Hedonic Quality Adjustment for Broadband Internet Access Services in the US Producer Price Index

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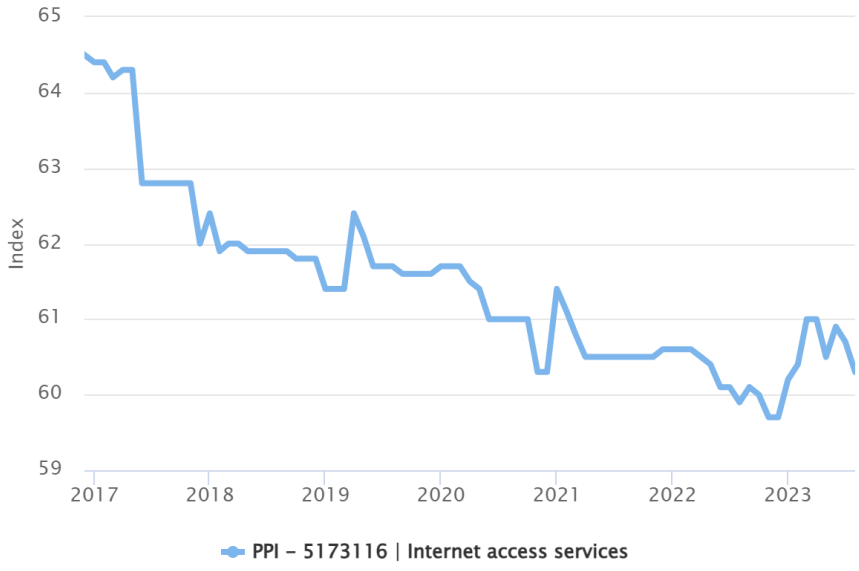
Introduction

The 2017 North American Industrial Classification System (NAICS) defines Wired Telecommunications Carriers as establishments primarily engaged in operating and/or providing access to transmission facilities and infrastructure that they own and/or lease for the transmission of voice, data, text, sound, and video using wired telecommunications network facilities. The US Bureau of Labor Statistics (BLS) Producer Price Index (PPI) for Wired Telecommunications includes broadband internet access services. NAICS 517311, Wired telecommunications carriers corresponds to ISIC 6110, Wired telecommunication activities.

BLS tracks producer prices for broadband internet access services using either average revenue per plan or an actual transaction price for a particular plan. The average revenue per plan consists of the average revenue per month per subscriber for a particular internet service plan not bundled with other services. This type of price permits the inclusion of both new and existing plan customers.

Figure 1 shows the index movement for Internet Access Services (5173116).

Figure 1: Index values of 5173116 Internet access services since December 2016



Broadband internet access services are subject to rapid technological change because download and upload speeds have typically increased over time. This means specific items within the PPI broadband internet access services sample are periodically replaced with items with faster download and upload speeds. To account for these changes and hold to our matched model methodology, we must determine the value of quality adjustment (VQA)—the dollar value of the change in broadband download or upload speed. Ideally, PPI survey participants would provide this information, but often this is not possible. As a result, we use a hedonic model to estimate the value of the change in speed.

History of the model

BLS introduced a hedonic quality adjustment model for broadband services in the PPI for internet access services with the release of data for December 2016. This model was an Ordinary Least Squares (OLS) regression using broadband data collected from PPI respondents as the sample.

The service characteristics used as variables included:

- dummy variables for selected companies
- a dummy variable for type of service (residential or business)
- two interaction variables[1]

The company dummy variable helps to incorporate various service quality factors that would otherwise not be captured. For this model and all subsequent models the independent variable used for quality adjustment is log(download speed) and the dependent variable is log(price). In the US broadband internet service market, a plan's upload speed is typically the same as or a fixed ratio of the download speed, so it is only necessary for the model to include download speed.

The hedonic model takes the form:

$$\log(\text{price}) = A + \beta_1(\log(\text{download speed})) + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon$$

Where A is the intercept, $\beta_1 \ldots \beta_k$ are the regression coefficients, $X_2 \ldots X_k$ are the variables representing price-determining characteristics, and ε is the error term.

The formula used for quality adjusting a broadband item in the PPI is:

$$\text{VQA} = \left(\left(\frac{\text{New download speed}}{\text{Old download speed}}\right)^{\beta_1} - 1\right) \times \text{Old price}$$

β_1 is the coefficient of the natural logarithm of download speed. BLS refers to this value as the "VQA coefficient." In 2016, this value was 0.3075, meaning a one percent increase in download speed was associated with a 0.3075 percent increase in price.

While BLS re-estimated the model each year from an updated dataset, the methodology remained the same until 2022.

Table 1. Broadband Model 2016

	Estimate (Standard error)
log(Download speed)	**0.3075**** **(0.0977)**
Residential	0.0320 (0.3352)

[1] One explanatory variable may have an effect on another explanatory variable. For example, although type of service (business or residential) has an effect on the price, it also has an effect on download speed. This can be controlled for with an interaction variable. An interaction variable multiplies the two variables together. Notation for an interaction variable uses a colon, and takes the form $X_a : X_b$

Company A	0.5906*** (0.1025)
Company B	0.7529*** (0.1539)
Company C	0.7068*** (0.1551)
log(Download speed) : Residential	0.1411 (0.1096)
log(Download speed) : Company B	−0.8863*** (0.1684)
Intercept	2.8844*** (0.3072)
Residual standard error	0.0933
Adjusted R-squared	0.9400
F-statistic	59.17
*p < 0.05, ** P < 0.01, *** p < 0.001	

Table 2. Historical VQA coefficients, 2016-2021, old model

Year	log Download coefficient	Standard error
2016	0.3075	0.0977
2017	0.28416	0.04604
2018	0.24208	0.05236
2019	0.21824	0.04206
2020	0.23684	0.03577
2021	0.33565	0.06179

Changes to the model

In June 2022, BLS introduced a new PPI sample for NAICS 517311 Wired Telecommunications Carriers, which included a new selection of internet service providers (ISPs) and internet access service items. The preferred price to collect for this new sample was an average price, with transaction price being the fallback option, rather than a transaction price as requested in previous samples. While the presumption is that average prices reflect constant quality price change in a way transaction prices do not, collecting average prices resulted in fewer transaction prices in the index that could be used to generate the hedonic model.

Fortunately, BLS had begun contracting with a third-party data provider several years earlier. Each month this data provider collects telecommunications list prices, including prices for cable TV, wireless telephone, and residential internet service. This database contains thousands of prices. The main drawback to this database is that it only includes residential service, not business. However, although the price levels of these two services can be very different, the relationship between price and download speed is similar. In 2022, due to the lack of transaction price quotes in the new PPI wired

telecommunications carriers sample, BLS decided to switch the hedonic sample to this third-party source, rather than continue to use the data collected from PPI respondents.

In 2023, BLS then improved the model by using subgroup analysis based on transmission type. There are five transmission types: cable, digital subscriber lines (DSL), fiber optic, satellite, and wireless. We found that for lower-speed and less-popular transmission types in the US, i.e., DSL, satellite, and wireless, download speed has no significant relationship to price, unlike the speeds of cable and fiber internet. Due to this finding, BLS removed all DSL, satellite, and wireless items from the database, and now only uses the hedonic model to quality adjust cable and fiber items in the PPI. Together, cable and fiber represent over 70 percent of the internet access service market share in the US.[2] We have also found that DSL, satellite, and wireless items do not frequently experience speed increases, and these services had rarely been quality adjusted under the old model since its inception in 2016. Please see the Appendix for plots of the subgroups illustrating the relationship, or lack thereof, between price and download speed for certain transmission types.

We also considered controlling for geographic region and for metropolitan area, but any differences due to geography are typically differences due to the company providing the service, a variable for which the model already controls.

Current model

For the 2023 model, the VQA coefficient is 0.337264, meaning a one percent increase in download speed is associated with a 0.337264 percent increase in price. This is the value currently used to quality adjust cable and fiber items in the PPI.

Table 3. Broadband Model 2023

	Estimate (Standard error)
log(Download speed)	**0.337264** **(0.005252)**
Company A	0.865569 (0.033550)
Company B	−0.231771 (0.023228)
Company C	−0.399295 (0.034652)
Company D	−0.140149 (0.027225)
Company E	−0.410984 (0.047810)

[2] "2022 North American Fiber Status." *Fiber Broadband Association*. December 6, 2022.

Company F	−0.452491 (0.068055)
Company G	0.279759 (0.028155)
Intercept	2.370296 (0.032264)
Observations	2,281
Residual standard error	0.3291
R-squared	0.6661
Adjusted R-squared	0.665
F-statistic	566.6
All estimate values are statistically significant at the $p < 0.001$ level	

Table 4. 2023 Residuals

Min	1Q	Median	3Q	Max
-1.48573	-0.09536	0.01572	0.13389	2.12199

Table 5. Historical VQA coefficients, 2016-2023

Year	log(Download speed) coefficient	Standard error
2016	0.3075	0.0977
2017	0.28416	0.04604
2018	0.24208	0.05236
2019	0.21824	0.04206
2020	0.23684	0.03577
2021	0.33565	0.06179
2022[a]	0.143567	0.003294
2023[b]	0.337264	0.005252

[a] Used third-party database

[b] Used third-party database and excluded DSL, satellite, and wireless

Ongoing research

BLS considered using the third-party database to construct a time dummy hedonic model. Unlike the current hedonic quality adjustment model, which is simply used to quality adjust the items directly collected by PPI, a time dummy model would replace the collected items and matched model methodology entirely. This would be similar to the time dummy model introduced for the PPI for microprocessors in 2018.[3] This method was considered for the PPI for internet access services due to declining response rates in the previous sample. However, methodology changes were implemented in the new sample that resulted in better participation and mitigated response rate issues. For this reason, a time dummy model has not yet been implemented, but continues to be a subject of research.

[3] https://www.bls.gov/opub/mlr/2018/article/a-new-approach-for-quality-adjusting-ppi-microprocessors.htm

The current hedonic model for quality adjustment of internet access services is updated and run on an annual basis. However, because the third-party database used to construct the current model is updated monthly, we are able to run the model and update the VQA coefficient on a more frequent basis. BLS has been doing this on a research basis for the past several months to examine the data. Our plan is to implement the monthly VQA coefficients in October 2023. Building the model and selecting variables will continue to be an annual process.

Appendix

Figure 2: Scatterplot of log(price) versus log(download speed)

All items

Colored by transmission type

Size scaled by item count, n

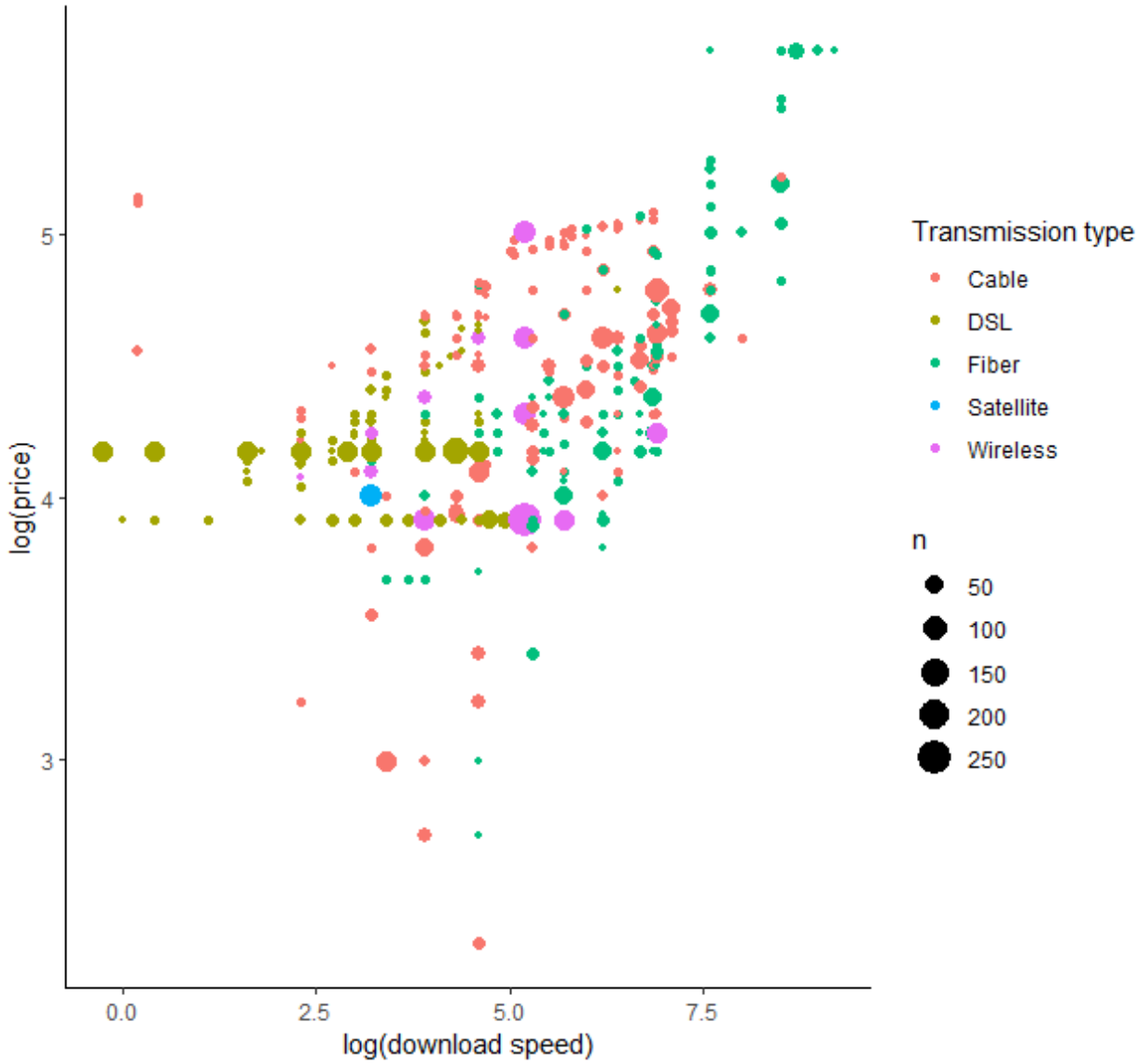


Figure 3: Cable items

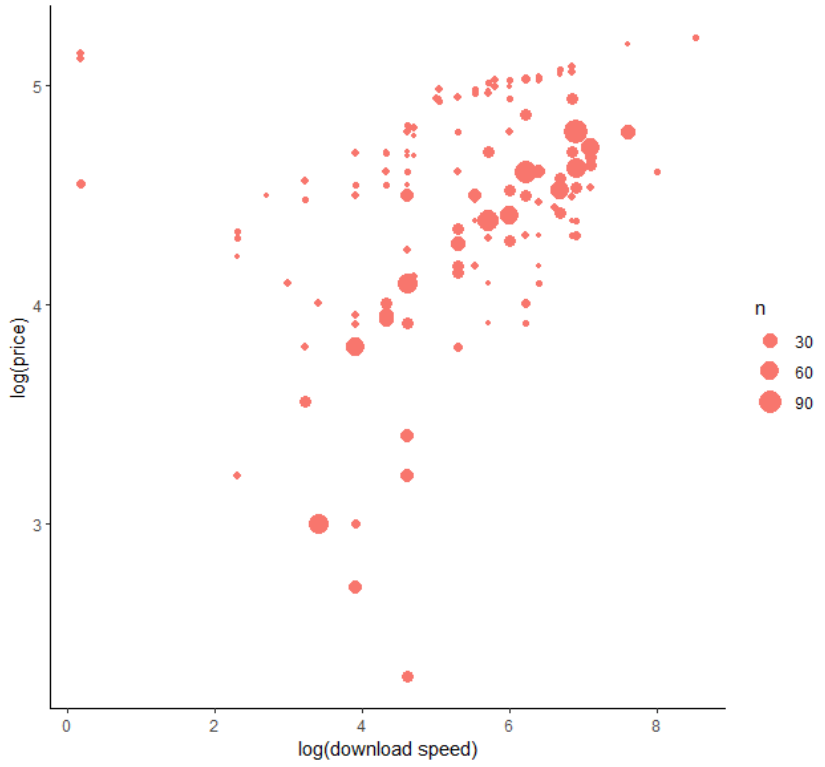


Figure 4: DSL items

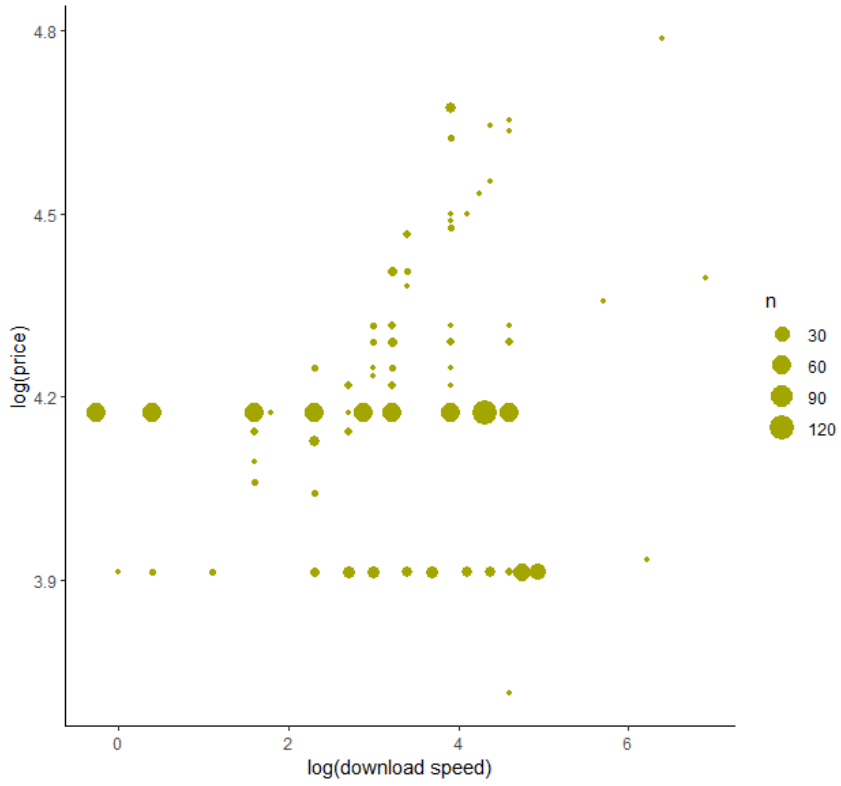


Figure 5: Fiber items

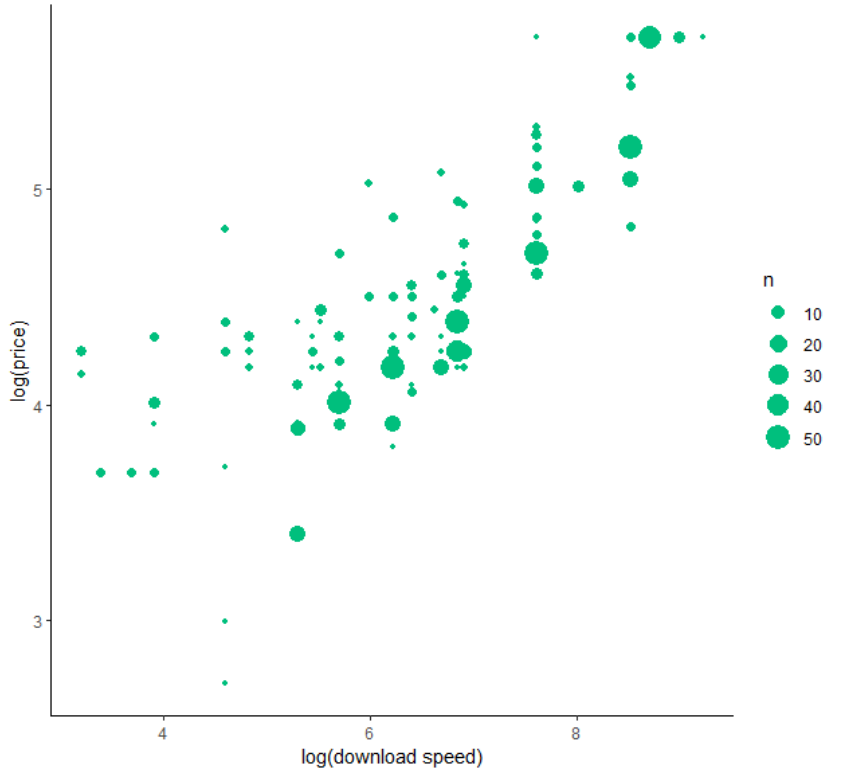


Figure 6: Wireless items