Information Economics and Policy 23 (2011) 200–211

Contents lists available at ScienceDirect

Information Economics and Policy

journal homepage: www.elsevier.com/locate/iep

Evidence of a modest price decline in US broadband services

Shane Greenstein *, Ryan McDevitt

Kellogg School of Management, Northwestern University, United States
Simon Graduate School of Business, University of Rochester, United States

ARTICLE INFO

Article history:
Received 30 June 2010
Received in revised form 22 March 2011
Accepted 23 March 2011
Available online 30 March 2011

JEL classification:
E31
L16
O33

Keywords:
Broadband
Price index
DSL
Cable
Internet access
Policy

ABSTRACT

In this paper, we construct a consumer price index for broadband services in the United States using over 1500 service contracts offered by DSL and cable providers from 2004 through 2009. This exercise frames a range of open questions about measuring price changes in a manner that informs policy discussions about US broadband services. We employ approaches used commonly for constructing a consumer price index by using a mix of matched-model methods and hedonic price index estimations to adjust for qualitative improvements. We find 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 5-years period, which is faster than the BLS estimates for the last 3 years. In contrast to other innovative industries that experience rapid price declines, such as computers or integrated circuits, the modest price decline for broadband services raises many questions.

1. Introduction

In the summer of 2000, only 4.4% of US households had broadband and most Internet-adopting households used dial-up (NTIA, 2004). The well-documented shift towards broadband occurred rapidly: the percent of broadband adopters had increased to 20% by October 2003, while only 34% still used dial-up. This trend continued throughout the remainder of the decade, as just over 5% of US households used dial-up by October 2009, while 63.5% had broadband. The contribution to US GDP also increased substantially during this era. The entire Internet-access market (broadband and dial-up) exceeded $39 B in the US after 2006, up from under half that in 1999 (Greenstein and McDevitt, 2009).

What happened to the price of broadband during and after its widespread adoption by US households? This question plays an essential role when assessing broadband policies, and when deflating economic growth into real terms. We address this question by using novel data for 2004 through 2009 to analyze over 1500 service contracts offered by DSL and cable providers. It allows us to employ standard methods for assessing price trends, namely, a mix of matched-model methods and hedonic price index estimation. We look for conclusive evidence of trends, such as widespread dramatic declines in quality-adjusted prices or a lack of change. In general, we find neither. Most of the evidence points towards modest price declines.

No broadband price index exists in the United States, so we model our study off the closest standardized process for the consumer price index (CPI), as practiced by the Bureau of Labor Statistics (BLS). The BLS constructs an Internet-access price index by combining data for both dial-up and household Internet-access services, using lagged expenditure surveys to weight price movements.[1] While

* Corresponding author at: Kellogg School of Management, Northwestern University, United States. Tel.: +1 847 467 5672.
E-mail address: greenstein@kellogg.northwestern.edu (S. Greenstein).

[1] This index is called “Internet Services and Electronic Information Service Providers.”

0167-6245/$ - see front matter
doi:10.1016/j.infoecopol.2011.03.002

this component contributes to a national CPI, pursuit of that purpose renders the BLS index nearly uninformative for other purposes, such as informing broadband policy. For example, the BLS also does not break out separate indexes for different technologies (e.g., DSL vs. cable) or regions (e.g., urban vs. rural), key topics for policy debate. In addition, the price for dial-up service dominates the index, and confidentiality rules make it impossible to see what happened to broadband's price. This limitation is problematic in late 2006 when a decline (likely) resulted from the actions of AOL and its competitors.[2]

The aim of this study is to provide a fuller picture of the price changes. It builds on our prior paper, Greenstein and McDevitt (2009), which shows that Internet-access price indexes would have had to decline an additional 1.6–2.2% per year between 1999 and 2006 to account for the user benefits generated from upgrading to broadband from dial-up access. That left open questions about what happened to quality-adjusted prices after adoption, when expenditure exceeds $500 a year in many households. More precisely, in this study 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 find no evidence of widespread dramatic price changes. We bound the declines between a 3% and 10% decline in quality-adjusted prices in just under 6 years. Lack of access to (confidential) data about the market share of services prevents us from being more precise.

Some readers of this study may conclude that standard methods do not work well in this setting, not that consumers benefited less than one would have thought. Our study will frame many related questions. Standard methods accommodate some patterns affiliated with diffusion of new technology and replacement of old generations, but there also is debate about whether measured quality (e.g., advertised rates for download speeds) does a good job of measuring actual experience (actual download speeds, disruption of service, change in content, and so on). Our study illustrates this theme, also found in industries where one fails to see product innovation reflected in rates of "quality improvement" in price indexes.[3] Prescription drugs are another example (e.g., Cockburn and Griliches, 1995).

With those important caveats in mind, these estimates contribute to several ongoing debates. Many policies in the US are premised on the belief that the diffusion of broadband lies at the heart of economic growth. To accelerate growth in provision, 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. The lack of a dramatic price decline in broadband (after deployment) suggests this market looks nothing like other parts of electronics, such as CPUs, laptops, printers or storage devices, where the quality-adjusted price declines regularly exceed double digits per year.[4] That raises questions about differences between Internet services and other electronics markets, and it highlights questions about the role of market structure and demand.[5]

As with prior work on price indexes for dial-up services, our findings raise questions about whether the BLS price index for Internet access provides a fully informative picture of price changes.[6] Our index declines (mildly) faster than the comparable BLS price index over a comparable period.

Our finding also contrasts with the findings by Williams (2008), who estimates a quality-adjusted index, sampled from data about broadband prices from the CPI database in November 2006. (Williams works for BLS, and has access to the data for the CPI Internet-access price index.) After a thorough and artful statistical 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. In contrast, we find that the quality adjustment can matter, albeit only by a modest amount. This difference arises from many sources: while we cover partially overlapping years, our estimates also cover more suppliers, a wider range of services, more contracts, and later years. We also do not use dial-up prices in our final index, as Williams does. We also lack (confidential) data about the market share of particular services, which BLS uses in its indexes.

2. Internet diffusion in the US

The diffusion of broadband to households began in the late 1990s, but adoption did not begin to accelerate until early in the first decade following the millennium. Much of this history is documented in Greenstein and McDevitt (2009). We refer interested readers to our prior work. Here we provide a short summary of the issues raised during that diffusion.

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 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.[7]

[2] In this case, AOL and its competitors changed their subscription dial-up service to an advertising-supported service in the fall of 2006. These effects were further exaggerated by the lag structure for updating the index. Though the expenditure shares are updated more quickly than typical household items in the CPI, their updating process (every three years) unavoidably introduces a lag into its construction. Confidentiality prevents any researcher from precisely discerning the causes.

[3] In that sense our study aims at a broad agenda in Internet economics, as outlined by Flamm et al. (2007), which examines the poor state of US statistics for the Internet and called for basing US broadband policy on economic reasoning and transparent statistical approaches. The study's exercise illustrates the economic importance of constructing price indices, and frames many of the challenges.

[4] See, e.g., Aizcorbe (2006), and Berndt and Rappaport (2001), or in general, examine any BLS price series in this time period for PCs, electronic equipment, or related hardware.

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

[6] Prior work suggests quality adjustments could make a difference to dial-up Internet access price indexes. 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.

[7] 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).

Cable-modem service involved a gradual upgrade to cable plants in many locales, depending on the generation of the cable system.[8] 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 robustly emerge from discussion. First, broadband gives the user a better experience than dial-up access, with considerable variance possible across users. Relatively, appropriate measurement for DSL and cable-modem services might not use the same metric or scale for both.[9] We will test for the latter implication, and find the data consistent with it.

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. This study will largely be unable to address prices for this service category.

Price indices for access services face numerous challenges. Principal among them, changes in the quality of the user experience with Internet access was difficult to disentangle from changes to other complementary components of the Internet. For example, online content improved during the decade. The broadband Internet enabled considerable variety of entertainment such as video and music sharing. This generates several tens of billions of dollars in advertising revenue.[10] 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. Even if that could be resolved, broadband access went through a number of improvements, such as delivering video services to outlying geographic locations with less delay or making access available in a wider set of locations. In many locations suppliers learned how to successfully allocate the capacity more efficiently, an improvement that users would experience as more reliability and faster response during moments of peak-load use.[11]

Our exercise highlights the measurement and interpretative challenges. For example, empirical evidence points towards an increase in the willingness to pay for broadband between 2003 and 2009 among US consumers with considerable online experience.[12] Combined with the results we show below, such evidence could suggest that experienced users got "more for their money." A consumer price index for all online activity would aim to measure that improvement. Our study, however, focuses on only one service, household access, so it will provide only a modest step towards realizing that broad goal.

3. 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 indexes for standalone contracts will measure the change in quality-adjusted price for P(Internet) between two periods. Price indexes for bundled contracts will measure the change in quality-adjusted price for P(both) between two periods.

These different price indexes may or may not move in concert. Most models of bundling predict they will be positively correlated, 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

[8] 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).

[9] 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.

[10] 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 smaller. Yahoo!'s revenues from ads are less than $7B.

[11] Industry trade publications in the latter part of the decade discuss numerous actions taken by vendors to more efficiently handle the loads placed on capacity by higher-bandwidth applications. Access lines, backhaul and backbone facilities are used more intensively. Customers experience this as improvement, and it is expensive to provide. Some of this improvement belongs in discussions about a producer price index for access, namely, changes in the cost to vendors of providing access services. The quality adjustment should measure how cost changed for a constant-quality service. In this study we focus on the concepts used to construct a consumer price index, namely, the prices paid by users for services and the quality received.

[12] For 2002 data and results see Savage and Waldman (2004). For 2009 data and results using comparable methods see Rosston et al. (2010).

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 indexes 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 indexes provide the same answer? The answer is close to yes when improvements manifest solely as price declines. If improvements manifest as quality improvement then the question cannot be answered without considerable detail. The appendix provides the standard analysis as to why. This is an empirical question and we will also address it.

4. Potential biases and omissions

Our approach leaves a gap in our price index. This is an important limitation. 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.
(3) Cable companies sell cable television services and Internet, and a household buys both.
(4) Cable companies sell cable television, telephone and Internet services, and a household buys all three from one firm (e.g., a "Triple Play" bundle).

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. However, because, a quality-adjusted index continues to sample price changes in proportion to lagged choices, it will mismeasure price changes for households that begin their purchase of broadband services with a standalone contract and then switch to a bundled contract The index oversamples standalone contracts in comparison to (less expensive) bundled contracts.

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. Moreover, 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 or small, and there is no way to know without more detail. In addition, 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.

Table 1
Summary statistics for variables, cable.

Across all years		Mean	Standard deviation	Min.	Median	Max.
Existing price ($)		46.17	14.29	16.95	44.95	84.95
Downstream speed (bps)		7123.21	6327.48	256.00	5000.00	30,000.00
Upstream speed (bps)		741.36	914.63	100.00	500.00	5000.00
Log of existing price		3.78	0.34	2.83	3.81	4.44
Log of downstream speed		8.51	0.92	5.55	8.52	10.31
Log of upstream speed		6.28	0.71	4.61	6.21	8.52
Summary by year						
2004	Existing price ($)	48.86	15.31	24.95	44.95	84.95
2004	Downstream speed (bps)	3341.11	1600.16	256.00	3000.00	6000.00
2004	Upstream speed (bps)	392.22	183.62	128.00	384.00	800.00
2005	Existing price ($)	49.79	15.06	24.95	44.95	84.95
2005	Downstream speed (bps)	4118.89	2184.01	256.00	4000.00	8000.00
2005	Upstream speed (bps)	418.89	191.77	128.00	384.00	768.00
2006	Existing price ($)	48.45	13.12	16.95	49.95	84.95
2006	Downstream speed (bps)	5230.42	2667.31	256.00	5000.00	12,000.00
2006	Upstream speed (bps)	512.16	272.86	200.00	384.00	1500.00
2007	Existing price ($)	44.36	13.76	16.95	44.95	67.95
2007	Downstream speed (bps)	7030.24	6364.51	768.00	6000.00	30,000.00
2007	Upstream speed (bps)	752.48	1040.62	100.00	500.00	5000.00
2008	Existing price ($)	43.27	13.98	16.95	44.90	69.95
2008	Downstream speed (bps)	8574.17	7255.24	768.00	8000.00	30,000.00
2008	Upstream speed (bps)	873.88	1024.94	256.00	512.00	5000.00
2009	Existing price ($)	51.35	14.99	19.89	53.00	83.00
2009	Downstream speed (bps)	9343.89	7697.68	768.00	8000.00	30,000.00
2009	Upstream speed (bps)	989.94	1113.31	256.00	768.00	5000.00

Table 2
Summary statistics for variables, DSL.

Across all years		Mean	Standard deviation	Min.	Median	Max.
Existing price ($)		58.43	24.36	15.00	49.99	105.95
Downstream speed (bps)		2933.17	2231.28	256.00	1500.00	12,000.00
Upstream speed (bps)		564.66	246.46	128.00	768.00	896.00
Log of existing price		3.98	0.42	2.71	3.91	4.66
Log of downstream speed		7.73	0.72	5.55	7.31	9.39
Log of upstream speed		6.20	0.59	4.85	6.64	6.80
Summary by year						
2004	Existing price ($)	58.11	21.90	26.99	49.99	105.95
2004	Downstream speed (bps)	1959.61	1194.94	256.00	1500.00	6000.00
2004	Upstream speed (bps)	479.74	272.04	128.00	384.00	896.00
2005	Existing price ($)	58.38	21.69	28.00	49.99	105.95
2005	Downstream speed (bps)	1921.67	1146.54	256.00	1500.00	6000.00
2005	Upstream speed (bps)	453.50	276.84	128.00	384.00	896.00
2006	Existing price ($)	57.81	25.22	19.99	49.95	105.95
2006	Downstream speed (bps)	2539.95	1725.23	256.00	1500.00	10,000.00
2006	Upstream speed (bps)	527.04	252.26	128.00	512.00	896.00
2007	Existing price ($)	57.27	25.26	19.99	49.95	105.95
2007	Downstream speed (bps)	3015.23	2161.18	256.00	3000.00	10,000.00
2007	Upstream speed (bps)	581.49	236.55	128.00	768.00	896.00
2008	Existing price ($)	60.02	25.03	15.00	50.50	105.95
2008	Downstream speed (bps)	3479.48	2546.13	256.00	3000.00	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)	3616.32	2777.80	768.00	3000.00	12,000.00
2009	Upstream speed (bps)	612.32	220.45	128.00	768.00	896.00

In sum, the size of the bias is an empirical question. The bias depends on both the degree of discount between standalone and bundled pricing, as well as the extent of switching among 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.

Finally, we note that our approach mimics the processes in the CPI, and not the construction of a producer price index. This difference is often a source of confusion during the diffusion of a new good. A consumer price index focuses on the gains to users from a decline in prices (and/or the change in price equivalent to improvements in quality). A producer price index focuses on the declines in costs to producers for a good they provide (and/or the change in cost equivalent to the change in quality). These two indices do not have to give the same result for new goods, such as broadband, because costs and prices do not necessarily move in concert during a new good's diffusion.

Confusion also arises for another reason: a standard consumer price index only begins to consider improvements after users have begun to purchase a good, whereas common language often makes note of more, such as all the technical improvements that made adoption feasible and desirable for users. Such technical improvement does not play a role in the standard construction of a consumer price index, generally speaking, and, specifically, it does not play a role in the CPI for broadband, as maintained by the BLS. This feature of consumer price indices is a long-standing topic for frontier economic research. Our prior work addresses this topic directly, and estimates the gains from adoption as equivalent to somewhere between 1.6% and 2.2% decline in the CPI per year for 1999–2006 (Greenstein and McDevitt, 2009). In contrast, this study focuses on standard BLS processes for constructing a consumer price index, focusing on expenditure after adoption.

5. Data

We use data from Point Topic, a well-known London-based consultancy which tracks worldwide broadband prices. The appendix provides details about how we constructed the final sample.

Tables 1 and 2 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.[13] Some also appear too high to be a typical residential contract.[14] For the sake of consistency with our procedures, we include these low and high observations. This worries us very little due to our goals; the *level of prices* will not cause a problem because price indices only highlight *changes in levels.* If trends in the *price changes* do not differ systematically at the highest or lowest end of the range, then the index will not be sensitive to including or excluding

[13] 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).

[14] This seems especially so of the most expensive DSL contracts, which includes some contracts at higher price levels than considered typical. Part of this is due to our procedures, which eliminated many DSL contracts that did not persist, or included a low six month discount before increasing in level.

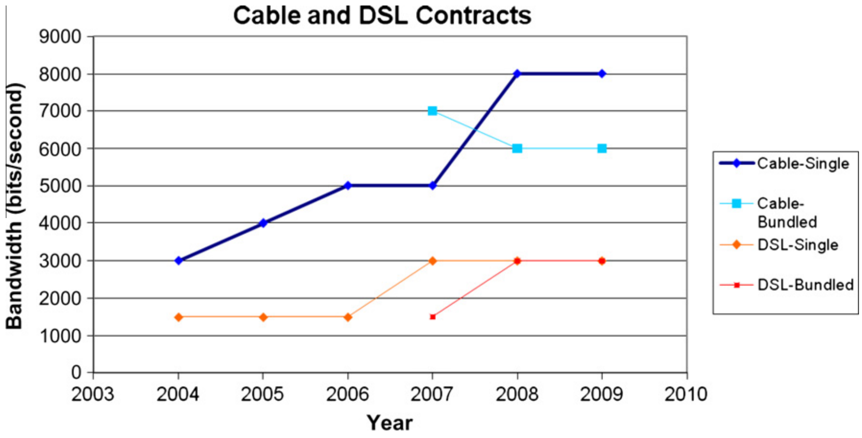

Fig. 1. Median download BPS for cable and DSL contracts.

these observations. That also suggests a way to test for sensitivity. We run a series of statistical tests. Generally, we will find that prices in the outlying ranges do not shape results.

Tables 1 and 2 illustrate one key feature of these data. Though the prices for services remain at nearly the same or a 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 bps. In 2009, these are $53.00 and 8000 bps. 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.

Fig. 1 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 10,000 bps. Fig. 1 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 Fig. 2 illustrate this conclusion. Median cable prices for a service with a 3000 bps 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 10,000 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 Fig. 3 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.

6. Hedonic estimates for quality adjustment

We consider a series of regressions for estimating quality adjustment over time and present in Table 3 seven different regressions, which is sufficient to illustrate the variance in the data. Model (1) presents our baseline regression, estimating 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.[15]

The baseline regressions have statistically significant estimates on all control variables, such as bandwidth and location. These also demonstrate the merits of separating DSL and cable-modem. Most coefficients differ between the two regressions, rejecting any test of equality between them.[16]

Table 3 shows that similar results tend to arise in virtually all the additional specifications. These models show

[15] 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.

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

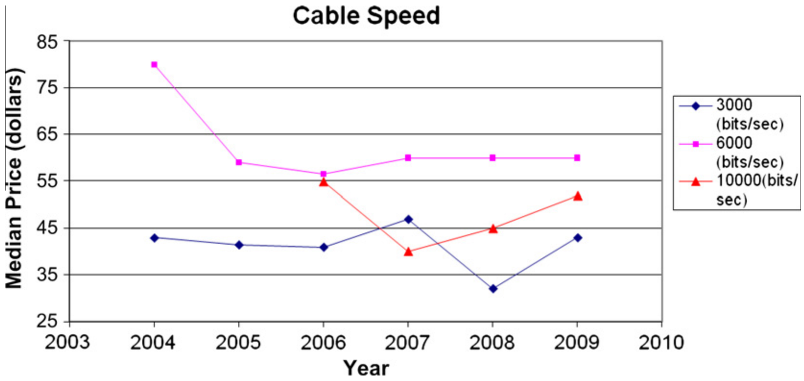

Fig. 2. Median prices at select speeds.

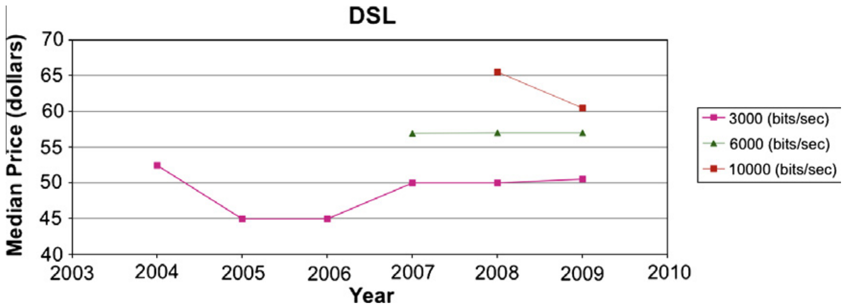

Fig. 3. Median prices at select speeds.

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.

Location also plays a role, with the Northeast appearing to have lower prices than the other areas. This result 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 effects 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.[17] 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.

[17] 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 10,000 download) increased in price from $43 to $58. The highest tier (2000 upload and 20,000 download) increased from $68 to $83. That is, respectively, a 65%, 45%, 34%, and 22% increase for 4 of the 16 cable contracts.

Table 3
Regression results.

Estimates	OLS Log price (1)		Median regression Log price (2)		OLS and firm FE Log price (3)		OLS Taylor (4)	
	Cable	DSL	Cable	DSL	Cable	DSL	Cable	**DSL**
y_2005	−0.065 (0.061)	0.034 (0.061)	**−0.097 (0.000)**	0.000 (0.024)	−0.088 (0.055)	0.069 (0.032)	−0.074 (0.058)	0.040 (0.060)
y_2006	**−0.147 (0.053)**	−0.035 (0.055)	**−0.227 (0.000)**	−0.034 (0.021)	**−0.181 (0.048)**	−0.002 (0.028)	**−0.150 (0.050)**	−0.042 (0.054)
y_2007	**−0.274 (0.049)**	**−0.097 (0.051)**	**−0.333 (0.000)**	**−0.107 (0.020)**	**−0.312 (0.046)**	−0.020 (0.027)	**−0.255 (0.047)**	**−0.114 (0.050)**
y_2008	**−0.326 (0.049)** –	−0.058 (0.052)	**−0.334 (0.000)**	**−0.107 (0.020)**	**−0.337 (0.046)**	−0.007 (0.028)	**−0.301 (0.047)**	−0.074 (0.051)
y_2009	**0.147 (0.055)**	−0.062 (0.058)	**−0.227 (0.000)**	**−0.107 (0.022)**	**−0.179 (0.051)**	−0.006 (0.031)	**−0.140 (0.053)**	−0.075 (0.057)
speed_Downstream							**0.000 (0.000)**	**0.000 (0.000)**
speed_Upstream							**0.000 (0.000)**	**0.002 (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 (0.025)**	**0.060 (0.024)**	**0.270 (0.000)**	**0.084 (0.009)**	**0.291 (0.024)**	**0.126 (0.014)**		
ln_speed_Up	**0.115 (0.039)**	**0.326 (0.029)**	**0.137 (0.000)**	**0.415 (0.011)**	**0.078 (0.041)**	**0.267 (0.020)**		
Ca	**0.295 (0.065)**	**0.530 (0.038)**	**0.431 (0.000)**	**0.655 (0.015)**			0.158 (0.109)	**0.531 (0.039)**
West	**0.249 (0.032)**	**0.122 (0.071)**	**0.274 (0.000)**	**0.242 (0.027)**			**0.166 (0.032)**	**0.115 (0.070)**
Midwest	**0.136 (0.032)**	**0.311 (0.071)**	**0.106 (0.000)**	**0.522 (0.027)**			**0.205 (0.030)**	**0.326 (0.072)**
Northeast	**−0.291 (0.068)**	**−0.276 (0.075)**	**−0.496 (0.000)**	**−0.310 (0.029)**			−0.159 (0.106)	**−0.267 (0.075)**
_cons	**0.766 (0.147)**	**0.985 (0.193)**	**0.684 (0.000)**	0.004 (0.077)	**1.042 (0.158)**	**0.885 (0.121)**	**3.183 (0.062)**	**2.796 (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 2004–2006** **(5)** **Cable**		**Years 2007–2009** **(6)** **DSL**		**Price level** **(7)** **Cable/DSL**		**New series** **(8)** **Cable/DSL**	
y_2005	−0.054 (0.058)	0.033 (0.063)			−2.570 (2.848)	1.637 (3.515)	−0.0609 (0.061)	0.039 (0.061)
y_2006	**−0.147 (0.052)**	−0.027 (0.058)			**−5.874 (2.460)**	−0.874 (3.161)	**−0.129 (0.054)**	−0.009 (0.050)
y_2007					**−10.833 (2.286)**	**−4.234 (2.933)**	**−0.2644 (0.049)**	**−0.093 (0.051)**
y_2008			**−0.055 (0.030)**	0.030 (0.036)	**−13.136 (2.263)**	−2.639 (3.000)	**−0.319 (0.048)**	−0.059 (0.052)
y_2009			**0.123 (0.039)**	0.030 (0.043)	**−5.086 (2.541)**	−3.038 (3.327)	**−0.148 (0.054)**	−0.066 (0.057)
ln_speed_Down	**0.232 (0.044)**	**0.112 (0.044)**	**0.264 (0.032)**	0.008 (0.028)	**8.777 (1.172)**	**2.557 (1.383)**	**0.262 (0.024)**	**0.063 (0.024)**
ln_speed_Up	**0.148 (0.079)**	**0.206 (0.042)**	**0.144 (0.051)**	**0.460 (0.039)**	**7.640 (1.802)**	**19.520 (1.654)**	**0.124 (0.039)**	**0.325 (0.028)**
Ca	0.091 (0.124)	**0.474 (0.071)**	**0.392 (0.088)**	0.518 (0.044)	**15.397 (3.006)**	**29.431 (2.186)**	**0.301 (0.064)**	**0.526 (0.037)**
West	**0.190 (0.065)**	0.105 (0.076)	**0.268 (0.039)**	−0.036 (0.068)	**10.261 (1.503)**	**8.635 (4.124)**	**0.244 (0.032)**	**0.127 (0.071)**
Midwest	**0.150 (0.063)**	**0.404 (0.151)**	**0.126 (0.038)**	**0.158 (0.087)**	**5.982 (1.481)**	**19.037 (4.077)**	**−0.293 (0.067)**	**−0.271 (0.075)**
Northeast	−0.131(0.116)	**−0.268 (0.087)**	**−0.378 (0.096)**		**−14.022 (3.143)**	**−14.026 (4.360)**	**0.143 (0.032)**	**0.304 (0.071)**
First in a series							−0.044 (0.031)	−0.050 (0.046)
_cons	**0.904(0.290)**	**1.271 (0.368)**	0.309 (0.181)	**0.512 (0.225)**	**−79.471 (6.848)**	**−115.321 (11.177)**	**0.723 (0.150)**	**0.965 (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.

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 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 3 show a variety of experiments with distinct specifications. Median regressions in Column (2) are qualitatively similar, suggesting that 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.[18] 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 2004–2006, and with a 12.3% increase over 2007–2009. Depending on specification (not shown), we estimate the decline between 06 and 07 at 10–13%, so the *total* decline over the 6 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) presents estimates with price levels as the endogenous variable (instead of log of price). The price decline is just over five dollars for cable-modem service. The estimated decline is not statistically different from zero for DSL, near three dollars in the point estimate, quite modest once again.

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 make this estimate 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 result reduces concerns 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 cost 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 3 present a consistent picture. The benchmark estimates for price changes vary only slightly with different specifications and with the types of variables we use as controls. We have experimented with other specifications and controls and reached a qualitatively similar conclusion.[19] 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.

7. Price indexes for standalone contracts

From the benchmark regressions in Table 3, we calculate three types of indexes of the standalone data – Laspeyres, Paasche and Fisher – and present them in Table 4. We also use different weights. The 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.[20] We use the June statistics, since they are available from 2004–2008, and we use 2008 data to weight the 2009 estimate (in the Paasche and Fisher index).

The simplest method of calculating the indexes is to exponentiate the year-dummy coefficients from Table 3, adjusting the estimates for bias (see Berndt, 1991).[21] The

[18] Pakes (2003) argues that hedonics are best done by running separate regressions for each time period. Unfortunately, the data are too thin for that here, and this is the most this data can support.

[19] 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.

[20] 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.

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

Table 4
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

results using the point estimates are presented in Table 4. The price index does not vary with our weighting scheme, which is not surprising since quality-adjusted prices decline very little.[22] 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 3. 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.[23] 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.[24]

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 has no major effect on the results. Because matched-model indexes 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.[25] 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.

With the same data, we then experimented with an augmented matched model. 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.

8. Price indexes for bundled contracts

Table 5 shows the augmented matched-model indexes for bundled contracts. Matched-model methods worked for 382 pairs of contracts out of the 402 examined. For twenty matches of bundled contracts, we observe improvements in 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 5 shows calculated indexes with a different approach, using the same weights for the same years as in Table 4. 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 recalculated a price index for just these firms. Since these firms provide services for the majority of users, the calculations offer clues about whether the majority of

[22] Laspeyres, Paasche and Fisher indexes 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.

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

[24] 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.

[25] 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 indices, 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.

Table 5
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

users experienced a faster or slower price decline than that measured by our index.[26] 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 5, we weighted by firm users. That is, 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.

Though it supports of our overall conclusion, the latter finding raises an open question. DSL users of popular services may have had a mildly better experience than our estimates show. Reweighting the estimates with data about market share could alter the aggregate index, making it mildly higher.

9. Interpreting the price indexes

Proper interpretation of Tables 4 and 5 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 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 result we conclude that households that began their broadband experience with one type of contract experienced a mild price decline after adoption.

However, Table 5 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 standalone and bundled contracts. 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. Point Topic does not provide those data.[27] However, such information does exist in (confidential) household expenditure data and pricing data, which BLS s collects for its own price indexes.[28]

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 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 3 years, January 2007–November 2009, the index *increases* by 3.1%.[29]

This comparison is not ideal, but it is suggestive. The broadband prices must comprise more than half the BLS 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 placed downward pressure on prices. We safely conclude that this 3-years price history could not have arisen if there had been large price declines in broadband services,

[26] 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.

[27] Another potential source of public data 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.

[28] Note, however, that proper action requires more than just the routine adjustments. BLS routinely discounts the products purchased within a bundle, as is appropriate. However, in this case, this change will only be noticed in the occasional surveys that track household expenditure. So there will need to be an adjustment given to weights for receiving the service from different bundles.

[29] 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.

irrespective of whether these were standalone or bundled contracts.

10. What we learned

In this paper, we estimated the size of the price declines for 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 focused on evidence in the first two categories. Our evidence points towards, at most, a total modest decline in broadband prices after adoption. We place the price decline at as much as a 10% decline in quality-adjusted prices over a little more than 5 years, or under 2% a year in nominal terms. In real terms, however, the declines become more substantial, at nearly 5% per year. A lack of data about market share for broadband providers makes it impossible for us to say more with much precision.

Our results contribute several important new findings to policy discussions. First, the results suggest that 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. Second, 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 changes.

Our findings frame many open questions about measuring the economic gains to households from switching between standalone and bundled contracting forms after adopting broadband. Properly estimating those/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 patents, personal computers – where frequent surveying would have measured gains more accurately.

Acknowledgements

We thank David Burstein, Richard Clarke, Link Hoewing, Robert Seamans, Scott Wallsten, Randy Weiss, Brendan Williams, and anonymous referees 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.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.infoecopol.2011.03.002.

References

Aizcorbe, Ana, 2006. Why did semiconductor price indexes fall so fast in the 1990s? Economic Inquiry, 44(3), 485–496 (Oxford University Press).
Berndt, Ernst, 1991. The Practice of Econometrics – Classical and Contemporary. Addison-Wesley.
Berndt, Ernst R., Rappaport, Neal J., 2001. Price and quality of desktop and mobile personal computers: a quarter-century historical overview. American Economic Review 91 (2), 268–273 (May).
Cockburn, Iain, Griliches, Zvi, 1995. Generics and new goods in pharmaceutical price indexes. American Economic Review 84 (5), 1213–1232.
Crandall, Roberts, 2005. Broadband communications. In: Martin, Cave, Sumit, Majumdar, Ingo, Vogelsang (Eds.), Handbook of Telecommunications Economics. Elsevier, Amsterdam, The Netherlands, pp. 156–187.
Flamm, K., Friedlander, A., Horrigan, J., Lehr, W., 2007. Measuring Broadband: Improving Communications Policy Making Through Better Data Collection. Pew Internet and American Life Project, Washington, DC (November). <http://www.pewinternet.org/pdfs/PIP_Measuring%20Broadband.pdf>.
Greenstein, Shane, 2010. Innovative conduct in computing and internet markets. In: Bronwyn, Hall, Nathan, Rosenberg (Eds.), Handbook of Economics of Innovation, vol. 1. Elsevier (Chapter 11).
Greenstein, Shane, McDevitt, Ryan, 2009. The Broadband Bonus: Accounting for Broadband's Impact on US GDP. NBER Working Paper 14758.
NTIA, 2004. A Nation Online: Entering the Broadband Age. <http://www.ntia.doc.gov/reports.html>.
Pakes, Ariel, 2003. A reconsideration of hedonic price indices with an application to PCs. American Economic Review 93 (5), 1578–1596.
Rosston, Greg, 2006. The Evolution of High-Speed Internet Access, 1995–2001. Information and Economic Policy.
Rosston, G., Savage, S.J., Waldman, D., 2010. Household Demand for Broadband Internet Service. SIEPR Paper 09-008. <http://siepr.stanford.edu/publicationsprofile/2109>.
Savage, S.J., Waldman, D., 2004. United states demand for internet access. Review of Network Economics 3 (3), 228–247.
Stranger, Greg, Shane, Greenstein, 2007. ISP pricing in the shadow of firm turnover: ISPs during the 1990s. International Journal of Industrial Organization 26 (3), 625–642.
Williams, Brendan, 2008. A Hedonic Model for Internet Access Service in the Consumer Price Index. Monthly Labor Review (July).