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A Further Review of the Internet Association's Empirical Study on Network Neutrality and Investment

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In a recent PERSPECTIVE, I reviewed a report authored by Dr. Christopher Hooton of the Internet Association on the impact of Net Neutrality regulation on broadband infrastructure investment (hereinafter the "*IA Report*").[1] My earlier review of the *IA Report* focused mainly on Dr. Hooton's difference-in-differences ("DiD") model, which from an empirical perspective is the only analysis he offered that could plausibly quantify the effects of the regulation since it involves a counterfactual.[2] As I demonstrated, among other defects, Dr. Hooton's analysis was fatally flawed in that he analyzed mostly fabricated investment data. Results derived from the artificial investment data, stretching from 2014 to year 2020, have no meaningful policy interpretation since they do not measure actual investment behavior.[3]

In addition to the DiD analysis, Dr. Hooton reported results from a number of other regression analyses. As I also noted in my earlier review, these models have no plausible causal interpretation with regard to Net Neutrality regulation since Dr. Hooton's models amount to little more than comparing average capital spending levels (or cumulative investment) over time without any adjustment for inflation or the construction of a counterfactual (i.e., what investment "should have been").

In this PERSPECTIVE, I return to Dr. Hooton's analysis. My interest in further analysis stems from Dr. Hooton's claim that his evidence leans in the direction of a positive investment effect in that his "regression coefficients of interest were positive in all but one case."[4] (That negative case being his primary DiD analysis.) Closer inspection of these "positive" cases reveals errors as severe, if not worse than, the errors plaguing his DiD analysis, including the fabrication of much of his data.

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First, Dr. Hooton's analysis of USTelecom's data on U.S. broadband investment for years 1996 through 2015 employs data that have been corrupted in some way. Dr. Hooton's results are not consistent with the actual USTelecom data, a fact easily demonstrated. Second, as with his DiD analysis, Dr. Hooton fabricates (via interpolation) three-fourths of the data he analyzes from SNL Kagan for cable industry broadband investment. These data also measure cumulative investment, not annual investment. His only remaining "positive" effect is derived from investments in roads, canals, bridges, and other transportation infrastructure, so it has no bearing on Net Neutrality.

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After adjusting for inflation and correcting for data corruption and improper definitions of investment, all the investment effects, based on Dr. Hooton's own models, are found to be negative and statistically significant, and the performance of the statistical models are much improved. His chosen models show sizable reductions in investment subsequent both to the initial proposal of reclassification in 2010 and to the *2015 Open Internet Order*.

Analysis of USTelecom Data

First, let's look at the USTelecom data on broadband investment.[5] The data covers the years 1996 through 2015, for 20 total observations. From Table B4 of the *IA Report*, the simplest model is Dr. Hooton's "Baseline" model, which permits an easy check on the data via replication. The regression is,

$$Y_t = \beta_0 + \beta_1 D + \varepsilon_t, \qquad (1)$$

where Y_t is the investment level in year t, D is a dummy variable for treatment years, ε_t is the econometric disturbance term, and the β's are the estimate coefficients.

Dr. Hooton's simple model does little more than compute the average investment levels in the two periods. Average investment before the treatment is β_0, while investment after the treatment is $\beta_0 + \beta_1$. The practical purpose of such a model is that the t-statistic on β_1 is a direct test of a statistically-significance difference in the two averages. No causal interpretation is available from such an analysis, especially when using data unadjusted for inflation.

For reference, note that the average investment level prior to 2011 is $73.67 billion and after 2010 is $73 billion.[6] The β coefficients from Dr. Hooton's simple model should produce those averages based on the calculations just described. That is, β_1 should equal 73.67 and β_1 should equal -0.67. (In 2016 dollars, the means are 94.3 and 75.2, respectively.)

Dr. Hooton's results are summarized in Table 1. As shown in the table, the F-Statistic of the model is not statistically-significant (prob = 0.88). In layman's terms, this F-statistic implies Dr. Hooton's regression model is no better than no model at all. The Adjusted-R^2 is also negative, suggesting Dr. Hooton has too much model for so little data.

Table 1. Hooton's Results

	Coef.	St. Err.
β_0	73.3684***	3.83
β_1	2.6316***	17.11
F-Stat	0.0236	
R^2	0.0013	
Adj-R^2	-0.0542	

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

Inspection of the coefficients in Table 1 reveal a very serious problem. The β_0 coefficient is 73.4, which is slightly smaller than it should be (73.67). More problematic, the coefficient β_1 is off by a large margin. According to Dr. Hooton's reported results, average investment after 2010 would be 76 [= 73.4+2.6], which is not even close to the actual average investment level of 73. It appears the data has been corrupted in some way, or else there is some carelessness in the estimation or the reporting of results.

Replication Using Correct Data

Using the USTelecom data, I estimate the same model and obtain very different but accurate results. The coefficients are summarized in Table 2. There are a few notable findings.

Table 2. Replication of Hooton

	Coef.	St. Err.
β_0	73.6667***	4.31
β_1	-0.6667	8.62
F-Stat	0.0100	
R^2	0.0003	
Adj-R^2	-0.0552	

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

First, unlike Dr. Hooton's results, my coefficients replicate the data exactly. The average investment level prior to the treatment is 73.67 and after is 73 [= 73.67 – 0.67].

[T]he correct coefficient β_1 is negative, not positive, a fact easily confirmed by comparing the averages over the two periods. So Dr. Hooton's claim that all but one of his models show positive effects is false. The correct effect is negative for the USTelecom data.

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Using Inflation-Adjusted and Correct Data

Since the value of the dollar changes over time, a competent analysis of time-series data adjusts for inflation.[7] Dr. Hooton did not. Here, I use the GDP deflator to adjust the data to 2016 dollars.[8] Table 3 summarizes the results of the Hooton's simple model using these inflation-adjusted data. Newey-West standard errors are used to account for autocorrelation of the data.[9]

Table 3. Inflation-Adj. Data (NW)

	Coef.	St. Err.
β_0	94.2972***	9.86
β_1	-18.2038*	9.91
F-Stat	3.37*	
R^2	0.17	

Stat. Sig. *** 1%, ** 5%, * 10% (Newey-West).

From Table 3 we see that the F-statistic is now significant at the 10% level, and the R^2 is much larger.[10] Better methods make for a better model. Observe also that the β_1 coefficient is negative, large, and statistically significant at the 10% level. Average investment in broadband infrastructure is 19% lower after 2010 [= 18.2/94.3], a significant difference in all respects and not unlike those reported in my DiD analyses of investment effects.[11]

Table 4. Inflation-Adj. Data (Robust)

	Coef.	St. Err.
β_0	94.2972***	7.50
β_1	-18.2038**	7.59
F-Stat	5.75**	
R^2	0.10	

Stat. Sig. *** 1%, ** 5%, * 10% (Robust).

Table 4 summarizes the model when estimated with heteroskedastic-robust standard errors (thereby ignoring autocorrelation), which

Dr. Hooton's employs. The coefficients are unchanged, but the t-statistics and model's statistics are different. The model is now statistically significant at the 5% level (F = 5.75). The coefficient β_1 is negative, large, and statistically significant at the 5% level or better. By this model, broadband investment is 19% lower after the Commission put reclassification on the table in 2010.

Plainly, there are serious problems with Dr. Hooton's analysis; corrupt data and failing to adjust for inflation top the list. Fixing some of the flaws renders results very different from those he reports. Dr. Hooton's chosen model now has at least some explanatory power, and *the coefficient Dr. Hooton intends to measure the effect of Net Neutrality regulation is negative, large, and statistically different from zero*. According to Dr. Hooton's model and correct USTelcom data, investment in broadband infrastructure is down 19% since then-Chairman Julius Genachowski first proposed in 2010 to reclassify broadband Internet access as a common carrier telecommunications service under Title II.

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Analysis of SNL Kagan Data

Regression results reported in Table B3 of the *IA Report* rely on SNL Kagan's cumulative investment data by cable operators and also show positive coefficients on β_1. The positive coefficient is little surprise since the SNL Kagan data measures *cumulative* investment, not annual investment. Since investment is positive (and depreciation is ignored), the cumulative investment level will rise over time and naturally be larger in later than in earlier years. The cumulative nature of the data should have been obvious to Dr. Hooton as the the "infographic" Dr. Hooton cites as his source states plainly, "[s]ince 1996, cable has investment over $250 billion in capital infrastructure."[12]

Using the SNL Kagan infographic as a data source presents a serious problem. This "infographic" does not list cumulative investment for each year, but reports only five data points (1996, 2000, 2004, 2009, 2016). Where, then, does the rest of the data come from? As with his DiD analysis, Dr. Hooton just makes the data up. To do so, he interpolates the data for the years between those for which he has data (i.e., he draws a straight line between the available data).

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Table 5 compares the results from Table B3 of the *IA Report* and my replication of it.[15] Note that here Dr. Hooton uses a 2015 treatment date (including both 2015 and 2016). The replicated results are very similar and I suspect any differences reflect differences in rounding. Unlike the USTelecom data, the coefficients do match the data. However, the results are based on cumulative investment, not annual investment.

Table 5. SNL Kagan Data Replication

	Hooton	Replication
β_0	109.78***	109.82***
	(15.68)	(15.67)
β_1	133.72**	133.76**
	(50.80)	(50.77)
F-Stat	5.75**	
R^2	0.10	
Stat. Sig. *** 1%, ** 5%, * 10% (St. Errors).		

Investment can be computed by differencing the cumulative investment data. Table 6 presents the results of the regression using inflation-adjusted investment as the dependent variable. These results have little meaning since almost all the data is computed using linear interpolation. My analysis here is merely illustrative.

Table 6. SNL Kagan Data, Investment

	Newey-West	Robust
β_0	14.91***	14.91***
	(0.49)	(0.39)
β_1	-1.60***	-1.60***
	(0.53)	(0.42)
F-Stat	9.24***	14.80***
R^2	0.12	0.28
Stat. Sig. *** 1%, ** 5%, * 10% (St. Errors).		

Using annual investment rather than cumulative investment, the effect of the *2015 Open Internet Order* is shown to be negative and statistically different from zero. Using Dr. Hooton's chosen SNL Kagan data and model, investment is found to be down 11% since the *2015 Open Internet Order*, a result completely at odds with his claims.

A Look at the OECD Data

As noted in my earlier PERSPECTIVE, much of the data used in Dr. Hooton's DiD analysis is fabricated and does not measure actual investment. The OECD data ends in 2013, and Dr. Hooton fills in data from 2014 through 2020 using a forecast model.[16] Such an approach to assessing the investment impacts of Net Neutrality has no validity.

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The OECD does have a few years of actual investment data after 2010. Thus, it is possible to apply the standard DiD regression to the data, including as a control the average (per-capita) investment of non-US OECD members (for which data is available for all years).[17] The differences ("DiD") regression is,

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

where y_{it} is the (natural log of the) the per-capita investment for entity i at time t, D is a dummy variable that equals 1 for the U.S. after 2010 (0 otherwise), μ_i is fixed effect for each entity 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.[18] The δ coefficient is the DiD estimator.

Table 7. DiD, US and OECD

	Coef (t-stat)	Coef (Rob. t-stat)
δ	-0.144 (-1.31)	-0.144 (-2.59)**
F-Stat	13.45***	
R^2	0.95	
Obs.	33	

Stat. Sig. *** 1%, ** 5%, * 10% (St. Errors).

The results of the estimation of Equation (2) are summarized in Table 7. Year 2010 is excluded as a transition year.[19] The δ coefficient is negative and statistically different from zero (with robust standard errors). The model is statistically significant and the R^2 is high. Investment is 13% lower after 2010.[20]

Table 8. DiD, US and OECD (excl. Members with Net Neutrality)

	Coef (t-stat)	Coef (Rob. t-stat)
δ	-0.131 (-1.13)	-0.131 (-2.22)**
F-Stat	14.01***	
R^2	0.95	
Obs.	33	

Stat. Sig. *** 1%, ** 5%, * 10% (St. Errors).

To better coincide with Dr. Hooton's analysis, I use the OECD's *Communications Outlook* (2013) to exclude member states that have Net Neutrality policies from the OECD average.[21] Equation (2) is estimated again using the narrower selection of member states as the control. The results are similar, with a statistically significant 12.3% reduction in investment in the U.S. after 2010.

For reasons outlined in my previous PERSPECTIVE, Dr. Hooton's use of the OECD data for a DiD analysis is questionable. OECD member countries vary significantly in their investment levels and behaviors, and differ along many other dimensions as well. Also, the use of per-capita data may conflate population and investment effects. Certainly, a much richer analysis is required to attribute an causal interpretation to such findings. These results do illustrate, however, that when using what data is available from the OECD, without fabricating additional data, investment in the U.S. is plausibly down after 2010.

Other Positive Coefficients

Dr. Hooton's other "positive" results are based on data so profoundly defective they do not require as thorough an analysis. His Table B2 reports a positive coefficient from a DiD analysis, but that coefficient (akin to β_1) is estimated with only fabricated data over the treatment period (2015-2020).[22] The problems with these results are obvious enough.

Table B5 reports results on investment in transportation infrastructure ("Inland Infrastructure Investment"), including roads, bridges, ports, canals, and so forth. The relevance of these data to understanding Net Neutrality regulation is a mystery. Moreover, it is unclear what the results mean given the specification of the model.

Conclusion

In my earlier analysis of the *IA Report*, I noted that I did not cover all the mistakes in Dr. Hooton's statistical analysis. In this PERSPECTIVE, I look closer at the *IA Report* and attempt to replicate Dr. Hooton's analysis of the USTelecom and SNL Kagan data. Replication uncovers even more very serious and fatal flaws. For the USTelecom data, Dr. Hooton's reported results do not match the data (which is easily confirmed). Thus, it appears Dr. Hooton has employed corrupted data. Fixing his errors shows that investment is down 19% since reclassification was first introduced in 2010 by then-Chairman Julius Genachowski.

Dr. Hooton's analysis of the SNL Kagan data on cable investment improperly uses *cumulative* investment (rather than annual investment), and 16 of his 21 data points are fabricated. Dr. Hooton appears to have no qualms with manufacturing data to make his point. Switching to annual investment data, the *2015 Open Internet Order* is found to reduce cable broadband investment by 11%, a result completely at odds with Dr. Hooton's claims.

As I noted in my original critique, Dr. Hooton deserves credit for attempting to up the ante on the level of analysis by pro-Net Neutrality advocacy. Still, while mistakes are not uncommon in empirical work, the number of and sorts of errors found in Dr. Hooton's work are unacceptably large and severe. The *IA Report* is, put bluntly, statistical malpractice.

By all accounts, Title II has serious implications for the provision of broadband. Consequently, the investigation of the regulatory approach requires careful and competent analysis. Dr. Hooton's analysis is neither careful nor competent, and thus offers no useful information for policymaking.

NOTES:

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1 G.S. Ford, *A Review of the Internet Association's Empirical Study on Network Neutrality and Investment*, PHOENIX CENTER POLICY PERSPECTIVE No. 17-09 (July 24, 2017) (available at: http://phoenix-center.org/perspectives/Perspective17-09Final.pdf); C. Hooton, *An Empirical Investigation of the Impacts of Net Neutrality*, Internet Association (2017) (available at: https://cdn1.internetassociation.org/wp-content/uploads/2017/07/InternetAssociation_NetNeutrality-ImpactsInvestigation.pdf).

2 For a concise description of DiD, *see* https://www.mailman.columbia.edu/research/population-health-methods/difference-difference-estimation. For more details, *see, e.g.*, B.D. Meyer, *Natural and Quasi-Experiments in Economics*, 13 JOURNAL OF BUSINESS & ECONOMIC STATISTICS 151-161(1995).

3 Dr. Hooton claims to forecast observations using an AR(2) model, but the near linear forecasts in Figure 1 suggests he did not use that model (or did not use it properly). Hooton, *supra* n. 1 at p. 11.

4 *Id.*, *supra* n. 1 at p. 14.

5 For the USTelecom data, Dr. Hooton cites P. Brogan, *Broadband Investment Ticked Down in 2015*, USTELECOM RESEARCH BRIEF (December 14, 2016) (available at: https://www.ustelecom.org/sites/default/files/Broadband%20Investment%20Down%20in%202015.pdf). In sequence (1996-2015), the investment levels are: 55, 65, 72, 92, 118, 111, 72, 57, 58, 62, 70, 70, 71, 64, 68, 68, 69, 75, 77, 76.

6 Note that I am assuming the dummy variable *D* is for years 2011 onward based on my attempts at replication, but I note that data corruption complicates this assessment. If 2010 is used as the treatment date, the means are 74.1 in the pre-treatment period and 72.24 in the treatment period, for a difference of -1.86.

7 In some instances, such an adjustment may not be necessarily, but this is not one of them.

8 ECONOMIC RESEARCH - FEDERAL RESERVE BANK OF ST. LOUIS: GROSS DOMESTIC PRODUCT: IMPLICIT PRICE DEFLATOR (GDPDEF) (available at: https://fred.stlouisfed.org/series/GDPDEF). In sequence (1996-2016), the deflators are: 0.688, 0.700, 0.708, 0.718, 0.735, 0.752, 0.763, 0.778, 0.800, 0.825, 0.851, 0.873, 0.891, 0.897, 0.908, 0.927, 0.944, 0.959, 0.977, 0.987, 1.000.

9 W.K. Newey and K.D. West, *A Simple, Positive Semi-definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix*, 55 ECONOMETRICA 703–708 (1987).

10 The Psuedo-R^2 is computed as the squared correlation coefficient of *Y* and the predicted *Y* from the model.

11 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); G.S. Ford, *"Regulatory Revival" and Employment in Telecommunications*, PHOENIX CENTER POLICY PERSPECTIVE No. 17-05 (June 12, 2017) (available at: http://phoenix-center.org/perspectives/Perspective17-05Final.pdf); *see also* G.S. Ford, *Reclassification and Investment: A Statistical Look at the 2016 Data*, PHOENIX CENTER POLICY PERSPECTIVE No. 17-08 (July 13, 2017) (available at: http://phoenix-center.org/perspectives/Perspective17-08Final.pdf).

12 NCTA Industry Data (available at: https://www.ncta.com/industry-data/item/3199).

13 It is my understanding that the unreported years in the infographic are not accurate representations of the underlying data but for inserted for aesthetic purposes.

14 Hooton, *supra* n. 1 at p. 11.

15 For expositional reasons, I have scaled the data to billions of dollars.

16 My own forecast of the data using an AR(2) process is very different than that illustrated in the *IA Report*'s Figure 1. I do not believe Dr. Hooton has properly used the forecast approach, or else improperly described what he did.

NOTES CONTINUED:

17 A balanced panel is used and a simple average of OECD member states is calculated.

18 *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; 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).

19 Including 2010 renders slightly larger, but comparable, results.

20 The marginal effect is exp(δ) – 1.

21 Details are available at: http://www.oecd.org/sti/broadband/2-9.pdf. Only countries clearly indicated with "No" are included. Dr. Hooton states he excludes countries with Net Neutrality policies, but fails to provide a list or any other indication of which countries he excludes. Hooton, *supra* n. 1 at p. 13.

22 The OECD data Dr. Hooton uses ends in 2013.