

The Broadband Bonus:

***Accounting for Broadband Internet's Impact on U.S.
GDP***

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Comments welcome.

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Abstract

How much economic value did the diffusion of broadband create? We provide benchmark estimates for 1999 to 2006. We observe \$39 billion of total revenue in Internet access in 2006, with broadband accounting for \$28 billion of this total. Depending on the estimate, households generated \$20 to \$22 billion of the broadband revenue. Approximately \$8.3 to \$10.6 billion was additional revenue created between 1999 and 2006. That replacement is associated with \$4.8 to \$6.7 billion in consumer surplus, which is not measured via Gross Domestic Product (GDP). An Internet-access Consumer Price Index (CPI) would have to decline by 1.6% to 2.2% per year for it to reflect the creation of value. These estimates both differ substantially from those typically quoted in Washington policy discussions, and they shed light on several broadband policy issues, such as why relying on private investment worked to diffuse broadband in many US urban locations at the start of the millennium.

I. 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.¹ By March 2006, a sharply contrasting picture emerged: Approximately 47 million households (and growing) had broadband connections, while 34 million (and declining) used dial-up.²

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 and more expensive alternative, albeit one available in only a few places and from a limited set of providers, if any. Then over time, broadband became more reliable and more widely available, and as that happened, many households paid to upgrade their Internet service.

The upgrade to broadband motivates a seemingly straightforward question: What was the contribution to new economic value created through the replacement of dial-up access with broadband? This type of question has appeared in prior literature measuring new goods, and prior work has developed two conventional approaches: One focuses on the creation of new economic growth, as measured by new gross domestic product (GDP), and the other focuses on new consumer surplus. Neither economic yardstick is better than the other, because each measures something different.

¹ NTIA (2004) is the source for these statistics.

² See Horrigan (2007) at <http://www.pewinternet.org/>.

Addressing this topic is not solely of academic interest but also informs long-standing policy interest in deployment of the “last mile,” that is, the supply of services for delivering data between the national/global data grid and end-users. In recent times the revenue associated with the last mile was quite large. In fact, Internet access revenue measurements reached \$39 billion in 2006. For some time, there has been debate about the structure for maximizing the economic gains from building this infrastructure.³ Most of the literature does not examine -- but instead assumes -- that the infrastructure led to large economic gains. In contrast, this paper examines the potential for the (mis)measurement of those gains.

Here, we calculate a benchmark for the two conventional approaches to measuring economic gains. We render these numerical estimates in the spirit of Johnson, who states, “That, sir, is the good of counting. It brings every thing to a certainty, which before floated in the mind indefinitely.”⁴ In other words, we provide numerical estimates where before there had been none. This establishes the plausible range of the size of the measured economic gains from the upgrade to broadband.

Our findings are as follows: While broadband accounted for \$28 billion of GDP in 2006 (out of \$39 billion in total for Internet access), we estimate that approximately \$20 to \$22 billion was associated with household use. Of that amount we estimate that broadband’s deployment created approximately \$8.3 to \$10.6 billion of new GDP. In

³ The policy concern arises from the belief that this infrastructure plays a key role in fostering others, and from international ranking showing that the United States has lower deployment than many other developed countries. 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 and discussion of issues, see Atkinson, Correa, and Hedlund (2008).

⁴ From *Boswell’s Life of Johnson*.

addition, between \$6.7 and \$4.8 billion is new consumer surplus. In both cases, this is above and beyond what dial-up would have generated. The newly created GDP is between 40% and 50% of measured total GDP, while consumer surplus (which is not measured) is between 31% and 47% of the newly created GDP. We can express the latter gain as an equivalent decline in prices. We show that Internet access price indices would have to decline 1.6% to 2.2% per year to account for the consumer benefits generated from upgrading to broadband.

Our estimates are interesting for a number of reasons. First, they are much lower than those typically quoted by Washington-based policy analysts and lobbyists, who regularly quote outsized economic benefits from the deployment of broadband in the range of hundreds of billions of dollars.⁵ We believe our estimates suggest that these outsized estimates are dangerously misleading at best and are rendered with flawed economic reasoning and incorrect statistical approaches.⁶

Second, our estimate also differs from the CPI (Consumer Price Index) for Internet access. We correct a historically inaccurate inference about the pricing of Internet access and conclude that the official index's timing of price decline is actually several years too late.

⁵ Crandall and Jackson (2001) forecast is a typical example, emphasizing indirect benefits with a title that discusses a "\$500 Billion dollar opportunity." Crandall (2005) cites the same study and others, pegging the gains at \$300 billion. More recently, Connected Nation (2008) pegs the benefits from national deployment of broadband in *only* rural areas at \$134 Billion. For a summary of these and other studies, see Atkinson, Correa, and Hedlund (2008), which stresses both the direct effects from building broadband and a large number of secondary economic consequences, once again, coming to very large gains.

⁶ For example, the report by Connected Nation (2008) uses estimates of the growth brought about by broadband in urban areas to estimate its impact in rural areas. Such estimates do not control for endogeneity or the projecting of results to ranges of data far out of sample. The report also adds additional benefits to broadband by focusing on the "indirect" benefits from deployment of broadband. The language of "direct and indirect" benefits obscures the boundary between private willingness to pay and externalities, as found in conventional economic approaches.

Third, our second conclusion leads to another implication: We inform understanding about why the national policy of the last decade has had the effects it did. Initially, most federal policy sought to subsidize the deployment of dial-up technologies to less-served areas and users⁷; but, at the outset of the millennium, policy changed.⁸ The new policies relied largely on the private incentives of private actors to deploy broadband technologies, without subsidy or any regulatory intervention. In retrospect, they seemed to work well—that is, wire line-based broadband diffused widely. Yet, this outcome was puzzling in light of the lack of price change measured in the CPI. In fact, our findings resolve this puzzle: Price indices undervalued the gains to users, and these gains were what motivated the upgrade at many households. In addition, our recalculation of conventional GDP estimates illustrates that the incremental gain to a broadband supplier from creating new revenue covered the costs of investments in urban and suburban areas. In short, there was no policy magic to relying on private incentives. Private benefits simply exceeded private costs if both are measured correctly.

As emphasized by Fogel (1962), Bresnahan and Gordon (1997), and many others, neither yardstick for economic gains is easy to measure in ways consistent with standard

⁷ In the early 1990s, US national policy focused on deploying technologies that allowed for higher data-transfer rates over telephone lines, such as ISDN (Integrated Service Date Networks), which supported bandwidth speeds of 128k. Later, changes to access and interconnection policies altered investment incentives for incumbent local exchange providers. 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 still, the FCC (Federal Communications Commission) reclassified broadband investment outside the range of procedures used to review common carriers, raising incentives for such investment. For an overview, see Goldstein (2005), Neuchterlein and Weiser (2005) and Greenstein (2008).

⁸ It is no exaggeration to say that policy was shaped by events, such as the implosion of competitive local exchange competitors (the so-called “Telecom meltdown”), the AOL/Time Warner merger, the dot-com bubble burst, and Worldcom’s and Enron’s bankruptcies. So too did the effects of the administration change on the legal interplay between the FCC and courts reviewing its decisions. For an overview, see, e.g., Goldstein (2005), Neuchterlein and Weiser (2005) and Greenstein (2008).

economic foundations. In this case, rendering benchmarks requires accurate data on prices and quantities for household use of the Internet, and these must be interpreted through an appropriate model. While we do not present any statistical advances in this paper, we do illustrate the importance of using well-known economic methods for an on-going policy debate, particularly where such methods are regularly overlooked. Assembling the best publicly available sources of data is also another of this paper's contributions. A third contribution is the calibration exercise we perform using different assumptions consistent with the available data. That exercise exposes the importance of specific assumptions and focuses attention on areas that require improvement and more precision. In that sense, our study is in line with the sentiments expressed by Flamm and colleagues (2007),⁹ who argue for putting US broadband policy on a footing more firmly founded in conventional economic reasoning and transparent statistic approaches.

Our plan is as follows: In Section II, we briefly discuss our approach to measuring the economic value generated by broadband. In Section III, we measure the diffusion and pricing of Internet access services during the years between 1999 and 2006 in relation to the GDP and CPI. In Section IV, we discuss the data we collect; and in Section V, we perform our simulations of the value created by the diffusion of broadband. Finally, in Section VI, we conclude with an assessment of future directions for policy discussions.

⁹ Flamm, Friedlander, Horrigan, and Lehr (2007) focuses on a wide range of issues, such as measuring productivity and assembling new data to accommodate novel on-line economic behavior. The primary goal of this paper is to dig deeply into one aspect of this broad agenda.

II. The Measurement of Economic Benefits from New Goods

There is an established literature for measuring the economic gains from the deployment of a new good. It has been widely accepted since Fogel (1962) that it is an error to focus solely on the demand for and supply of the new good. Instead, attention should be paid to the additional benefits beyond what would have occurred without the deployment of the new good. Fogel famously illustrated this concept by measuring the contribution of railroads to economic growth in the United States in the mid-Nineteenth Century, while stressing the economic growth above and beyond what canals would have provided had they continued to operate. In this paper, there is an analogous measurement—between the deployment of broadband and what would have occurred had broadband never deployed, i.e., had dial-up continued to operate at a large scale.

Here, we measure two gains from the new good by addressing two questions: First, what is the increase in revenue (GDP) above and beyond what would have been generated had dial-up continued? Second, what is the increase in consumer surplus beyond what would have occurred had dial-up continued? When doing these exercises we will follow convention and not worry about *which* vendor or user gains or loses, but will only compute an aggregate measure.

We focus on revenue instead of producer surplus because we are hampered by the lack of precise information about the unit cost of provision, which is necessary for an estimate of producer surplus at each point in time. Instead, we examine the difference in revenue between vendors with broadband and those without, absent multiplier and

general equilibrium effects. That is, we estimate how much the GDP increased in the Internet access market as a result of the deployment of broadband. Then, to provide a ballpark of the producer surplus generated, we compare that estimate against estimates for upgrade costs for an initial broadband build-out and typical variable costs per year.

To measure consumer surplus ideally, we should measure the difference in “areas under the demand curves” between the actual demand for broadband and what consumer surplus would have demanded had dial-up continued and not been replaced by broadband. This is challenging to do for many reasons, but one is primary here: We cannot observe what the dial-up market would have looked like had broadband not diffused. Instead of measuring two demand curves, we get close to our ideal measure by looking at estimates of user willingness to pay for the upgrade to broadband.

Our approaches provide a more precise interpretation of the economic gains from broadband in comparison to the approach commonly employed in policy discussions today, which focuses on “indirect/direct” benefits from the upgrade.¹⁰ Here, we measure the economic factors considered by parties involved in a transaction—anything that shapes the perceived or anticipated costs of using dial-up, the willingness to pay for an upgrade to broadband, and/or the decision not to return to dial-up. The following factors shape revenue for suppliers: Sale of second lines, revenue for dial-up access, and revenue for broadband access. The following factors shape the anticipated value of broadband service and, hence, the willingness to pay for an upgrade: Savings on a second line,

¹⁰ Such reasoning can be found throughout policy discussion about the economic benefits from diffusion of broadband. See e.g., Atkinson, Correa, and Hedlund (2008) for a summary.

savings on commute time, anticipated health and entertainment benefits, and anticipated savings on phone bill (e.g., if user moves to VoIP, or Voice-Over Internet Protocol).

Our understanding of these factors circumscribes our interpretation of the estimates, which do not include externalities, such as benefits or costs not considered by the parties involved in the transaction. For example, our interpretation does not include externalities to suppliers, such as the benefits to Cisco from selling more Wi-Fi equipment to users, to Amazon from additional sales because broadband users experience more satisfying service, or to Google from more advertisement sales because users stay on-line longer. Similarly, our interpretation does not include externalities to users. Those would be unanticipated or unperceived costs or gains—such as the unanticipated slowness that one neighbor’s use imposes on another’s in a cable architecture, or the benefits that one person’s participation in a p2p (peer-to-peer) network confers on another (as long as there is no membership fee).

II. i. Gaps in Measurement

While our exercise follows the spirit of Fogel (1962), we recognize the criticism that technical change in a key nationwide infrastructure motivates an endogenous response in complementary goods and services (see, e.g., David 1969). This alternative approach would argue that had broadband never diffused, many of the complementary services (e.g., downloadable music, video sharing) might not have been invented, or alternative innovations might have dominated an industry where dial-up had primacy, thereby altering the demand for dial-up. In this alternative view, the Fogel-exercise is misspecified when these complementary services have great economic significance. Further,

that misspecification invariably becomes more likely, and of greater economic importance, as time passes.

We avoid addressing such debates for two reasons. First, we focus on such a short time period (eight years). More to the point, our data will show that most US households have comparatively little experience with using on-line broadband. Second, most surveys of on-line household use after broadband upgrades show only mild changes in the time and composition of activity on-line. These changes are not symptoms of radical transformations in economic behavior, as would occur if the entry of complementary services were economically important to the economic gains realized by users who adopt broadband.¹¹

The approach in this paper will lead to much smaller estimates of the economic benefits from the diffusion of broadband than found in existing policy studies. This arises for several reasons: First, as noted, we follow the spirit of Fogel's research and others have not.¹² Second, this study does not count any indirect benefits. In our reading of other studies, it appears that the presence of indirect benefits has been license for analysts to blur the boundary between internalized benefits and externalities in economic growth. At worse, analysts have added many benefits to the deployment of broadband far out of scale with the private benefits motivating adoption.¹³ Third, we calibrate against the

¹¹ Surveys show that the greatest changes in behavior among new users of broadband occur in music downloading and total time on-line, not in the general distribution of time spent among different categories of activities other than music. See e.g., <http://www.pewinternet.org/>.

¹² For example, Crandall and Jackson (2001) calculate the entire area under the demand curve for broadband, but leave open question as to whether that consumer surplus would have arisen with dial-up anyway.

¹³ See, e.g., Connected Nation (2008) for an especially egregious example of misuse of this license.

actual diffusion pattern of broadband over eight years, not any forecast of an ideal year or adoption pattern. Calibrating against history (instead of a forecast) grounds estimates and removes considerable hype.

III. Measuring Broadband Services

III.i. Internet Deployment Policy

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, involved an upgrade of the bandwidth for many households.

For all intents and purposes, during this period, broadband service was delivered to households primarily in two forms of wire-line service — over cable or telephone lines. The former involved a gradual upgrade to cable plants in many locales, depending on the generation of the cable system.¹⁴ 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 choices typically supported higher bandwidth *to* the household than *from* it—called *Asymmetric Digital Subscriber Line* (ADSL) in the latter case. Some

¹⁴ 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. See Crandall (2005). 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 Internet Service Provider (ISP), as occurred after the AOL/Time Warner merger. See Rosston (2006).

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 households with faster Internet access and better on-line applications. In addition, broadband services are also “always on,” and users perceive that as a more convenient service.¹⁵ Broadband also may allow users to 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/bandwidth of lines, the number of users in the neighborhood in a cable system, the geographic location of a system in the national grid, the frequency of use of sites with geographically dispersed caching, and the time of day at which the household performs most activities. In brief, generalizations are hard to make beyond the obvious: Broadband gives the user a better experience than dial-up access.¹⁶

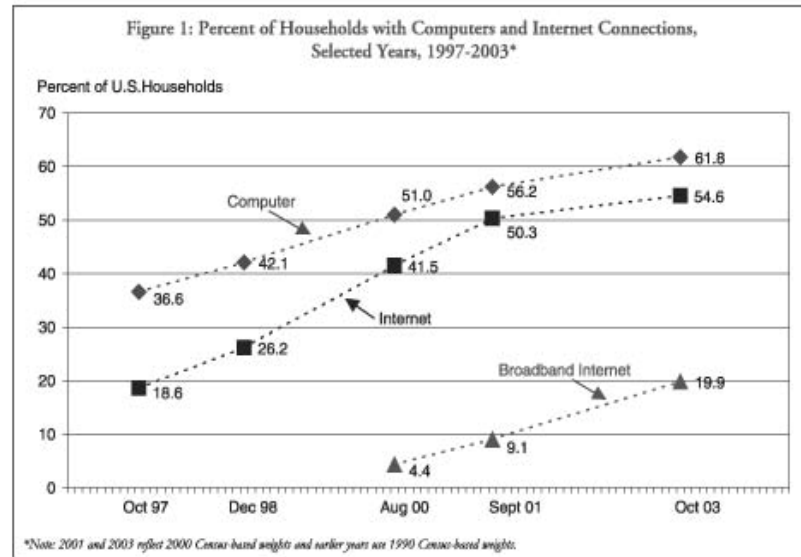
III.ii. Measuring Diffusion

Broadband was available in only a few locations in the 1990s and the early 2000s, but it became more available over time. User demands for high-bandwidth applications increased as households became familiar with high-bandwidth Internet applications (such

¹⁵ Surveys show that a maximum rate of 14.4K (kilobytes per second) and 28.8K were predominant in the mid 1990s for dial-up modems. The typical bandwidth in the late 1990s was 43K to 51K, 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 (megabytes per second), depending on the user choices and vendor configuration.

¹⁶ Download speed may not reach the 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.

as music downloading). Firms also rolled out new services as more users acquired broadband (e.g., Web2.0 applications), which then generated even more adoption.



This story is consistent with Figure 1, which provides a summary of the federal government’s efforts to collect data about the adoption of the Internet.¹⁷ 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 these surveys were discontinued for some time.¹⁸ Recent data about household use, collected by the Pew Internet and American Life Project, show that the diffusion continued in the anticipated direction, accelerating

¹⁷ 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). The survey was stopped after 2003, then reinitiated in 2007. The latest data are not available, as of this writing. CPS Supplement surveys prior to 1997 also examined PC use at home, but asked about use of generic on-line services, such as CompuServe, not Internet access. For simplicity and consistency, we stick with Figure 1.

¹⁸ The descriptive results were published in reports authored by staff at the NTIA. See NTIA (2004).

somewhat.¹⁹ Notably, adoption reached over 47% of households by 2006. We will discuss this data in more detail below. In Table 1, we provide a summary of another set of efforts by the FCC to measure the deployment of broadband lines, information that the FCC collects from surveys of firms.²⁰ It tells the same story as Figure 1, but from the vendor-side of the market: Vendors were increasingly deploying broadband lines, presumably to meet growing household demand.

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	1342.5	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.²¹

There are no revenue estimates for household broadband services, but we can place a bound on an estimate for the combination of household and business revenues. The US Bureau of the Census estimates revenues 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).²² We

¹⁹ See <http://www.pewinternet.org/>.

²⁰ The FCC has never asked about deployment of dial-up. It also has never asked about the prices of broadband.

²¹ See <http://www.fcc.gov/wcb/iatd/comp.html>, *Broadband Reports*, Table 3, for precise definitions. This table covers any line with at least 200kps in *either* direction.

²² 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 all the estimates consistent over time.

expect that between 60% and 75% of the revenue in Table 2 is from households, depending on the year and access mode.²³

The growth in revenues in Table 2—from \$5.5 billion in 1998 to \$39 billion in 2006—is astonishing for an entirely new market, especially one that did not start growing quickly until after 1995. Broadband revenues comprise approximately half the total revenue over the eight years, beginning with less than 6% in 1999 and growing to 72% of the total revenue in 2006.

These revenue levels are important to stress, because access fees generated most of the revenue during the first decade of the commercial Internet. The typical household spent more than three-quarters of its time on-line at free or advertising-supported sites, devoting most of its Internet budget to access fees, not subscription fees.²⁴ Although subscription-based services and advertising services have started growing rapidly after 2003, the amount spent on access fees each year far exceeds advertising revenue. Advertising revenue is now growing at a more rapid pace than subscription fees, and it may exceed access revenue soon, but not as of this writing.²⁵

²³ We came to that estimate by the following means. First, our estimates below suggest household revenue for the Internet overall makes up 70% to 75% of the total revenue. Second, the FCC broadband deployment report puts the number of broadband lines to households at roughly two-thirds of the total number of lines deployed. Since revenue per line for business likely exceeds that for households, it is plausible that household revenue is closer to 60% of total revenue. See Table 13: High Speed Services for Internet Access at <http://www.fcc.gov/wcb/iatd/comp.html>. Hence, in the text we say “60% to 75%”. Note that Table 1 and 2 are not comparable, since Table 1 is for households only, while Table 2 is for households and business.

²⁴ See, e.g., Goldfarb (2004).

²⁵ The following will provide a sense of the magnitudes of different activities. In the *2006 Annual Service Survey*, Web Search Portals (NAICS 518112) generated \$6.3 billion in advertising in 2006, out of \$9.1 billion in total revenue. This is up from \$4.5 billion and \$3.3 billion in advertising revenue in 2005 and 2004, respectively. In addition, Internet Publishers (NAICS 516) generated \$2.6 billion in revenue in 2006, up from \$2.3 billion and \$1.8 billion in 2004 and 2005, respectively. That is still far less than the \$39 billion in access revenue in 2006.

TABLE 2 Adjusted revenue for access markets (millions of dollars)

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.

III.iii. Measuring Prices

Another way to measure technical progress is through the decline in prices. The CPI for Internet access is officially called *Internet services and electronic information providers*, which the Bureau of Labor Statistics began compiling in December 1997, after approximately 20% of US households had adopted the commercial Internet.²⁶ 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>.

²⁶ 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.

The series has a distinct pattern: It indicates that the official price index for Internet access in the United States went mildly down and up during the five years of the dot-com boom and bust, between December 1997, and December 2002.²⁷ It then declined 5% over the next three years, between December 2002, and December 2005—again, a mild decline for a downturn. Then, in late 2006, it declined more than 18% from its base (i.e., $(94.5 - 77.2)/94.2 = .183$). We note that the drop continued (illustrated with the quote from 12/07). It settled at a 23% from its base in January 2007 (i.e., $(94.5 - 73.4)/94.5$) and it stayed there for the year.²⁸ 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.²⁹

We believe this pattern is primarily due to America On Line's (AOL) pricing decisions. 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.³⁰ 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

²⁷ With only a few exceptions, the index does not change much month to month or year to year, so we could have taken a sample of another month and gotten a similar picture.

²⁸ 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 United States demonstrated the following patterns: Computer software and accessories declined 42%; personal computers and peripheral equipment declined 88%; telephone hardware, calculators, and related consumer items declined 55%; and wireless telephone services declined 35%.

²⁹ The indexes in July, August, and September 2006 are 97.3, 94.7, and 93.1, respectively. The index then drops to 87.0 in October, 81.1 in November, and 77.2 in December, settling at 73.4 in January 2007.

³⁰ AOL did retain a number of revenue-generating activities other than advertising. For example, it gave users the option to maintain an email account for a nominal fee (e.g., \$5/month).

than one-quarter of the US households that used the Internet.³¹ When one vendor makes up approximately 25% of an index and it announces a 100% decline in price, it is tautological that the index must decline by 25%. 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 were moving downward and upward at the same time.³²

To bolster our contention that AOL’s price change was primarily responsible for the observed trends, we note two other examples consistent with that theory. First, after AOL’s merge with CompuServe in the summer of 1999, when its market share was much larger, AOL attempted to give price breaks to former CompuServe users (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—May through July. The effect lasted only as long as AOL’s promotion; thereafter the index returned to its previous level.³³ Second, 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 the time

³¹ 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 a 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.

³² 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.

³³ 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.

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.³⁴

Nevertheless, our speculation is not completely air-tight because we only have partial information about non-AOL providers, which make up the other half of dial-up supply. Market share is skewed among this category of providers, but there was also a considerable amount of restructuring over time, so it is difficult to speculate how actual market events corresponded to BLS's sampling.³⁵ The little systematic and public evidence we do have is consistent with the explanation that nominal prices did not change.³⁶

Another piece of evidence regarding the price index is also quite speculative. It has to do with broadband prices, which slowly (and only recently) have become a bigger part of the price index.³⁷ For cable modem service and DSL service, price levels also have been largely unchanged: Respectively, somewhere between \$36 and \$40, plus or

³⁴ Our data on AOL come from Alex Goldman's market share rankings, at http://www.isp-planet.com/research/rankings/usa_h.html.

³⁵ Rosston (2007) documents a large decline in the price of backbone services. This raises a related question: Why did access prices *not* drop with the emergence of a backbone glut in the United States, 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.

³⁶ Stranger and Greenstein (2007) estimate prices for dial-up by *all the other* dial-up providers for 1993–1999. They find little change in the median or average nominal prices between 1996 and early 1999 (i.e., without controlling for quality). For example, the *median* price of a contract 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 the beginning of the commercial Web).

³⁷ Table 3 partially hints at this fact. In that table, which included both household and business revenues, broadband revenue does not exceed dial-up revenue until 2004. Household revenue would track that pattern closely, perhaps lagging slightly because the rate of household adoption of broadband lags business adoption. In addition, BLS survey procedures would add an additional delay into incorporating that changing fraction of expenditure.

minus a few dollars.³⁸ Except for a few publicized (but largely unused) marketing schemes to lower prices to satisfy regulatory requirements, several sources indicate that broadband price levels paid by users have not changed much. There has been evidence of price declines only very recently (i.e., 2006) and only for the DSL prices in the Pew reports.³⁹

III.iv. Diffusion and Prices

Like many new goods, broadband did not diffuse immediately to all households. Slowness by itself is nothing remarkable for a new good, but it is puzzling in light of the stable transactional prices observed in the data, as a price decline cannot be pegged as the catalyst for adoption in this case, as it often is for later adopters of new goods. Our preferred hypothesis for this puzzle is consistent with a key motivation for this paper: Unmeasured factors shaped outcomes.

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.⁴⁰ For example, in many neighborhoods broadband was not available in any form for some time after 2000.⁴¹ Even when it became available, it may not have been reliable enough to spur

³⁸ 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 (July, 2008).

³⁹ John Horrigan, private communication (July, 2008).

⁴⁰ This theme arises often in NTIA (2004) and <http://www.pewinternet.org/>.

⁴¹ 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 had access to DSL lines, while 96% had access to a

many households to switch quickly from dial-up, thereby inducing users to wait until vendors improved the infrastructure or service arm of the organization.⁴² 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.

Said another way, standard price index survey procedures 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 it does not because there was no measured price change.⁴³ Finding the price change and acquiring a more complete price index requires complete information about all the factors deterring or motivating adoption, which is difficult—perhaps impossible—for most price agencies to collect.

IV. Data

In Table 4, we summarize the data used to simulate the economic gains from the diffusion of broadband. Here, we provide important information about our sources and their limitations.

cable modem provider. See Table 14, broadband deployment reports, available at <http://www.fcc.gov/wcb/iatd/comp.html>.

⁴² Comparing broadband deployment reports from the FCC shows evidence of upgrading by cable system upgrades. See the Broadband Deployment Reports at <http://www.fcc.gov/wcb/iatd/comp.html>, particularly Table 5, High Speed Lines by Information Transfer Rates.

⁴³ This explanation is an example of what economists label a *substitution bias*. Such 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* (Boskin et al. 1996) or Braithwait (1980). 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).

IV.i. 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 and then multiply this percentage of adopters by the total number of households.⁴⁴ Data about household use of dial-up and broadband Internet comes from two sources, the NTIA (National Telecommunications and Information Administration) and Pew.⁴⁵ 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.⁴⁶ Data about total number of households come from the US Census estimates.

**TABLE 4 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

Sources: See text.

⁴⁴ 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 the end of the sample. 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 inform us about other relevant factors for measurement, as will become clear in the discussion.

⁴⁵ 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.

⁴⁶ Pew's surveys ask a variety of questions, most recently including questions about bandwidth, prices and use, 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 (July, 2008).

IV.ii. Second Lines.

Table 4 provides estimates of the total number of households in the United States with at least one second line. We gather this from FCC reports, which do not break out second-line use into its primary purpose.⁴⁷ Prior research has shown that several factors determined the growth of second lines in the 1990s, including use of the Internet.⁴⁸ 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.⁴⁹ 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 2006.⁵⁰

These trends put bounds on estimates of the second lines supporting Internet dial-up. For example, 16 million households had an active second line in 2003, a decline from 18.4 million in 2002. The 2.4 million drop in second phone lines represents the upper bound for dropped lines by broadband adopters, meaning that a maximum of 53% of dial-up converts dropped a line that year.⁵¹ More broadly, that percentage varies between 2002 and 2006, rising no higher than 53% and falling no lower than 25%.⁵²

In our base specification, we reduce the volatility in the estimates from the role of second lines. Specifically, 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

⁴⁷ See the FCC's 2007 *Trends in Telephone Service*, 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>.

⁴⁸ See, e.g., Duffy-Deno (2001), and Eisner and Waldon (2001).

⁴⁹ The other primary driver of the decline in second lines is the growth of cell phone use.

⁵⁰ 2006 is the last available year, as of this writing.

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.

line between 1999 and 2001. That results in the right level of dropped second lines by 2006, but we view this as a conservative approach (i.e., a deliberate undercount).

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.

IV.iii. New Users and Converts.

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.⁵³ He did not mention this for earlier periods because it simply was not a significant factor until then.⁵⁴

Those facts help pin down several assumptions about conversions. We have no way to know the rate of conversions precisely since public surveys only ask about total adoption in a given year, not any yearly tally of new Internet users. Yet, we are certain

⁵³ 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/>.

⁵⁴ Horrigan, private communication (July, 2008).

that the vast majority of the broadband adopters between 1999 and 2004 were former dial-up users, and we are not so confident about the same fact in more recent years.

Hence, we assume the following: 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, to remain consistent with Horrigan's observation, it must be less than 50% of the 14 million adopters between 2004 and 2005. In other words, we assume that 10 million new Internet users among broadband adopters is too high a number, 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 alternative 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).

To test the importance of this assumption, we calculate implausible extreme bounds (81% convert rate and 100% convert rate for all years). These bounds will move estimates in a predictable direction, but result in outcomes outside the range of what we consider plausible, so they show how this assumption affects the final estimation. Below, in rows three and four of Table 5, 6, and 7, we provide a summary of such extreme bounds in comparison to our benchmark estimate.

IV.iv. 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-up to \$20.⁵⁵ We choose that price because it is the reported average dial-up price for users in two CPS Supplements in the 1990s.⁵⁶ 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.⁵⁷

V. Benchmarks

We begin with estimates of the revenue generated by broadband and then consider estimates of consumer surplus. Following that, we provide an estimate of an equivalent 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 4) and are

⁵⁵ 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.

⁵⁶ 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 close to monthly prices) in only two years and not thereafter. The consumer expenditure survey, however, continued to ask about on-line expenditures for Internet services every year. While it is not a price index, it looks 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).

⁵⁷ For US price quotes, see e.g., Savage and Waldman (2004), Chen and Savage (2007), Crandall, Sidak, and Singer (2002), Rappoport et al (2003), and Flamm and Chadhuri (2007).

learning how changes to key assumptions about the underlying features of diffusion alter inferences about consumer surplus and new revenue generation.

Throughout we maintain the comparison between broadband and a counterfactual, namely, what would have been supplied by dial-up in the event that broadband had not arisen. We keep this counterfactual straightforward: for example, we do not consider endogenous technical change, such as how other complementary services might have changed (e.g., music or video downloads) had the counterfactual technology (dial-up) remained dominant and un-replaced by broadband.

V.i. Creation of New Revenue

We begin with a calculation of a single year, 2003, to illustrate how we provide a 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 was somewhere between \$36 and \$40 a month in 2003, residential broadband generated an annual revenue of somewhere between \$8 billion ($\$36/\text{month} \times 12 \text{ months} \times 18.5 \text{ million households}$) and \$8.9 billion (if the price is \$40/month).

We first estimate how many broadband users formerly used dial-up. On the basis of our previously stated assumption that with a adoption rate of 81%, 30 million users of broadband were converts, the new adopters of the Internet (not converts) generated between \$455 million of revenue (if the price was \$36) and \$505 million of revenue (if the price was \$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, that is, when the revenue source changed while staying within the same firm. 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, there was a loss of revenue from retired second phone lines, with which many households had supported their dial-up Internet. Using 2003 as an 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 million 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.

TABLE 5. New revenue created by broadband each year (millions of dollars)

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. See Appendix.

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

We conduct similar calculations for each year, 1999–2006, which we provide in the Appendix and summarize in Table 5. 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 the sample (i.e., 47 million households x 12 months x \$40 per month).

We are interested in understanding how much our assumptions matter for a benchmark. Table 5 shows the results. Specifically, if prices are \$36 instead of \$40, then the total estimate reaches \$8.3 billion (41% 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 in the expected direction, 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. This means that 60% to 50% of the measured revenue replaces revenue in dial-up and second lines with revenue in broadband—an amount that is a combination of *business stealing* (when revenue goes from one company to another) or cannibalization .

We redid our simulations with one additional change: We accounted for changes in AOL's prices. Since AOL's prices only go up or down by a dollar or two until the last year, this makes little difference to the aggregate index. The only appreciable effect is that converts no longer save \$20 at the end of 2006, since AOL's prices become zero after September, 2006. That reduces the cannibalized revenue from converts by approximately \$500 million in 2006.⁵⁸ This makes a little difference in that year, but does not change any other inference.

Table 5 and our discussion stress how to decompose the results in 2006 into the contribution attributable to adoption in each year. There is one additional way to look at these results, in terms of the total benefits over the eight years from 1999 to 2006. The largest gains come from those households who adopt in 1999. In their first year of adoption they generate a 226 million dollar gain (in the baseline estimate with a high price). We assume they receive the same benefit in all subsequent seven years in comparison to the alternative, which is going back to dial-up. The same reasoning holds for the group who adopts the next year in 2000. By this reckoning the total revenue gains over the eight years are $8*226.9 + 7*536.4 + \dots + 1322 = 36.8$ (29.0) billion for high (low) price baseline estimate.

Is that a big number? It depends where one looks. It is 36% (29%) of the size of the total revenue (\$100B) generated by dial-up over the same time period (adding

⁵⁸ We get that by assuming that AOL has 13.1 million households in 2006, which is a 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 twelve, 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.

revenue from 1999 to 2006 from Table 2). Of course, the majority of it comes from the latter part of the sample when there is more adoption.

Although these calculations tell us nothing about the cost to deploy and support broadband or, for that matter, the precise level of profitability from its deployment, they do say something about the economic incentives to perform upgrades. Namely, while cable companies were the dominant supplier of broadband at the beginning of our sample, Pew's survey finds that local telephone companies had a slightly higher market share than cable companies by 2006,⁵⁹ but a slightly lower price as well.

We also could add several additional observations about how cable and telephone companies differed: Cable did not cannibalize any existing revenue stream, such as from second telephone lines or an existing dial-up ISP (e.g., Ameritech.com). Telephone companies, meanwhile, faced regulatory uncertainty in the earlier part of this sample period over the treatment of their investments. Not surprisingly, cable firms gained residential broadband revenue sooner than telephone companies did (see Table 1).⁶⁰ The only big revenue losers were dial-up ISPs, from whom all the business stealing took place.

⁵⁹ This is one place where the data from Pew and the FCC do not entirely agree. Table 1 (from the FCC) gives high market share to cable in the most recent years (2005 and 2006) while Table 3 (from NTIA and Pew) does not. They generally agree in prior years. If the FCC's data are correct, then the statement in the text is not correct, and cable firms have done much better in recent times than the telephone firms.

⁶⁰ The evidence for this statement is partially evident in Table 1, which shows the growth of household lines. Over this period, cable reached levels of adopters typically two years sooner than similar levels by telephone firms. It is only partially evident in Table 2, which shows revenue growth, because this includes both household and business growth. Cable firms, however, get very little of their revenue from business customers, while telephone companies get a much higher fraction. For example, comparing FCC statistics on broadband diffusion to all users with those for residential users for January 2006 suggests that less than 3% of the cable lines go to business customers (0.8 out of 29.1 million), while business generates a much higher fraction of telephone company revenue: Just over 10% of ADSL lines (2.4 out of 22.5 million) and 35% of fiber lines (244 out of 685 thousand). See Tables 1 and 3 in the reports for high-speed services for Internet access, available at <http://www.fcc.gov/wcb/iatd/comp.html>. Hence, Table 2 also suggests that cable modem access grew sooner than DSL.

Costs also played a role in these events, although the costs varied by setting (e.g., density) and time period (e.g., declining over time) Most estimates from the early millennium put the cost of initial upgrading of lines to cable and DSL at \$400 to \$500 per household in most urban settings, with slightly higher estimates for suburban settings (e.g., an additional \$100 dollars) and much higher estimates for rural settings (e.g., another \$500 to \$1000 per household or more). In all cases, these cost estimates decline to the industry rule-of-thumb for per-household upgrade costs—as little as \$250 (for cable) and \$150 (for basic DSL) for residences in dense urban settings in most recent times.⁶¹ In most cases, post-adoption maintenance costs are estimated to be low, at just over \$100 per household per year.⁶²

What do those costs mean? Consider the following illustration for a cable firm that does not experience any cannibalization. For the sake of illustration, consider the problem facing that firm if it upgrades its system for 2500 homes and expects only 20% of them to take up the service. At a cost of \$250 per household, that means new revenues (at \$480 a year) in Internet service, by themselves, cover the cost of the upgrade in three

⁶¹ David Burstein, private communications, September 2008. See also Crandall (2005) for a range of estimates from a variety of sources. In a cable setting this assumes the HFC network has already been built out to support two-way access. Following OECD (2007), Chapter 5, in the case of DSL, this assumes the main cost elements are: Customer Premises Equipment (modem); Local Loop (access/operational fee for the copper twisted pair); Digital Subscriber Line Access Multiplexer (DSLAM); Aggregation Network (L2 switch); Broadband Remote Access Server (BAS); and a Management System. For a closely related set of estimates, see <http://www.ictregulationtoolkit.org/en/PracticeNote.aspx?id=2899>. For more recent estimates, see Elixmann et al.'s (2008) WIK Consult Report.

⁶² Note what these assumptions imply for a static definition of producer surplus using yearly variable costs. At \$480 dollars per year in revenue and \$100 in yearly cost, the variable profits per household are \$380. With 47 million households in 2006, that leads to \$17.8 B. That static view seems less relevant to us than a definition that incorporates the cost of initial retrofit to enable cable modem service or DSL service, which is the spirit of the discussion below.

years.⁶³ Additional revenue through telephone and other services resulted in covering those costs sooner. Higher take-up rates also resulted in covering costs sooner. Earlier in the period those costs were higher, so costs were covered later. A similar calculation holds for DSL.⁶⁴ In other words, for most systems, the private incentives to upgrade were sufficient to motivate investing in upgrading most urban and suburban areas. Similarly, take-up rates would need to be extraordinarily high to justify even a monopoly build-out in most rural areas.⁶⁵

Table 5 leads to a reinterpretation of one common occurrence in recent communications industry lobbying: Cable firms have crowed in public forums about the industry's willingness to invest in the last decade, as represented by their aggregate capital expenditure. The industry's total capital expenditures between 1999 and 2005 amounted to \$87.1 billion, never dropping below \$10 billion in any given year. Some of this covered the costs replacing depreciated capital, of course. Yet, the acceleration in expenditure after 1998 (from \$5 to \$10 billion or more annually) is consistent with

⁶³ Since only 20% adopt, the cost per adopting household would be \$1250. In three years the maintenance expense is \$300, which means variable revenue is approximately \$1160 on a \$40/month contract. Thus, the costs of upgrade are covered approximately after three years. Of course, this does not count the interest costs of borrowing, which would increase costs as well.

⁶⁴ The calculation is more plausible with cable firms than telephone firms for reasons alluded to in the text, because national broadband policy for cable investment did not appreciably change over this period. Hence, it is possible to examine investment and its consequences in a constant regulatory policy environment. In contrast, the changes in telephone broadband investment were complex over this time period, so providing a firm date for their change is difficult since it involves both regulatory actors and court decisions in a long interplay. For overview of changes to regulatory policy, see Goldstein (2005), Neuchterlein and Weiser (2005), and for a focus on Internet access see Greenstein (2008).

⁶⁵ For example, consider a cable firm that does not face any cannibalization issues. Even with a 50% take up rate, the economics are not favorable for a \$40 service for a rural community of 500 homes with \$1500 per household upgrade costs and \$100 per household maintenance costs. Without considering borrowing costs, investment costs are not covered until after eight years of revenue. For a local rural telephone firm facing cannibalization issues and a similar cost structure for DSL, the upgrade may be technically infeasible (due to length of lines), as well as simply cost-prohibitive.

expenditure aimed to convert cable systems to a digital delivery of cable services,⁶⁶ as well as facilitate additional services, such as telephone and Internet access.⁶⁷

Once again, we can summarize the implication for interpreting regulatory policy in broadband: The proper benchmark for calculating such returns was not the total revenue of the market in any given year. Rather, it was the incremental gains in revenue to those parties from incremental investment aimed at that market. Several factors played a role in calculating incremental gains, such as the identity of the producer, the size of potential business stealing and cannibalization, and the speed of household willingness to respond to new options. Looking at it this way, it should come as no surprise that private firms invested large sums of money when the *incremental* gains from doing so were potentially large, as they were for cable firms facing no cannibalization issues over all this time period, and as they were for both cable firms and telephone firms that faced low upgrade costs in urban and suburban settings later in this time period.

V.ii. Creation of Consumer Surplus

In most studies, estimates of broadband demand indicate that there is substitution between different forms of broadband—that is, 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,

⁶⁶ The number of digital households increased from 12.2 million households in 2001 to 30.4 in 2006. See <http://www.ncta.com/Statistic/Statistic/DigitalCableCustomers.aspx>.

⁶⁷ The number of households with voice service from cable firms grew from 1.5 million in 2001 to 7.5 at the outset of 2006. The growth has accelerated thereafter, reaching 15.1 at the end of 2007. See <http://www.ncta.com/Statistic/Statistic/ResidentialTelephonyCustomers.aspx>.

with broadband constraining dial-up demand, but not vice-versa.⁶⁸ 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.⁶⁹

For our estimates of consumer surplus we rely on one set of estimates from Savage and Waldman (2004). It is representative of the type of findings seen in other studies, but a easier to use in this context. These authors conducted an extensive survey of dial-up and broadband users in 2002. We prefer this study because it is based on slightly later data, and also because it is a survey of both users and nonusers. In addition, the authors used this survey to directly estimate “willingness to pay” measures for attributes of dial-up and broadband service, which facilitates some simple accounting of the value of broadband in comparison to dial-up for existing dial-up users. This is sufficient for illustrations below.⁷⁰

⁶⁸ For example, Rappoport, Kridel, Dunnt-Deno, and Alleman (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 Rappoport et al. They find that demand for broadband is comparatively more insensitive to prices and that their detailed data show that demographic factors shape demand quite a bit. Cardona et al. (2008) find qualitatively similar results to Rappoport 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.

⁶⁹ For example, Rappoport et al. (2003) 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, Sidak, and Singer (2002) find an own-price elasticity of -1.184 for a slightly different sample in a similar time period. Using the same sample, Rappoport, Taylor, and Kridel (2003), page 82, estimate elasticities for different price levels, finding evidence of more elastic demand. The estimates range from close to 1 for DSL and cable modem prices close to \$20 a month, and they change in the expected direction. For \$30 DSL prices they estimate a price elasticity of -2.1, and for cable modem prices of \$40 they estimate -2.35. 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.

⁷⁰ To be clear, this choice comes with one drawback. It does not fully account for heterogeneity in household willingness-to-pay. It average outs such differences. We do not believe such accounting would

Savage and Waldman's estimates of the willingness to pay for broadband are net of benefits users receive from dial-up. To remain consistent with their model we assume 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 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.⁷¹

alter our benchmark calculations much, but we acknowledge it is an open question. The study of Rappoport, Taylor and Kridel (2003) takes steps in that direction, but did not provide sufficient information to make a full estimate (such as the distribution of dial-up among this population and its correspondence to WTP for broadband, or standard errors on their estimates of heterogeneous demand).

⁷¹ It is reassuring that the average in the Savage and Waldman study, which examines a sample of only previous dial-up users, is in the same range as the estimates for Willingness-to-Pay from Rappoport, Taylor and Kridel (2003), which examines a sample of all households. In the latter case the average WTP in their entire sample is \$36.8 for cable and \$32 for DSL. Among a truncated sample of likely adopters, those with Willingness to Pay for broadband above \$40, the average WTP is \$53.45 for cable and \$52.05 for DSL. Note: to make their these estimates into a WTP for a conversation from dial-up to broadband, one would then need to have information about (or to make assumptions about) the distribution of former dial-up users in this sample and, among that sub-sample, make further assumptions about their use of second telephone lines.

The Savage and Waldman estimates provide an estimate for the number of users who switched from dial-up, but not one for new users to the Internet. New adopters started becoming more frequent after the 2002 survey used by Savage and Waldman. Even though some of the new adopters (surely) had experience with the Internet (e.g., as students or at work), we take a conservative approach to estimating surplus for nonconverts. 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.⁷²

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 the quantity demanded must result in the number of adopting households, as in Table 4. Then we calculate the level of consumer surplus consistent with Savage and Waldman's estimates, while varying assumptions about prices and conversions.

⁷² This is one place where the Savage and Waldman estimates are much easier to use than the estimates of Rappoport, Taylor and Kridel. Though the latter provide a skewed distribution Willingness to Pay, they give no other indication about how these estimates compare against observable features of the data, such as whether households had prior experience with dial-up Internet.

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 the price is \$40/\$36 and we assume that no household drops its second phone line), to \$11.35/\$15.35 per month after 2002 (when we assume that all converts dropped their second line).

Table 6 provides a summary of these results. The approximately 40 million households that 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 6 Consumer surplus in millions of dollars
(as a fraction of sum of consumer surplus plus revenue)**

Year	Total	1999	2000	001	002	003	004	005	006
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. See Appendix.

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 5 and 6 also shows how different assumptions shape estimates of the distribution of 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.⁷³ 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, respectively.

Comparing two assumptions—that 100% of broadband users upgraded from dial-up (an aggressive conversion, which is too high) versus 81% of them (an unaggressive conversion, which is too low)—alters total surplus only a little, but it 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. Nevertheless, 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 commensurate loss for producer surplus. Assuming an unaggressive conversion has just the opposite effect.

Plainly stated, the information in 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. 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.

⁷³ 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 $4687.9 + 11410.5 = \$16,098.4$.

Once again, Table 6 and our discussion stress how to decompose the results in 2006 into the contribution attributable to adoption in each year. Once again, there is one additional way to look at these results, in terms of the total benefits over the eight years from 1999 to 2006. The largest consumer surplus accrues to those households who adopt in 1999. In their first year of adoption they receive a 68 million dollar gain (in the baseline estimate with a high price), and then we assume they receive the same amount in all subsequent seven years. By this reckoning the total revenue gains over the eight years are $8*68 + 7*160.9 + \dots + 658 = 15.4$ (22.2) billion for high (low) price baseline estimate.

Is this a large number? By comparison with the size of the total new revenue, which is \$36B (\$29B), the gains to consumers generated by broadband over the same time period is 42% (76%) of the size of total new revenue gains. Notice that in either simulation new consumer surplus plus new revenue sum to approximately \$51B, so prices simply determine the distribution of gains.

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 it truncates the level of that valuation among the biggest fanatics. We have not counted this highly inelastic demand in our valuation.

Second, we have made no adjustment to these estimates to account for the change in AOL's pricing. While we are comfortable with this lack of adjustment—especially considering how AOL's price change shapes our estimates—adoption is a slow process; and the price decline came too late in 2006 to have an effect on broadband adoption. It

almost goes without saying, but nobody expects that most broadband users would switch back to dial-up even if some dial-up became free.

Third, survey research tends to find a larger willingness to pay from users who are paying not to have something taken away after they have experienced it than those who are 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.

V.iii. An Adjusted Price Index

Standard economic reasoning suggests that the price index will be mismeasured when a new good results in large consumer surplus. That must be true in this example too. We briefly walk through the mechanics just to (1) verify that intuition, (2) provide a range for the estimates, and (3) decompose the causes.

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. Thus, the starting point is straightforward. Converts were willing to pay a virtual price of \$51.35 per month on average, 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. In other words, against a \$40 (\$36) price for broadband, an average of \$11.35 (\$15.35) consumer surplus is equivalent to 22 % (30%) of the monthly price paid by converts for service.

We now ask how far a price index would have to fall in order to capture the gains that converts experienced. Table 7 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: (1) dial-up users, (2) existing broadband users, (3) new broadband users who are new Internet users, and (4) broadband users making an upgrade this year. In the baseline specification, converts to broadband (who do not retire a second line, by construction) experience 13% decline in price (from \$46 to \$40) from 1999 to 2001, which we represent as 0.87. Converts from 2002 to 2006 (who do retire a second line, by construction) experience a 22% decline in price (from \$51.35 to \$40), which we represent as 0.78. We assume all others experience no price decline, which we represent as 1.0.

TABLE 7 Weighted average of price decline.

Year	1999	2000	001	002	003	004	005	006	Average
Baseline high price	99.6	99.3	98.4	98.9	98.3	97.5	96.6	98.7	98.4
Baseline low price	99.4	98.9	97.3	98.5	97.7	96.7	95.5	98.3	97.8
Aggressive conversion	99.6	99.3	98.4	98.7	97.9	96.7	96.0	98.2	98.1
Not aggressive	99.7	99.4	98.7	98.9	98.3	97.5	96.6	98.8	98.5

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 7 shows that this exercise results in an average price decline between 0.984 and 0.978, because in most years only a small percentage of Internet access households upgraded to broadband. That means the price index for all Internet access should decline between 1.6% and 2.2% a year by 2006. In this exercise the correction is largest in the most recent years, when there are more upgrades as a percentage of all Internet households.

Another way to represent the price decline is through a Paasche and Laspeyres index over eight years—that is, using either the populations in 1999 and 2006 as the baseline. The baseline for the population matters because there was so much change in the characteristics of this population over these eight years. Table 4 shows that in 1999, there were 34.5 million dial-up users and 0.9 million broadband users. In 2006, there were 47 million broadband users and 34.7 million dial-up users. Hence, the 2006 Paasche and Laspeyres indices will use different base populations because of (1) the entry of new Internet users who later convert to broadband; (2) the entry of new Internet users who use dial-up in 2006; and (3) the entry of new users who go straight to broadband.

The different base years matters. If the population in 2006 serves as the baseline, then 48.9% ($39.1/81.7$) of households adopted broadband after converting from dial-up in the baseline estimates. In the baseline estimates, 24.5% ($9.6/39.1$) of households experienced a 13% price decline in 1999–2001 and 59.8% ($23.4/39.1$) experienced a 22% price decline from 2002–2006.⁷⁴ Over eight years that adds up to an 8.0% decline in the

⁷⁴ It is plausible because we have 47 million broadband adopters by 2006. We began with 0.9 million in 1999 and 7 million are new Internet users between 2002 and 2006 by construction. Of the

Internet access price index, even with high broadband prices (i.e., \$40). It is an 11.2% decline in prices with lower broadband prices (i.e., \$36). In contrast, if the 1999 population serves as the baseline, then it is plausible that all of the users converted to broadband by 2006.⁷⁵ We assume adoption behavior consistent with our baseline model. That is, 9.6 million households experienced a 13% (21%) price decline between 1999 and 2001 if broadband prices are \$40 (\$36). We assume the remainder ($34.7 - 0.9 - 9.6 = 24.2$) upgraded between 2002–2006, and that translates into a 22% (\$30) price decline. Accordingly, when broadband prices are \$40 (\$36), then this population experiences an 18.4% (27.3%) price decline.⁷⁶

The Paasche and Laspeyeres index brackets the estimates in Table 7. The minimum is 8.0% (11.2%) and the maximum is 18.4% (27.4%), or an average of 1.0% (1.4%), and 2.1% (3.4%) decline per year. Our baseline results are 1.6% (2.2%), just between the minimum and maximum.⁷⁷ While the middle estimate is almost as much as AOL's pricing decision in 2006, there is a big difference in the *timing* of the recorded price decline. AOL's pricing decision concentrates the change in one year. In contrast,

remainder, 9.6 million convert from dial-up to broadband between 1999 and 2001. Hence, if all households converted, then 23.4 million households converted between 2002 and 2006. This is well below 39.5 ($47 - 7 - 9.6 - 0.9$). See Appendix.

⁷⁵ This seems natural to us since because it does not come close to the total 39.1 million broadband converts between 1999 and 2006.

⁷⁶ Using the 2006 broadband population as the baseline, we can estimate a price index that leaves out dial-up users, but is averaged over a different base. In the baseline estimate when prices are \$40 (\$36) we find that 20.8% ($9.6/46.1$) of upgrading households experienced an average of a 13% (21%) price decline from 1999–2001 and 63.9% ($29.5/46.1$) experienced a 22% (30%) price decline from 2002–2006, while 15.1% ($7/46.1$) experienced no price decline. That yields a 16.7% (23.4%) price decline over all eight years for upgrading households. Including all broadband users (i.e., adding the 0.9 million adopters prior to 1999) yields 16.3% and 22.9%, respectively.

⁷⁷ The comparison in the text is over the entire population of households, and each household experiences only one upgrade, by construction. Hence, to make them comparable it is appropriate to look at the average rate of decline per year.

accounting for the upgrade *when users upgraded* would have realized a large fraction of the benefits many years sooner.

That simulation informs the puzzling inconsistency between widespread adoption of broadband, as documented in Table 1, and the lack of measured appreciable decline in transactional prices over eight years, as displayed in Table 3. A properly measured broadband price index shows a large change in prices, resolving this apparent puzzle. If the pricing concentrates on a population of households that were early adopters of the Internet, then the unmeasured price decline is quite large.

We now decompose the underlying cause of these conclusions by asking: How much price decline arises from the retirement of second phone lines? As it turns out, second lines are not 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 for \$5.35, but consumer surplus is now responsible for \$10. These expenses only shape decision making during 2002–2006 in the baseline estimates. In other words, removing the savings on the second line from the price index would remove anywhere from a 30% to 40% of the total savings in 2002–2006, or 21% to 28% of the savings for 1999–2006.

BLS price indices do not normally count the savings 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, but we are not fully sympathetic due to the misunderstanding it produces for policy. Accounting should take

place somewhere, and if not, the absence of such accounting should be acknowledged so policy users of the price indices can properly interpret what they observe.

VI. Conclusion

We contend that conventional accounting of broadband's effect on the US economy mismeasures its true economic impact. While broadband accounts for \$28 billion of the GDP in 2006, approximately \$20 to \$22 billion is associated with household use in 2006. Of that amount, we show that approximately \$8.3 and \$10.6 billion of it is additional revenue (above and beyond what dial-up would have generated), and between \$6.7 and \$4.8 billion is consumer surplus. 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. The upgrade was equivalent to an unmeasured decline in price of between 1.6% and 2.2% per year in all Internet access prices.

The paper has focused on measuring the factors that shaped the anticipated incremental costs and benefits from the national upgrade to broadband. More accurate measurement illustrates why policy oriented towards relying on private investment succeeded as it did: The incremental returns were sufficiently large enough to generate large investments by broadband providers, especially cable firms. It also illustrated why the gains from the upgrade were large to users in spite of seemingly unchanged nominal

transactional prices. The commonly used government statistics, such as a BLS price index, did not measure the full gains to broadband adopters.

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 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, Yahoo! portal, MSN instant messaging client, or caching by Akamai. These investments increase the quality of the Internet experience for users.

In addition, our estimates did not include an analysis of the benefits versus costs not considered by parties involved in the transaction. In the body of the text we included a range of examples that might incrementally shape the experience at Cisco, Amazon, and Google. We would expect similar externalities to shape the experience of a wide range of firms, including Apple, Microsoft, and Intel, as well as many venture capitalists. We expect many more such examples. Similarly, we did not include externalities to users, and we can plausibly think of several related mechanisms that would produce both positive and negative externalities. However, we have tried not to allow the presence of externalities in broadband economics to become a license to inflate the gains from the deployment of broadband, so we await further work on this topic.

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 in one specific case, and by showing their scale, motivate others to undertake related exercises with greater care than previously shown.

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Appendix

Adjustments for Table 2.

Table 2 is constructed from the Annual Service Survey, conducted by the US Census. The Census Service Annual Survey is available for NAICS 51, as archived on <http://www.census.gov/econ/www/servmenu.html>. The annual surveys differ from the five-year economic censuses. The annual service surveys are estimates of economic activity, not complete censuses of economic activity. 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 quickly. The Census alters the sampling frame frequently (as often as every three or four years), but it does not 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).

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 data in published reports and to use the latest publication, which sometimes corrects for errors in sampling frame.

We take advantage of a lucky break in 2004. The Census published two sets of estimates, one using an 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, 2002, and 2003).

Cable modem revenue

For 1998, 1999, and 2000, the original data were taken from the tables for NAICS 5175, from the 2000 report. The data in 2001, 2002 and 2003 came from the listing for NAICS 5175, from the report for 2004, which uses a new sampling frame that differs from prior years. The data for 2004, 2005, and 2006 came from NAICS 5175, from the 2005 report, which also used a new sampling frame. Due to a change in the sampling frame, the data from 2004–2006 were no longer consistent with the data from 2001–2003. For 2004, there were estimates using both sampling frames, and the data for the new sampling frame (used in 2004–2006) were found to be 10% higher than the old sampling frame (used in 2001–2004). 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 came from NAICS 5133 and do not include backbone services. Data for 2004, 2005, and 2006 came from NAICS 5171, from the 2006 report, which used a new sampling frame. As with the other data, due to a change in the sampling frame, the data from 2004–2005 were potentially inconsistent with the data from 2001–2003. For 2004, there were estimates using both sampling frames and the data for the new sampling frame (used in 2004–2006) was found to be inconsistent with the

old sampling frame (used in 2001–2004). 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 backwards to data for 1999, 2000, 2001, 2002, and 2003. These have growth rates similar to growth in total DSL lines, as reported by the FCC data on user growth in DSL lines—both business and household users, not just households as reported in Table 1 (though the data were taken from the same source). 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 were taken from the tables for NAICS 514191, from the 2000 report. The data in 2001, 2002, and 2003 came from the table for NAICS 514191, which used a new sampling frame from prior years. The data for 2004, 2005, and 2006 were for NAICS 5181111, from the 2006 report, which also used a new sampling frame. Due to a change in the sampling frame, the data from 2004–2006 were no longer consistent with the data from 2001–2003. For 2004, there were estimates using both sampling frames. The data for the new sampling frame (used in 2004–2006) were found to be 33% higher than the old sampling frame (used in 2001–2004). For consistency, data in 2001, 2002, and 2003 were adjusted upward 33%.

Wireless revenue

The data for 2004 and 2005 came from NAICS 517212, from the report for 2005. The report includes Internet access services for wireless carriers, but not satellite services.

Disclosure issues prevented publication in 2006.

Prior to adjustment for sampling frame inconsistencies, the reports from the Census Annual Survey (for 1998–2000, 2001–2003, 2004–2006) originally appeared 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	

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		0%	0%	0%	(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		\$ -	\$ -	\$ -	\$ 660	\$ 660	\$ 660	\$ 660	\$ 660
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
Cumulative 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	\$ 362,987,440
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									
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)		\$ 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
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

	1999		2000		2001		2002		2003		2004		2005		2006	
	Year		Year		Year		Year		Year		Year		Year		Year	
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		0%		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)		\$ -		\$ -		\$ -		\$ -		\$ -		\$ -		\$ -		\$ -
Canonized 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

	1999		2000		2001		2002		2003		2004		2005		2006	
Year																
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		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		73,280,000		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	\$	\$ 9,240,000,000	\$	\$ 7,725,600,000	\$
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)	\$ 77,565,600,000	\$	\$ 261,014,400,000	\$	\$ 790,430,400,000	\$	\$ 273,326,400	\$	\$ 457,185,600	\$	\$ 736,257,600	\$	\$ 1,113,825,600	\$	\$ 490,017,600	\$
Carrollized 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																
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	\$
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%	
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	\$	\$ 1,925,998,386	\$
Total Gross Benefits for Broadband Since 1999	\$ 316,386,000	\$	\$ 1,142,229,600	\$	\$ 3,562,704,000	\$	\$ 4,636,999,030	\$	\$ 6,433,942,868	\$	\$ 9,327,764,714	\$	\$ 13,705,597,613	\$	\$ 15,631,585,999	\$

Simulations: \$40 Cases

Broadband Bonus - Base Case

	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	0%	0%	0%	(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	\$ 2,327,136,000
Broadband Adopters (NIU) Revenue (Annual Δ)	\$ -	\$ -	\$ -	\$ 303,696,000	\$ 507,984,000	\$ 818,064,000	\$ 1,237,584,000	\$ 544,464,000
Canibalized 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	\$ 1,980,434,766
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

Assumptions:

Usage Rates:	1999	2000	2001	2002	2003	2004	2005	2006
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	0%	0%	0%	33%	33%	33%	33%	33%
% Converts Dropping Second Phone line	0%	0%	0%	6.60	6.60	6.60	6.60	6.60
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)	-	-	-	-	-	-	-	-
Canonicalized 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

	1999		2000		2001		2002		2003		2004		2005		2006	
Assumptions:	Year															
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%	60.0%	66.0%	66.0%	73.0%	73.0%	77.0%	77.0%	83.0%	83.0%	83.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	25.0%	35.0%	35.0%	42.0%	42.0%	49.0%	49.0%	57.0%	57.0%	57.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	35.0%	29.0%	29.0%	29.0%	29.0%	26.0%	26.0%	26.0%	26.0%	26.0%
Costs:																
Broadband Cost	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40	\$ 40
Dial-up Cost	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20
Second Phone Line Cost	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20	\$ 20
Converts:																
% Converts	81%	81%	81%	81%	81%	81%	81%	81%	81%	81%	81%	81%	81%	81%	81%	81%
# Second Lines	23,600,000	26,200,000	26,000,000	26,300,000	26,000,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000	9,000,000	7,700,000	6,600,000	5,700,000	4,900,000	4,200,000
Δ In Second Lines	0%	11.5%	0%	100,000	0%	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,700,000)	(1,700,000)	(1,700,000)	(1,700,000)	(1,700,000)	(1,700,000)	(1,700,000)
% Converts Dropping Second Phone line	0%	0%	0%	0%	0%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 6.60	\$ 6.60	\$ 6.60	\$ 6.60	\$ 6.60	\$ 6.60	\$ 6.60	\$ 6.60	\$ 6.60	\$ 6.60	\$ 6.60
Additional Benefit of Broadband	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26	\$ 26
Calculators:																
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	87,600,000	94,000,000	101,000,000	108,000,000	115,000,000	122,000,000	129,000,000	136,000,000
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	54,000,000	62,000,000	71,000,000	81,000,000	91,000,000	101,000,000	111,000,000	121,000,000
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	34,720,000	34,720,000	34,720,000	34,720,000	34,720,000	34,720,000	34,720,000	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	18,570,000	23,570,000	28,570,000	33,570,000	38,570,000	43,570,000	48,570,000	53,570,000	58,570,000
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	16,335,700	21,679,700	27,023,700	32,367,700	37,711,700	43,055,700	48,400,000	53,744,000	59,088,000
Broadband Adopters (New Internet Users)	179,550	424,650	1,225,500	632,700	1,058,300	1,704,300	2,578,300	3,602,300	4,776,300	6,000,300	7,274,300	8,598,300	9,972,300	11,396,300	12,870,300	14,344,300
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	48,841,700	68,821,700	93,396,700	123,971,700	160,546,700	203,121,700	251,696,700	306,271,700	367,846,700
Cumulative Broadband Adopters (NIU)	179,550	604,200	1,829,700	2,462,400	3,520,700	5,217,400	7,795,700	11,374,000	16,150,300	22,126,600	29,400,900	38,175,200	48,561,500	60,657,800	74,544,100	90,330,400
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	\$ 28,579,200,000	\$ 39,444,800,000	\$ 53,310,400,000	\$ 70,176,000,000	\$ 92,041,600,000	\$ 120,907,200,000	\$ 157,772,800,000	\$ 204,638,400,000	\$ 262,504,000,000
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	\$ 8,332,800,000	\$ 7,725,600,000	\$ 7,110,400,000	\$ 6,495,200,000	\$ 5,880,000,000	\$ 5,264,800,000	\$ 4,649,600,000	\$ 4,034,400,000	\$ 3,419,200,000	\$ 2,804,000,000
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	\$ 7,664,496,000	\$ 10,052,976,000	\$ 12,441,456,000	\$ 14,829,936,000	\$ 17,218,416,000	\$ 19,606,896,000	\$ 22,000,000,000	\$ 24,388,480,000	\$ 26,776,960,000
Broadband Converts (NIU) Revenue (Annual Δ)	\$ 86,184,000,000	\$ 290,016,000,000	\$ 878,256,000,000	\$ 303,696,000	\$ 1,082,808,000	\$ 1,818,064,000	\$ 2,553,320,000	\$ 3,287,784,000	\$ 4,022,248,000	\$ 4,756,712,000	\$ 5,491,176,000	\$ 6,225,640,000	\$ 6,960,104,000	\$ 7,694,568,000	\$ 8,429,032,000	\$ 9,163,496,000
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	\$ 2,553,320,000	\$ 3,412,880,000	\$ 4,322,440,000	\$ 5,231,992,000	\$ 6,141,544,000	\$ 7,051,096,000	\$ 7,960,648,000	\$ 8,870,200,000	\$ 9,779,752,000	\$ 10,689,304,000
Retired Second Phone Line Revenue	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
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	\$ 5,151,844,400	\$ 6,895,138,200	\$ 8,632,432,000	\$ 10,369,725,800	\$ 12,107,019,600	\$ 13,844,313,400	\$ 15,581,607,200	\$ 17,318,901,000	\$ 19,056,194,800
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	\$ 4,322,044,560	\$ 5,639,039,800	\$ 6,956,035,000	\$ 8,273,030,200	\$ 9,590,025,400	\$ 10,907,020,600	\$ 12,224,015,800	\$ 13,541,011,000	\$ 14,858,006,200
Avg. Monthly Broadband Benefit for Converts	\$ 6.00	\$ 6.00	\$ 6.00	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35	\$ 11.35
Implied Decline in Price for Converts	15%	15%	15%	28%	28%	28%	28%	28%	28%	28%	28%	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	\$ 2,132,044,560	\$ 2,867,539,800	\$ 3,603,035,000	\$ 4,338,530,200	\$ 5,074,025,400	\$ 5,809,520,600	\$ 6,545,015,800	\$ 7,280,511,000	\$ 8,016,006,200
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	\$ 6,581,544,800	\$ 8,651,490,400	\$ 10,721,436,000	\$ 12,791,381,600	\$ 14,861,327,200	\$ 16,931,272,800	\$ 19,001,218,400	\$ 21,071,164,000	\$ 23,141,109,600
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	\$ 20,449,220,800	\$ 27,780,715,600	\$ 35,112,210,400	\$ 42,443,705,200	\$ 49,775,199,600	\$ 57,106,694,000	\$ 64,438,188,400	\$ 71,769,682,800	\$ 79,101,177,200