more on AOL's market share see Alex Goldman's market share rankings, at http://www.isp-planet.com/research/rankings/usa_h.html, who lists AOL at 24% to 26% market share for 2003.

[26] Almost certainly some prices other than AOL's were decreasing. That would have to be true to account for the other mild declines in the index.

returned to its previous level. [27]

This interpretation is also consistent with the index's other salient feature: namely, that no large change in nominal prices occurred for seven years. Since the late 1990s, AOL's dial-up service has been $21.95 (plus or minus a dollar). Its prices never went down dramatically except the two times just mentioned. For most of time covered by this index (1998-2005), AOL was the dominant dial-up national provider by far, with a market share between 40% and 60% for dial-up firms.[28] And, until broadband began to represent a higher fraction of revenue (it became greater than half after 2003), the index could not decline much while one firm dominated and its prices remained unchanged.

What about the prices for non-AOL providers, who make up the other half of dial-up supply? Market share is skewed among this category of providers, but there is also a considerable amount of restructuring over time, so it is difficult to speculate how actual market events corresponded to BLS' sampling. The little systematic and public evidence we do have is consistent with the explanation that nominal prices did not change. Greenstein and Stranger (2007) estimate prices for dial-up by *all the other* dial-up providers for 1993 - 1999. They find little or no change in the median or average nominal prices between 1996 and early 1999 (i.e., without controlling for quality).[29]

For cable modem service and DSL service price levels also have been largely

[27] The price index was 103.4 in April of 1999. It declined to 77.5 in May, 53.5 in June, and 79.4 in July, and returned to 99.0 in August.

[28] Our data on AOL come from Alex Goldman's market share rankings, at http://www.isp-planet.com/research/rankings/usa_h.html.

[29] For example, the *median* price of a contrast for 28K service is $19.95 and does not change between May 1996 and January 1999. The *average* price (unweighted by market share) for this same set of contracts in the same time period is $22.64 and $19.01. Most of the major price decline occurs prior to 1997, before BLS initiates the index; that is, between January 1995 and May 1996 (which is coincident with the initial diffusion of the commercial browser and explosive beginning of the web).

unchanged: respectively, somewhere between $36 and $40, plus or minus a few dollars.[30] Except for a few publicized (but largely unused) marketing schemes to lower prices to satisfy regulatory requirements, several sources indicate that price levels paid by users have not changed much. There has been evidence of price declines only very recently – i.e., 2006, and only in the DSL prices in the Pew reports.[31]

We have offered an interpretation that solves a puzzle, but, in doing that, we have heightened concerns. Our interpretation suggests that the lack of change in nominal prices accounts for most of the stability in the index, and only the AOL price decline has moved this index down any appreciable amount.[32] Broadly speaking, that means this price index declines because of what happened to those who continued to use dial-up (while broadband diffused). The index says little or nothing about the improvement being experienced by most households who did switch to broadband. Why should the official price index for a rapidly diffusing good move *only* when the dominant supplier of the *old good* reaches a crisis that leads to a decline in its price? Moreover, why should the official price index not reflect the upgrade experienced by the majority of users?

2. C. Measurement problems are likely

Like many new goods, broadband did not diffuse immediately to all households. That slowness by itself is nothing remarkable for a new good, but it is puzzling set next to

[30] This is the price level in the 2002 sample in Savage and Waldman (2004). Pew's estimates are similar for 2004 and 2006, with a decline in the average price of DSL in the most recent sample. John Horrigan, private communication.
[31] John Horrigan, private communication.
[32] This pattern also raises a related question: why did access prices *not* drop coincident with the emergence of a backbone glut in the US, beginning in 2001 and thereafter? After all, the price for backbone services is a key cost input into the provision of access service. That question awaits further research.

the evidence of measured stable transactional prices. We will argue that it is consistent with unmeasured factors deterring adoption of broadband. That explanation is consistent with a key point: standard price indices measure only transactions that occur, not those that are prospective.

What unmeasured factors played a key role in stopping adoption decisions? Plenty of reports suggest there were changes in the availability, bandwidth, reliability, and anticipated performance for broadband over this time period.[33] For example, in many neighborhoods broadband was not available in any form for some time after 2000.[34] Even when it became available, it may not have been reliable enough to spur many households to quickly switch from dial-up, inducing to wait until vendors improved the infrastructure or service arm of the organization.[35] Many households also waited until they changed their use in sequence (e.g., learned how to use the Internet for music downloading on an iPod), which then led to the upgrade.

We hypothesize that these unmeasured determinants of broadband adoption induced a *substitution bias.*[36] While this setting generates some unique challenges, but the core economic issues are not new, the biases endemic to this setting resembles those

[33] This theme arises often in NTIA and Pew studies. See NTIA (2004) and http://www.pewinternet.org/.
[34] For example, NTIA 2004 reports (from a 2003 survey) that over 20% of rural Internet users did not believe they had broadband available, while just under 5% of urban Internet users make such a statement. A large number of households also report that access was too expensive. Other common reasons given for no Internet or broadband include lack of interest and lack of a computer at home. Even as late as 2007, the FCC reports that only 82% of US households have access to DSL lines, while 96% have access to a cable modem provider. See Table 14, broadband deployment reports, available at http://www.fcc.gov/wcb/iatd/comp.html.
[35] Comparing broadband deployment reports from the FCC shows evidence of upgrading by cable system upgrades. See the Broadband Deployment Reports available at http://www.fcc.gov/wcb/iatd/comp.html, particular Table 5, High Speed Lines by Information Transfer Rates.
[36] Substitution biases are quite common within categories of goods, as users move market share to the cheaper good, while the price index only records change in price, not the full change in expenditure. See e.g., the Boskin Commission report (1996) or Braithwait (1980).

found in prior examples. The size of the biases is the interesting open question.[37]

There are two root causes to this bias. First, when users switch between dial-up and broadband, it is due to an unmeasured drop in price or an unmeasured increase in quality of delivered services, though there is no adjustment for that in the official indices. To be fair to the BLS, while this observation is quite simple to describe, it is difficult to fix.[38] Standard price index survey procedures will measure the price at which the new good transacted but *not* the price that previously deterred the user from adoption. The price index should fall, but does not because there has been no measured price change. That is quite difficult to fix since doing so requires complete information about all the factors deterring or motivating adoption, which is difficult – perhaps impossible – for most price agencies to collect.

Second, standard price index construction overemphasizes the price change for the old good compared to the new good. This second observation has been noticed by prior researchers in other contexts, and they have proposed several pragmatic fixes. We prefer a fix that "links in" the price for broadband with an adjustment. We prefer this approach because it gets closer to treating broadband as a "new good," which is what broadband was for most households during this time period. How large should that adjustment be? We follow the literature and suggest the adjustment should reflect the

[37] Previously documented examples include the replacement of general purpose retailing outlets with discount outlets (Reinsdorf, 1993), the diffusion of generic drugs in competition with branded pharmaceuticals (Griliches and Cockburn, 1994), and the movement of voice communications from land line telephony to cellular telephony (Hausman, 1997).

[38] Though analysts often casually talk about "broadband becoming more available" it was never the case that a high speed option was unavailable to households. However, prior to the diffusion of DSL and cable-supported Internet the available options were not very satisfying (e.g., ISDN), or very expensive (e.g., a household could always order a T-1 line from a local telephone company). In recent times almost any household could get a satellite connection for some Internet access if they are willing to pay for it (and tolerate the quality), which most households have not done except those not served by line options.

additional value created by the upgrade to the new good.

To be clear, the standard recommendation is not to use the percentage decline from unmeasured price. Instead, the standard recommendation is to use the adopters' reservation value for the new good; that is, the price index should use the maximum of what a user would have been willing to expend to get the new good prior to adopting the new good. As is well known, this can be recovered only with estimates of the demand for the new good after the good has diffused.

Before considering such estimates, we note another complication: For some households, the upgrade between dial-up and broadband also affects their demand for a second telephone line to support a dial-up account; that is, when a household switches to broadband they often retire that line. The net gain from moving to broadband is higher than otherwise recorded because, in effect, the net expenditure difference between dial-up and broadband was much lower for some households than the price index for Internet access directly recorded. Yet, neither the telephone index nor the Internet access index reflects this gain. In what follows, will be careful to account for that factor.

3. Data

Table 3 summarizes the data we use to simulate the economic gains from the diffusion of broadband. Here, we provide important information about our sources and their limitations.

Adoption of the Internet. To derive the total number of adopters, we estimate the percentage use of dial-up and broadband technologies across all households, then

multiply this percentage of adopters by the total number of households.[39] Data about household use of dial-up and broadband Internet come from two sources, the NTIA and Pew. [40] We use the NTIA estimates through 2003, and use the Pew estimates thereafter. Pew's data are good for measuring adoption, but incomplete for measuring price and quality.[41] Data about total number of households come from the US Census estimates.

Table 3: Household Statistics, 1999 – 2006 (MM)

Year	1999	2000	2001	2002	2003	2004	2005	2006
Total Households	105.0	106.0	107.0	108.0	109.0	110.0	111.0	112.0
Total Internet Adopters	35.5	44.0	53.8	56.7	59.5	66.0	73.3	81.8
Total Broadband Adopters	0.9	3.2	9.6	13.0	18.5	27.5	41.1	47.0
Total Dial-up Adopters	34.5	40.8	44.2	43.7	41.0	38.5	32.2	34.7
Total Second Phone Lines	23.6	26.2	26.3	18.4	16.0	13.8	12.1	10.5

Second lines. Table 3 also provides estimates of the total number of households in the US with at least one second line. We gather this from FCC reports, which do not break out second line use into its primary purpose.[42] Prior research has shown that several factors determined the growth of second lines in the 1990s, including use of the

[39] We prefer this because it builds on surveys of users rather estimates of broadband deployment, such as those kept by the FCC. That choice does not matter until recently. While the FCC numbers do not differ much from Pew's overall, they do differ recently. We prefer the Pew data because it is consistent with the data from the NTIA, and surveys of users also informs us about other relevant factors for measurement, as will become clear in the discussion.

[40] For years between 1997 and 2003 when we have no direct observation, we interpolate between the two closest known measures of adoption percentage with a target towards midyear.

[41] Pew's surveys ask a variety of questions, most recently including questions about prices and use. While its answer are incomplete about prices and bandwidth, the results display extensive coverage about what activities users do on-line and how that has changed over time. The survey did not ask about prices until 2002 and bandwidth until 2004, but did not get complete answers. For example, 80% of respondents do not know the bandwidth of their broadband in the 2005 survey. John Horrigan, private communication.

[42] See Trends in Telephone Service, 2007, Table 7.4, Additional Residential Lines. This is the most recent available data as of this writing. It is available at http://www.fcc.gov/wcb/iatd/trends.html.

Internet.[43] The growth and decline in households with second lines is highly correlated with the growth of dial-up Internet access and its replacement with broadband lines.[44] For example, in the latter part of the 1990s, the use of second lines grows from 11.4% in 1994, to 26.3% in 2001. It declines after 2001 – from 26.3% to 10.5% in 2006.[45] This puts bounds on estimates of the second lines supporting Internet dial-up.

New users and switchers. Neither the NTIA reports nor the Pew reports provides statistics for each year about whether new broadband adopters are new users of the Internet or "converts" from dial-up. At first there was good reason for this lack of information; there was no question that virtually all household broadband adopters had experience with dial-up before upgrading. Some new users, however, moved directly to broadband in later years. In his report describing adoption behavior in the Pew survey between 2005 and 2006, John Horrigan mentions that new users of the Internet comprised a large percentage of the adopters of broadband that year.[46] He did not mention this for earlier periods because it simply was not a significant factor until then.[47] We make several assumptions about "conversions" that are consistent with Horrigan's observation.

Price levels. We do not observe prices directly. Consistent with the generally reported patterns for nominal prices and for simplicity, we assume for all of our simulations that price is unchanging over time and we set the average price level for dial-

[43] See, e.g., Duffy-Deno (2001), and Eisner and Waldon (2001).
[44] The other primary driver of the decline in second lines is the growth of cell phone use.
[45] 2005 is the last available year, as of this writing.
[46] John Horrigan does highlight that few adopters of broadband went straight to broadband without first using dial-up. Horrigan also states that 4 (out of 8) million broadband adopters were new users of the Internet between 2005 and 2006, and never before had Pew's surveys found a percentage anywhere near that high. See http://www.pewinternet.org/.
[47] Horrigan, private communication.

up to $20.[48] We choose that price because it is the reported average dial-up price for users in two CPS Supplements in the 1990s.[49] We assume the average price for broadband is either $36 or $40, depending on the simulation we conduct. Again, this is consistent with reported price levels in Pew reports and other research.[50]

4. Benchmarks

We begin with estimates of the revenue generated by broadband, and then move on to estimate consumer surplus. Following that, we provide an estimate of a properly adjusted price index. Throughout, we try to maintain a conservative stance and show how a range of assumptions alter the qualitative results. To be clear, this is a calibration and an accounting exercise. When we vary parameters we are not estimating demand; rather, we are holding fixed the known facts about broadband's deployment (i.e, Table 3), and learning how changes to key assumptions about the underlying features of diffusion alter inferences about consumer surplus and new revenue generation.

4. A. Creation of new revenue

We begin with a calculation of a single year, 2003, to illustrate how we provide a

[48] We could examine the effect from small price fluctuations. We do not do so below, since, for obvious reasons, the qualitative results change things very little.

[49] It is also the median price in Savage and Waldman (2004) and Stranger and Greenstein (2007). The CPS supplement asked about monthly expenditure (which looks quite close to monthly prices) in only two years and not thereafter. However, the consumer expenditure survey continued to ask about on-line expenditures for Internet services every year. Similar to the CPS, while it is not a price index, it looks quite close to prices (but does not distinguish between use of broadband and dial-up until after 2001). The difference between some expenditure and none is a good indicator of a household's use of the Internet, and correlates with changes in other levels of expenditure for related goods, such as music and videos, as well as other forms of entertainment. See Hong (2007).

[50] For US price quotes, see e.g., Savage and Waldman (2004), Chen and Savage (2007), Crandall et al (2003), Rappoport et al (2003), and Flamm and Chadhuri (2007).

full accounting of the new revenue affiliated with broadband. In the process of explaining a single year, we will articulate the principles that apply to all years.

Because the average price of residential broadband access is somewhere between $36 and $40 a month, residential broadband generated annual revenue in 2003 of somewhere between $8 billion ($36/month × 12 months × 18.5 million households) and $8.9 billion (if the price is $40/month). That is not the same as the GDP created from the introduction of the new good, however, since broadband replaced dial-up in many households. The additional revenue created should compare new broadband revenue to cannibalized dial-up revenue.

We first estimate how many broadband users formerly used dial-up. We have no way to know this number precisely since public surveys only ask about total adoption in a given year, not any yearly tally of new Internet users. We are quite certain that the vast majority of the broadband adopters between 1999 and 2004 were former dial-up users, but we do not want to assume too much about more recent years. For our baseline specification we will assume 100% (all 10 million households) are converts in 1999-2001. There are approximately 37 million additional adoptions in 2002-06, with 31 million of those occurring prior to 2005. The number of new users finally becomes large enough to notice near the end of our sample, but cannot exceed 50% of the 6 million adopters in 2006, and, as noted earlier, it is must be less than 50% of the 14 million adopters between 2004 and 2005. In other words, assuming 10 million new Internet users among broadband adopters is too high, and 3 million is too low. For lack of better number, we will split the difference and assume 7 million in our baseline specification,

then test alternatives assumptions.

For our baseline estimate, that means 30 million broadband adopters between 2001 and 2006 were converts from dial-up. For convenience, we will assume an 81% conversion rate for 2002 through 2006 (instead of concentrating it all in 2005 and 06). In the appendix, we calculate implausible extreme bounds (81% convert rate and 100% convert rate for all years), and show how this assumption affects the final estimation. Below, in rows three and four of Table 4, we provide a summary of such changes in comparison to our benchmark estimate.

As an illustration, those assumptions imply that the new adopters of the Internet (not "converts") generated between $455 million of revenue (if price is $36) and $505 million of revenue (if price is $40) in 2003. "Converts" – those who switched from dial-up – generated between $1.9 billion and $2.1 billion.

We next calculate the proportion of revenue generated by dial-up converts that was cannibalized. If the average price of dial-up Internet access was $20 a month, then that accounts for $1.1 billion of cannibalized revenue.

That is not all, however. In addition to the loss of dial-up revenue, many households supported their Internet with a second telephone line. For example, 16 million households had an active second line in 2003, which represents a decline from 18.4 million in 2002. The 2.4 million decline in second phone lines represents the upper bound for dropped lines by broadband adopters, meaning that a maximum of 53 percent

of dial-up converts dropped a line that year.[51] That percentage varies between 2002 and 2006, raising no higher than 53% and falling no lower than 25%.[52] In our base specification, we will assume something in that neighborhood, but reduce the volatility in the estimates from the role of second lines. That is, we assume that one third of broadband adopters drop a second line between 2002 and 2006, while we will assume no broadband adopter drops a second line between 1999 and 2001. We view this not as an undercount, but rather as a conservative approach.

A second telephone line can cost a household as little as $16 a month in some cities and as much as $24 before including per minute usage charges, which are generally low. For our simulations, we use an average of $20. Using 2003 as illustration once again, newly retired phone lines from dial-up converts amounted to a loss of $357 million in revenue for phone companies in 2003. That puts the total opportunity cost of lost dial-up revenue and second line revenue at $1.4 billion.

In summary, broadband created additional revenue between $964 billion and $1.2 billion in 2003. That accounts for both new revenue and cannibalized revenue from former dial-up users and retired second phone lines.

We conduct similar calculations for each year, 1999 – 2006, which we provide in the appendix and summarize in Table 4. The aggregate revenue gain for 1999-2006 stemming from broadband adoption is $10.6 billion in our baseline specification when broadband prices are $40. That is 46% of an estimated $22.6 billion in GDP at the end of

[51] Strictly speaking, the upper bound could be larger if more than 2.4 million broadband adopters dropped a second line at the same time others were adding lines, since we observe only a net change.
[52] In other years, we get different percentages, and prior to 2002 there is no decline in use of second lines one year to the next.

the sample (i.e., 47 million households x 12 months x $40 per month).

Table 4. New revenue created by broadband each year. (Millions $)

Year	Total	1999	2000	2001	2002	2003	2004	2005	2006
Baseline high price	10595.4	226.9	536.4	1548	737.4	1233.4	1986.3	3005	1322
Baseline low price	8337.4	181.4	429.1	1238.4	577.6	966.1	1555.8	2353.6	1035.4
Aggressive conversion	8326.5	226.9	536.4	1548	535.4	895.6	1442.3	2182	959.9
Not aggressive	11410.5	269.8	724.5	2132.1	737.4	1233.4	1986.3	3005	1322

Source: Authors' calculations.

Baseline high price: Broadband Price = $40; 100% are converts 1999-01; 81% converts 2003-06
Baseline low price: Broadband Price = $36; 100% are converts 1999-01; 81% converts 2003-06
Aggressive conversion: Broadband Price = $40; 100% are converts 1999-06
Not aggressive conversion: Broadband Price = $40; 81% converts 1999-06

Clearly the assumptions matter for the levels of estimates, but that insight is not the point. We are more interested in understanding how much those assumptions matter for a benchmark. Specifically, if prices are $36 instead of $40, then the total estimate reaches $8.3 billion (41% out of $20.3 billion). If all broadband adopters are converts (which is higher than plausible) and prices are $40, then our estimates of revenue gains are $2.3 billion lower than in the baseline case. If 81% of adopters are converts every year (which is lower than plausible) and prices are $40, then our estimates are $0.9 billion higher.

In other words, while changes to each of these assumptions move the estimate for the level of created new revenue *in each year*, none of these alters the general pattern *over time,* as more households switch from dial-up to broadband. Under any estimate, the

additional revenue from the adoption of broadband is large, somewhere between 40% and 50% of measured revenue for households.

We can summarize it bluntly: Measured revenue is what shows up in GDP, but the measured revenue is only part of the story. Approximately 40% to 50% of that measured revenue is new, and 60% to 50% replaces revenue in dial-up and second lines with revenue in broadband. It is a combination of what economists call merely "business stealing" (when revenue goes from one company to another) or "cannibalization" (when revenue stays at the same firm).

We redid our simulations with one additional change: we accounted for changes in AOL's price. Since AOL's prices are largely unchanged over time except in the last year, this makes little difference to the aggregate index. The only effect is that converts no longer save $20, since AOL's prices become zero after September, 2006. That reduces the cannibalized revenue from converts by approximately $500 million in 2006.[53] This makes a little difference in that year, but does not change any other inference.

Although these calculations tell us nothing about the cost to deploy and support broadband or, for that matter, its profitability, these numbers do say something about the suppliers who won and lost. While cable companies were the dominant supplier of broadband at the beginning of our sample, Pew's survey finds that local telephone

[53] We get that by assuming that AOL has 13.1 million households in 2006, which is 38% decline from the prior year, when the level was 19.5 million households. Those 6.4 million households faced an opportunity cost of $20 a month for eight months of 2006 instead of twleve, which reduces the opportunity cost close to $500 million. Our data on AOL come from Alex Goldman's market share rankings, at http://www.isp-planet.com/research/rankings/usa_h.html.

companies have a slightly higher market share than cable companies by 2006,[54] but a slightly lower price as well. Hence, each type of firm had a similar level of broadband revenue in 2006. Cable and telephone companies each gained from the additional revenue from broadband, but cable gained more because it did not cannibalize revenue for second telephone lines. The only big revenue losers were dial-up ISPs, which is no surprise.

4. B. Creation of consumer surplus

In most studies, estimates of broadband demand indicate that there is substitution between different forms of broadband – i.e., substitution between cable and DSL, but only weak substitution between dial-up and broadband. The latter places some constraint on demand for broadband, but not much. There also is evidence of upgrade behavior, with broadband constraining dial-up demand, but not vice-versa.[55]

Estimates of broadband demand generally find that it is elastic, though US estimates tend to be less so than those of households in other countries. For example, Rappoport et al. (2002) report an own-price elasticity of -1.46 for DSL for a nested logit model applied to a sample of US households in 2000, while Crandall et al (2003) find an

[54] This is one place where the data from Pew and the FCC do not agree. Table 1 (from the FCC) gives high market share to Cable in the most recent years while Table 3 (from NTIA and Pew) does not. If the FCC's data are correct, then the statement in the text is not correct, and cable firms have done much better than the telephone firms.

[55] For example, Rappoport et al (2003) find that broadband service is partially a substitute for dial-up, with cross price elasticities of .7 among those with dial-up service, while dial-up does not act as a substitute for those with broadband (cross price elasticity of .02). The cross price elasticities between cable and DLS are in the .6 and .7 range. Flamm and Chadhuri (2007) use the 2002 Pew Survey and try imputing fewer prices than in Rappaport. They find that demand for broadband is comparatively more insensitive to prices, and find that their detailed data shows that demographic factors shape demand quite a bit. Cardona et al find qualitatively similar results to Rappaport et al, with cross price elasticities between broadband and narrow band of no greater than .5, and that only when these are the only two options. Often their estimates are smaller.

own-price elasticity of -1.184 for a slightly different sample in a similar time period.[56]

We rely on one set of estimates from Scott Savage and Don Waldman (2004). It is representative of the type of findings seen in other studies, but a little easier to use in this context. These authors conducted an extensive survey of dial-up and broadband users and non-users in 2002. We prefer this study because it is based on later data, and also because it is a survey of users and non-users. In addition, the authors used this survey to directly estimate "willingness to pay" measures for categories of users, which facilitates some simple accounting. This is sufficient for our purposes below.[57]

Savage and Waldman's estimates of the willingness to pay for broadband are net of benefits users receive from dial-up. In their model, users adopt broadband if the additional benefit exceeds the additional cost of converting. The conversion cost sums two things: the increase in subscription fees and the net savings in expense for a second line. If the price of broadband is $36, then the average increase in subscription fee is $16 ($36 less $20). Additionally, many converts dropped a second phone line, saving, on average, $20 per month for those who dropped. This impact affects the "average" consumer surplus of converts differently each year, depending on the average drop rate.

For example, Savage and Waldman's lowest estimate of the average willingness to pay for broadband's speed is around $11 per month, and their highest is around $22 for

[56] Estimates on samples of households in other countries tend to find more elastic demand. For example, Pereira and Ribeiro (2006) find an own price elasticity for broadband (cable and DSL) of -2.84 for a sample of households in Portugal. In a sample of Austrian households Cardona et al (2007) find similar elasticities for broadband (approximately -2.5) in areas where there are many options, and more inelastic demand (approx -0.97) when DSL is the only broadband option and dial-up provides the only competition to DSL.

[57] To be clear, the novelty of our exercise is to provide a benchmark, and we do not view this as an end of the discussion. We would be delighted to see more study of how more detailed estimates of heterogeneity in household willingness-to-pay alters our benchmark calculations.

the most experienced and educated user. They also find that users pay more for broadband because it is more reliable and always on - between $1 and $18 more, depending on how much more reliability the user perceives in broadband. Savage and Waldman assume that dial-up has half the reliability of broadband, yielding an additional value of $9 on average.

The Savage and Waldman estimates provide an estimate for the number of users who are switching from dial-up, but not new users to the Internet. This phenomenon started becoming more frequent after the 2002 survey used by Savage and Waldman. Even though some of these new adopters (surely) have experience with the Internet (e.g., as students or as users at work), we will take a conservative approach to estimating surplus for "non-converts." We assume their willingness to pay is what they paid (i.e., they received no consumer surplus). This is consistent with our focus on generating a conservative estimate of the substitution bias arising solely from upgrade behavior among previous dial-up users.

In our base specification, if the subscription fees for broadband are $40 a month, and someone converts from a $20 a month dial-up account, then the conversion cost is $20, and we call that the maximum conversion cost. For those who paid the maximum conversion cost, the low end of the estimates of willingness-to-pay is just enough to cover the additional cost.

To be clear, this is one place in the study where we are performing a calibration, not estimating demand. We do not use this model to predict which household did and did not adopt broadband, as Savage and Waldman did. Rather, we assume that quantity

demanded must result in the number of adopting households, as in Table 3. Then we calculate the level of consumer surplus consistent with Savage and Waldman's estimates, while varying assumptions about prices and conversions.

A full accounting of this surplus can be found in the appendix. It varies from $6/$10 per month on average in 1999-2001 (when price is $40/$36 and we assume nobody drops a second phone line), to $11.35/$15.35 per month after 2002 (when we assume that all converts dropped their second line).

Table 5 provides a summary of these results. The approximately 40 million households who converted to broadband since the beginning of the dial-up market received an additional benefit from their conversion. It amounts to somewhere between $4.7 billion and $6.7 billion in 2006.

Table 5, Consumer surplus in Millions of $ (As fraction of total surplus)

Year	Total	1999	2000	2001	2002	2003	2004	2005	2006
Baseline high price	(31.2%) 4818.7	68	160.9	464.4	367.2	614.2	989.2	1496.5	658.3
Baseline low price	(44.4%) 6735.7	113.4	268.2	774	496.7	830.9	1337.9	2024.1	890.5
Aggressive conversion	(43.2%) 6349.7	68	160.9	464.4	503.5	842.1	1356.3	2051.8	902.7
Not aggressive	(30.0%) 4687.9	55.1	130.3	376.1	367.2	614.2	989.2	1496.5	658.3

Source: Authors' calculations.

Baseline high price: Broadband Price = $40; 100% are converts 1999-01; 81% converts 2003-06
Baseline low price: Broadband Price = $36; 100% are converts 1999-01; 81% converts 2003-06
Aggressive conversion: Broadband Price = $40; 100% are converts 1999-06
Not aggressive conversion: Broadband Price = $40; 81% converts 1999-06

Comparing Tables 4 and 5 also shows how different assumptions shape the estimates of the distribution of the gains from innovation. In the two baseline cases, the total gains from the diffusion of broadband reach just over $15 billion, though they differ in the distribution of return.[58] As expected, higher prices lead to lower consumer surplus as a fraction of new value generated, that is, 31.2% and 44.4% for broadband prices equal to $40 and $36.

Assuming all broadband users upgraded from dial-up (aggressive conversion, which is too high) or 81% (unaggressive, which is too low) alters total surplus only a little, but does alter estimates of the distribution of returns. Aggressive conversion reduces total surplus by $0.8 billion (compared to the baseline), while unaggressive conversion increases it by $0.6 billion. However, these assumptions provide a very different distribution of gains from innovation: 43.2% and 30.0%, respectively. In comparison to the baseline simulation, assuming an aggressive conversion of dial-up users to broadband yields a large gain for consumer surplus and a consummate loss for producer surplus. Assuming less aggressive conversion has just the opposite effect.

To say it bluntly, Table 5 gives a sense of the range of changes that come about from changes in the assumptions, but the direction of change is not surprising. Rather, these estimates place limits on the range of the benchmark for consumer surplus.

[58] In the $40 baseline estimate, the total gains are 4818.7 + 10595.4 = 15414.1. In the $36 baseline estimate the total gains are 6735.7 + 8337.4 = $15073.1. When only 81% of the broadband adopters have upgraded from dial-up, then a reduction in price reduces new producer surplus each year, but increases consumers surplus by only 81% of the new revenue for vendors. The 19% consumer surplus is lost to our assumption that new Internet users generate no consumer surplus. The estimates for total surplus are not the same under different prices except under the assumption that all broadband users are converts from dial-up. Accordingly, in the simulation at $40 (and $36) with aggressive conversion the total is 6349.7 + 8326.5 = $14,676.2. At $40 without aggressive conversion, the total is 4687.9 + 11410.5 = $16,098.4.

Consumer surplus is between 31.2% and 44.4% of the new revenue generated, and this is entirely an unmeasured gain from the diffusion of broadband.

Once again, we stress that these are benchmark estimates. First, other researchers found considerable heterogeneity in the demand for broadband, with some adopters of broadband willing to pay far above the market price. The Savage-Waldman estimate also measures some of this "inelastic demand," but truncates the level of that valuation among the biggest fanatics. We have not counted this highly inelastic demand in our valuation.

In addition, we have made no adjustment to these estimates for the change in AOL's pricing. While we are comfortable considering how AOL's price change shapes our estimates of revenue, adoption is a slow process. The price decline came too late in 2006 to have much effect on broadband adoption, if any. It almost goes without saying, but nobody expects most broadband users to switch back to dial-up despite some dial-up becoming free.

Third, survey research tends to find a larger willingness to pay from users who are (a) paying not to have something taken away after they have experienced it, rather than (b) paying for something they have yet to experience. Savage and Waldman corrected for this effect by asking both users and nonusers about their valuations. However, the survey was conducted before widespread broadband adoption, so the answers about value would most likely be higher if the survey were conducted today among actual users.

4. C. An adjusted price index

Standard economic reasoning suggests that the price index will be mis-measured

when consumer surplus from a new good is large. We briefly walk through the mechanics, just to verify that intuition, provide a range for the estimate, and decompose the causes.

Against a $40 ($36) price for broadband, $11.35 ($15.35) consumer surplus is equivalent to a 28 (43) percent of the monthly price paid by converts for service. Or, to say it a different way, converts were willing to pay $51.35, but had to pay less. For converts, this was equivalent to a decline in price of $11.35 ($15.35), but none of this was measured.

Table 6, Weighted average of price decline, all access & *broadband only*

Year	1999	2000	2001	2002	2003	2004	2005	2006	Average
Baseline high price	99.6 *86.9*	99.3 *90.3*	98.4 *91.2*	98.9 *95.3*	98.3 *94.6*	97.5 *94.1*	96.6 *94.1*	98.7 *97.7*	98.4 *93.1*
Baseline low price	99.4 *78.3*	98.9 *84.7*	97.3 *85.4*	98.5 *93.8*	97.7 *92.7*	96.7 *92.1*	95.5 *92.0*	98.3 *97.0*	97.8 *89.4*
Aggressive conversion	99.6 *86.9*	99.3 *90.8*	98.4 *91.2*	98.7 *94.3*	97.9 *93.3*	96.7 *92.8*	96.0 *92.7*	98.2 *96.7*	98.1 *92.3*
Not aggressive	99.7 *89.4*	99.4 *92.5*	98.7 *92.9*	98.9 *95.3*	98.3 *94.6*	97.5 *94.1*	96.6 *94.1*	98.8 *97.8*	98.5 *93.8*

Source: Authors' calculations.

Baseline high price: Broadband Price = $40; 100% are converts 1999-01; 81% converts 2003-06
Baseline low price: Broadband Price = $36; 100% are converts 1999-01; 81% converts 2003-06
Aggressive conversion: Broadband Price = $40; 100% are converts 1999-06
Not aggressive conversion: Broadband Price = $40; 81% converts 1999-06

Table 6 illustrates this result, calculating a weighted average of the price change for each year as if only converts experienced a price decline. Weights fall into four categories: dial-up users, existing broadband users, new broadband users who are new

Internet users, and broadband users making an upgrade this year. Only those making an upgrade experience a price decline. That is, dial-up users, new users of the Internet, and experienced broadband users all experience no nominal change in prices. In the baseline specification converts to broadband experience 87% decline in price (from $46 to $40) from 1999 to 2001, and a 78% decline in price (from $51.35 to $40) from 2002 to 2006. We also calculate a similar weighted average for only broadband users. That second index somewhat artificially exaggerates the importance of upgrades early in the index because so many broadband adopters are converts as a percentage of total broadband users. We show similar simulations for other assumptions, as in the prior tables.

Table 6 shows that the price index should decline between 1.6% and 2.4% a year by 2006. Accordingly, the contribution of broadband is much higher than the recorded level. The correction is largest in the most recent years, when there are more upgrades as a fraction of all Internet households and the implied price decline is higher (from counting conversion of second lines).

The retirement of phone lines is not quite as important as new surplus from conversion. For example, in our baseline estimates for $40 broadband, the gain is $11.35. The dropped second phone line is responsible for $5.35, while the consumer surplus is responsible for $6. When the baseline price is $36, then consumer surplus is comparatively more important. The second line is still responsible $5.35, but consumer surplus is now responsible for $10. So, removing the savings on the second line from the price index would remove anywhere from a 30% to 40% of the total savings.

That decomposition is relevant because price indices do not normally count the

saving of expenditure in one category (on a second telephone line) as an input into calculating the price index for another (Internet access). We appreciate this procedural norm and must note that we are not fully sympathetic with its consequences. More precisely, that objection should not be used as an excuse to do nothing; accounting should take place somewhere. We object to the present silence on web sites for the BLS, FCC, Census, NTIA, and others government web sites that track broadband diffusion. Silence about mis-measured gains and costs leaves policy discussion uninformed. That is a pity, since the basic economics is not conceptually difficult. The important challenge, as we have tried to illustrate, is rendering those concepts in a concrete form that helps move policy forward.

5. Conclusion

We contend that conventional accounting of broadband's effect on the U.S. economy understates its true economic impact. The increasing use of residential broadband created approximately $15 billion in additional value in the GDP by the end of 2006. Approximately $8.3 to $10.5 billion shows up as new revenue in GDP. Broadband created approximately $6.7 billion in consumer surplus, and as little as $4.8 billion. The upgrade was equivalent to an unmeasured decline in price of between 1.6% and 2.4% per year. Those are big numbers in a household market worth $20 to $22 billion dollars.

We have focused on topics for which we can put some bounds on the size of the measurement issues, albeit imperfectly. However, we do not want to leave the impression that this settles measurement questions, as many other issues related to quality adjustments still remain decidedly unsettled. Since these are quite difficult to measure,

they will likely prove difficult to fix. As a brief example, many broadband firms have recently upgraded the bandwidth of their lines without increasing prices for consumers; such upgrades are difficult to record and measure. In addition, the Internet access price index does not adjust for the improvement in the quality of the many free complements that have become available over this time period, such as improvements in the Google search engine, the Yahoo! portal, the MSN instant messaging client, or the caching by Akamai, to name just a few. The most popular sites, such as web portals and e-retailing sites, have invested to increase the quality of the experience for users. Backbone capacity across the country has also grown substantially, so that a data packet is less likely to be slowed, cueing at a public exchange point.

We do not, therefore, view our own attempts here as the final word on the estimation of the size of these effects; rather, we view them as an attempt to benchmark the size of the issues, which are large, and motivate others to undertake related exercises. We aspire to end the silence about the measurement issues and we look forward to more estimates of the size of the mis-measurement of the Internet economy.

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Appendix: Adjustments for Table 2.

Table 2 is constructed from the Annual Service Survey, conducted by the US Census. They differ from the five year economic censuses. The annual service surveys are estimates of economic activity, not complete censuses of economic activity, and they are designed to provide short run estimation at a greater frequency than every five years.

In general these estimates are based on a particular sampling frame (i.e., data collected from a small group of firms). In rapidly changing industries such sampling frames can, and do (!), become outdated quite quickly. Though the Census alters the sampling frame frequently (as often as every three or four years), it apply new lessons to old data. That is, it does not use a new sampling frame to re-estimate archival data. Hence, historical inconsistencies run throughout this data, particularly in years when new sampling frames are introduced (in this case that occurs between 2000 and 2001, and between 2003 and 2004).

In general, the Annual Survey does not provide guidance about how to adjust data to make inconsistent historical data consistent with each other. Conversations with employees indicated no plans to correct historical inconsistencies. In all cases, we try to stay as close as possible to published data and to use the latest publication, which sometimes corrects for errors in sampling frame. In 2004 we catch a break. Census published two sets of estimates, one using the old sampling frame and (a few months later) one using the new. This permitted a direct comparison of the two sampling frames and a correction for prior years (i.e., 2001, 02 and 03).

Cable modem revenue: For 1998, 1999 and 2000, the original data are taken from the tables for NAICS 5175, from the 2000 report. The data in 2001, 2002 and 2003 come from the listing for NAICS 5175, report for 2004, which uses a new sampling frame that differs from prior years. The data for 2004, 2005 and 2006 come from NAICS 5175, from the 2005 report, which also uses a new sampling frame. Due to change in sampling frame, the data from 2004-06 were no longer consistent with the data from 2001-03. For 2004 there were estimates using both sampling frames and the data for the new sampling frame (used in 2004-06) was found to be 10% higher than the old sampling frame (used in 2001-04). For consistency, data in 2001, 2002 and 2003 were adjusted upward 10%.

DSL revenue: The Census Annual Survey did not report DSL revenue as a separate item prior to 2001. The data for 2001, 2002 and 2003 originally come from NAICS 5133, and do not include backbone services. Data for 2004, 2005 and 2006 come from NAICS 5171, from the 2006 report, and use a new sampling frame. As with the other data, due to change in sampling frame, the data from 2004-05 was potentially inconsistent with the data from 2001-03. For 2004, there were estimates using both sampling frames and the data for the new sampling frame (used in 2004-06) was found to be inconsistent with the old sampling frame (used in 2001-04). Data in 2001, 2002 and 2003 were not adjusted by a fixed percentage, because doing so would have led to implausibly high revenue in 2001 and 2002 that would be inconsistent with FCC and Pew data on the number and growth of deployed DSL lines. To generate a series consistent with 2004 and with the FCC data on deployment, we started with 2004 and worked back to data for 1999, 2000, 2001, 2002, and 2003. These have growth rates similar to growth

in total DSL lines, as reported in FCC data on growth in DSL lines to all users (not just households, as reported in Table 1). These replace all reported numbers in 2001, 2002, and 2003, and these replace missing values in 1999 and 2000.

Dial-up revenue: The original data in 1998, 1999 and 2000 are taken from the tables for NAICS 514191, of the 2000 report. The data in 2001, 2002 and 2003 come from the table for NAICS 514191, which used a new sampling frame from prior years. The data for 2004, 2005 and 2006 are for NAICS 5181111, from the 2006 report, which also used a new sampling frame. Due to change in sampling frame, the data from 2004-06 was no longer consistent with the data from 2001-03. For 2004 there were estimates using both sampling frames. The data for the new sampling frame (used in 2004-06) was found to be 33% higher than the old sampling frame (used in 2001-04). For consistency, data in 2001, 2002 and 2003 were adjusted upward 33%.

Wireless revenue: The data for 2004 and 2005 come from NAICS 517212, in the report for 2005. It includes Internet access services for wireless carriers, but not satellite services. Disclosure issues prevented publication in 2006.

The Census Service Annual Survey is available for NAICS 51, as archived on http://www.census.gov/econ/www/servmenu.html. Prior to adjustment for sampling frame inconsistencies, the reports from the Census Annual Survey (for 1998-2000, 2001-03, 2004-06) original appear as follows:

	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Dial-up revenue	5499	8966	12345	10339	10596	10656	14081	12240	10983
Cable revenue	138	274	903	2364	3743	6702	9435	11139	13156
DSL revenue				4917	4343	4329	11924	13561	15066
Wireless revenue							668	1140	.

Appendix: Simulations - $36 Cases

Broadband Bonus - Base Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	100%	100%	100%	81%	81%	81%	81%	81%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
Δ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	945,000	2,235,000	6,450,000	2,697,300	4,511,700	7,265,700	10,991,700	4,835,700
Broadband Adopters (New Internet Users)	-	-	-	632,700	1,058,300	1,704,300	2,578,300	1,134,300
Cumulative Dial-up to Broadband Converts	945,000	3,180,000	9,630,000	12,327,300	16,839,000	24,104,700	35,096,400	39,932,100
Cumulative Broadband Adopters (NIU)	-	-	-	632,700	1,691,000	3,395,300	5,973,600	7,107,900
Annual Broadband Revenue	$ 408,240,000	$ 1,373,760,000	$ 4,160,160,000	$ 5,598,720,000	$ 8,004,960,000	$ 11,880,000,000	$ 17,742,240,000	$ 20,321,280,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual Δ)	$ 408,240,000	$ 965,520,000	$ 2,786,400,000	$ 1,165,233,600	$ 1,949,054,400	$ 3,138,782,400	$ 4,748,414,400	$ 2,089,022,400
Broadband Adopters (NIU) Revenue (Annual Δ)	-	-	-	$ 273,326,400	$ 457,185,600	$ 736,257,600	$ 1,113,825,600	$ 490,017,600
Cannibalized Dial-up Revenue	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 647,352,000	$ 1,082,808,000	$ 1,743,768,000	$ 2,638,008,000	$ 1,160,568,000
Retired Second Phone Line Revenue	-	-	-	$ 213,626,160	$ 357,326,640	$ 575,443,440	$ 870,542,640	$ 382,987,440
Total Conversion Cost	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 860,978,160	$ 1,440,134,640	$ 2,319,211,440	$ 3,508,550,640	$ 1,543,555,440
Additional Revenue from Broadband	**$ 181,440,000**	**$ 429,120,000**	**$ 1,238,400,000**	**$ 577,581,840**	**$ 966,105,360**	**$ 1,555,828,560**	**$ 2,353,689,360**	**$ 1,035,484,560**
Avg. Monthly Broadband Benefit for Converts	$ 10.00	$ 10.00	$ 10.00	$ 15.35	$ 15.35	$ 15.35	$ 15.35	$ 15.35
Implied Decline in Price for Converts	28%	28%	28%	43%	43%	43%	43%	43%
Annual Total Broadband Benefit (Converts)	**$ 113,400,000**	**$ 268,200,000**	**$ 774,000,000**	**$ 496,713,190**	**$ 830,838,578**	**$ 1,337,993,186**	**$ 2,024,143,538**	**$ 890,503,826**
Revenue + Consumer Surplus	**$ 294,840,000**	**$ 697,320,000**	**$ 2,012,400,000**	**$ 1,074,295,030**	**$ 1,796,943,938**	**$ 2,893,821,746**	**$ 4,377,832,898**	**$ 1,925,988,386**
Total Gross Benefits for Broadband Since 1999	**$ 294,840,000**	**$ 992,160,000**	**$ 3,004,560,000**	**$ 4,078,855,030**	**$ 5,875,798,968**	**$ 8,769,620,714**	**$ 13,147,453,613**	**$ 15,073,441,999**

Broadband Bonus - Conservative Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	100%	100%	100%	100%	100%	100%	100%	100%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
Δ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
Broadband Adopters (New Internet Users)	-	-	-	-	-	-	-	-
Cumulative Dial-up to Broadband Converts	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Cumulative Broadband Adopters (NIU)	-	-	-	-	-	-	-	-
Annual Broadband Revenue	$ 408,240,000	$ 1,373,760,000	$ 4,160,160,000	$ 5,598,720,000	$ 8,004,960,000	$ 11,880,000,000	$ 17,742,240,000	$ 20,321,280,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual Δ)	$ 408,240,000	$ 965,520,000	$ 2,786,400,000	$ 1,438,560,000	$ 2,406,240,000	$ 3,875,040,000	$ 5,862,240,000	$ 2,579,040,000
Broadband Adopters (NIU) Revenue (Annual Δ)	-	-	-	$ -	$ -	$ -	$ -	$ -
Cannibalized Dial-up Revenue	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 799,200,000	$ 1,336,800,000	$ 2,152,800,000	$ 3,256,800,000	$ 1,432,800,000
Retired Second Phone Line Revenue	-	-	-	$ 263,736,000	$ 441,144,000	$ 710,424,000	$ 1,074,744,000	$ 472,824,000
Total Conversion Cost	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 1,062,936,000	$ 1,777,944,000	$ 2,863,224,000	$ 4,331,544,000	$ 1,905,624,000
Additional Revenue from Broadband	**$ 181,440,000**	**$ 429,120,000**	**$ 1,238,400,000**	**$ 375,624,000**	**$ 628,296,000**	**$ 1,011,816,000**	**$ 1,530,696,000**	**$ 673,416,000**
Avg. Monthly Broadband Benefit for Converts	$ 10.00	$ 10.00	$ 10.00	$ 16.60	$ 16.60	$ 16.60	$ 16.60	$ 16.60
Implied Decline in Price for Converts	28%	28%	28%	46%	46%	46%	46%	46%
Annual Total Broadband Benefit (Converts)	**$ 113,400,000**	**$ 268,200,000**	**$ 774,000,000**	**$ 663,336,000**	**$ 1,109,544,000**	**$ 1,786,824,000**	**$ 2,703,144,000**	**$ 1,189,224,000**
Revenue + Consumer Surplus	**$ 294,840,000**	**$ 697,320,000**	**$ 2,012,400,000**	**$ 1,038,960,000**	**$ 1,737,840,000**	**$ 2,798,640,000**	**$ 4,233,840,000**	**$ 1,862,640,000**
Total Gross Benefits for Broadband Since 1999	**$ 294,840,000**	**$ 992,160,000**	**$ 3,004,560,000**	**$ 4,043,520,000**	**$ 5,781,360,000**	**$ 8,580,000,000**	**$ 12,813,840,000**	**$ 14,676,480,000**

Broadband Bonus - Aggressive Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	81%	81%	81%	81%	81%	81%	81%	81%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
Δ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	765,450	1,810,350	5,224,500	2,697,300	4,511,700	7,265,700	10,991,700	4,835,700
Broadband Adopters (New Internet Users)	179,550	424,650	1,225,500	632,700	1,058,300	1,704,300	2,578,300	1,134,300
Cumulative Dial-up to Broadband Converts	765,450	2,575,800	7,800,300	10,497,600	15,009,300	22,275,000	33,266,700	38,102,400
Cumulative Broadband Adopters (NIU)	179,550	604,200	1,829,700	2,462,400	3,520,700	5,225,000	7,803,300	8,937,600
Annual Broadband Revenue	$ 408,240,000	$ 1,373,760,000	$ 4,160,160,000	$ 5,598,720,000	$ 8,004,960,000	$ 11,880,000,000	$ 17,742,240,000	$ 20,321,280,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual Δ)	$ 330,674,400	$ 782,071,200	$ 2,256,984,000	$ 1,165,233,600	$ 1,949,054,400	$ 3,138,782,400	$ 4,748,414,400	$ 2,089,022,400
Broadband Adopters (NIU) Revenue (Annual Δ)	77,565,600.00	261,014,400.00	790,430,400.00	$ 273,326,400	$ 457,185,600	$ 736,257,600	$ 1,113,825,600	$ 490,017,600
Cannibalized Dial-up Revenue	$ 183,708,000	$ 434,484,000	$ 1,253,880,000	$ 647,352,000	$ 1,082,808,000	$ 1,743,768,000	$ 2,638,008,000	$ 1,160,568,000
Retired Second Phone Line Revenue	-	-	-	$ 213,626,160	$ 357,326,640	$ 575,443,440	$ 870,542,640	$ 382,987,440
Total Conversion Cost	$ 183,708,000	$ 434,484,000	$ 1,253,880,000	$ 860,978,160	$ 1,440,134,640	$ 2,319,211,440	$ 3,508,550,640	$ 1,543,555,440
Additional Revenue from Broadband	**$ 224,532,000**	**$ 608,601,600**	**$ 1,793,534,400**	**$ 577,581,840**	**$ 966,105,360**	**$ 1,555,828,560**	**$ 2,353,689,360**	**$ 1,035,484,560**
Avg. Monthly Broadband Benefit for Converts	$ 10.00	$ 10.00	$ 10.00	$ 15.35	$ 15.35	$ 15.35	$ 15.35	$ 15.35
Implied Decline in Price for Converts	28%	28%	28%	43%	43%	43%	43%	43%
Annual Total Broadband Benefit (Converts)	**$ 91,854,000**	**$ 217,242,000**	**$ 626,940,000**	**$ 496,713,190**	**$ 830,838,578**	**$ 1,337,993,186**	**$ 2,024,143,538**	**$ 890,503,826**
Revenue + Consumer Surplus	**$ 316,386,000**	**$ 825,843,600**	**$ 2,420,474,400**	**$ 1,074,295,030**	**$ 1,796,943,938**	**$ 2,893,821,746**	**$ 4,377,832,898**	**$ 1,925,988,386**
Total Gross Benefits for Broadband Since 1999	**$ 316,386,000**	**$ 1,142,229,600**	**$ 3,562,704,000**	**$ 4,636,999,030**	**$ 6,433,942,968**	**$ 9,327,764,714**	**$ 13,705,597,613**	**$ 15,631,585,999**

Appendix: Simulations - $40 Cases

Broadband Bonus - Base Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	100%	100%	100%	81%	81%	81%	81%	81%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
Δ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	945,000	2,235,000	6,450,000	2,697,300	4,511,700	7,265,700	10,991,700	4,835,700
Broadband Adopters (New Internet Users)	-	-	-	632,700	1,058,300	1,704,300	2,578,300	1,134,300
Cumulative Dial-up to Broadband Converts	945,000	3,180,000	9,630,000	12,327,300	16,839,000	24,104,700	35,096,400	39,932,100
Cumulative Broadband Adopters (NIU)	-	-	-	632,700	1,691,000	3,395,300	5,973,600	7,107,900
Annual Broadband Revenue	$ 453,600,000	$ 1,526,400,000	$ 4,622,400,000	$ 6,220,800,000	$ 8,894,400,000	$ 13,200,000,000	$ 19,713,600,000	$ 22,579,200,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual Δ)	$ 453,600,000	$ 1,072,800,000	$ 3,096,000,000	$ 1,294,704,000	$ 2,165,616,000	$ 3,487,536,000	$ 5,276,016,000	$ 2,321,136,000
Broadband Adopters (NIU) Revenue (Annual Δ)	-	-	-	$ 303,696,000	$ 507,984,000	$ 818,064,000	$ 1,237,584,000	$ 544,464,000
Cannibalized Dial-up Revenue	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 647,352,000	$ 1,082,808,000	$ 1,743,768,000	$ 2,638,008,000	$ 1,160,568,000
Retired Second Phone Line Revenue	-	-	-	$ 213,626,160	$ 357,326,640	$ 575,443,440	$ 870,542,640	$ 382,987,440
Total Conversion Cost	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 860,978,160	$ 1,440,134,640	$ 2,319,211,440	$ 3,508,550,640	$ 1,543,555,440
Additional Revenue from Broadband	**$ 226,800,000**	**$ 536,400,000**	**$ 1,548,000,000**	**$ 737,421,840**	**$ 1,233,465,360**	**$ 1,986,388,560**	**$ 3,005,049,360**	**$ 1,322,044,560**
Avg. Monthly Broadband Benefit for Converts	$ 6.00	$ 6.00	$ 6.00	$ 11.35	$ 11.35	$ 11.35	$ 11.35	$ 11.35
Implied Decline in Price for Converts	15%	15%	15%	28%	28%	28%	28%	28%
Annual Total Broadband Benefit (Converts)	**$ 68,040,000**	**$ 160,920,000**	**$ 464,400,000**	**$ 367,242,790**	**$ 614,276,978**	**$ 989,239,586**	**$ 1,496,541,938**	**$ 658,390,226**
Revenue + Consumer Surplus	**$ 294,840,000**	**$ 697,320,000**	**$ 2,012,400,000**	**$ 1,104,664,630**	**$ 1,847,742,338**	**$ 2,975,628,146**	**$ 4,501,591,298**	**$ 1,980,434,786**
Total Gross Benefits for Broadband Since 1999	**$ 294,840,000**	**$ 992,160,000**	**$ 3,004,560,000**	**$ 4,109,224,630**	**$ 5,956,966,968**	**$ 8,932,595,114**	**$ 13,434,186,413**	**$ 15,414,621,199**

Broadband Bonus - Conservative Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	100%	100%	100%	100%	100%	100%	100%	100%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
Δ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
Broadband Adopters (New Internet Users)	-	-	-	-	-	-	-	-
Cumulative Dial-up to Broadband Converts	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Cumulative Broadband Adopters (NIU)	-	-	-	-	-	-	-	-
Annual Broadband Revenue	$ 453,600,000	$ 1,526,400,000	$ 4,622,400,000	$ 6,220,800,000	$ 8,894,400,000	$ 13,200,000,000	$ 19,713,600,000	$ 22,579,200,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual Δ)	$ 453,600,000	$ 1,072,800,000	$ 3,096,000,000	$ 1,598,400,000	$ 2,673,600,000	$ 4,305,600,000	$ 6,513,600,000	$ 2,865,600,000
Broadband Adopters (NIU) Revenue (Annual Δ)	-	-	-	$ -	$ -	$ -	$ -	$ -
Cannibalized Dial-up Revenue	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 799,200,000	$ 1,336,800,000	$ 2,152,800,000	$ 3,256,800,000	$ 1,432,800,000
Retired Second Phone Line Revenue	-	-	-	$ 263,736,000	$ 441,144,000	$ 710,424,000	$ 1,074,744,000	$ 472,824,000
Total Conversion Cost	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 1,062,936,000	$ 1,777,944,000	$ 2,863,224,000	$ 4,331,544,000	$ 1,905,624,000
Additional Revenue from Broadband	**$ 226,800,000**	**$ 536,400,000**	**$ 1,548,000,000**	**$ 535,464,000**	**$ 895,656,000**	**$ 1,442,376,000**	**$ 2,182,056,000**	**$ 959,976,000**
Avg. Monthly Broadband Benefit for Converts	$ 6.00	$ 6.00	$ 6.00	$ 12.60	$ 12.60	$ 12.60	$ 12.60	$ 12.60
Implied Decline in Price for Converts	15%	15%	15%	32%	32%	32%	32%	32%
Annual Total Broadband Benefit (Converts)	**$ 68,040,000**	**$ 160,920,000**	**$ 464,400,000**	**$ 503,496,000**	**$ 842,184,000**	**$ 1,356,264,000**	**$ 2,051,784,000**	**$ 902,664,000**
Revenue + Consumer Surplus	**$ 294,840,000**	**$ 697,320,000**	**$ 2,012,400,000**	**$ 1,038,960,000**	**$ 1,737,840,000**	**$ 2,798,640,000**	**$ 4,233,840,000**	**$ 1,862,640,000**
Total Gross Benefits for Broadband Since 1999	**$ 294,840,000**	**$ 992,160,000**	**$ 3,004,560,000**	**$ 4,043,520,000**	**$ 5,781,360,000**	**$ 8,580,000,000**	**$ 12,813,840,000**	**$ 14,676,480,000**

Broadband Bonus - Aggressive Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	81%	81%	81%	81%	81%	81%	81%	81%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
Δ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	765,450	1,810,350	5,224,500	2,697,300	4,511,700	7,265,700	10,991,700	4,835,700
Broadband Adopters (New Internet Users)	179,550	424,650	1,225,500	632,700	1,058,300	1,704,300	2,578,300	1,134,300
Cumulative Dial-up to Broadband Converts	765,450	2,575,800	7,800,300	10,497,600	15,009,300	22,275,000	33,266,700	38,102,400
Cumulative Broadband Adopters (NIU)	179,550	604,200	1,829,700	2,462,400	3,520,700	5,225,000	7,803,300	8,937,600
Annual Broadband Revenue	$ 453,600,000	$ 1,526,400,000	$ 4,622,400,000	$ 6,220,800,000	$ 8,894,400,000	$ 13,200,000,000	$ 19,713,600,000	$ 22,579,200,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual Δ)	$ 367,416,000	$ 868,968,000	$ 2,507,760,000	$ 1,294,704,000	$ 2,165,616,000	$ 3,487,536,000	$ 5,276,016,000	$ 2,321,136,000
Broadband Adopters (NIU) Revenue (Annual Δ)	86,184,000.00	290,016,000.00	878,256,000.00	$ 303,696,000	$ 507,984,000	$ 818,064,000	$ 1,237,584,000	$ 544,464,000
Cannibalized Dial-up Revenue	$ 183,708,000	$ 434,484,000	$ 1,253,880,000	$ 647,352,000	$ 1,082,808,000	$ 1,743,768,000	$ 2,638,008,000	$ 1,160,568,000
Retired Second Phone Line Revenue	-	-	-	$ 213,626,160	$ 357,326,640	$ 575,443,440	$ 870,542,640	$ 382,987,440
Total Conversion Cost	$ 183,708,000	$ 434,484,000	$ 1,253,880,000	$ 860,978,160	$ 1,440,134,640	$ 2,319,211,440	$ 3,508,550,640	$ 1,543,555,440
Additional Revenue from Broadband	**$ 269,892,000**	**$ 724,500,000**	**$ 2,132,136,000**	**$ 737,421,840**	**$ 1,233,465,360**	**$ 1,986,388,560**	**$ 3,005,049,360**	**$ 1,322,044,560**
Avg. Monthly Broadband Benefit for Converts	$ 6.00	$ 6.00	$ 6.00	$ 11.35	$ 11.35	$ 11.35	$ 11.35	$ 11.35
Implied Decline in Price for Converts	15%	15%	15%	28%	28%	28%	28%	28%
Annual Total Broadband Benefit (Converts)	**$ 55,112,400**	**$ 130,345,200**	**$ 376,164,000**	**$ 367,242,790**	**$ 614,276,978**	**$ 989,239,586**	**$ 1,496,541,938**	**$ 658,390,226**
Revenue + Consumer Surplus	**$ 325,004,400**	**$ 854,845,200**	**$ 2,508,300,000**	**$ 1,104,664,630**	**$ 1,847,742,338**	**$ 2,975,628,146**	**$ 4,501,591,298**	**$ 1,980,434,786**
Total Gross Benefits for Broadband Since 1999	**$ 325,004,400**	**$ 1,179,849,600**	**$ 3,688,149,600**	**$ 4,792,814,230**	**$ 6,640,556,568**	**$ 9,616,184,714**	**$ 14,117,776,013**	**$ 16,098,210,799**