P E R S P E C T I V E S

PHOENIX CENTER FOR ADVANCED LEGAL & ECONOMIC PUBLIC POLICY STUDIES

Assessing Broadband Policy Options: Empirical Evidence on Two Relationships of Primary Interest

George S. Ford, PhD*

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The Biden Administration and the U.S. Congress are contemplating spending tens of billions of dollars on policy interventions to increase the deployment of broadband networks with the objective of increasing broadband adoption. While several proposals are on the table, it appears that there are two types of subsidies under consideration: (1) subsidies for new network deployment to unserved areas; and (2) subsidies for the construction and operation of government-owned networks in possibly already served areas for the purpose of reducing prices by increasing "competition."[1] Other policies to reduce price, including rate regulation, are also being considered.

Economics has much to say about allocating resources among varied policy options, with the over-riding prescription that subsidy dollars should be spent where the payoff is highest.[2] Though the "best" mixture of funding across the options presented here is a complex issue, much headway may be made by quantifying two empirical relationships: (1) the relationship between adoption and network *availability*; and (2) the relationship between adoption and broadband service *price* (i.e., the own-price elasticity of demand).[3] (This latter relationship speaks to several policy options including, among others, rate regulation and consumer subsidies.)

In this PERSPECTIVE, I use data on broadband, adoption (for fixed services including cable, DSL, and fiber) and an index of broadband prices to estimate both relationships. Other things equal, the data suggest that a home newly-passed by a broadband network has a very high probability of adopting broadband, not unlike the average adoption rate (about 85%). Expanding broadband availability to unserved areas will have a potent effect on adoption.

Though the "best" mixture of funding across the options presented here is a complex issue, much headway may be made by quantifying two empirical relationships: (1) the relationship between adoption and availability; and (2) the relationship between adoption and price (i.e., the own-price elasticity of demand).

The data are much less encouraging about expanding adoption through pricing policies. The own-price elasticity of demand is estimated to be approximately -0.50 at the sample mean price, indicating a rather weak response of adoption to price reductions (a 10% price drop increases adoption by only 5%). Consumers' inelastic response of adoption to price suggests price-based policies—whether directly-regulated price reductions or price reductions putatively induced from the insertion of a subsidized competitor—will do little to expand adoption.[4]

A policy's effect on adoption is not the sole consideration. Policies to encourage increased broadband adoption must be evaluated relative to their costs, and not just their effectiveness at increasing adoption. Expanding availability to unserved areas is a costly policy with a high adoption payoff. Price cuts, conversely, have a relatively small effect on adoption, but many price-based policies are similarly costly. While quantifying the relative net-benefits of the policy options is beyond the scope of this work, the evidence does suggest expanding availability is likely to provide the largest benefits.

Economic Framework

The primary broadband policy proposals presently under consideration may be categorized as being of two types: (1) expanding availability; and (2) reducing prices. Lower prices may arise from price regulation or competition. A simple demand curve figure illustrates, albeit crudely, the impacts of these policy options.

Figure 1. Policy Impacts

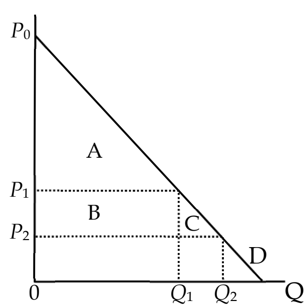


Figure 1 illustrates an aggregate demand curve (labeled D), with price on the vertical and quantity on the horizontal axis, for broadband subscriptions in a hypothetical market. There are three price-quantity pairs: at price P_0 the quantity is zero; at price P_1 the quantity is Q_1; and at price P_2 the quantity is Q_2. In unserved markets, broadband cannot be purchased at any price and the quantity is zero. Thus, we may view the demand curve D as the latent demand for broadband in unserved markets. (I ignore here the fact an unserved market presumably has much higher costs than does a served market.)

Consider first the policy of new availability of broadband service. Without broadband available, the "price" faced by households is essentially infinite (or P_0 in Figure 1)—broadband cannot be purchased at any price. Expanded availability at price P_1 obtains subscription increases of quantity Q_1 (from zero). This effect on adoption is large, as it reflects a very large hypothetical price cut, from an infinite price to some finite price at which quantity demanded is positive. The gain in consumer surplus is the triangular area labeled A in the figure; economic welfare increases by the surplus minus the cost of deployment (assuming prices exceed operating costs).

Consumers' inelastic response of adoption to price suggests price-based policies—whether directly-regulated price reductions or price reductions putatively induced from the insertion of a subsidized competitor—will do little to expand adoption.

Now consider the effect of a price reduction in a market where broadband already is available to all households. If price is reduced from P_1 to P_2, then adoption rises from Q_1 to Q_2. In the figure, this effect is much smaller than the effect on adoption from expanding broadband availability (for a market of equal size and similar preferences to an unserved market). The increase in consumer surplus from a price reduction equals the area C; the area B is a transfer from households of one type (investors) to households of another type (broadband subscribers). A more inelastic (steeper) demand curve makes for a smaller area C, so price cuts are mainly transfers (the area B).[5] Note that these surplus changes do not measure welfare effects since the welfare change includes the costs of obtaining the new surplus. For instance, obtaining the area A requires the construction of a costly network.

The own-price elasticity of demand describes how much quantity changes for a given price reduction, and is computed using

$$\eta = \frac{\Delta Q/Q}{\Delta P/P} = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q} \quad (1)$$

or the percentage change in quantity divided by the percentage change in price (which is dimensionless in Q and P). By the law of demand, the elasticity is always negative, though it is often expressed in absolute value terms. If η is smaller than 1.0 (in absolute value), then demand is described as inelastic; demand is elastic if η is greater than 1.0 (in absolute value). When demand is inelastic, the response to quantity is small relative to the percent change in price. That is, consumers are not very sensitive to price changes. The own-price elasticity of demand is typically not constant across prices and becomes more inelastic at lower prices (or, higher quantities). A monopolist prices in the elastic region of demand, so inelastic demand suggests the presence of competition.[6]

With broadband adoption at about 85% for the nation, the expectation is that η is inelastic.[7] A crude approximation may be made by considering an extreme case: say the average price for broadband is $60 and if price were cut to zero then the adoption rate is 100% (though it may exceed 100% as some homes may have multiple connections at a price of zero). The slope of the linear demand curve ($\Delta Q/\Delta P$) is -0.003, so the price elasticity is about -0.22 by Equation (1). While this approach is only a rough approximation, it does suggest that the own-price elasticity will be small simply because the adoption rate is already so high.[8]

On the own-price elasticity of demand, a caveat is worth mentioning. In markets where there are multiple services of varying qualities sold at different prices, as with broadband services, there is not a *single* own-price elasticity—there are many own-price and cross-price elasticities. An estimate of a single own-price elasticity of demand, as is done here, should be thought of as some type of average effect of price on adoption.

Two key empirical relationships of interest for evaluating broadband policy are set forth in this analysis. First, what is the relationship between adoption and availability: $\Delta Q/\Delta H$, where H is "homes passed." Second, what is the relationship between adoption and price reductions, which is measured by η. Estimates of these two relationships are of considerable policy relevance, and I turn to estimating those relationships now.

…the demand for broadband is highly inelastic.

Data

Estimating these two relationships of interest requires data on adoption, availability, and price. Adoption data are obtained from the one-year estimates of the American Community Survey ("ACS") for year 2019. This microdata sample consists of over three million respondents. The one-year estimates of the ACS are drawn from cities larger than 65,000 persons, and this limitation to larger areas may introduce some bias in the estimates. Aside from the respondent, the lowest level of geographic aggregation in the data in Public Use Microdata Areas ("PUMA"), which contain not fewer than 100,000 persons. All analysis is conducted at the PUMA level. There are 2,345 PUMA in the estimation sample, so the sample is quite large.

Broadband availability for each PUMA is constructed using the June-2019 Form 477 data, which is available at the Census Block level. As the ACS does not inquire about broadband services of a particular speed (say, 25/3 Mbps) but simply asks whether the respondent has a high-speed connection ("using cable, fiber or DSL service"), the broadband availability share (*H*) is computed with Form 477 data using speeds of 10 Mbps download and 1 Mbps upload speeds to best match the adoption data. Satellite services are excluded from the analysis.[9] Availability is a household-weighted share at the PUMA level (using 2010 households).[10]

Data on the cost of providing broadband service at the census block level is obtained from CostQuest.[11] The cost data is linked to the Form 477 data at the block level and aggregated to the PUMA. The cost data includes six cost groups that when aggregated produce a share of homes in each cost group. Variables measuring the summed share of the two lowest cost groups and the share of highest cost group are used.

Price data for what households actually pay for broadband service are unavailable. In its place, a sample of broadband prices in different geographies is obtained from BroadbandNow.[12] This source provides price data for what BroadbandNow claims to be the lowest-priced broadband service (meeting the 25/3 Mbps standard) at the five-digit zip code level.[13] Zip codes are linked to PUMAs using the cross-walk provided by Geocorr 2018.[14]

Ideally, the price variable would be a measure of average prices actually paid by consumers at the margin of subscriptions (i.e., new subscribers).[15] Such data are not available. To what extent these minimum prices measure actual consumer experience is unknown, though the sample mean (about $46) appears below the standard folk evidence for average prices (about $60).[16] Still, if the minimum prices are correlated with average prices faced by households at the margin of adoption, which seems plausible though untestable, then the estimated elasticity is a valid one.[17] All results, of course, are conditioned on the validity of these prices as a measure of actual experience.

Estimation

The demand curve for broadband services is estimated by the regression,

$$Q_i = \beta_0 + \beta_1 P_i + \beta_2 H_i + \Omega X_i + \varepsilon_i \qquad (2)$$

where for area *i* (a PUMA) Q_i is the broadband penetration rate, P_i is the monthly price, H_i is broadband coverage (10/1 Mbps), X_i is a set of covariates including family income, the share of persons with at least some tertiary education, and the minority share of the population (Hispanic, Black, and Native American), and ε_i is a heteroskedastic disturbance term.

Since Q_i and P_i may be jointly determined, the equation is estimated by Instrumental Variables ("IV") regression.[18] Excluded instruments for price are two cost variables and population density. As a robustness check, I also estimate the bounds on the price coefficient (β_1) assuming imperfect instruments using the approach of Nevo and Rosen (2012).[19]

Results

Equation (2) is estimated by two-step feasible Generalized Method of Moments ("GMM") for the 2,345 observations. Since the dependent variable is a proportion, the disturbance is heteroskedastic (by definition), so robust standard errors are used for all hypothesis tests. I consider two model specifications. Model A has price and income in linear form (a lin-lin model) while Model B applies the natural log transformation to both variables (a lin-log model).[20] The lin-log specification implies a non-linear and convex demand curve.

Results are summarized in Table 1. All the coefficients on the covariates are of expected sign and all are statistically significant at the 5% level or better. Price, age, and minority share have negative coefficients while broadband coverage, tertiary education, and income have positive coefficients. The Psuedo-R^2 are quite large for cross sectional data and larger for the lin-log specification.[21]

Table 1. Regression Results

	Model A: lin-lin	Model B: lin-log
P	-0.008***	-0.383***
H	0.858***	0.813***
Income	0.020**	0.044***
Tertiary	0.187***	0.122***
Minority	-0.189***	-0.192***
Constant	-0.222	1.416***
N	2,345	2,345
F-stat	203***	234***
Psuedo-R^2	0.214	0.233
95% C.I. on β_1	-0.010, -0.007	-0.446, -0.321
Nevo-Rosen Bounds	-0.010, -0.006	-0.471, -0.285

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

From a statistical standpoint, the IV estimation is acceptable. The null hypothesis that the equation is under identified is rejected at the 1% level (by the Kleibergen-Paap rk LM statistic) and the Cragg-Donald Wald F-statistic easily exceeds the Stock-Yogo critical values.[22] The joint null hypothesis that the instruments are valid is not rejected at anywhere near traditional levels (by Hansen's *J* statistic).[23] Finally, the null hypothesis of the Hausman test that price is exogenous (uncorrelated with the disturbance) is rejected at the 1% level.[24] The 95% confidence interval of the price coefficient and the 95% Nevo-Rosen bounds of the price coefficient are provided in the last two rows of the table.[25]

…price regulation is unlikely to have a material effect on economic welfare and would consist mostly of transfers (since the change in quantity is small).

Own-price and income elasticities may be calculated from the coefficients on price (*P*) and income. Table 2 summarizes these elasticities for the two specifications computed at the sample means. The elasticities are almost identical across the two specifications. The 95% confidence interval of the elasticity estimate and the Nevo-Rosen bounds are reported. The price elasticity is estimated to be just under -0.50 in both models. The 95% confidence intervals of the elasticity and the Nevo-Rosen bounds are comparable with the elasticity ranging from -0.58 to -0.33. Thus, the demand for broadband is highly inelastic.

Table 2. Elasticities

	Model A: Lin-Lin	Model B: Lin-Log
Price Elasticity	-0.46	-0.47
95% Conf. Interval	-0.58, -0.40	-0.56, -0.40
Nevo-Rosen Bounds	-0.55, -0.33	-0.58, -0.35
Income Elasticity	0.03	0.05

The estimated elasticity is comparable to other estimates. Though using an admittedly crude calculation, Rosston and Wallsten (2019) estimate the own-price elasticity of demand for broadband (for low-income households) to be only about 0.10 to 0.13.[26] Using data better suited to estimate an own-price elasticity, Carare, McGovern, Noriega, and Schwarz (2015) report an own-price elasticity of demand of 0.67 among non-adopters.[27] Using survey evidence from 2019, Williams and Zhao (2020) estimate an own-price elasticity of -0.08.[28] All three studies report an inelastic response of adoption to price changes, indicating that while price cuts may increase adoption they are not be a panacea for universal adoption.

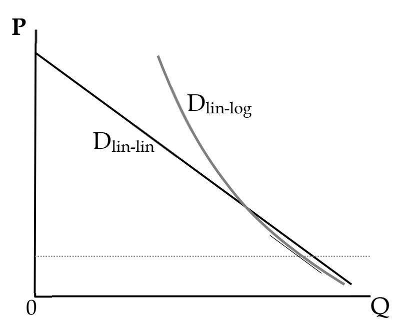
Table 3 summarizes the price elasticities at various price points. The table illustrates the difference functional form has on the results. For the lin-lin model, the elasticities range from about -1.25 to -0.26 between $80 and $30, while the range is only -0.67 to -0.40 for the lin-log model. This difference is not surprising, since the Lin-Log specification is non-linear (convex) in price.[29]

Table 3. Elasticities at Price Points

Price	Model A: Lin-Lin	Model B: Lin-Log
$80	-1.254	-0.667
$70	-0.947	-0.661
$60	-0.714	-0.558
$50	-0.531	-0.506
$40	-0.384	-0.455
$30	-0.263	-0.402

We can see the difference in the specifications in Figure 2. The lin-log specification is non-linear in price (and convex) whereas the lin-lin specification in linear in price. The choke price for the lin-lin specification (the intercept) is about $150 (or P_0 in Figure 1) and $330 for the lin-log specification. The dashed horizontal line is the sample average price where the two elasticities are approximately equal.

Figure 2. Demand Specifications



An inelastic demand for broadband points to several policy relevant facts. First, price reductions are unlikely to have a sizable effect on adoption—a 10% reduction in price increases adoption by a little less than 5%. Second, on average, broadband prices are not monopolistic since a monopolist sets price in the elastic region of demand. Third, price regulation is unlikely to have a material effect on economic welfare and would consist mostly of transfers (since the change in quantity is small). Fourth, subsidized competition, which has little-to-no support in economic theory, is unlikely to improve adoption rates by much even if it lowers price as networks are costly to build and the adoption effects are small. All these findings are a consequence of the small response of adoption to price cuts.

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The effect of expanded availability is approximately measured by the coefficient on the *H* variable. The coefficient is about 0.84 across the two models, suggesting that increasing homes passed by 100 homes increases adoption roughly by about 84 homes. With broadband adoption at about 85% today, the result suggests homes newly passed by a broadband network will increase adoption at about the average adoption rate. This result is encouraging and suggests expanding availability will have a high adoption payoff.

The income elasticity is about 0.04, so broadband is a "normal" good (i.e., consumption rises with income). The elasticity is relatively small, however, so broadband is not a "luxury" good (i.e., a good whose income elasticity is greater than 1.0). This result comports with the idea that today broadband is more of a necessity than a luxury.

Estimating Costs and Benefits

As intuition suggests and the empirical results show, expanding availability has a sizable effect on adoption. The increase in consumer surplus (area A in Figure 1) could be sizable, though such benefits must be offset by the cost of deploying network. Assuming 15% of homes are presently unserved and that 85% of those homes would subscribe to broadband if it were available (adding 17.9 million new subscribers), the annual consumer surplus for expanding availability to all Americans is about $9.6 billion annually, about $90 billion in present value over 10 years, and about $180 billion in present value over 20 years. This amounts to a per-home added surplus of about $540 a year (or $5,000 in 10-year present value and $10,000 in 20-year present value).[30] The cost to deploy broadband to these unserved homes is estimated to be about $60 billion to $80 billion (ignoring the social cost of obtaining subsidy dollars), so the cost-benefit calculation (based on consumer surplus) is favorable based on the 10-year present value (based on private surplus alone).[31] Certainly, some households will cost well more than $5,000 to serve, so justifying federal subsidies in such cases must be based on some sort of social payoff from increased connectivity.[32]

... broadband prices are not monopolistic since a monopolist sets price in the elastic region of demand.

Consider, alternately, the effects of a 10% price cut off a $60 average price (or $6) posited to result from the subsidized entry of a municipal broadband network (a generous assumption, given the lack of any evidence of a price effect). If such a cut is applied nationally, then adoption increases from 85% to 89.3%, adding 5.95 million homes to the broadband "haves."[33] The reduction in dead-weight loss (area C in Figure 1) is only $214 million, well below the $9.6 billion in benefits of extending networks to unserved areas or imposing rate regulation.[34] While the average addition to consumer surplus from passing a new home is $540, the average surplus from the price cut is only $36 per new adopter.[35]

Price cuts make for small additions to surplus (due in part to the inelastic demand) and will certainly fall well below the cost of producing them. Under no plausible scenario (and most implausible ones) would subsidized overbuilding make sense from an economic perspective with the costs per home passed in the thousands of dollars.[36] Similarly, price regulation is unlikely to draw a material increase in adoption but it would impose substantial administrative costs and produce unintended consequences as firms respond to the regulation.

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Conclusion

As the federal government contemplates policy interventions in the broadband marketplace, empirical evidence on the nature of that market may help produce better policy. In this PERSPECTIVE, a few of these important empirical relationships are quantified. In all, the results suggest that programs aimed at expanding availability to unserved areas are likely to have larger positive effects on broadband adoption than are price-based policies such as subsidized GON overbuilding. Passing unserved homes with a new broadband network increases subscriptions at essentially the embedded mean adoption rate, which is very high (85%). A cost-benefit analysis, at least for many currently unserved homes, seems likely to succeed (based on surplus gains). In contrast, the inelasticity of demand suggests price cuts implemented through direct price regulation or subsidized overbuilding are both unlikely to have material effects on adoption and produce small benefits.

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 There is no compelling evidence that municipal overbuilds reduce prices in markets that are served absent a government-owned network and the cross-subsidies required for the municipal networks distort rather than promote competition. *See*, *e.g.*, T.R. Beard, G.S. Ford, L.J. Spiwak, and M. Stern, *The Law and Economics of Municipal Broadband,* 73 FEDERAL COMMUNICATIONS LAW JOURNAL 1 (2020) (available at: http://www.fclj.org/wp-content/uploads/2020/09/MunicipalBroadbandArticleFINAL.9.2.20.pdf).

2 T.R. Beard, G.S. Ford and M. Stern, *Bridging the Digital Divide: What Has Not Worked But What Just Might*, PHOENIX CENTER POLICY PAPER NO. 56 (June 2020) (available at: https://www.phoenix-center.org/pcpp/PCPP56Final.pdf).

3 Competition also may strike at non-price margins, but that possibility is ignored here.

4 *C.f.* G.S. Ford, *Confusing Relevance and Price: Interpreting and Improving Surveys on Internet Non-Adoption,* 45 TELECOMMUNICATIONS POLICY (March 2021) (available at: https://doi.org/10.1016/j.telpol.2020.102084).

5 Transfers are sometimes viewed as taking money from firms and giving it to consumers—a shift taken as favorable in certain circles. In fact, only humans care about money; a firm is a merely a legal device representing a collection of humans. Thus, a transfer is taking money from one group of humans and giving it to another group of humans. Only the dead weight loss (area C) is newly created surplus.

6 The own-price elasticity of demand equals -1.0 when marginal cost is zero; demand is elastic when marginal cost is positive. Since a monopolist sets output where marginal revenue equals marginal cost (which is always positive), the monopolist will set its price in the elastic region of demand.

7 U.S. Census data shows broadband adoption in the home to be 85.7% in November-2019 (available at: https://www.ntia.doc.gov/data/digital-nation-data-explorer#sel=wiredHighSpeedAtHome&disp=map). In this sample, the percent of homes with broadband connections is about 83%.

8 Broadband is likely an experience good. As such, it may be that inframarginal users, having experienced broadband, have more inelastic demand than marginal users (a kinked demand curve). *See*, *e.g.*, A. Okun, PRICES AND QUANTITIES: A MACROECONOMIC ANALYSIS (1981); S. Drakopoulos, *A Behavioral Approach to Kinked Demand Curves*, MPRA PAPER No. 90373 (1992).

9 Excluding fixed wireless services has no meaningful effect on the estimates.

10 Adoption and availability are obtained from disparate sources and consequently are unlikely to match up exactly.

11 George S. Ford, *Form 477, Speed-Tests, and the American Broadband User's Experience,* PHOENIX CENTER POLICY PERSPECTIVE NO. 21-03 (March 31, 2021) (available at: http://www.phoenix-center.org/perspectives/Perspective21-03Final.pdf).

12 Data available at: https://github.com/BroadbandNow/Open-Data/blob/master/broadband_data_opendatachallenge.csv.

13 The variable is defined as: "Lowest Priced Terrestrial Broadband Plan: The Lowest Regular Monthly Priced Terrestrial (Wired + Fixed Wireless) Residential Standalone-Internet Broadband (25 Mbps Download/3 Mbps Upload) Plan available in the zip."

14 Available at: https://mcdc.missouri.edu/applications/geocorr2018.html.

15 Since the data do not match the price to a provider and include terrestrial wireless providers, it is not possible to determine whether the price is for a large provider or a provider that serves only portions of the market. This is regrettable because doing so would have permitted analysis to be focused on zip codes where the stated price is likely to be widely available.

16 C. McNally, *How Much is Internet?*, REVIEWS.ORG (December 8, 2020) (available at: https://www.reviews.org/internet-service/how-much-is-internet).

17 Actual experience is influenced by the tier of service and prices may vary by speed.

NOTES CONTINUED:

18 The model is estimated using `-ivreg2-` in Stata 17.

19 A. Nevo and A.M. Rosen, *Identification with imperfect instruments*, 94 REVIEW OF ECONOMICS AND STATISTICS 659-671 (2012). This procedure is implemented in Stata 17 using the `-imperfectiv-` command.

20 A log-log specification is feasible since the dependent variable is not zero. Yet, the adoption rate is on the unit interval, so the log-log specification is not generalizable. The estimated elasticity from the log-log specification is comparable to those of the other models.

21 The Psuedo-R^2 is computed as the squared correlation coefficient of the model's prediction and the actual dependent variable.

22 E. Sanderson and F. Windmeijer, *A Weak Instrument F-Test in Linear IV Models with Multiple Endogenous Variables*, 190 JOURNAL OF ECONOMETRICS 212-221 (2015); J.H. Stock and M. Yogo, *Testing for Weak Instruments in Linear IV Regression*, in D.W.K. Andrews and J.H. Stock, eds., IDENTIFICATION AND INFERENCE FOR ECONOMETRIC MODELS: ESSAYS IN HONOR OF THOMAS ROTHENBERG (2005) at pp. 80-108.

23 F. Hayashi, ECONOMETRICS (2000) at pp. 277-8.

24 *Id*., at pp. 233-4. I note that the price coefficient is positive (though very small) for least-squares regression.

25 The ordinary least squares estimate of the price coefficients are negative and statistically significant in both models, but both are close to zero (-0.00037 and -0.0164) and imply own-price elasticity estimates of about -0.02.

26 G.L. Rosston and S. Wallsten, *Increasing Low-Income Broadband Adoption through Private Incentives*, Working Paper (available at: https://ssrn.com/abstract=3431346).

27 O. Carare, C. McGovern, R. Noriega, and J. Schwarz. *The Willingness to Pay for Broadband of Non-Adopters in the U.S.: Estimates from a Multi-State Survey*, 30 INFORMATION ECONOMICS AND POLICY 19-35 (2015).

28 M.A. Williams and W. Zhao, *Expert Report of Michael A. Williams and Wei Zhao*, NTCA–The Rural Broadband Association (May 7, 2020) at Table 7 (available at: https://www.ntca.org/sites/default/files/documents/2020-05/2020-05-07%20-%20Williams-Zhao%20report%20Final.pdf).

29 Including price and its square in the lin-lin model points to a convex function in the relevant range.

30 This estimate is based on expanding availability to 21 million homes (15% of 140 million), 85% of which adopt, with a maximum willingness to pay of $150 monthly (the choke price from the estimated lin-lin demand curve) and a market price of $60. The consumer surplus (area A in Figure 1) is 0.5[(150-60)·12·140000000·0.15·0.85]. At a 1.4% real discount rate, the NPV factor is 9.6 and the 20-year factor is 18.6. *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs: Appendix C*, OMB CIRCULAR NO. A-94 (Revised November 2018).

31 J. Engebretson, *Economists Put the Tab at $61 Billion to Bring Fiber Broadband to Rural U.S.*, TELECOMPETITOR (July 11, 2018) (available at: https://www.telecompetitor.com/economists-put-the-tab-at-61-billion-to-bring-fiber-broadband-to-rural-u-s); S. Donaldson, *Rural Broadband is an $80 Billion Problem*, Farm and Dairy (October 28, 2020) (available at: https://www.farmanddairy.com/news/rural-broadband-is-an-80-billion-problem/636030.html).

32 A discussion of such social premia are provided in T.R. Beard, G.S. Ford, L.J. Spiwak, and M. Stern, *The Broadband Adoption Index: Improving Measurements and Comparisons of Broadband Deployment and Adoption*, 62 FEDERAL COMMUNICATIONS LAW JOURNAL 343 (2010) (available at: https://www.phoenix-center.org/papers/FCLJBAI.pdf).

33 The new adoption rate is 0.85(1+(-0.1)(-0.5)) and the number of new subscribers is 140,000,000(0.85(-0.1)(-0.5)).

34 The surplus gain is $\Delta P \Delta Q/2$ or 72*5,950,000/2.

35 The average surplus gain is 214,200,000/5,950,000 for new subscribers.

36 Entry above the equilibrium number of firms reduces welfare and subsidized entry worsens the effects. *See*, *e.g.*, *The Law and Economics of Municipal Broadband*, *supra* n. 1. Moreover, the effect of competition is baked into the subsidies for network construction, so most of the added surplus is offset directly by increased taxes which imposes costs of their own. From an economic standpoint, subsidizing overbuilding is not a sensible policy—it is decidedly a non-economic idea.