NBER WORKING PAPER SERIES

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Working Paper 16166
http://www.nber.org/papers/w16166

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2010

We are affiliated with Kellogg School of Management, Northwestern University, and Simon School of Business, University of Rochester, respectively. We thank Robert Seamans, David Burstein, Scott Wallsten, Randy Weiss, and Brendan Williams for many comments. We thank Maja Butovich, Tam Le, Brittany Jaekel, and Benjamin Rothschild for their excellent research assistance. The Kellogg School of Management provided funding through the chair of Elinor and Wendell Hobbs. We are responsible for all remaining errors. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 16166
July 2010
JEL No. L86,O33,O47

ABSTRACT

In this paper, we construct a price index for broadband services in the United States between 2004 and 2009. We analyze over 1500 service contracts offered by DSL and cable providers in the United States. We employ a mix of matched-model methods and hedonic price index estimations to adjust for qualitative improvements. In general, we find some evidence of a quality-adjusted price decline, but the evidence points towards a modest decline at most. Our estimates of the price decline range from 3% to 10% in quality-adjusted terms for the five-year period, which is faster than the BLS estimates for the last three years. These modest price declines look nothing like other parts of electronics, such as computers or integrated circuits, which raises many questions. The results also inform a range of policy discussions about US broadband services.

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Introduction

What happened to the price of broadband during and after its widespread adoption by US households? This is a key question for understanding the economic gains from the adoption and use of broadband in the new millennium. At the decade's outset, only 4.4% percent of households had broadband, while most Internet-using households had dial-up. According to the latest survey of the Pew Internet and American Life Project, fewer than 10% of US households had dial-up Internet connections by April 2009, while 63% of US households had broadband. In this study we offer a broadband price index for the period of most-rapid growth and diffusion, 2004 to 2009.

Two broad policy discussions about broadband deployment in the US motivate constructing a price index. First, many policies in the US are premised on the belief that the diffusion of broadband lies at the heart of considerable economic growth. To accelerate growth, US policy delegated discretion over broadband investment to private firms, under the assumption that private firms faced strong incentives to invest and improve the infrastructure.[2] Indeed, the entire Internet-access market (broadband and dialup) has grown at an astonishing pace in the new millennium, exceeding $39 billion in total revenue in the US after 2006, starting from almost half that at that beginning of the decade. Price indices can, and should, play a major role in assessing policies contributing to such growth. Such indices measure improvements in competitive performance in markets with few suppliers, as in broadband, and when calculated properly, can deflate economic growth into real terms.

Such a broadband price index does not exist in the United States, however. Though the Bureau of Labor Statistics (BLS) maintains a price index for Internet access as part of the Consumer Price Index (CPI),[3] the BLS index combines price data for both dial-up and household Internet-access services, using lagged expenditure surveys to weight price movements. As a result, the price for dial-up service

[2] These policy debates have a long history. Greenstein and McDevitt (2009) provide a summary of many of these arguments.

[3] This index is called "Internet Services and Electronic Information Service Providers."

dominates the index for most of the first decade of the millennium, which renders the BLS index almost useless for assessing the effectiveness of US broadband policy.

Other issues also cloud the usefulness of the BLS index for assessing policy issues. For example, the BLS index makes no adjustment for increases in quality, such as increases in download bandwidth for either dial-up or broadband services. It also makes no adjustment for household increase in the quality of Internet access when households switch between dial-up and broadband services, common in the first decade of diffusion. The index also contains a misleading dramatic decline in late 2006 – a decline that most likely resulted from the behavior of AOL and its dial-up competitors, further exaggerated by the lag structure in updating the index. That event obscures what happened to broadband prices at that time.[4]

The above recounting of issues relates to our second motivation. Our prior paper, Greenstein and McDevitt (2009), measured user switching behavior between dial-up and broadband. We showed that Internet-access price indices, such as the type BLS maintains, would have to decline 1.6% to 2.2% per year between 1999 and 2006 to account for the consumer benefits generated from upgrading to broadband from dial-up access. However, we did not examine the experience after the upgrade, nor estimate whether price increased or declined, or quality improved. As more households switch to broadband, it becomes a more important part of the price index. Not adjusting this component introduces a potentially large gap for a recurring household expenditure that exceeds $500 a year in many households. A quality-adjusted price index could address this gap.

In this study, we analyze novel evidence from over 1500 service contracts offered by DSL and cable providers between 2004 and 2009. We employ a mix of matched-model methods and hedonic price index estimation to adjust for qualitative improvement. We look for conclusive evidence of trends, namely, widespread dramatic declines in quality-adjusted prices or a widespread lack of change. In general, we find neither. Most of the evidence points towards modest price declines at most.

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[4] Though the expenditure shares are updated more quickly than typical household items in the CPI, their updating process (every three years) still introduces a lag into its construction. That lag led to a misleading result after AOL and its competitors changed their subscription dial-up service to an advertising-supported service, a move AOL initiated in the fall of 2006 after it had lost considerable market share to broadband. Following standard procedure, the BLS index exaggerated its importance by using lagged market share data for dial-up.

More precisely, we divide prices into three categories – standalone prices, bundled prices, or households switching between these two forms – and we present evidence about the first two. We conclude there is no evidence of widespread dramatic price declines. Instead, we find some evidence of modest declines in quality-adjusted prices. We bound it between a 3% and 10% decline in quality-adjusted prices in just under six years. Lack of access to (confidential) data about the market share of services prevents us from being more precise.

These estimates contribute important new findings to several ongoing debates. First, despite rapid growth in adoption and revenue in broadband over the period we examine, 2004-2009, the lack of any dramatic price decline in broadband rejects any claim that US policy generated dramatic change in the price of broadband services. Second, and more broadly, it suggests this market looks nothing like other parts of electronics, such as CPUs, lap tops, printers or storage devices, where the quality-adjusted price declines regularly exceed double digits per year.[5] That raises many questions about differences between mass-market Internet services and other parts of electronics in the determinants of prices, as well as questions about the role of market structure and demand.[6]

Third, although the price declines are modest, our index declines faster than the BLS price index for Internet access over a period that allows us to make a direct comparison. As with prior work on price indices for dial-up services, this finding raises questions about whether the BLS price index for Internet access provides an informative picture of price change.[7]

We are not the first to explore this topic. Interested in improving the CPI price index for Internet access, Williams (2008) estimates a quality-adjusted index for broadband prices, sampled from data about broadband prices from the CPI database in November 2006 (Williams is employed by BLS, and has access to the data for the CPI Internet-access price index). After a thorough and artful statistical

[5] See, e.g., Aizcorbe (2006), and Berndt and Rappaport (2001).

[6] See, e.g., the discussion in Greenstein (2010).

[7] Prior work also suggests quality adjustments could make a difference to dial-up Internet access price indices. For example, Stranger and Greenstein (2007) did such quality adjustments for dial-up Internet access and found it made a difference to the measured rate of price decline.

exploration of 135 price quotes, Williams concludes that the quality adjustments make little substantial difference to a price index for all Internet access ending in 2006.

We cover partially overlapping years, but differ from Williams in a number of ways. Like Williams, we would like to improve BLS procedures. However, our study primarily aims to inform other aspects of the national policy discussion about broadband, which focuses attention at different issues, such as the differences between cable and telephone suppliers. By comparison our estimates also cover many more suppliers, a wider range of services, many more contracts, and additional later years. We also do not use dial-up prices in our final index, as Williams does. In contrast to Williams, we do find that the quality adjustment can matter, albeit, only by a modest amount. We also lack the one thing BLS has – namely, (confidential) household expenditure surveys to estimate the market share of particular services – which prevents us from making a weighted index.

While this study is motivated by contemporary policy debate, it aims at a much broader agenda. The study addresses one of the priorities outlined by Flamm, Friedlander, Horrigan, and Lehr (2007), who examined the poor state of US statistics for the Internet and called for basing US broadband policy on economic reasoning and transparent statistical approaches.[8]

Internet diffusion in the US

The diffusion of broadband began before the millennium, but adoption did not begin to accelerate until early in the first decade following the millennium. Much of this experience is documented in Greenstein and McDevitt (2009). We refer interested readers to our prior work.

During this decade, broadband service was delivered to households primarily in two forms of wire-line service—over cable or telephone lines. Some cable firms built out their facilities to deliver these

[8] Flamm, Friedlander, Horrigan, and Lehr (2007) focus 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 our paper is to dig deeply into one aspect of this broad agenda.

services in the late 1990s, and many—especially telephone companies—waited until the early-to-mid 2000s. At the very end of the period, there was a growing use of another channel, fiber to the home.[9]

Cable-modem service involved a gradual upgrade to cable plants in many locales, depending on the generation of the cable system.[10] Broadband over telephone lines 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.

The quality of a user's experience is shaped by many factors, 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, but two conclusions emerge from this discussion. First, broadband gives the user a better experience than dial-up access. However, there is variance. Relatedly, DSL and cable-modem services differ to such an extent that proper measurement might not use the same metric or scale.[11]

Non-wire-line services were also available over the period, via satellite or modified forms of terrestrial Wi-fi. These services tended to be expensive and limited, so they were very popular in locations where wired services did not exist, and not very popular outside such areas. Near the very end of our sampling period, a new set of wireless broadband services began to gain market traction, primarily in the form of smart phones. Though smart phones had been available in a variety of models for many years, it is commonly acknowledged that the category primarily appealed to a business buyer until the introduction

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[9] 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).

[10] 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 a choice over another Internet Service Provider (ISP), as occurred after the AOL/Time Warner merger. See Rosston (2006).

[11] 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.

of the Apple iPhone. Recent reports suggest the Apple iPhone dominates household purchases in this product category for the time being. This study will largely be unable to address this category.

The quality of the user experience was shaped by one other factor, improvements in online content. This activity supports many of the new information services, news services, blogs, and other Web2.0 sites created in the first decade of the new millennium. The broadband Internet has enabled considerable variety of entertainment of this form. Such activity generates several tens of billions of dollars in advertising revenue.[12] A generous interpretation of the growth of these sites might consider this an improvement in broadband quality as well. That is, more entertainment increased willingness to pay for Internet access. However, it is unclear how much of this improvement to attribute to broadband and how much to attribute to the providers of content supported by online advertising.

Though we have little to say below about the economic boundary between the quality of access services and ad-supported entertainment, we highlight the open question because it alters the interpretation of our results. Empirical evidence on the willingness to pay for broadband indicates an increase between 2003 and 2009 among US consumers with considerable online experience.[13] Our price index for access is informative whether or not there is a big increase, but such evidence could suggest that experienced users are getting "much more for their money".

Starting an index

When should a broadband index begin? Most surveys suggest that any price index about broadband needs to go back as far as possible into the beginning of the millennium.

[12] The dominant online advertising company, Google, can illustrate why entertainment advertising revenue cannot add up to more than ten to twenty billion. Google alone makes just over $22B a year in revenue, with approximately two thirds of that coming from AdWords, the auctioning of words to advertise next to search activity. Approximately one third comes from AdSense, the Google effort to sell advertising to third party sites, such as news, entertainment and blog sites. The second largest online advertiser, Yahoo!, is also small. Yahoo!'s revenues from ads are less than $7B. There is simply not enough revenue to add up to more than several tens of billions of dollars in revenue per year. As of this writing that is lower than the revenue for Internet access subscriptions.

[13] For 2002 data and results see Savage and Waldman (2003). For 2009 data and results using comparable methods see Rosston, Savage and Waldman (2010).

For example, federal efforts to collect data about the adoption of the Internet began in 2000, and found 4.4% of US households had adopted broadband by August of that year. Further surveys found rapid growth in adoption, reaching close to 20% of households by 2003.[14] Recent data about household use, collected by the Pew Internet and American Life Project, show that adoption reached over 47% of households by 2006. Further, as noted in the introduction, by April 2009, 63% of US households had broadband, which is the vast majority of all Internet households.[15]

TABLE 1. 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 Greenstein and McDevitt (2009), appendix, for adjustments.

Estimates for revenue for household broadband services also lead to the same conclusion. The US Bureau of the Census estimates revenues and publishes these in its *Annual Service Survey.* Table 1 provides a summary of these reports, to which we have made considerable adjustments to correct for related measurement issues (see appendix to Greenstein and McDevitt (2009)).[16] We expect that between 60% and 75% of the revenue in Table 1 is from households, depending on the year and access mode.[17]

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

15 See http://www.pewinternet.org/.

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

17 We came to that estimate by the following means. First, estimates in Greenstein and McDevitt (2009), 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 Tables 1 and 2 are not comparable, since Table 1 is for households only, while Table 2 is for households and businesses.

Table 1 shows revenue grew from $5.5 billion in 1998 to $39 billion in 2006. This record is astonishing for an entirely new market. Broadband revenues comprise approximately half the total revenue for Internet access over the eight years, beginning with less than 6% in 1999 and growing to 72% of the total revenue in 2006. Once again, we conclude that starting earlier in the decade is better.

Bundled and standalone purchases

This study will distinguish between a standalone purchase and a bundled purchase. Unlike a standalone purchase, the price for a bundled purchase accounts for joint purchase of two or more services.

To understand the difference, consider a setting in which a firm offers Internet at a price, P(Internet), and cable-television services at a price, P(Cable Services), and offers a bundle of both at a discount, namely, P(both)/[P(Internet) + P(Cable Services)] < 1. Price indices for standalone contracts will measure the change in quality-adjusted price for P(Internet) between two periods. Price indices for bundled contracts will measure the change in quality-adjusted price for P(both) between two periods.

These different price indices may or may not move in concert. Most models of bundling predict they will be positively correlated in most scenarios, but there is no reason to expect a perfect correlation. For example, if the price of one good is fixed (such as telephone service), then most models of bundling forecast that a fall in the cost of Internet services will generate a decline in the prices of standalone and bundled services. There is no theoretical reason to expect prices to fall to the same degree in both types of contracts, however, because the decline is a function of the demand for each service and the relationship between those demands. In addition, differences in local industry structure (whether firms offer cable television and/or telephone services) could influence the preferences across different price structures. Hence, the extent of the fall is an empirical question.

This study takes two approaches to measuring these price changes. For standalone contracts, we make a price index directly from the hedonic price index. For both standalone and bundled contracts, it will be possible to construct an augmented matched-model index for the majority of contracts. Matched-model indices take an average of the ratio of prices for previous-period and next-period goods, where the two goods are observationally identical. We augment this standard procedure with quality adjustments for the small number of cases where that arises. These supplements come from hedonic price estimation for standalone contracts, which is the only series for which we can make such an estimate.

Will the two indices provide the same answer? The answer is close to yes when improvements manifest solely as price declines. If improvements manifest qualitatively then the question cannot be answered without considerable detail. It depends on the rate of qualitative improvement and how firms create new services and commercialize them.

To appreciate why, consider and compare the two methods. In a hedonic price estimate, a researcher estimates a relationship between P_{it} and X_{it} as part of the goal to estimate qualitative change not otherwise explained by changes in characteristics of the good. In the simplest method, known as the exponentiation method, a research estimates $\ln(P_{it}) = \beta^*X_{it} + \varepsilon_{it}$, where X includes dummy variables for the time of observation, namely X_t. In the simplest specification, all systems from the same year are assumed to have the same rate of improvement, so the coefficient on X_t, namely β_t, provides the basis for estimating general rates of change relative to a base year, β_0, for a system from years 0 and t.[18]

In a matched-model method, the price for same service is compared over time. In the simplest form, the index is contracted from a weighted average of $(P_{it})/(P_{it-1})$.[19] In our case, we lack information about market share, so we construct an unweighted index. This simple index should give a similar result as a hedonic index in a setting with no qualitative change and all prices starting at time 0. Only rates of price decline would matter in either case.

A matched-model index lacks a correction for qualitative change, but that index can be augmented to make it more comparable to a hedonic. How can this be done? In principle it could occur with an estimate for β for the characteristics of X_i that underwent improvement. That would permit an adjustment to the relative price change, $(P_{it})/(P_{it-1})$, to occur at the same time as the qualitative

[18] See Berndt (1993) for a full explanation.
[19] The weights usually are derived from surveys about market share data or household expenditure.

improvement. Such augmentation accounts for qualitative change in the same proportion as a hedonic price index.

That adjustment leaves one factor uncovered, however. Each new entering service in a matched-model index must be integrated into an index. In most matched-model indices, a new service at time t starts with the assumption that the index has the same level as the broad index. In other words, if the index reaches 100 at time 0 and reaches 97 at time t, then the new service is added to the old index as if all price changes in that new service are equivalent to $97*(P_{it})/(P_{it-1})$. That will not produce any meaningful difference with a hedonic index if the X_t for the new service at time t is close to the average for all other services. By similar reasoning, a matched model will tend to be faster (or slower) than a hedonic estimate if the majority of new services tend to be introduced at qualitative levels less valuable (or more valuable) than those typical for the hedonic surface at time t. There is no theoretical reason to expect this to go one way or another.[20] It is an empirical question.

Potential bias

Our approach leaves a gap in our price index. So too do standard BLS price methods. The gap develops because standalone and bundled contrasts arise within four general categories of channels for purchasing broadband services. In this time period the channels are as follows:

(1) Households buy only DSL or Cable Internet from a supplier, and nothing else.

(2) Telephone companies sell telephone services and Internet/DSL, and a household buys both from one such firm.

(3) Cable companies sell cable television services and Internet, and a household buys both from one such firm.

(4) Cable companies sell cable television, telephone and Internet services, and a household buys all three from such a firm (e.g., a “Triple Play” bundle).

[20] For a similar intuition with quite different causes in the context of the entry of generic pharmaceuticals, see Cockburn and Griliches (1995).

A standalone purchase arises in three circumstances. First, it arises when a household falls into category (1) above, and by definition, the purchase is standalone. Second, it arises when a household falls into categories (2) and (3) above, but the vendor prices the Internet service as if it were a standalone item. This occurs for many reasons, such as regulatory restraints on a telephone company's pricing. It also can arise for simple marketing reasons, such as an assessment at a vendor that bundled pricing is not worthwhile.

Anecdotes suggest the first three groups were very common at the start of the decade in the US, as was standalone pricing. Industry watchers believe the fourth became increasingly common in the latter part of the decade. The data we present below are consistent with this premise. That is, we see vendors attempting to offer bundled contracts in the middle of the decade, but it is not very prevalent. We observe increasing frequency after the last quarter of 2006, both "triple play" contracts combining cable, Internet and phone, and other forms of bundling combining Internet with one other service. From this pattern we infer that it is likely that household purchase of bundled contracts also increased in the latter part of the decade.

The latter behavior produces an issue for standard price indices. If a price index follows standard BLS procedures, then it will do a good job in a few scenarios, and a problematic job under one scenario. Here is a good scenario: A quality-adjusted price index will serve as a useful deflator for household broadband expenditure when households begin their purchase with a standalone or bundled contract and retain that type of contract throughout the period. In brief, standard procedures measure the price change when households persist in their economic choice. Here is the problematic scenario: A quality-adjusted price index will mismeasure price changes for households that begin their purchase of broadband services with a standalone contract and switch to a bundled contract.

Here is an intuitive explanation why. Consider a household that switches between standalone and bundled contracts. Such a household gets a one-time gain from the discount on the bundled purchase. However, according to standard BLS sampling procedures, the index continues to sample price changes in proportion to lagged choices. As a result, it oversamples standalone contracts in comparison to (less expensive) bundled contracts.

In general, BLS could collect such information, but only does so with a lag.[21] We also do not have such information in this study.

To be fair, this gap ought to be modest in any given year, but could add up over time. To appreciate these points, consider the following example (once again, based on common experience). If the discount for purchasing a triple-bundled contract (combining Internet, telephone and cable) reduces expenditure from $140 to $125, this is a 14.3% discount from base. If an Internet service is $45, then the Internet price index for this service should record a new price of $40.18 for the household if the discount is applied proportionately to all services in the bundle. However, if the switch to the bundle is unmeasured, then the price decline is not measured. If five percent of households in the country make this type of switch in one year, then the price index should decline 0.7%, but does not. Though this is a modest change, such changes add up over time if more households make a similar switch.[22]

This argument has several implications. First, it suggests that BLS procedures, as well as those we use below, will do a reasonable job measuring price change for any *new* adopter who *begins* with a bundled contract. Second, the problem of outlet bias is likely to be most acute for *early* adopters of broadband services who *later* switched to bundled pricing. Because many households adopted broadband in the first half of the decade, it is possible for the issue to be large, and there is no way to know without more detail. Third, total prevalence of bundled contracts alone provides an upper bound on the issue, since measures of total prevalence combine both new adopters and old switchers from standalone contracts. Fourth and finally, the size of the bias is an empirical question, and it depends on both the degree of discount between standalone and bundled pricing, as well as the extent of switching among

[21] BLS samples contracts based on the frequency with which households purchase them. It then gets price data from the firms who offer those contracts. It generates a resample every several years. This procedure will overlook any household gain from a switch in channels until the new household survey reveals a change in channel.

[22] The intuition is analogous to the switch between dial-up and broadband Internet, as documented in Greenstein and McDevitt (2009).

early users of broadband with standalone contracts. We have no basis for making an estimate, so this is an open question for future work. What we provide today highlights this open question.

Data and method

We looked for available data, and it led us to favor the data at Point Topic, a consultancy based out of London. Point Topic covers broadband access back to at least 2002 for many countries. The company also claims to distinguish between household and business users in its adoption/price data, which is another key detail. In general, the data about US adoption and revenue from Point-Topic do not substantially differ from the prior estimates for the US.

Note the key strength and limitation of Point Topic's data. These data are a consistent source across years. Definitions remain consistent, and so do reporting standards, which permits meaningful comparisons over time. Nonetheless, Point Topic must make some estimates about quality and prices, as would any analyst in this market, particularly for poorly recorded variables, such as maximum bandwidth capabilities (e.g., speed). If there are big errors in Point Topic's estimates, then the fixed-effect estimates (below) ought to take care of some of the issues, provided the errors are correlated over time within a firm.

Point-Topic does not have data on the market share of services, its main weakness for our purposes. It provides data about the total number of subscribers to a company's services, but we would have to make arbitrary assumptions to infer the market share of particular services from these reports.

Constructing a sample for analysis

Table 2a provides a summary of the sample we analyze. We first start with Point Topic surveys on broadband providers in the US. Ideally, the data obtained from Point Topic should include only residential plans and their prices for existing customers, which will focus the index on the prices for recurring services. However, Point Topic goes to great lengths to include virtually every available plan, and their policies are too inclusive for our purposes. We adjust the data in the following manner.

First, we divide the data into DSL and cable service. We further divide the data into standalone and bundled pricing. We do this manually by identifying plans with "double" and "triple" in the names or in settings where the firms explicitly explain what they offer. For example, if the name says "TV+Phone+Internet," that plan is assumed to be a triple play. Relatedly, we look for bundled pricing, so we do not count a telephone firm's offering of DSL as bundled unless we observe it explicitly.

Second, we looked to exclude observations that provide misleading information about recurring household expenditure. We manually check the plan names and exclude all business plans. For example, all plans with "business" or "office" in the name are excluded. Multi-lined plans are also eliminated from the data set for the same reason.

Third, we exclude plans that appear to be temporary experiments in marketing. More concretely, we only keep plans that appear in more than one reporting period (namely, three months). Relatedly, this issue appears to be particularly acute for standalone contracts, so for such data we keep plans that appear in at least two *adjacent* years.[23] In addition, we make sure that the recorded price is the actual effective price, and not the introductory rate. For example, we exclude all plans named with "Intro" or "Lite." Furthermore, we remove a few plans with unrealistically cheap prices, which appear to be typographical errors.

That leaves us with 365 standalone cable contracts and 660 standalone DSL contracts, as stated in Table 2a. For bundled contracts, similar procedures resulted in 303 cable contracts and 267 DSL contracts, as stated in Table 2a.

We inspected the bundled contracts and found the data too thin for our purposes prior to the fourth quarter of 2006. We also had to remove many observations after 2006 with incomplete information or without a complete match. That resulted in 208 bundled cable contracts, and 194 bundled DSL

[23] For example, if a plan appears only in 2004 and 2006, it will not be kept in the data set. In addition, if a plan appears in 2004, 2006 and 2007, the 2004 observations will be excluded while its 2006 and 2007 observations are kept.

contracts for analysis. Table 2b provides a distribution of the quarters in which these arose, denoting the time period by the time of the later match. For example, 22 cable contracts and 15 DSL contracts offered in the first quarter of 2007 match against the same contract in the fourth quarter of 2006. The table shows the fraction of the triple-play contracts, the most common bundle at the outset. Their fraction falls over time, as firms also offer more bundles that combine Internet with one other service.

For the statistical analysis of standalone contracts, we take the result of Table 2a and we trim the data further. We observe that data before 2003 is too thin to support statistical estimation of any sort, so we keep only residential standalone plans appearing in or after 2004 (including those that matched with other contracts in 2003). We then remove outliers. We find the 95% highest price in any year. All plans with prices below or at 95% are in the "trimmed data set." Inspection of the eliminated plans suggests this is a good approach. The eliminated plans are mostly DSL, mostly from Speakeasy.net, and they all have very unrealistic prices of more than $150. Their names usually contain "SysAdmin" or "Gamer," indicating they were unlikely aimed at a typical household. Those procedures resulted in 269 standalone cable contracts and 536 standalone DSL contracts.

Table 2b shows the median download bandwidth for the contracts in that sample.[24] That informs Figure 1, which illustrates three points. First, the median download speed increases over time in our sample. That is consistent with perception in the industry that bandwidth has gradually increased over time. It also reinforces our core motivation for having procedures for adjusting prices for quality. Second, the features of standalone contracts can differ from the features of bundled contracts in overlapping years, so it is important to try to correct for such characteristics in estimating prices. Third, cable download bandwidth tends to be higher than DSL download bandwidth, as represented by these data, which reinforces concerns that the relationship between measured bandwidth and price differs between the two services.

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[24] The median download speed for bundled contracts from cable firms in 2007 begins at a mildly higher level than standalone contracts from cable firms in the sample for that year, as shown in Table 3a. By 2009 the situation is mildly reversed. The median download speed for bundled contracts for DSL firms in 2007 starts at a lower level than standalone contracts, becoming the same in 2008 and 2009, as shown in Table 3b.

We next count the number of standalone plans observed in each year, and show this in Table 2c. To be clear about the definition of these numbers, if a company has only 1 plan but this plan appears in 3 quarters in 2004 and 2 quarters in 2005, the "Number of Contracts" shows 3 in 2004 and 2 in 2005. As Table 2c makes clear, we have data from all years, but it is slightly weighted towards the latter half of the sample years.

Table 2c summarizes location information for standalone contracts, gathered from Point Topic reports and Seamans (2009).[25] We create a series of dummies, one for a firm present in each of the following areas: California, other parts of the West, the Midwest, the Northeast or the Southern US.[26] The latter is omitted. The dummies are not mutually exclusive because a company may have presence in multiple locations. The dummies are proxies for a variety of regulatory and economic factors shaping costs in different regions, and, as we will show, the information will not be very useful. The estimates using company fixed-effects will supersede the estimates using location.

Tables 3a and 3b present variables for all standalone contracts we analyze: price, downstream and upstream speeds and their logs by service type (cable and DSL). Some prices appear to be low.[27] For the sake of consistency with our procedures, we include these low observations. To test for sensitivity to their inclusion, we run a series of statistical tests. Generally, a few observations do not shape our results.

Tables 3a and 3b illustrate one key feature of this data. Though the prices for services remain at nearly the same or higher nominal level, the quality of service tends to increase over time. For example, in 2004 the median cable modem contract price is $44.95, while the median upload bandwidth is 3000

[25] We located the presence of a company in Point Topic's reports. However, many times Point Topic recorded only the name of the town, and we use our own judgment and other information about the firm's strategy to decide the state. If no information was available in Point Topic, we further looked at the company website and searched for press releases. We also contacted some firms directly and asked sales representatives.

[26] The West includes: OR, MT, NM, CO, WY, WA, ID, UT, AZ, NV. The Northeast includes: MA, DE, RI, PA, NJ, NY, MD, CT, DC. The Midwest includes: WI, IL, MI, OH, IN, IA, MO, SD, ND, MN, KY, TN, KS, MS, NE.

[27] For example, Cable's lowest price is $16.95 for RCN's "1.5 Mbps Cable Modem". A plan called "Cox Economy" from Cox Communications costs only $16.99, but the speeds are relatively low (256 for upstream, 768 for downstream). DSL's lowest price is $15.00 for AT&T Yahoo High Speed Internet Express DSL. Windstream Communications also has the "Broadband 1.5 Mbps" plan, which started at 29.99 but then dropped to 19.99. However, other Windstream plans went down in prices too, so we did not drop it either. Cincinnati Bell "Zoomtown 768 Kbps" plan costs $16.95, but the speeds seem low (384 for upstream, 768 for downstream).

bps. In 2009, these are $53.00 and 8000. For DSL, service we observe a similar pattern, with prices at $49.99 in 2004 and 2009, and bandwidth improving from 1500 bps to 3000 bps. We conclude that this is a setting where quality adjustment could improve price index measurement.

Figure 2 illustrates related trends in standalone prices, and suggests several of the challenges this study faces. The Figure shows the average price for each of two services, cable and DSL, at three levels of download bandwidth – 3000, 6000 and 10000 bps. Figure 2 does not reveal much about the overall tendencies of prices, as it is simply not possible to gain much sense for price trends from observing a few simple graphs. The core question requires more-extensive statistical analysis.

A few features of Figure 2a illustrate this conclusion. Median cable prices for a service with 3000 download bandwidth start at just under $45, rise slightly and fall slightly in our sample, but end up at roughly the same place. Median prices at 6000 start at a higher price, around $80, and fall to about $57. Prices for 10000 download are not even available until 2006 from any firm in our sample, and the median price thereafter falls, landing between the average prices for the other two services. While that seems odd on the surface, it is plausible for numerous reasons. The set of firms offering service at a bandwidth changes from one period to the next. Moreover, prices at different levels come from sets of different firms in different locations facing different users, offering different upload speeds, as well as potentially offering different additional services.

The median DSL prices in Figure 2b highlight the same conclusion, albeit with different challenges. The median price for 3000 download bandwidth in 2004 is just above $50 and then falls before rising again. There are no prices for higher bandwidth until later. Again, these come from different firms in different settings. They reach levels that differ from cable prices. No simple answer will suffice.

Hedonic estimates for quality adjustment

We experimented with a series of regressions for estimating quality adjustment over time. We present seven different regressions in Table 4, which is sufficient to illustrate the variance in the data.

Model (1) presents our baseline regression. It regresses the log price on log upstream and downstream speeds, year and location dummies. Though we estimated more than seven additional models, the next seven are sufficient to illustrate the robustness of our estimates. Model (2) presents a Quantile regression at the median using the same variables from Model (1). In Model (3) we add company dummies to Model (1), testing for the importance of measurement error correlated within firm across years. Model (4) presents a translog specification of Model (1) to test whether this specification shapes the time dummies at all. Model (5) and Model (6) split Model (1) into two sets of years, 2004-2006 and 2007-2009. Model (7) regresses the level of prices on the same variables as found in Model (1). Model (8) adds one variable for the first year of a new service, testing for a type of pattern that could produce differences between a matched model and hedonic index.[28]

The baseline regressions have statically significant estimates on all control variables, such as bandwidth and location. These estimates also demonstrate the merits of separating DSL and cable-modem regressions. Virtually all the coefficients differ between the two regressions, rejecting any test of equality between them.[29]

We elaborate on the results in the baseline regression in Table 4, because these results tend to arise in virtually all the additional specifications. It shows that both upload and download speeds play a role in pricing. In both DSL and cable prices, higher bandwidths for both upstream and downstream lead to higher prices, as expected. Both can make a large difference in the price of bandwidth. For example, at the mean of the data, doubling download bandwidth leads to a 26% increase in cable-modem prices, while doubling bandwidth leads to a 6% increase in price for DSL service. Upload speeds also matter. Doubling upload bandwidth increases cable-modem prices by 11%, while doubling DSL upload bandwidth (which is rare in practice) increases price by 32%. These estimates are plausible and within the range of variance found in this data.

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[28] Also recorded are the number of observations and R2. For median regression, the reported R2 is Stata's pseudo R2=1-sum_adev/sum_rdev.

[29] We experimented with a wider set of specifications than shown in Table 4, and always rejected equality between DSL and cable-modem regressions.

Location also plays a role, with the Northeast appearing to have lower prices than the other areas. This could be interpreted as evidence of lower costs affiliated with serving denser locations, as typically found in the Northeast. However, we hesitate to interpret these controls too strictly, since firms may be in many locations. In addition, firms have many other characteristics, so the estimate also could arise from an endogeneity bias affiliated with location; namely, the "type" of firm that tends to locate in the Northeast (in addition to potentially elsewhere) has lower costs than those that do not locate there, and the reasons are unobservable. Tests of the coefficients with firm fixed effect will take care of these concerns.

Most interesting are the time-dummy coefficients in the baseline regression. Cable-modem prices decline on average by 14.7% between 2004 and 2009. In 2008 the estimates indicate a decline of 32% from 2004 before rising between 2008 and 2009. Even with comparatively large standard errors in each year, all the estimates show evidence of some price decline after quality adjustment.

The price rise from 2008 to 2009 appears anomalous in light of the patterns in prior years. Close inspection of the data shows that this result reflects a real event. Between the fourth quarter of 2008 and the first quarter of 2009, Point Topic shows that RCN increased the prices of all its services by $15 with no accompanying change in quality.[30] The estimates treat that as a price rise, and they are averaged in with the other (mostly unchanging) prices.

The DSL estimates are much more modest by comparison, with most of the estimates not statistically different from zero. The point estimates show (at best) a 9.7% decline in 2007 from the base year of 2004, and a modest 6.2% decline in 2009. However, it is not statistically significant. The evidence for a widespread and dramatic quality-adjusted price decline is weak at best.

Close inspection of the data suggests why these results arise. The vast majority of prices do not change from one observation to the next in situations where we can compare two identical contracts across periods. More than 80% of the "matched" observations involve no qualitative improvement or

[30] According to Point Topic's reports, the price for RCN's lowest-quality broadband plan (384 upload and 1500 download) increased from $23 to $38. The next tier (384 upload and 5000 download) increased from $33 a month to $48. The next tier (800 upload and 10000 download) increased in price from $43 to $58. The highest tier (2000 upload and 20000 download) increased from $68 to $83. That is, respectively, a 65%, 45%, 34%, and 22% increase for 4 of the 16 cable contracts.

price change between periods. Moreover, the number of price declines and qualitative improvements exceeds the number of price rises, but only by a small number. That still leaves room for improvement through the introduction of new services, but it also suggests that any estimate of the changes between periods is sensitive to actions from a few contracts. For a similar reason it is not surprising that the price index has large standard errors, and moves in different directions from one period to another.

The columns in Table 4 show a variety of experiments with distinct specifications. Median regressions in column (2) are qualitatively similar, suggesting outliers have not played a major role in the benchmark estimates. The time-dummy estimates are only modestly higher. The estimates with company-fixed effects in column (3) are qualitatively similar for cable prices. The results further reinforce the finding of no change in prices for DSL. Column (4) includes a Taylor expansion of bandwidth as a control, and finds time-dummy estimates quite similar to the benchmark.

Columns (5) and (6) split the sample into two time periods, and present the most interesting differences with the benchmark. By standard statistical tests, this split is superior to imposing a uniform specification across all years. We do not dwell on that finding, however, since the inference about change over time does not differ qualitatively. The aggregate estimated decline in cable prices is still quite modest, with a 14.7% decline over 2004-06, and with a 12.3% increase over 2007-09. Depending on specification (not shown), we estimate the decline between 06 and 07 at 10% to 13%, so the *total* decline over the six years closely resembles our first benchmark, at around 14%. The DSL estimates show modest price changes, similar to the 6% in the benchmark and not statistically different than zero.

Column (7) estimates the benchmark on price levels in the spirit of illustrating that the specification really does not shape the inference. The total price decline is just over five dollars for cable-modem service. The estimated decline is not statistically different from zero for DSL, albeit near three dollars in the point estimate. Once again, we conclude that these declines are quite modest for six years.

Finally, Column (8) reproduces the basic specification with the addition of one variable for a new introduction. This new variable equals one during the first year of a service, and zero otherwise, for all services introduced after 2004. Recall that we estimate this on a sample that already removed many "introductory prices," which tend to have a very short life before the user must upgrade to a yearly contract. So this coefficient measures the tendency of a new service to enter above or below the existing hedonic surface. In both the DSL and cable regressions the coefficient estimate on the new variable is negative, but statistically insignificant. That reduces worries about major systematic measurement errors for new services, but it does suggest it is possible for the matched-model index to differ from the hedonic.

The starting point of the data provides another illustration. The 2004 average costs of cable is almost $49, and of DSL $58. While cable prices decline in nominal terms in some years over the sample time period, the sample average is higher by the final year. DSL prices largely do not change in the sample. However, our estimates can adjust those results for the quality of services. Cable quality improved enough to result in a 14% price decline, while DSL's quality improvement led to a 6% price decline. That is approximately $6.85 and $3.50, respectively, if we take the point estimates on face value. Face value needs a cautious interpretation, however, because it ignores the lack of statistical significance for the latter estimate, and, in both cases, ignores a standard error affiliated with forecasting.

Overall, the estimates in Table 4 present a consistent picture. The benchmark estimates for price changes vary only slightly with different specifications and types of variables we use as controls. We have experimented with other specifications and controls and reached a qualitatively similar conclusion.[31] We conclude first that there is little evidence of widespread quality-adjusted dramatic price decline in this series. If anything, the estimates point towards modest decline. We also conclude that the benchmark estimates are sufficient for purposes of illustrating price change over time.

Price indices for standalone contracts

From the benchmark regressions in Table 4, we calculate three types of indices of the standalone data – Laspeyres, Paasche and Fisher – and present them in Table 5. We also use different weights. The

[31] This is not surprising since the fixed-effect estimates do not qualitatively differ from the benchmark. We also tried a specification that included size of firm, size of customer base, number of offerings for the firm, as well as vintage effects. The estimates in Table 3 are representative of the findings.

first weight is taken from Point Topic reports, for all companies about which we have information. We simply aggregate the user data at service level (Cable or DSL) and by year, and then weight the price changes from DSL and Cable to construct an aggregate price index for all broadband. Actual usage data only contain Q1 2009, so we project the whole year based on this first quarter. The second weight comes from FCC estimates for cable and DSL lines.[32] We use the June statistics, since they are available from 2004-2008, and we use the 2008 data to weight the 2009 estimate (in the Paasche and Fisher index calculations).

The simplest method of calculating the indices is to exponentiate the year-dummy coefficients from Table 4, adjusting the estimates for bias (see Berndt, 1991).[33] The results using the point estimates are presented in Table 5a. The price index does not vary with our weighting scheme, which is not surprising since quality-adjusted prices decline very little.[34] Indeed, if we were to use the lower bounds of these estimates, the price index would hardly decline at all.

In general, we find modest overall price declines from the point estimates, consistent with the estimates in Table 4. We find overall price declines of just over 10% for just under the six years. Close inspection shows that most of the decline comes from the decline in quality-adjusted prices in the cable-modem services. The lack of price decline in DSL services tends to damper any aggregate price decline, irrespective of the weighting scheme.[35] Indeed, these estimates are probably too high. If we had set the rate of price change in DSL to zero – reflecting the lack of statistical significance (instead of using point estimates) – the aggregate estimate would have been mildly lower.[36]

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[32] See the FCC website, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-292191A1.pdf, accessed in December 2009. We experimented with both Tables 3 and 4 and found that the definitions did not matter. The paper shows the data from Table 4.

[33] With imprecise estimates, such adjustment can be significant, though it makes only a modest difference in this case.

[34] Laspeyres, Paasche and Fisher indices could give quite different results with data on better market share, but the method used in the baseline gives every contract an equal weight, so this use of market share makes little difference.

[35] We experimented with a variety of estimates, including those shown in columns (2), (3) and (4), and generally got similar results. This is not surprising since the coefficient estimates are so modest.

[36] This is not a surprise. DSL comprises a bit over a third of the users, but the point estimate falls at about half the rate of cable-modem services. Hence, setting the rate of price decline in DSL to zero could not diminish the aggregate rate of decline by much.

We performed one other robustness check, comparing a matched-model with the hedonic results. If measurement errors are randomly distributed, then including or excluding observations will have no major effect on the results. Because matched model indices are potentially sensitive to the starting point in the series, and the initial hedonic results suggested a systematic tendency for the first entry in a series to be lower, we worried that measurement error was not random. To test for this concern, we considered "starting the series at the second observation" for many cases when we had reason to worry that Point Topic did not (or could not) record precise information about the service as it was introduced.[37] Eliminating the most worrisome cases resulted in a slightly smaller sample, 235 cable and 498 DSL contracts. We estimated the same set of hedonic regressions as above, and found that the qualitative inferences from the regression results were essentially unchanged.

We then experimented with an augmented matched model for the same data. In one clear case of a price increase (between 2008 and 2009 for cable prices), both methods give a similar result, as we would expect. For the other years, when quality improvement occurs, the augmented matched model estimates a slower rate of quality-adjusted price decline than the hedonic model. Cable prices show an aggregate 13% price decline in the augmented matched-model index from 2004 until 2008, which is about half the rate estimated by the hedonic index. The rate increases in 2009, which brings the total change to 1% over all the years. DSL prices decline by 2% in the augmented matched-model index from 2004 to 2009, which is a slower rate of price decline. That result is consistent with the introduction of new services at better price/quality points than estimated by a hedonic surface, not merely measurement error.

Price indices for bundled contracts

Table 5b shows the augmented matched-model indices for bundled contracts. Matched-model methods worked for 382 pairs of contracts out of the 402 examined. For twenty matches of bundled

[37] Anomalous changes in the characteristics of a service were good clues of this potential issue. For example, a service might be listed at 1536 download bandwidth in its first year and 1500 thereafter. The change would produce an effect on price indinces, but it is due to measurement error. In a few cases, this resulted in the elimination of a few series of contracts and services that the supplier discontinued quickly after introduction, possibly because the services did not sell especially well.

contracts, we observe different download or upload speeds. In each case, we infer the price-equivalent value of the qualitative change from the hedonic estimates, and then calculate the new implied price ratios, adjusting observed prices accordingly. As noted earlier, due to thin data availability, we calculate these only from the fourth quarter of 2006 to the second quarter of 2009. We assume 2006 is the base year and make quality adjustments for 2009 similar to those for standalone contracts.

Table 5b calculates indices with different approaches to providing weights, using the same weights for the same years as in Table 5a. In general, these weights do not matter because the price declines over the period are quite modest, lower than those found in the standalone contracts. The total price decline is 1.4% or 2.4% for the eleven quarters from 4Q, 2006 to 2Q, 2009, depending on weight.

Point Topic identifies the number of users for the largest firms, so we also recalculated a price index for just these firms. Since these firms provide services for the majority of users, the corresponding calculations offer clues about whether the majority of users experienced a faster or slower price decline than that measured by our index.[38] This procedure has a major drawback; namely, it depends on a small number of firms, and it leads us to exclude observations from many firms, especially in 2007. Unlike Table 5b, we calculated the average rate of decline for each firm, and then weighted it by the number of users for that firm. We found similar rates of price decline for cable firms (just over 2%), and high rates for DSL (just over 9%), resulting in a mildly faster combined rate of price decline.

This finding does not change our overall conclusion, but it does raise an open question. If DSL users of popular services have had a mildly better experience than our estimates indicate, then reweighting the estimates with data about market share could alter the aggregate index, making it mildly higher.

[38] The point topic data cover eight to ten firms, depending on the year. This look adequate, but not ideal. To get a sense for what fraction of users this covers we examined Alex Goldman's rankings of US ISPs, which he estimated and published between 2Q, 2001 and 3Q, 2008. For example, in 4Q, 2005, the largest five broadband ISPs (excluding AOL and Earthlink) accounted for 42% of broadband contracts, while in 3Q, 2008, the largest five accounted for 60% of broadband contracts. The top five are (in order) Comcast, AT&T/SBC, Verizon, Roadrunner, and Charter, with Qwest and Cablevision close behind.

Interpreting the price indices

Proper interpretation of Tables 5a and 5b requires care. Both tables show a modest price decline from the starting level in nominal terms. In real terms, however, the decline is more substantial, as the price of broadband Internet declined during a period in which the aggregate price of goods was increasing between 2-3% per year. If the typical household budget keeps pace with inflation, the fraction of expenditure going to broadband services declines, by definition. From this we conclude that households that began their broadband experience with one type of contract experienced a mild price decline after adoption.

However, Table 5b does not provide a complete measure of the gains to a household that first adopted a standalone contract and replaced it with a bundled contract. As noted earlier, our estimates cannot account for the size of the gains from a switch between channels. Doing that would require information about the prices of broadband and the prices of the other components of the bundle, including telephony and cable TV services without Internet. Those data requirements exceed the information provided by Point Topic. Such information does exist in (confidential) household expenditure data and pricing data, which BLS could collect for its own price indices.[39]

In addition, we cannot properly apportion price changes in the bundle to its individual components without further estimates of the relative elasticities of demand for each service. Because we have evidence of a recent price increase in standalone prices during a period of decline for bundle prices, we hypothesize that firms are exploiting the relatively inelastic demand for broadband Internet by bundling it with a product with a relatively more elastic demand: residential phone service. This further complicates an analysis of broadband price changes, and is an issue that requires additional study.

With these exceptions and important caveats in mind, we compare our index to the BLS Internet access index. The BLS index in January 2007 is a good place to start for such a comparison since at that

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[39] Another potential source of such data also fails to settle the matter. The CPS supplement, which was collected every two years and yielded data for the well known NTIA (2004), stopped collecting expenditure data after 1999.

point the BLS index no longer contains the results of changes to dial-up service prices. We expect, and indeed find, our index to move faster than BLS's because we include some quality adjustment. The BLS index suggests there has not been any such large benefit going to households. The BLS index displays slower price decline than our results. Over nearly three years, January 2007 to November 2009, the index *increases* by 3.1%.[40]

This comparison is not ideal, but it is suggestive. The broadband prices must comprise more than half this index, but the exact percent is confidential, so we cannot be certain how much of the price increase comes from broadband prices and how much comes from dial-up prices. However, it is easy to make an educated guess because dial-up vendors faced sharply declining demand for their services during this time period, which should have depressed prices. We safely conclude that this three-year price history could not have arise if there had been large price declines in broadband services, irrespective of whether these were standalone or bundled contracts.

Summary

In this paper, we estimated the size of the price declines in broadband service in the United States between 2004 and 2009 using more-extensive data and methods than any other research to date. We divided the price changes into three categories: standalone prices, bundled prices, and households switching between these two forms. We found no evidence of dramatic price declines in the first two categories. Rather, we found some evidence of modest price declines.

Our evidence points towards, at most, a total modest decline in broadband prices after adoption. We place the price decline at, perhaps, as much as a 10% decline in quality-adjusted prices over a little more than five years, or under 2% a year in nominal terms. In real terms, however, the declines become

[40] Specifically, the index starts at 73.4 in January 2007, reaches a low of 72.6 in October, and ends the year at 73.1. The following year, 2008, is no better, starting at 72.9 in January, which is the low point of the year. It ends at a higher level, in this case, 75.9. The following year, 2009, begins at 76.2 in January, reaches a peak of 77.5 in April, and reaches a November level of 75.7, which is the low point of the year. This is the most recent data available. See http://data.bls.gov/PDQ/outside.jsp?survey=cu , US City average for Internet Services and Electronic Information Providers. Accessed December 27, 2009.

more substantial, perhaps at nearly 5% per year. A lack of data about market share makes it impossible for us to say more with much precision.

Our results contribute several important new findings to policy discussion. First, the lack of any dramatic price decline in broadband rejects any claim that US policy results in dramatic quality-adjusted price declines in broadband services. Second, the results suggest this market looks nothing like other parts of electronics, such as computers or integrated circuits, where the quality-adjusted price declines each year regularly exceed double digits. That raises many questions about differences between mass-market Internet services and other parts of electronics in determinants of prices, as well as questions about the role of market structure and demand. Third, although the price declines are modest, our index declines faster than the BLS price index for Internet access over a period that allows us to make a direct comparison. This finding raises questions about whether the BLS price index for Internet access provides an informative picture of price change.

Our findings also raise an open question about the economic gains to households from switching between standalone and bundled contracting forms after adopting broadband. Properly estimating those gains/benefits requires information about the extent of the discount and the prevalence of the switching among experienced households. Notably, this example adds to a growing list of examples that underwent a rapid change in a short period of time – such as dial-up Internet access, pharmaceuticals coming off patent, personal computers – where frequent surveying would have measured gains more accurately.

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Table 2a. Number of broadband plans

Bundle	Type	Residential plans in or after 2004	Existing plans with more than 1 quarter data point	Appear in at least 2 adjacent years
0	cable	405	373	365
0	dsl	737	670	660
1	cable	371	330	303
1	dsl	355	316	267

Table 2b. Bundled contracts

Ending Yr/Q	07/1	07/2	07/3	07/4	08/1	08/2	08/3	08/4	09/1	09/2	Total
Cable											
Number	22	15	11	15	21	24	29	30	22	19	208
% Triple bundle	82%	80%	73%	73%	62%	63%	55%	53%	59%	58%	
Med download bps	7000	7000	6000	7000	5000	6000	6000	6000	6000	6000	
DSL											
Number	15	18	14	19	21	22	14	20	26	25	194
% Triple bundle	40%	44%	50%	53%	48%	41%	21%	20%	27%	24%	
Med download bps	1500	3000	1500	1500	3000	3000	3000	3000	3000	3000	

Table 2c. Standalone contracts in the sample and location

Company	Type	CA	West	NE	MW	2004	2005	2006	2007	2008	2009
ALLTEL	dsl	0	0	1	1	1	2	2	0	0	0
AT&T	dsl	1	1	1	1	0	2	3	15	12	6
Adelphia Communications	cable	1	1	1	1	2	2	4	3	0	0
BellSouth	dsl	0	0	0	1	4	2	6	3	0	0
Bright House	cable	1	0	0	0	1	1	1	0	0	0
Cable One	cable	0	1	0	1	2	2	7	14	12	6
Cablevision	cable	0	0	1	0	0	0	0	4	4	2
Charter Communications	cable	1	1	1	1	2	2	1	1	0	0
Cincinnati Bell	dsl	0	0	0	1	6	3	6	11	9	6
Comcast	cable	1	1	1	1	0	2	4	10	7	4
Covad Communications	dsl	1	1	1	1	2	1	2	4	1	0
Cox Communications	cable	1	1	1	0	3	3	6	13	15	8
DirecTV	dsl	1	0	1	1	4	2	2	0	0	0
EMBARQ	dsl	0	1	1	1	0	0	3	11	20	10
Earthlink	dsl	1	1	1	1	1	2	2	0	0	0
Frontier Communications	dsl	1	1	1	1	0	0	0	0	1	2
Insight Communications	cable	0	0	0	1	1	0	2	2	8	4
Mediacom	cable	0	0	0	1	1	1	1	0	0	0
Qwest	dsl	1	1	1	1	5	4	6	12	9	4
RCN	cable	1	0	1	0	1	0	5	11	15	8
SBC	dsl	1	0	0	1	9	5	5	0	0	0
Speakeasy.net	dsl	1	1	1	1	23	19	28	58	60	30
Sprint	dsl	0	1	0	1	4	2	2	0	0	0
Surewest Communications	dsl	1	0	0	0	0	2	4	16	14	8
Time Warner Cable	cable	1	1	1	1	5	5	7	17	24	3
Verizon	dsl	1	1	1	1	2	2	2	2	4	2
Windstream Communications	dsl	0	1	1	1	0	0	2	8	8	6

Table 3a. Summary statistics for variables, cable

Across all years		Mean	Standard deviation	Min	Median	Max
Existing Price ($)		46.17	14.29	16.95	44.95	84.95
Downstream Speed (bps)		7,123.21	6,327.48	256.00	5,000.00	30,000.00
Upstream Speed (bps)		741.36	914.63	100.00	500.00	5,000.00
Log of Existing Price		3.78	0.34	2.83	3.81	4.44
Log of Downstream Speed		8.51	0.92	5.55	8.52	10.31
Log of Upstream Speed		6.28	0.71	4.61	6.21	8.52
Summary by year						
2004	Existing Price ($)	48.86	15.31	24.95	44.95	84.95
2004	Downstream Speed (bps)	3,341.11	1,600.16	256.00	3,000.00	6,000.00
2004	Upstream Speed (bps)	392.22	183.62	128.00	384.00	800.00
2005	Existing Price ($)	49.79	15.06	24.95	44.95	84.95
2005	Downstream Speed (bps)	4,118.89	2,184.01	256.00	4,000.00	8,000.00
2005	Upstream Speed (bps)	418.89	191.77	128.00	384.00	768.00
2006	Existing Price ($)	48.45	13.12	16.95	49.95	84.95
2006	Downstream Speed (bps)	5,230.42	2,667.31	256.00	5,000.00	12,000.00
2006	Upstream Speed (bps)	512.16	272.86	200.00	384.00	1,500.00
2007	Existing Price ($)	44.36	13.76	16.95	44.95	67.95
2007	Downstream Speed (bps)	7,030.24	6,364.51	768.00	6,000.00	30,000.00
2007	Upstream Speed (bps)	752.48	1,040.62	100.00	500.00	5,000.00
2008	Existing Price ($)	43.27	13.98	16.95	44.90	69.95
2008	Downstream Speed (bps)	8,574.17	7,255.24	768.00	8,000.00	30,000.00
2008	Upstream Speed (bps)	873.88	1,024.94	256.00	512.00	5,000.00
2009	Existing Price ($)	51.35	14.99	19.89	53.00	83.00
2009	Downstream Speed (bps)	9,343.89	7,697.68	768.00	8,000.00	30,000.00
2009	Upstream Speed (bps)	989.94	1,113.31	256.00	768.00	5,000.00

Table 3b. Summary statistics for variables, DSL

Across all years	Mean	Standard deviation	Min	Median	Max
Existing Price ($)	58.43	24.36	15.00	49.99	105.95
Downstream Speed (bps)	2,933.17	2,231.28	256.00	1,500.00	12,000.00
Upstream Speed (bps)	564.66	246.46	128.00	768.00	896.00
Log of Existing Price	3.98	0.42	2.71	3.91	4.66
Log of Downstream Speed	7.73	0.72	5.55	7.31	9.39
Log of Upstream Speed	6.20	0.59	4.85	6.64	6.80

	Summary by year					
2004	Existing Price ($)	58.11	21.90	26.99	49.99	105.95
2004	Downstream Speed (bps)	1,959.61	1,194.94	256.00	1,500.00	6,000.00
2004	Upstream Speed (bps)	479.74	272.04	128.00	384.00	896.00
2005	Existing Price ($)	58.38	21.69	28.00	49.99	105.95
2005	Downstream Speed (bps)	1,921.67	1,146.54	256.00	1,500.00	6,000.00
2005	Upstream Speed (bps)	453.50	276.84	128.00	384.00	896.00
2006	Existing Price ($)	57.81	25.22	19.99	49.95	105.95
2006	Downstream Speed (bps)	2,539.95	1,725.23	256.00	1,500.00	10,000.00
2006	Upstream Speed (bps)	527.04	252.26	128.00	512.00	896.00
2007	Existing Price ($)	57.27	25.26	19.99	49.95	105.95
2007	Downstream Speed (bps)	3,015.23	2,161.18	256.00	3,000.00	10,000.00
2007	Upstream Speed (bps)	581.49	236.55	128.00	768.00	896.00
2008	Existing Price ($)	60.02	25.03	15.00	50.50	105.95
2008	Downstream Speed (bps)	3,479.48	2,546.13	256.00	3,000.00	12,000.00
2008	Upstream Speed (bps)	618.67	220.67	128.00	768.00	896.00
2009	Existing Price ($)	58.61	24.63	20.00	49.99	105.95
2009	Downstream Speed (bps)	3,616.32	2,777.80	768.00	3,000.00	12,000.00
2009	Upstream Speed (bps)	612.32	220.45	128.00	768.00	896.00

Table 4. Regression results

Estimates	OLS Log Price (1)		Median Regression Log Price (2)		OLS & FE Log Price (3)		OLS Taylor (4)	
	Cable	**DSL**	**Cable**	**DSL**	**Cable**	**DSL**	**Cable**	**DSL**
y_2005	-0.065	0.034	**-0.097**	0.000	-0.088	0.069	-0.074	0.040
	(0.061)	(0.061)	**(0.000)**	(0.024)	(0.055)	(0.032)	(0.058)	(0.060)
y_2006	**-0.147**	-0.035	**-0.227**	-0.034	**-0.181**	-0.002	**-0.150**	-0.042
	(0.053)	(0.055)	**(0.000)**	(0.021)	**(0.048)**	(0.028)	**(0.050)**	(0.054)
y_2007	**-0.274**	**-0.097**	**-0.333**	**-0.107**	**-0.312**	-0.020	**-0.255**	**-0.114**
	(0.049)	**(0.051)**	**(0.000)**	**(0.020)**	**(0.046)**	(0.027)	**(0.047)**	**(0.050)**
y_2008	**-0.326**	-0.058	**-0.334**	**-0.107**	**-0.337**	-0.007	**-0.301**	-0.074
	(0.049)	(0.052)	**(0.000)**	**(0.020)**	**(0.046)**	(0.028)	**(0.047)**	(0.051)
y_2009	**-0.147**	-0.062	**-0.227**	**-0.107**	**-0.179**	-0.006	**-0.140**	-0.075
	(0.055)	(0.058)	**(0.000)**	**(0.022)**	**(0.051)**	(0.031)	**(0.053)**	(0.057)
speed_Downstream							**0.000**	**0.000**
							(0.000)	**(0.000)**
speed_Upstream							**0.000**	**0.002**
							(0.000)	**(0.000)**
sp_UxD							**0.000**	**0.000**
							(0.000)	**(0.000)**
sp_Down_sq							**0.000**	0.000
							(0.000)	(0.000)
sp_Up_sq							**0.000**	**0.000**
							(0.000)	**(0.000)**
ln_speed_Down	**0.265**	**0.060**	**0.270**	**0.084**	**0.291**	**0.126**		
	(0.025)	**(0.024)**	**(0.000)**	**(0.009)**	**(0.024)**	**(0.014)**		
ln_speed_Up	**0.115**	**0.326**	**0.137**	**0.415**	**0.078**	**0.267**		
	(0.039)	**(0.029)**	**(0.000)**	**(0.011)**	**(0.041)**	**(0.020)**		
Ca	**0.295**	**0.530**	**0.431**	**0.655**			0.158	**0.531**
	(0.065)	**(0.038)**	**(0.000)**	**(0.015)**			(0.109)	**(0.039)**
West	**0.249**	**0.122**	**0.274**	**0.242**			**0.166**	**0.115**
	(0.032)	**(0.071)**	**(0.000)**	**(0.027)**			**(0.032)**	**(0.070)**
Midwest	**0.136**	**0.311**	**0.106**	**0.522**			**0.205**	**0.326**
	(0.032)	**(0.071)**	**(0.000)**	**(0.027)**			**(0.030)**	**(0.072)**
Northeast	**-0.291**	**-0.276**	**-0.496**	**-0.310**			-0.159	**-0.267**
	(0.068)	**(0.075)**	**(0.000)**	**(0.029)**			(0.106)	**(0.075)**
_cons	**0.766**	**0.985**	**0.684**	0.004	**1.042**	**0.885**	**3.183**	**2.796**
	(0.147)	**(0.193)**	**(0.000)**	(0.077)	**(0.158)**	**(0.121)**	**(0.062)**	**(0.108)**
Other Statistics								
Num obs	269	536	269	536	269	536	269	536
R2	0.723	0.456	0.456	0.355	0.783	0.858	0.755	0.480

Estimates	Years 04-06 (5)		Years 07-09 (6)		Price Level (7)		New Series (8)	
	Cable		DSL		Cable/DSL		Cable/DSL	
y_2005	-0.054	0.033			-2.570	1.637	-0.0609	0.039
	(0.058)	(0.063)			(2.848)	(3.515)	(0.061)	(0.061)
y_2006	**-0.147**	-0.027			**-5.874**	-0.874	**-0.129**	-0.009
	(0.052)	(0.058)			**(2.460)**	(3.161)	**(0.054)**	(0.050)
y_2007					**-10.833**	**-4.234**	**-0.2644**	**-0.093**
					(2.286)	**(2.933)**	**(0.049)**	**(0.051)**
y_2008			**-0.055**	0.030	**-13.136**	-2.639	**-0.319**	-0.059
			(0.030)	(0.036)	**(2.263)**	(3.000)	**(0.048)**	(0.052)
y_2009			**0.123**	0.030	**-5.086**	-3.038	**-0.148**	-0.066
			(0.039)	(0.043)	**(2.541)**	(3.327)	**(0.054)**	(0.057)
ln_speed_Down	**0.232**	**0.112**	**0.264**	0.008	**8.777**	**2.557**	**0.262**	**0.063**
	(0.044)	**(0.044)**	**(0.032)**	(0.028)	**(1.172)**	**(1.383)**	**(0.024)**	**(0.024)**
ln_speed_Up	**0.148**	**0.206**	**0.144**	**0.460**	**7.640**	**19.520**	**0.124**	**0.325**
	(0.079)	**(0.042)**	**(0.051)**	**(0.039)**	**(1.802)**	**(1.654)**	**(0.039)**	**(0.028)**
Ca	0.091	**0.474**	**0.392**	0.518	**15.397**	**29.431**	**0.301**	**0.526**
	(0.124)	**(0.071)**	**(0.088)**	(0.044)	**(3.006)**	**(2.186)**	**(0.064)**	**(0.037)**
West	**0.190**	0.105	**0.268**	-0.036	**10.261**	**8.635**	**0.244**	**0.127**
	(0.065)	(0.076)	**(0.039)**	(0.068)	**(1.503)**	**(4.124)**	**(0.032)**	**(0.071)**
Midwest	**0.150**	**0.404**	**0.126**	**0.158**	**5.982**	**19.037**	**-0.293**	**-0.271**
	(0.063)	**(0.151)**	**(0.038)**	**(0.087)**	**(1.481)**	**(4.077)**	**(0.067)**	**(0.075)**
northeast	-0.131	**-0.268**	**-0.378**		**-14.022**	**-14.026**	**0.143**	**0.304**
	(0.116)	**(0.087)**	**(0.096)**		**(3.143)**	**(4.360)**	**(0.032)**	**(0.071)**
First in a series							-0.044	-0.050
							(0.031)	(0.046)
_cons	**0.904**	**1.271**	0.309	**0.512**	**-79.471**	**-115.321**	**0.723**	**0.965**
	(0.290)	**(0.368)**	(0.181)	**(0.225)**	**(6.848)**	**(11.177)**	**(0.150)**	**(0.194)**
Other Statistics								
Num obs.	74	184	195	352	269	536	269	536
R2	0.709	0.352	0.730	0.537	0.659	0.457	0.725	0.456

Bold: Statistically significant at 10% level.

Table 5a. Price index estimates for standalone contracts

Yr	Price index estimate		BB price index, weight from point topic			BB price index, weight from FCC Table 4		
	Cable	DSL	Laspeyres	Paasche	Fisher	Laspeyres	Paasche	Fisher
04	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
05	0.937	1.035	0.973	0.973	0.973	0.973	0.973	0.973
06	0.863	0.965	0.903	0.903	0.903	0.901	0.902	0.902
07	0.760	0.908	0.818	0.819	0.818	0.816	0.818	0.817
08	0.722	0.944	0.809	0.809	0.809	0.806	0.808	0.807
09	0.864	0.940	0.893	0.894	0.894	0.892	0.893	0.893

Table 5b, Price index for bundled contract

Yr	Price index estimate		BB price index, weight from Point Topic			BB price index, weight from FCC Table 4		
	Cable	DSL	Laspeyres	Paasche	Fisher	Laspeyres	Paasche	Fisher
06	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
07	0.951	1.045	0.991	0.995	0.993	0.966	0.988	0.977
08	0.961	1.011	0.982	0.984	0.983	0.969	0.981	0.975
09	1.001	0.943	0.976	0.975	0.976	0.992	0.978	0.986

Figure 1. Median download BPS for cable and DSL contracts

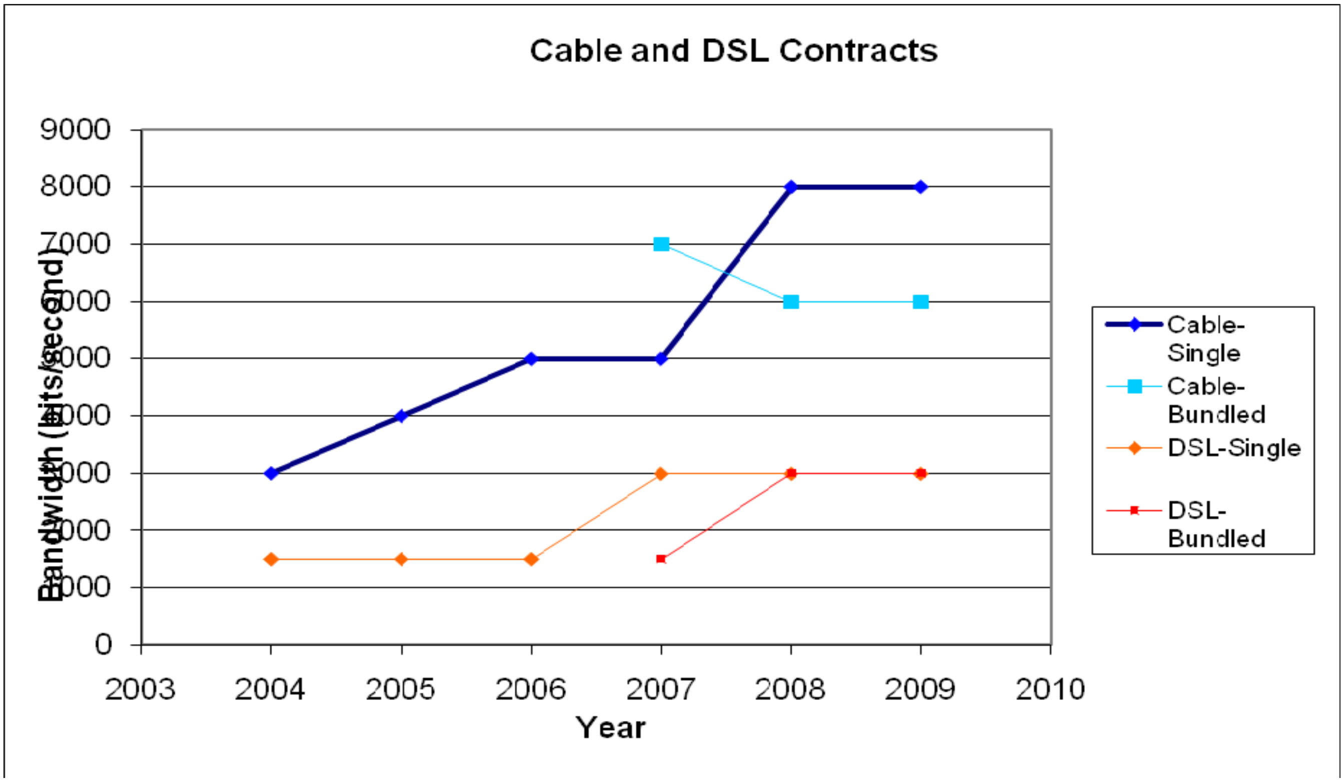

Figure 2. Median prices at select speeds