APPENDIX B: TECHNICAL ANALYSIS OF RESIDENTIAL ACCESS TO BROADBAND

TO

THE RESIDENTIAL AND COMMERCIAL BENEFITS OF RURAL BROADBAND: EVIDENCE FROM CENTRAL APPALACHIA

FINAL REPORT

JULY 2005

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Introduction

This appendix describes the econometric methods employed the results and a discussion of the strengths and limitations of each of the findings for residential demand. A summary of the data employed in detailed review of this literature is included in a separate appendix, as are the technical details of our estimates of commercial impacts. We report much of our findings in the text, and to limit duplicative reporting, will focus this section on diagnostics, and findings not specifically included in the text of the main report.

The Regional Access Model

In evaluating our region we tested a model similar to those extant in the literature (e.g. Grubesic, 2002; and others). Our model sought to evaluate the regional

characteristics at the zip code level that would predict broadband access. Our model of choice is a probit model which allows us to estimate the marginal contribution of variables to the probability of the zip code enjoying residential broadband access. Specifically we test the following model:

Equation B-1

$$\Pr(Y_1 = 1 | x_i\beta) = 1 - f(-x_i\beta)$$

where the probability of a region *i* having broadband access is a function of the explanatory variables x_i and their estimated coefficients. This is known colloquially as the Probit model. We report the marginal probability for ease of interpretation. The marginal probability is estimated at the mean of the individual variable values.

Table B-1, Probit of Broadband Access, 2000 n=4,382

Variable	Marginal Probability
Median HH Income	.464511D-05***
Percent Population aged 5 to 24	0.51546513***
Percent Population aged greater than 65	0.12561247**
Percent of Adults without High School Diplomas	-0.64198532***
Age of House	-0.00094726***
Population Density	.380459D-04***
McFadden's R2	0.08
Positive Prediction Success	.70
Negative Prediction Success	.611

We note in the text that the quality of the statistical fit between broadband access and these demographic data decline over time. We come to this conclusion by estimating this model (using 2000 Census values throughout) on broadband access data for each year, 1999-2003. The goodness of fit statistic (McFadden's R2) declines from roughly .16 to .07. This change may be attributable to two possible dynamics (or a combination thereof). First, the underlying Census data must be changing over this sample period thus weakening the relationship between broadband access and the demographics. Second, the rapidly growing access to broadband is weakening the statistical relationship between

broadband and the regional demographics. We believe the latter is undoubtedly the stronger effect.

Residential Demand for Broadband

Several studies of residential demand for broadband access have emerged in journals, conference presentations or as working papers.[1] These studies evaluate individual data, including price, access choice and demographic characteristics. Broadband uses are also a potential feature of these studies. Perhaps the most important feature of many of these studies are estimates of the price elasticity of access for broadband. This is one of the four major research topics for broadband identified by the Rand Institute.[2] The following table provides a summary of these studies findings, a graph of which appears as Figure 3, pg 15 of the main study test.

Table B-2, Residential Broadband Access Elasticities

Study	Year of Data	Hi	Lo	Med
Goolsbee (2001)	1999	-3.76	-2.15	
Faulhaber and Hagendorn (2000)	1999			-1.53
Rappaport, Kridel, Talyor and Alleman (2004)	2000			-1.491
Crandall, Sidak and Singer (2002) {Cable Hi, DSL lo}	2000	-1.184	-1.22	-1.491
Kridel, Singer and Rappaport (2000)	2000	-1.79	-1.079	
Duffy-Deno (2000)	2000	-1.35	-0.81	-1.08
Duffy-Deno (2001)	2000			-0.59
Varian (2002)	2001	-3.1	-1.3	
Gilmour (2002)	2001	-2.06		
Chaudhuri & Flynn (2005)	2002	-0.04	-0.04	
Yankee Group (2005)	2002	-0.76	0	-0.38
Crandall, Jackson and Singer (2003)	2003	-0.14	-0.09	
Ipsos Insight (2003)	2003			-2.8
Ida (2005)	2003			-0.15
Burton & Hicks, This study (2005)	2005	-0.005	-0.003	

Our estimates of these elasticities of access were performed by testing the data on the survey described in Appendix A. We employed an ordered logit, a technique which

[1] See Goolsbee, 2001; Rappaport, Kridel, Taylor and Alleman, 2004; Crandall, Sidak and Singer, 2000; Kridel, singer and Rappaport, 2000; Chaudhuri and Flynn, 2005 and Crandall, Jackson, and Singer, 2003 and Faulhauber and Hagendorn, 2000.

[2] Balkovich, Edward, Walter S. Baer, and Ben Vollaard (2003) Research Topics for Informing Broadband Internet Policy, Issue Paper, Rand.

was earlier applied by Rappaport, Kridel, Taylor and Alleman [2004]. We begin with the relationship

$$y = \beta' X + e$$

where

$$y = [0,1,2]$$

When the respondent has not internet access, dial-up or broad respectively. Thus, the ordered logit takes the form:

$$\text{Prob}\begin{pmatrix} y = 0 \\ y = 1 \\ y = 2 \end{pmatrix} = \Phi\begin{pmatrix} -\beta' X \\ u_1 - \beta' X + \beta' X \\ u_2 - \beta' X - u_2 + \beta' X \end{pmatrix}$$

These results were reported in the text as Table 2 (page 13). The standard errors were calculated using the Huber-White method.[3]

As noted in the text, this model included an imputed price for individuals in zip codes where the actual price was known. This method was employed to provide a price estimate in this specification, which is obviously desirable. The results of this estimate are for a price elasticity of access which is neither economically nor statistically different from zero. Alternatively, we could test the model without price, which provides us insight on the remaining variables (without the concerns of employing the imputed price). A comparison of the coefficients between the two methods provides a de facto robustness test of the model. Table B-3 contains these estimates for the Logit specification.

[3] Huber, P.J.. 1967. "The behavior of maximum likelihood estimates under non-standard conditions." *Proceedings of the fifth Berkeley symposium on mathematical statistics and probability.* Vol 1: 221-223.. Berkeley, CA: University of California Press. and White, Halbert (1980) "A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity." *Econometrica.* 48: 817-838.

Table B-3, Dial-up or Broad for Internet Broadband Access
(Ordered Logit Estimates, Models with and without imputed Price)

Variable	Coefficient	Coefficient
Have Broadband at Work	-0.242714**	-0.290128***
Number of Adults in Family	0.781561***	0.77337***
Number of Kids in Family	0.595455***	0.476195***
Age of Youngest Family Member	-0.012353	0.019346
Percent Population > 25 with BA degree	-4.766761	5.191601**
Median Age	-0.045488	0.001716
Median HH income	0.0000835***	0.0000386***
Broadband Price (actual, but not necessarily known)	0.004993	…
c1	1.209799	2.987228**
c2	2.214068	4.255908***
Pseudo R^2	0.11	0.10
Likelihood Ratio Statistic (8 d.f.)	65.19***	124.42***
Akaike Information Criterion	1.94107	1.93602

***** statistically significant to the 0.01 level, ** statistically significant to the 0.05 level, * statistically significant to the 0.10 level, † statistically significant to the .20 level.**

Clearly, the two models perform quite similarly with very similar magnitudes. The sole notable difference is the impact of education which changes from zero to positive, and highly significant. The important results (other than confirming our interpretation of opportunity cost) are that access elasticity of demand is best viewed as not different from zero.

Summary

The econometric techniques and the modeling approaches used here represent no theoretically novel elements. The initial probit analysis confirms earlier findings that the dominant influences on regional broadband access are educational attainment and age structure. The ordered logit model offers challenges that are unlikely to be treated with a strategy which differs dramatically from that which we have attempted. Given the rather low percentage of survey respondents who are familiar with broadband price, our study (like others before it) have applied an imputed price (the actual, though not necessarily

known price) to estimate demand. This is a strategy employed by earlier researchers, and will likely extend to future analysis.

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