PERSPECTIVES

PHOENIX CENTER FOR ADVANCED LEGAL & ECONOMIC PUBLIC POLICY STUDIES

Broadband Speeds Post-Reclassification: An Empirical Approach

George S. Ford*

June 27, 2017

The Federal Communications Commission ("FCC") recently released a *Notice of Proposed Rulemaking* in which it proposed to reverse the Obama Administration's controversial *2015 Open Internet Order*.[1] Accordingly, stakeholders are actively in search of evidence for the "good" and "bad" of the decision to reclassify broadband Internet service from an "information service" to a common carrier "telecommunications service" under Title II of the Communications Act, an arcane legal regime almost no one understands.[2]

Recently, without any reference to the Net Neutrality debate, the cable industry trade association NCTA made the unsurprising observation that broadband speeds in the U.S. continue to rise, as they always have.[3] Seeing all things through the lens of Net Neutrality these days, Public Knowledge Senior Vice President Harold Feld immediately laid claim to the trend, asserting that the data in NCTA's post supports the FCC's reclassification decision. According to Mr. Feld, the speed trend confirms that the "Title II Virtuous Circle" is "totally working" because "the rate of [broadband speed] increase has accelerated since the FCC adopted the Title II Reclassification Order in February 2015."[4]

Mr. Feld's empirical claim appears based solely on his casual and visual inspection of the data. Visual inspection is useful for some purposes, but the claim of an "acceleration" in speed increases is difficult to support without more formal statistical analysis. So, in this PERSPECTIVE, I apply a battery of statistical and graphical approaches in search of evidence of an extraordinary change in the U.S.'s average broadband speed.

[A]ll the statistical procedures detect a statistically significant decline in the rate of average broadband speed increases for the U.S. subsequent to the 2015 Open Internet Order, and the graphical analysis supports these findings. *** ["B]ut for" the FCC's 2015 Open Internet Order, U.S. broadband speeds would have been about 10% higher—or about 1.5 Mbps faster—on average.

As I demonstrate below, all the statistical procedures detect a statistically significant decline in the rate of average broadband speed increases for the U.S. subsequent to the *2015 Open Internet Order*, and the graphical analysis supports these findings. Indeed, accepting Mr. Feld's theory about the relationship between speed and reclassification, "but for" the FCC's *2015 Open Internet Order,* U.S. broadband speeds would have been about 10% higher—or about 1.5 Mbps faster—on average. Thus, in direct contradiction to Public Knowledge's claim, reclassification appears to have significantly retarded expected broadband speed increases.[5] It seems that the *2015 Open Internet Order* has

broken the virtuous circle (to the extent such a thing exists).[6]

Conceptual Background

As usual, Mr. Feld's argument is a-theoretic—perhaps forgivable in that he is an attorney and not an economist (and holds economics, except when done poorly by non-economists, in low regard).[7] Though Mr. Feld's writing style is informal and peppered with characteristic sass, it is possible to piece a story together about how Mr. Feld believes the speed data relate to Net Neutrality. Note that in quoting his blog, I retain Mr. Feld's slang in the form of run-on words.

At the center of Mr. Feld's argument is the Akamai speed data, which he claims show "the rate of increase [in the U.S. average broadband speed] has accelerated since the FCC adopted the Title II Reclassification Order in February 2015." Mr. Feld claims this alleged "acceleration" in speed confirms his "prediction that non-discrimination (and Title II) lead to fasterbetterbroadband," [sic] and demonstrates that the "Title II Virtuous Circle" is "totally working."

In his discussion, Mr. Feld sets forth a very clear "theorem" about the pace of speed changes and the desirability of Title II and the effectiveness of the virtuous circle. According to Mr. Feld's logic,

- If the pace of speed increases accelerates, then Title II is "good" and the virtuous circle is working;
- But if the pace of speed increases decelerates, then Title II is "bad" and the virtuous circle is broken.

Of course, if the pace of speed increases is unchanged, then the data offer no new insight on the impact of the reclassification decision. Thus, we are left with an empirical question—has the pace of speed increases changed following the *2015 Open Internet Order*? An empirical question requires an empirical answer. Fortunately, since the Akamai speed data is readily available, Mr. Feld's theorem is directly testable.

[I]n direct contradiction to Public Knowledge's claim, reclassification appears to have significantly retarded expected broadband speed increases. It seems that the 2015 Open Internet Order has broken the virtuous circle (to the extent such a thing exists).

Statistical Analysis

According to Mr. Feld's theorem on speeds and reclassification, the change in the pace of speed increases determines whether reclassification is "good" or "bad" and whether the "virtuous circle" is working or broken. With the publicly-available Akamai data, it is straightforward to apply statistical methods to determine whether the pace of speed increases post-reclassification has accelerated, decelerated, or remained the same.

In applying these methods, there are a number of considerations. First, what is the relevant date to test for a change? Over this period, important dates to consider include: (1) 4Q14, President Obama's YouTube video encouraging Chairman Wheeler to adopt a Title II approach to Net Neutrality;[8] (2) 1Q15, the release of the *2015 Open Internet Order* in February;[9] (3) 4Q16, Donald Trump is elected President and the media reports that the *2015 Open Internet Order* will get the "ax";[10] and (4) 1Q17, the first quarter of the Trump Administration and the appointment of Ajit Pai as FCC Chairman.[11]

As for the reclassification "treatment date," plausible arguments may be made for either

4Q14 or 1Q15, since it was abundantly clear President Obama's YouTube video redirected Chairman Tom Wheeler to reclassification.[12] In an event study like this one, the nexus of treatment to outcomes may arise when the treatment is inevitable, not when it is formalized. For instance, a company's stock price may decline on news or expectations of poor earnings long before an official earnings report is released. I will consider both quarters (4Q14, 1Q15) as treatment dates in my analysis.

I exclude from the sample 1Q17, the last quarter of data available, since two weeks after the 4Q16 presidential election USA TODAY reported that reclassification was headed for the "ax under Trump."[13] One month later, then-FCC Commissioner Ajit Pai—President Trump's choice for FCC Chairman—announced that it was time to "fire up the weed whacker and remove those [Net Neutrality] rules that are holding back investment, innovation, and job creation."[14] In future empirical research, 1Q17 and possibly 4Q16 (when Obama "advised" FCC Chairman Tom Wheeler to reclassify in a YouTube video) will serve as the treatment date for the (likely) return of broadband to Title I status, so including it in an analysis of the Title II treatment period is inappropriate.[15]

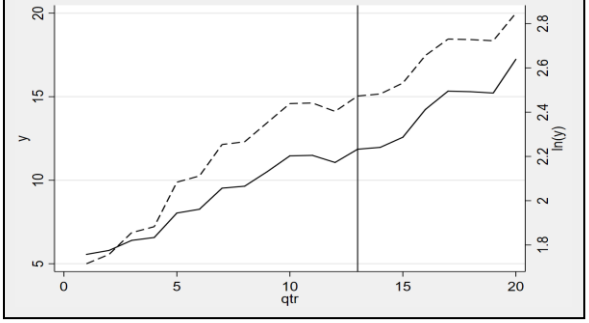
Also, there is the issue of "acceleration" or "deceleration." Average broadband speeds increase over time—it's what they do. Thus, to determine whether the pace has increased or decreased requires a counterfactual. That is, what would the pace of broadband speed increases been "but for" the *2015 Open Internet Order?* There a few ways to formulate a counterfactual. I choose two approaches. First, I gather a group of controls from other countries also appearing in the Akamai data. As detailed below, this control group is chosen so that the countries closely match the speed levels and trends for the U.S. prior to the *2015 Open Internet Order*. Second, a counterfactual can be constructed by using historical speed increases in the U.S. to forecast future speed increases.

Average broadband speeds increase over time—it's what they do. Thus, to determine whether the pace has increased or decreased requires a counterfactual. That is, what would the pace of broadband speed increases been "but for" the 2015 Open Internet Order?

At First, Keep It Simple

To begin, let's keep the analysis quite simple. In Figure 1, the Akamai speed data for the U.S. is illustrated in both the level and natural log transformation. While it is risky to draw strong conclusions by simply looking at the graph, I detect no material increase in the pace of increases following 1Q15, which is indicated by the vertical line. If anything, the visual inspection suggests the opposite—a slight decline in the pace of increase.

Figure 1. Akamai Speed Data: 1Q12 - 4Q16



Some descriptive statistics may shed some light on this empirical question. In 2012, average broadband speed in the U.S. was 6.08 Mbps. By 2014, average speed had increased to 11.13 Mbps, an 83% increase. After the *2015 Open Internet Order*, speeds averaged 14.22 Mbps. From 2014, the increase in speed was 28%, which is obviously much lower than the pre-reclassification speed increase between 2012 and 2014. Moving clear of the *2015 Open*

Internet Order, the average speed in 2016 was 15.77 Mbps, a 42% increase since 2014. This percentage growth is about half that observed in the two-years preceding the *2015 Open Internet Order*. In the levels, speeds after reclassification rose 3.1 Mbps whereas before it rose 5.5 Mbps. Speeds are rising slower after reclassification.

Thus, we are left with an empirical question—has the pace of speed increases changed following the 2015 Open Internet Order? An empirical question requires an empirical answer.

Adding a little rigor to the inspection of the figure and the descriptive statistics, I estimate the average rate of *growth rate* before and after the *2015 Open Internet Order*.[16] The growth rates for the two periods are computed using a spline function,

$$ln(y_t) = \beta_0 + \beta_1 t + \beta_2 R(t - t^*) + e_t, \qquad (1)$$

where $\ln(y_t)$ is the natural log of average speed in the U.S. in quarter t, t is a quarterly trend variable, t^* is the quarter of the treatment date, R is a dummy variable that equals 1 after the *2015 Open Internet Order* (0 otherwise), and e_t is the econometric disturbance term.[17] Because of the natural log transformation, the coefficient β_1 measures the *average* instantaneous growth rate in the pre-treatment period, and β_2 measures the average instantaneous growth rate in the treatment period. (Or, the coefficients measure the trends in log speeds).

To begin, I set the treatment date at 1Q15. Prior to the treatment, speeds were growing at an average rate of 6.5% (β_1 = 0.0646).[18] After reclassification, the average growth rate fell to 3.8% (β_2 = 0.0382).[19] The difference in average growth rates is 2.6 percentage points, a difference that is statistically significant at better than the 5% level.[20]

Switching to the treatment date of 4Q14, the pre-treatment average growth rate is 6.5%, while the average growth rate in the treatment period is 3.9%.[21] Again, the difference in the average growth rates is statistically different from zero at better than the 5% level.[22]

Figure 2. Change in Average Growth

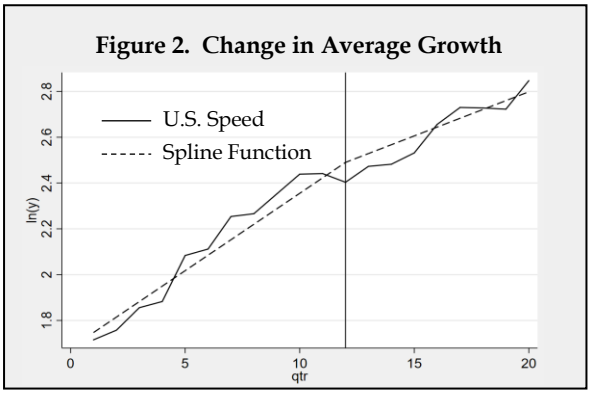


Figure 2 includes the actual speed data and the prediction from the regression (with the 4Q14 treatment date). These results are consistent with the visual inspection of Figure 1 and the descriptive statistics—the pace of growth of broadband speeds has decelerated since reclassification. So, based on this simple analysis, it appears that the Feldian theory of reclassification and speed holds that Title II is "bad" and the "virtuous circle" is broken.

Difference-in-Differences Estimator

The simple approach above compares growth in the past using only U.S. data. We do not have from this analysis any idea as to what speed increases might have looked like without the *2015 Open Internet Order*, or with an order adopting the Title I approach to Net Neutrality. We can up the sophistication a bit to get further evidence on this apparently important question for Net Neutrality advocacy by constructing a counterfactual using comparable countries.

One way to approach the impact of reclassification on speed, if there is any, is to

look for an extraordinary jump in average speeds in the U.S. as a result of the *2015 Open Internet Order* with reference to a counterfactual. To do so, I employ the standard formulation of the regression based difference-in-differences estimator ("DiD"):

$$y_{it} = \delta D + \lambda_t + \mu_i + \varepsilon_{it}, \quad (2)$$

where y_{it} is the the average speed of broadband connections in country i at time t, D is a dummy variable that equals 1 for the U.S. during the period following reclassification (0 otherwise), μ_i is fixed effect for each country in the sample i, λ_t is a time fixed effect common to all observations in time t, and ε_{it} is the econometric disturbance term that is assumed to be distributed independently of all μ and λ.[23] I use both the level and natural log transformation of speed in my analysis because there was no strong evidence pointing to the superiority of one or the other.

As noted above, average broadband speeds increase; they always have. Consequently, to determine whether an increase is extraordinary in some sense, a counterfactual is required. That is, what would average speeds in the U.S. been absent reclassification? For that purpose, I need a control group.

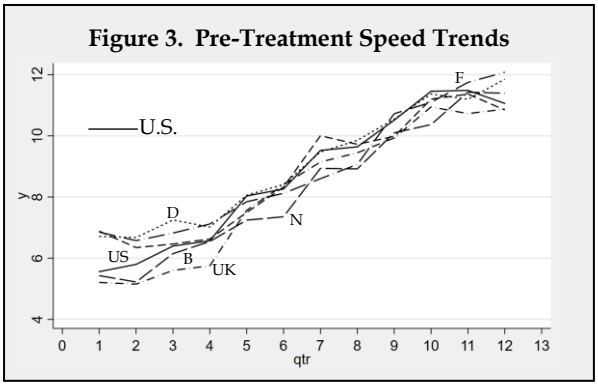
Control countries are selected based on two technical criteria. First, broadband speeds have an inherent scale, so the control pool is limited to countries with similar speeds (±15%) to the U.S. in 2012 (the first year of data) and 2014 (the last year before reclassification), thereby ensuring the countries are comparable during the pre-treatment period.[24]

Second, the control group must satisfy the parallel paths assumption, which holds that the pattern of outcomes for the control group after the treatment is an unbiased estimate of what would have happened to the treated group had the treated group not received the treatment. The assumption is untestable, but researchers typically apply visual inspection and a test of equal growth rates prior to the treatment to lend credibility to the assumption.[25] I do both for countries surviving the first selection criteria.[26]

Contrary to Mr. Feld's naïve assertion that Title II had an accelerating effect on speed, the data reveal that average speeds are lower than where they should have been "but for" reclassification. While average speeds are up, the U.S. is lagging behind expectations.

The final control group includes five countries: Belgium, Denmark, Finland, Norway, and the United Kingdom.[27] Figure 3 illustrates the speed data (in levels) for the U.S. and control countries for the 12 quarters in the pre-treatment. The pre-treatment trends and average speeds are alike.

Figure 3. Pre-Treatment Speed Trends



We can get a feel what to expect from the statistical analysis by looking at the average speeds over time. In Table 2, average speeds are summarized for the six countries in years 2012 (the initial period), 2014 (the year prior to the treatment), and the treatment period. In 2012, speeds were around 6 Mpbs, and by 2014 average speeds had nearly doubled to around 10 to 11 Mbps. During the treatment period, average speeds had risen to between 12 to 18 Mbps. As shown in the final column, the U.S.

is at the bottom of the percentage speed increases for the sample of countries after reclassification. U.S. average speed increased 83% between 2014 and 2012, but only 27.8% between 2014 and the treatment period.

Table 2. Average Speeds (Mbps)

Country	2012	2014	2015+	Increase (2014, 2015+)
U.S.	6.08	11.13	14.22	27.8%
Belgium	6.58	10.85	13.92	28.3%
Denmark	6.91	11.24	15.66	39.3%
Finland	6.84	11.41	16.45	44.2%
Norway	5.84	10.82	18.05	66.8%
U.K.	5.43	10.62	13.89	30.8%

Turning to the more formal statistical analysis, Equation (2) is estimated with 120 observations, with 6 countries and 20 observations each.[28] In this first model, I set the treatment date at 1Q15. The regression explains 95% of the variation in the dependent variable (as quantified by the R^2). Results are summarized in Table 3. The standard and robust t-statistics are provided, as well as the clustered t-statistics. Given the small number of countries in the sample, the latter are computed using the t-percentile method and the wild bootstrap.[29]

Table 3. DiD Estimates

Dep. Variable =	y	ln(y)
Coef: δ	-1.433	-0.088
T-Statistic	-2.74**	-2.37**
Robust T-Statistic	-4.33***	-3.93***
Clustered T-Statistic	-1.58*	-1.48**

Stat. Sig. * 10%, ** 5%, *** 1%.

Whether using y or ln(y) as the dependent variable, the DiD estimator (δ) is negative. On average, the U.S.'s average speed is 1.43 Mbps lower than the counterfactual in the treatment period. This difference is statistically significant at the 5% level or better (with one exception at the 10% level or better).[30] Using the natural log transformation of speed, the estimated coefficient is -0.088, indicating the U.S. is about 8.4% below the counterfactual.[31] The coefficient is also statistically different from zero at the 5% level or better.

Based on these results, I can *reject* the null hypothesis of "no relative speed difference" for the U.S. following the *2015 Open Internet Order*. Contrary to Mr. Feld's naïve assertion that Title II had an accelerating effect on speed, the data reveal that average speeds are *lower* than where they should have been "but for" reclassification. While average speeds are up, the U.S. is lagging behind expectations.

Next, I set the treatment date to 4Q14, when President Obama's YouTube video encouraging his political appointee to reclassify broadband.[32] By most accounts, reclassification was inevitable at the moment. Results from Equation (2) are summarized in Table 4, and are very similar to those in Table 3, so I won't discuss them further.

Table 4. DiD Estimates, Treatment 4Q14

Dep. Variable =	y	ln(y)
Coef: δ	-1.356	-0.085
T-Statistic	-2.62**	-2.32**
Robust T-Statistic	-4.21***	-3.79***
Clustered T-Statistic	-1.61*	-1.50**

Stat. Sig. * 10%, ** 5%, *** 1%.

Normally, researchers create a buffer between the pre-treatment and treatment periods by excluding periods in and around the treatment date (permitting some time for outcomes to adjust to new conditions). For the results in Table 5, I exclude (a) the first two quarters of 2015, (b) all four quarters of 2015, and (c) 4Q14-3Q14 as buffers.[33]

Table 5. Treatment Buffers		
Excluded Period	δ: y	δ: ln(y)
None	-1.433***	-0.088***
1Q15-2Q15	-1.695***	-0.101***
1Q15-4Q15	-1.695***	-0.094***
4Q14-3Q15	-1.735***	-0.100***
Stat. Sig. (t-stat) * 10%, ** 5%, *** 1% (Robust T-Stat).		

In all three cases, the DiD estimator gets larger (in absolute value) and the DiD coefficients remain statistically different from zero at the 5% level or better. After reclassification, the U.S. is lagging behind expectations in average broadband speed. "But for" the FCC's *2015 Open Internet Order,* U.S. broadband speeds would have been about 10% higher, or about 1.5 Mbps faster, on average.

Simple Forecasts

Given that Mr. Feld's claim focuses on a visual assessment of the Akamai data, I employ a simple forecast of average speed to add a more visual aspect to the analysis. This forecast can be compared to the actual average speed to determine whether there has been an acceleration of speed increases. There is not a lot of data here and the forecast extends many quarters forward, so there is an obvious data limitation. Nonetheless, a sliver of rigor might improve the assessment of the data, but the lack of data should be taken into consideration, as it is with the construction of the confidence intervals around the forecast.

This forecast approach has a slightly different interpretation than the DiD approach. In the DiD method, the average speeds in the U.S. are compared, in some way, to the average speeds in a comparable set of countries that serve as the counterfactual.[34] Here, I am forecasting the U.S. average speed using U.S. data. Thus, this comparison is one of the U.S. to the U.S., so to speak, at least as forecasted from historical data. This approach is more consistent with the spline function of Equation (1) and Figure 2 than it is the DiD estimator.

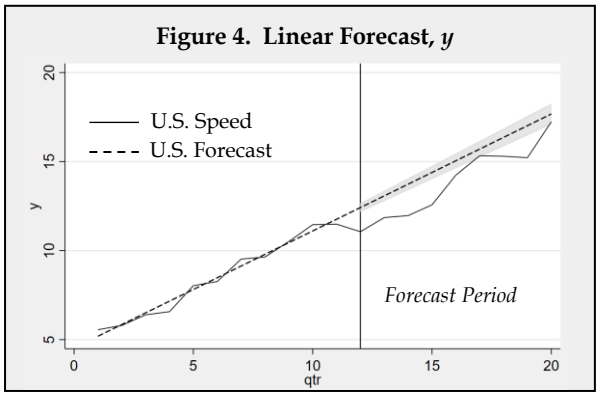
Given data limitations, I employ the most basic of forecast models:

$$y_t = \beta_0 + \beta_1 t + \nu_t, \quad (5)$$

where y_t is defined as before and t is a quarterly trend.[35] The parameters of the forecast equation are estimated using data from 1Q12 through 3Q14 (to stay clear of the reclassification decision), and the estimated equation is then used to predict speeds in the treatment period.[36]

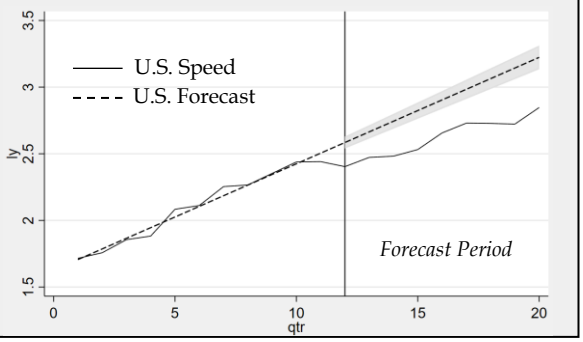
Figure 4 illustrates the results for the level of speed (y), including the 90% confidence bands.[37] As shown in the figure, the actual speed levels are mostly below the forecast and typically below the lower confidence limit. Speed is increasing, which is nice, but the figure suggests speeds are about 1.2 Mbps under expectations (consistent with the DiD estimates).

Figure 4. Linear Forecast, y



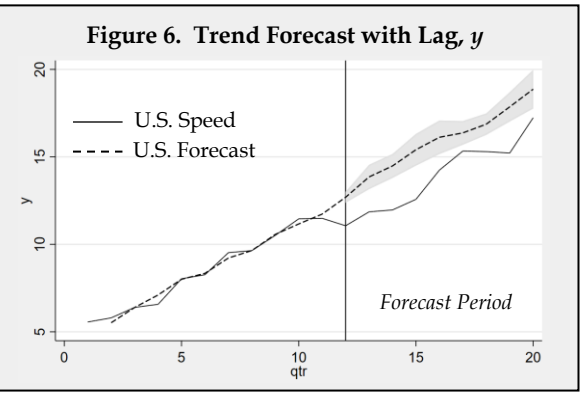
In Figure 5, the forecast for the natural log form of the dependent variable is illustrated. The transformation is important. Now, the actual speeds in the U.S. are well below the forecast (about 4.2 Mbps), consistently lying below the lower bound of the 90% confidence bands.

Figure 5. Linear Forecast, ln(*y*)



Including a one-period lag of *y* in the forecast equation results in the forecast and confidence limits shown in Figure 6. Now, the actual speed is consistently below the lower limit of the confidence interval, and the average loss of speed increases for the U.S. is 1.8 Mbps.

Figure 6. Trend Forecast with Lag, *y*

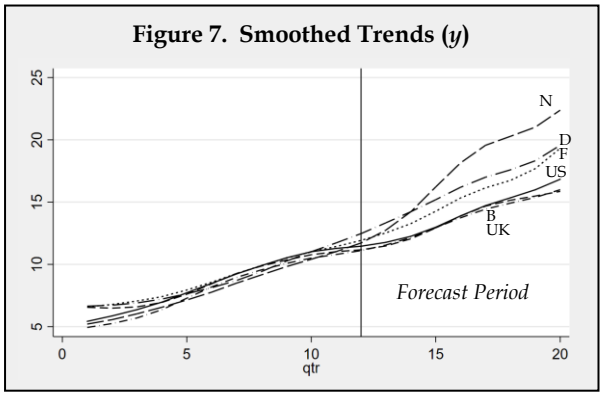


The forecast results are consistent with the DiD estimates. The trend forecasts indicate that speeds are increasing at a rate below expectations. The evidence reveals a slowing down of speed growth in the U.S. since the *2015 Open Internet Order*. Contrary to Mr. Feld's claims, speed increases have not "accelerated," but have decelerated following reclassification.

Graphical Methodologies

There are (at least) two other potentially interesting empirical methodologies for assessing the data. First, in order to more clearly see the trends in the data, I apply the Hodrick-Prescott Filter to the speed data over the entire sample.[38] This filter decomposes the trend in a series from its dynamic component, providing a cleaner look at the trend. I apply a very low smoothing parameter for quarterly data ($\lambda = 2$) to avoid aggressive smoothing.[39] The filtered data are illustrated in Figure 7.

Figure 7. Smoothed Trends (*y*)



The trend is U.S. speed is shown as the solid line, the vertical line indicates 4Q14. Countries, from largest to smallest in the last period, are Norway, Denmark, Finland, the U.S., Belgium and the U.K. (the last two being essentially equal). Visually, we see that speed in the U.S., while increasing, is unremarkable since reclassification, perhaps declining in the growth rate.[40]

Figure 8. Synthetic Counterfactual (*y*)

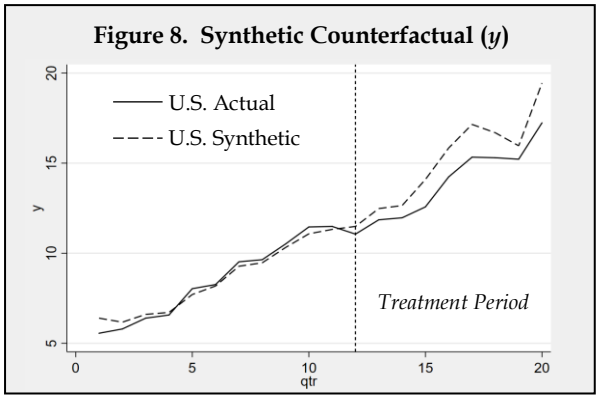


Figure 8 presents the results of the method of Synthetic Counterfactual. Without going into the technical details, the Synthetic Counterfactual is a linear combination of the control group that best fits the U.S. data in the pre-treatment period.[41] This linear combination is used to construct a counterfactual during the treatment period. The results show that the

actual average speed in the U.S. after reclassification is below the counterfactual.

In the treatment period, the average difference between the actual and counterfactual speed is 1.22 Mbps. In 2016, the average difference between the actual speed and the counterfactual is about 1.5 Mbps. These differences are consistent with the statistical analysis presented above.

The trend forecasts indicate that speeds are increasing at a rate below expectations. The evidence reveals a slowing down of speed growth in the U.S. since the 2015 Open Internet Order. Contrary to Mr. Feld's claims, speed increases have not "accelerated," but have decelerated following reclassification.

Speeds and Economic Welfare

In this PERSPECTIVE, I have taken Mr. Feld's theorem about speed and reclassification at face value. In fact, it is difficult to conceive of a unambiguous theoretical connection between Title II and speed increases. Average speed is the result of many factors, including availability (which is largely determined by past investments), measurement methods and anomalies, and, critically, the adoption choices of consumers.

At my home, for instance, I can purchase the standard connection of 60 Mpbs—which I do—or upgrade to a faster connection of 300 Mbps, which I can't see needing for many years. If I upgraded my connection, I would contribute to a faster national average rate, even though nothing has changed in the speed offerings of my provider. Also, average speeds will tend to increase as cable's share of the broadband market increases, as it has since the *2015 Open Internet Order*.[42] I doubt Mr. Feld would take this as a beneficial effect of reclassification.

By the same math, a highly successful Connect America Fund program, which requires only a 10 Mbps connection to receive funding, will drag down the national average speed.[43] Consequently, a slower growth in average speed may signal more broadband adoption in higher-cost and previously unserved areas, which is a good thing.

Up to a point, higher speeds for a given customers are beneficial. Average speeds across the nation, however, encapsulate many considerations. Plainly, economic welfare has no obvious relationship to average broadband speeds, and economic welfare is the standard by which policy is judged.

Up to a point, higher speeds for a given customers are beneficial. Average speeds across the nation, however, encapsulate many considerations. Plainly, economic welfare has no obvious relationship to average broadband speeds, and economic welfare is the standard by which policy is judged.

Conclusion

Despite eight years of harassment by the Obama Administration's FCC, broadband providers continue to offer quality services to the American public. Average download speeds are increasing, but they are expected to with or without reclassification. There's no reason speed should decline. Also, speeds are increasing in other, comparable countries as well. On the question of whether speeds are

improving relatively faster in the U.S. following the *2015 Open Internet Order*, the statistical evidence suggests the trend and growth in broadband speeds are below expectations subsequent to reclassification.

In some respects, the future looks bleak. Because of the regulatory revival at the FCC under the Obama Administration, investment in telecommunications networks is far below expectations and declined in 2016, which, in turn, may reduce relative broadband speeds far into the future.[44] Consumers will deal with the worst of the Obama Administration's regulatory excesses in future years, though we can hope that better policies put forth today are an elixir, fully restoring investment incentives in broadband networks.

NOTES:

* **Dr. George S. Ford** ***is the Chief Economist of the Phoenix Center for Advanced Legal and Economic Public Policy Studies. The views expressed in this Perspective do not represent the views of the Phoenix Center or its staff. Dr. Ford may be contacted at ford@phoenix-center.org.***

1 *In re Restoring Internet Freedom,* FCC 17-60, NOTICE OF PROPOSED RULEMAKING, __ FCC Rcd __, (rel. May 23, 2017) (available at: http://apps.fcc.gov/edocs_public/attachmatch/FCC-17-60A1.pdf); A. Selyukh, *FCC Chief Begins Rollback of Net Neutrality Regulations*, NPR (April 26, 2017) (available at: http://www.npr.org/sections/thetwo-way/2017/04/26/525705253/fcc-chief-begins-rollback-of-net-neutrality-regulations); *Protecting and Promoting the Open Internet*, REPORT AND ORDER ON REMAND, DECLARATORY RULING, AND ORDER, FCC 15-24, 30 FCC Rcd 5601 (rel. Mar. 12, 2015) (hereinafter "*2015 Open Internet Order*").

2 On the perversion of Title II by the FCC's *2015 Open Internet Order*, *see*, L.J. Spiwak, *USTelecom and its Aftermath*, PHOENIX CENTER POLICY BULLETIN No. 42 (June 2017) (available at: http://www.phoenix-center.org/PolicyBulletin/PCPB42Final.pdf); *see also* G.S. Ford and L.J. Spiwak, *Tariffing Internet Termination: Pricing Implications of Classifying Broadband as a Title II Telecommunications Service*, 67 FEDERAL COMMUNICATIONS LAW JOURNAL 1 (2015) (available at: http://www.fclj.org/wp-content/uploads/2015/02/Tariffing-Internet-Termination.pdf); G.S. Ford and L.J. Spiwak, *Non-Discrimination or Just Non-Sense: A Law and Economics Review of the FCC's New Net Neutrality Principle,* PHOENIX CENTER PERSPECTIVE NO. 10-03 (March 24, 2010) (available at: http://www.phoenix-center.org/perspectives/Perspective10-03Final.pdf).

3 *America's Internet Speeds Continue to Soar*, NCTA BLOG (June 2, 2017) (available at: http://www.ncta.com/platform/broadband-internet/americas-internet-speeds-continue-to-soar). While Akamai's data does indicate that speeds decline in some quarters for some countries, such an occurrence likely has more to do with measurement anomalies than any real speed differences for consumers. Akamai's data is available at: http://www.akamai.com/us/en/about/our-thinking/state-of-the-internet-report/state-of-the-internet-connectivity-visualization.jsp.

4 H. Feld, *NCTA Agrees Title II Virtuous Cycle Totally Working; Or, Pai's Economics v. the Actual Real World*, WETMACHINE BLOG (June 12, 2017) (available at: http://www.wetmachine.com/tales-of-the-sausage-factory/ncta-agrees-title-ii-virtuous-cycle-totally-working-or-pais-economics-v-the-actual-real-world). The speed claim is now prominent in Net Neutrality circles. *See, e.g.,* Open Technology Institute, *Net Neutrality and the Economy: How the FCC's Rules Promote Investment, Create Jobs, and Protect Consumers* (https://www.newamerica.org/oti/events/net-neutrality-and-economy-how-fccs-rules-promote-investment-create-jobs-and-protect-consumers). It should be noted that the FCC's virtuous circle argument is total nonsense. *See, e.g.,* G.S. Ford, *Bait-and-Switch – Or Why the FCC's 'Virtuous Circle' Theory is Nonsense*, BLOOMBERG BNA (May 18, 2015); M.L. Katz, *Wither U.S. Net Neutrality Regulation?*, 50 REVIEW OF INDUSTRIAL ORGANIZATION 441-468 (2017) (unpublished draft available at: https://techpolicyinstitute.org/wp-content/uploads/2016/05/MLKatzWitherUSNetNeutralityRegulation.pdf).

5 Other contributions to Public Knowledge's interpretation of the evidence include Rick Chessen of NCTA and Richard Bennett, a network engineer actively contributing to communications policy through the High Tech Forum. R. Chessen, *Dear Harold Feld*, NCTA BLOG (June 13, 2017) (available at: https://www.ncta.com/platform/public-policy/dear-harold-feld); R. Bennett, *Highly Illogical Broadband Claims*, HIGH TECH FORUM (June 13, 2017) (available at: http://hightechforum.org/highly-illogical-broadband-claims).

6 *See* Ford, *supra* n. 4; Katz, *supra* n. 4.

7 Mr. Feld likes to refer to those with formal PhDs in economics as folks who live in "Econ Cloud Cukoo Land" but to non-economists such as "Free Press' Dr. Erik Turner" [sic] as "folks who do practical economics in the real world." Feld, *supra* n. 4. For an analysis of work often treated by Mr. Feld as valid, *see, e.g.,* G.S. Ford, *Be Careful What You Ask For: A Comment on the OECD's Mobile Price Metrics*, PHOENIX CENTER POLICY PERSPECTIVE No. 09-03 (September 16, 2009) (available at: http://phoenix-center.org/perspectives/Perspective09-03Final.pdf); G.S. Ford, *Finding the Bottom: A Review of Free Press's Analysis of Network Neutrality and Investment*, PHOENIX CENTER POLICY PERSPECTIVE No. 09-03 (October 29, 2009) (available at: http://phoenix-center.org/perspectives/Perspective09-04Final.pdf); G.S. Ford, *Whoops! Berkman Study Shows "Open Access" Reduces Broadband Consumption* , PHOENIX CENTER POLICY PERSPECTIVE No. 09-05 (November 12, 2009) (available at: http://phoenix-center.org/perspectives/Perspective09-05Final.pdf); G.S. Ford and L.J. Spiwak, *Substantial Profits in the Broadband Ecosystem: A Look at the Evidence*, PHOENIX CENTER POLICY PERSPECTIVE No. 10-04 (April 22, 2010) (available at:

NOTES CONTINUED:

http://phoenix-center.org/perspectives/Perspective10-04Final.pdf); G.S. Ford, *Fabricating a Broadband Crisis? More Evidence on the Misleading Inferences from OECD Rankings*, PHOENIX CENTER POLICY PERSPECTIVE No. 10-05 (July 7, 2010) (available at: http://phoenix-center.org/perspectives/Perspective10-05Final.pdf); G.S. Ford, *Be Careful What You Ask For (Redux): A Comment on the New America Foundation's Mobile Price Metrics*, PHOENIX CENTER POLICY PERSPECTIVE No. 10-06 (November 11, 2010) (available at: http://phoenix-center.org/perspectives/Perspective10-06Final.pdf); G.S. Ford, *Do Municipal Networks Offer More Attractive Service Offerings than Private Sector Providers? A Review and Expansion of the Evidence*, PHOENIX CENTER POLICY PERSPECTIVE No. 14-01 (January 27, 2014) (available at: http://phoenix-center.org/perspectives/Perspective14-01Final.pdf); G.S. Ford, *Are Government-Owned Networks Abusing Market Power in the Set-Top Box Market? A Review of Rates*, PHOENIX CENTER POLICY PERSPECTIVE No. 16-03 (April 14, 2016) (available at: http://phoenix-center.org/perspectives/Perspective16-03Final.pdf); G.S. Ford, *Cost or Benefit? A Review of the Consumer Federation of America's Report on Regulating Special Access Services* PHOENIX CENTER POLICY PERSPECTIVE No. 16-03 (April 18, 2016) (available at: http://phoenix-center.org/perspectives/Perspective16-04Final.pdf); G.S. Ford, *Learning from Bad Technique: The WIK-Consult Report on Business Data Services*, PHOENIX CENTER POLICY PERSPECTIVE No. 16-07 (August 4, 2016) (available at: HTTP://PHOENIX-CENTER.ORG/PERSPECTIVES/PERSPECTIVE16-07FINAL.PDF).

[8] E. Wyatt, *Obama Asks F.C.C. to Adopt Tough Net Neutrality Rules*, NEW YORK TIMES (November 10, 2014) (available at: https://www.nytimes.com/2014/11/11/technology/obama-net-neutrality-fcc.html); *see also* L. Spiwak, *The "Clicktivist" In Chief*, THE HILL (November 12, 2014) (available at: http://thehill.com/blogs/pundits-blog/technology/223744-the-clicktivist-in-chief).

[9] *2015 Open Internet Order*, *supra* n. 1.

[10] M. Snider, *Net Neutrality, Beloved by Netflix, Looks Headed for the Ax Under Trump*, USA TODAY (November 22, 2016) (available at: https://www.usatoday.com/story/tech/news/2016/11/22/trump-team-appointees-indicate-net-neutrality-reversal/94266912).

[11] J. Puzzanghera, *Trump Names New FCC Chairman: Ajit Pai, who Wants to Take a 'Weed Whacker' to Net Neutrality*, LOS ANGELES TIMES (January 23, 2017) (available at: http://www.latimes.com/business/la-fi-pai-fcc-chairman-20170123-story.html).

[12] In this analysis, I accept the argument that the release of the *2015 Open Internet Order* is a treatment date for reclassification. In my own research, I choose 2010 (the year reclassification was first proposed for Net Neutrality) as the proper treatment date for the regulatory revival (including reclassification) at the FCC. *See G.S. Ford, "Regulatory Revival" and Employment in Telecommunications,* PHOENIX CENTER POLICY PERSPECTIVE No. 17-05 (June 12, 2017) (available at: http://www.phoenix-center.org/perspectives/Perspective17-05Final.pdf); G.S. Ford, *Net Neutrality, Reclassification and Investment: A Counterfactual Analysis*, PHOENIX CENTER POLICY PERSPECTIVE No. 17-02 (April 25, 2017) (available at: http://phoenix-center.org/perspectives/Perspective17-02Final.pdf); G.S. Ford, *Net Neutrality, Reclassification and Investment: A Further Analysis*, PHOENIX CENTER POLICY PERSPECTIVE No. 17-03 (May 16, 2017) (available at: http://phoenix-center.org/perspectives/Perspective17-03Final.pdf).

[13] Snider, *supra* n. 10.

[14] Remarks of FCC Commissioner Ajit Pai before the Free State Foundation's Tenth Anniversary Gala Luncheon, Washington, D.C. (December 7, 2016) (available at: https://apps.fcc.gov/edocs_public/attachmatch/DOC-342497A1.pdf).

[15] Including the single quarter has no effect on my conclusions, so the choice is not cherry-picking.

[16] Between 3Q07 and 3Q14 (29 observations), I cannot reject the null hypothesis of the non-parametric Kwiatkowski, Phillips, Schmidt, and Shin ("KPSS") test ("H0: the series is trend stationary") for the U.S. speed data. The small sample, of course, suggests the test has low power against the alternative. D. Kwiatkowski, P. Phillips, P. Schmidt, and Y. Shin, *Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root: How Sure Are We that Economic Time Series Have a Unit Root?*, 54 JOURNAL OF ECONOMETRICS 159-178 (1995).

[17] R.S. Pindyck and D.L. Rubinfeld, ECONOMETRIC MODELS & ECONOMIC FORECASTS (1991) at pp. 117-9. The disturbance may be heteroscedastic and serially correlated.

NOTES CONTINUED:

[18] The Newey-West t-statistic is 11.51 (prob < 0.01) and the bootstrapped t-statistic is 14.44 (prob < 0.01) (500 simulations with resampling restricted to pre- and treatment periods). The growth rates are instantaneous growth rates. A compound average growth rate can be computed using exp(β) – 1.

[19] The Newey-West t-statistic is 4.60 (prob < 0.01) and the bootstrapped t-statistic is 5.68 (prob < 0.01) (500 simulations with resampling restricted to pre- and treatment periods).

[20] The F-statistic is 4.02 (prob = 0.06) and the bootstrapped t-statistic on the difference is 2.23 (prob < 0.05).

[21] The t-statistics for β_1 are: (a) 12.14 (prob < 0.01) and (b) the bootstrapped t-statistic is 14.21 (prob < 0.01). The t-statistics for β_2 are: (a) 5.68 (prob < 0.01) and (b) the bootstrapped t-statistic is 6.50 (prob < 0.01).

[22] The F-statistic is 6.27 (prob < 0.05) and the bootstrapped t-statistic is 2.91 (prob < 0.05).

[23] *See, e.g.,* B.D. Meyer, *Natural and Quasi-Experiments in Economics*, 13 JOURNAL OF BUSINESS & ECONOMIC STATISTICS 151-161 (1995); J.D. Angrist and J.S. Pischke, MOSTLY HARMLESS ECONOMETRICS: AN EMPIRICIST'S COMPANION (2008); J.D. Angrist and A.B. Krueger, *Empirical Strategies in Labor Economics*, in HANDBOOK OF LABOR ECONOMICS (Volume 3A)(1999) (O. Ashenfelter and D. Card, eds.) at Ch. 23; *see also* D. Card, *The Impact of the Mariel Boatlift on the Miami Labor Market*, 43 INDUSTRIAL AND LABOR RELATIONS REVIEW 245-257 (1990); S. Galiani, P. Gertler, and E. Schargrodsky, *Water for Life: The Impact of the Privatization of Water Services on Child Mortality*, 113 JOURNAL OF POLITICAL ECONOMY 83-123 (2005) (available at: http://sekhon.berkeley.edu/causalinf/papers/GalianiWater.pdf).

[24] In 2012, this threshold creates an approximate 1 Mbps band around the mean.

[25] Meyer, *supra* n. 22. I use the 5% significance level for these tests.

[26] I exclude two countries with data that exhibits usual patterns in the speed trends (unusually large increase or decreases in speed) during the pre-treatment period (Ireland and Romania). These unusual changes are likely related to measurement anomalies than any general change in speed, casting doubt on the reliability of the data for these countries.

[27] Net Neutrality policies in these countries are varied and mostly under development. *See, e.g., Net Neutrality is an International Issue*, Norwegian Communications Authority (August 8, 2014) (available at: https://eng.nkom.no/topical-issues/news/net-neutrality-is-an-international-issue) ("The regulatory approach in Norway is however based upon co-regulation. The advantage of this is that the regulations can be made more dynamic without a heavier legislative process, whereas the drawback is that the arrangement is voluntary and lacks any formal means to impose sanctions."); *BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules*, BoR (16) 127 (August 30, 2016) (available at: http://berec.europa.eu/eng/document_register/subject_matter/berec/regulatory_best_practices/guidelines/6160-berec-guidelines-on-the-implementation-by-national-regulators-of-european-net-neutrality-rules). For a broader discussion of net neutrality policy in the EU, *see generally, Zero Rating Practices in Broadband Markets, Report Prepared for the European Union, Directorate-General for Competition* (February 2017) (available at: http://ec.europa.eu/competition/publications/reports/kd0217687enn.pdf); C. Marsden, *Comparative Case Studies in Implementing Net Neutrality: A Critical Analysis of Zero Rating*, 13 SCRIPTED 1 (May 2016) (available at: https://script-ed.org/wp-content/uploads/2016/04/marsden.pdf); L. Belli and C.T. Marsden, *European Net Neutrality, At Last?*, OPENDEMOCRACY (October 4, 2016) (available at: http://www.opendemocracy.net/luca-belli-christopher-t-marsden/european-net-neutrality-at-last); S. Mlot, *EU Approves Net Neutrality Rules, Critics Pounce*, PC MAG (October 28, 2015) (available at: http://www.pcmag.com/article2/0,2817,2493948,00.asp); *Regulation (EU) 2015/2120 of the European Parliament and of the Council*, Office Journal of the European Union (November 25, 2015) (available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2120&from=EN); E. Woollacott, *Votes for Net Neutrality in No Uncertain Terms,* FORBES (April 3, 2014) (available at: http://www.forbes.com/sites/emmawoollacott/2014/04/03/europe-votes-for-net-neutrality-in-no-uncertain-terms/#51b04f374e00).

[28] The equality of growth rates prior to the treatment period cannot be rejected at standard significance levels (t-stat = 0.89).

NOTES CONTINUED:

[29] A.C. Cameron, J.B. Gelbach and D.L. Miller, *Bootstrap-Based Improvements for Inference with Clustered Errors*, 90 REVIEW OF ECONOMICS AND STATISTICS 414-427 (2008) (available at: http://www.mitpressjournals.org/doi/abs/10.1162/rest.90.3.414?journalCode=rest or http://www.nber.org/papers/t0344).

[30] The literature recommends clustered standard errors for DiD analysis, but the number of countries evaluated here is too small for the technique. M. Bertrand, E. Duflo and S. Mullainathan, *How Much Should We Trust Differences-In-Differences Estimates?*, 119 QUARTERLY JOURNAL OF ECONOMICS 249-275 (2004).

[31] The marginal effect with $\ln(y)$ may be calculated using $\exp(\delta) - 1$, but it is very close to the coefficient for such a small positive value.

[32] Wyatt, *supra* n. 8.

[33] Ford, *supra* n. 12.

[34] Theoretically, the DiD estimator is not a comparison across countries, but uses other countries to serve as the counterfactual. That is, the control group offers the expected outcome in the U.S. absent the treatment, which cannot be directly observed.

[35] J. Wooldridge, INTRODUCTORY ECONOMETRICS (2003) at pp. 344-7; D. Gujarati, BASIC ECONOMETRICS (1995) at pp. 171-2.

[36] The Root Mean Squared Error of the forecast equation is smaller when setting the treatment date at 4Q14 (0.33 versus 0.48), the quarter the Obama YouTube video was released.

[37] Newey-West standard errors are used to compute the confidence bands.

[38] R. Hodrick and E. Prescott, *Post-War U.S. Business Cycles: An Empirical Investigation*, 29 JOURNAL OF MONEY, CREDIT AND BANKING 1-16 (1997); W. Enders, APPLIED ECONOMETRIC TIME SERIES (2004) at pp. 223-5.

[39] J.D. Hamilton, *Why You Should Never Use the Hodrick-Prescott Filter*, NBER WORKING PAPER No. W23429 (May 2017) (available at: http://ssrn.com/abstract=2971826).

[40] I have used a lot of linear expressions in the analysis. Testing for a quadratic trend using the smoothed data for the U.S. (regressing the smoothed y on t and t^2 over the entire sample) indicates the linear approximation is valid for both the pre-treatment and total sample. I use the smoothed data due to the apparent measurement anomalies in the Akamai data and the paucity of observations.

[41] For details, *see, e.g.,* A. Abadie, A. Diamond, and J. Hainmueller. *Comparative Politics and the Synthetic Control Method*, 59 AMERICAN JOURNAL OF POLITICAL SCIENCE 495-510 (2015); A. Abadie, A. Diamond, and J. Hainmueller, Synthetic *Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program*, 105 JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION 493-505 (2010). The weights are: Belgium (0.217), Denmark (0.288), Finland (0.22), Norway (0.137), and the U.K. (0.138), which sum to one.

[42] *Cable Wins More of Broadband Market*, LIGHTREADING (June 3, 2016) (available at: http://www.lightreading.com/services/broadband-services/cable-wins-more-of-broadband-market/d/d-id/723824). One plausible theoretical prediction about speeds comes from earlier research suggesting that Net Neutrality will tend to lead to increased concentration in the industry (that is, lead to fewer providers). T.R. Beard, G.S. Ford, T.M. Koutsky, and L.J. Spiwak, *Network Neutrality and Industry Structure*, 29 HASTINGS COMMUNICATIONS & ENTERTAINMENT LAW JOURNAL 149-170 (2007) (available at: http://phoenix-center.org/papers/CommEntNetworkNeutrality.pdf). The survivor of that process presumably offers the highest speeds (assuming speed measures quality). Thus, to some extent, a higher average speed may reflect higher industry concentration, an unfortunate yet predictable result of heavy-handed Net Neutrality regulations. *See also* L.J. Spiwak, *Professor Susan Crawford and the Looming "Cable Monopoly"*, @LAWANDECONOMICS BLOG (November 16, 2012) (available at: http://www.phoenix-center.org/blog/archives/899).

[43] FCC Connect America Fund (available at: https://www.fcc.gov/general/connect-america-fund-caf).

[44] *See* Ford, *supra* n. 12.