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

Final Report

July 2005

Prepared for:

West Virginia Development Office, A Vision Shared

Prepared by:

Mark L. Burton
Michael J. Hicks

CBER
MARSHALL UNIVERSITY
CENTER FOR BUSINESS AND ECONOMIC RESEARCH

Center for Business and
Economic Research
Marshall University
One John Marshall Way
Huntington, WV 25755

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Mark Burton, Research Professor – Marshall University,
Director of Transportation Economics, University of Tennessee – Knoxville

Michael J. Hicks, Research Professor – Marshall University,
Associate Professor of Economics, Air Force Institute of Technology

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Mike Swatts, *Frontier Communications*

Executive Summary

Introduction

Internet access via broadband telecommunications services is widely available throughout much of West Virginia. Indeed, 93 percent of zip codes have access to one or more high speed service providers.[1] Moreover, broadband usage is growing at blistering rate, with the number of subscribers increasing by well over 50 percent between December 2003 and December 2004 to a total of more than 155 thousand.[2]

Still, there are more than a few rural communities where broadband, high speed services are not available. This fact, combined with the growth in the number internet applications that require relatively high access speeds, has lead many rural residents and the policy-makers who represent them question whether current state policies are sufficient in this area. It is within this context that Marshall University's Center for Business and Economic Research (CBER) was asked to measure, as well as possible, the economic benefits achievable through the extension of existing broadband networks into locations where high-speed services are currently unavailable.

Study Methodology

Available broadband benefits its users in a variety of ways. Commercial users derive utility through applications that allow them to increase productivity and lower costs. Government agencies and educational institutions also use high-speed internet applications to lower costs and extend services. Residential users derive increased utility through improved access to a variety of high-speed applications that often relate to entertainment. While government and other institutional usage is important, high speed services are generally already available to would-be users. Therefore the current analysis is focused on the potential benefits to new non-government commercial and residential users.

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[1] Throughout this analysis we adopt the Federal Communication Commission definition of "high speed". This definition includes any service with a one-way speed of at least 200 kbps. The presence of broadband in a zip code does not mean that broadband is universally available within that zip code.

[2] See *High-Speed Services for Internet Access: Status as of December 31, 2004*, Federal Communications Commission, Industry Analysis and Technology Division, Wireline Competition Bureau, July 2005

To capture the potential benefits to new commercial users, the study team engaged in three separate avenues of investigation. First, firm level data were used to investigate productivity differences between firms located in areas with broadband access and firms located in areas where access was unavailable. Next, the study engaged in a county-level four-state analysis of both aggregate and sector-specific wages, under the hypothesis that increases in productivity should yield higher wages. Finally, we engaged in an industry-specific (albeit, qualitative) investigation of firm locations.

The data describing household behaviors and preferences were developed directly through a survey of 600 West Virginia households. These data were supplemented with 2000 U.S. Census data where necessary. The household data lend themselves to a very rich qualitative interpretation. Additionally, the study team statistically modeled both the decision to acquire any form of internet access and the subsequent decision between alternative forms of access.

Analytical Results

With regard to potential commercial benefits, all three analytical paths suggest that high-speed access is important, particularly to firms within the Services and Finance sectors. These conclusions are consistent with previous published research in the field. Indeed, in West Virginia, workers in those two sectors earn between one and two thousand dollars a year more than similar workers when they are located in areas with high speed, broadband access. Moreover, there appear to be a number of industries that simply will not locate in areas where broadband is unavailable.

From a state-wide policy perspective, the results point to an ongoing success rather than any sort of notable failure. The business community and policy-makers alike have correctly contended that broadband telecommunications services can contribute to increased firm productivity. The analysis suggests that broadband *already is* making this contribution and that the vast majority of firms that can benefit are doing so. Accordingly, the aggregate state-wide benefits from extending broadband access to additional commercial users are modest when compared to the benefits already achieved under current state policies.

The analysis of residential usage was also very informative. Approximately 50 percent of the residences surveyed have some form of internet access and of those households that do subscribe to internet services 42 percent do so via broadband. Both figures are below the national averages of 66 percent and 51 percent respectively. This outcome is likely attributable to West Virginia's relatively older population and an observable deficit in educational attainment.

The econometric model suggests that while household size, family incomes, and broadband access at work are important predictors of broadband usage, broadband pricing is not. This result is completely consistent with the body of existing literature on residential demand for broadband. The combined research suggests that residential consumers of broadband are quite insensitive to price. In fact, the price elasticity of residential demand for broadband access appears to be rapidly approaching zero given currently observed prices.

Overall, the survey results indicate a tremendous lack of information. Of the sample group as a whole, 51 percent were unable to say whether or not broadband is available to their household. Of those households that subscribe to traditional dial-up services, very few could provide information regarding the pricing of any available broadband alternative. Together, these results suggest that, in aggregate, there is not a significant amount of unmet residential demand.[3]

Study Conclusions and Policy Implications

The analysis of the relationship between broadband availability and productivity suggests that many commercial subscribers are currently realizing productivity gains because of their broadband access. As a consequence, the economic benefits attributable to further network extensions are modest compared to the gains that have already been achieved. Similarly, the gains attributable to the network extensions necessary to reach additional residential customers appear to be modest based on the household survey results. In summary, to date, state-wide

[3] The study team is certainly aware that there are any number of communities with residential users who do not share our conclusion.

policies have been effective in securing the benefits of broadband for most West Virginians for whom any benefits are possible.

This conclusion is not, however, an invitation to complacency. New broadband technologies and applications are appearing almost daily. What constitutes adequate broadband availability today may be simply unacceptable within a handful of years. Today, state policies and state and federal regulatory regimes appear adequate, and available benefits have been largely realized without sweeping governmental intervention. However, vigilance is paramount in a setting wherein currently undreamed of technologies may be commercially available in less than a generation. The emerging relationship between broadband and health care delivery alone is probably sufficient to warrant continuous monitoring and ongoing policy discussions. Policy-makers must remain informed and be prepared to change course very quickly should conditions warrant such actions.

Finally, the analyses included within the current study were intended to measure potential state-wide benefits attributable to network extensions, given currently available technologies. It is very likely that a disaggregation would quickly reveal individual communities or areas that both desire and need help in attaining broadband services. An important inquiry would be to determine why broadband is not available in areas where there is demand for it. It is our observation that state-level leaders can (and do) play an important role in identifying and brokering solutions for these communities. State-level personnel are capable of developing a level of expertise that simply cannot be replicated in every community. Therefore, from an economic vantage, this form of state intervention is an important remedy for what would otherwise be problems of asymmetric information. Intervention could also take the form of education in communities that have not yet received the full benefits of broadband in terms of business productivity and/or residential utility.

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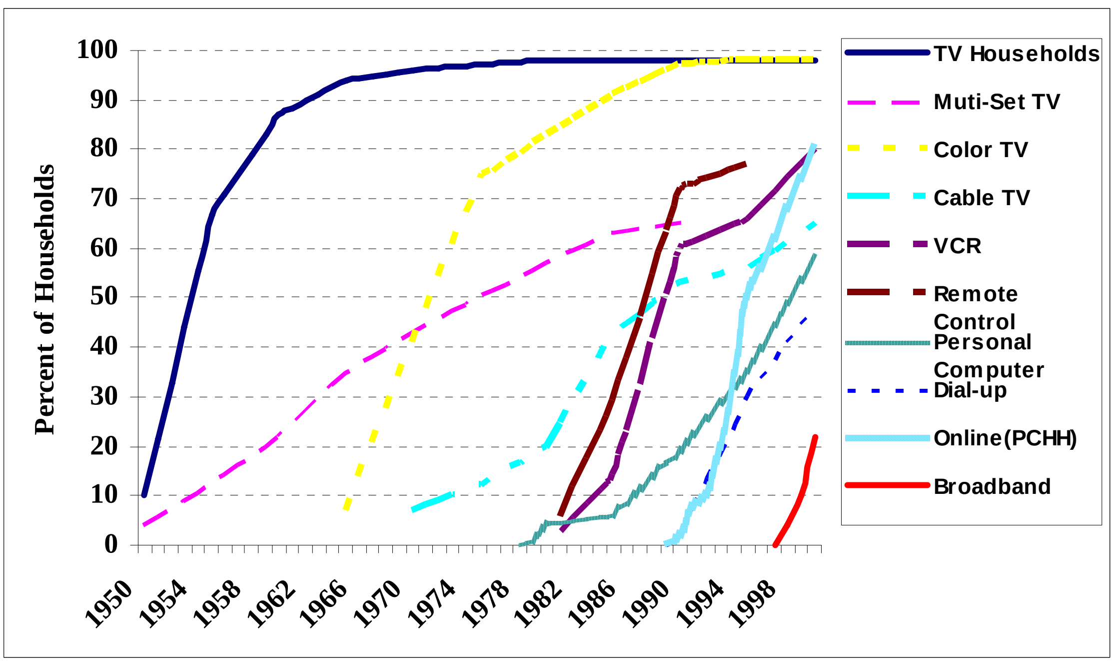
Figures and Tables

1. *Introduction and Motivation*

Loosely defined broadband is a set of telecommunications technologies used to transmit large volumes of digital information at high speeds. These technologies are valuable within the context of traditional data transmission applications and within a rapidly growing array of new commercial and residential applications. Perhaps because of the diversity of possible uses, broadband, as a whole, is being adopted more rapidly than nearly any other technological innovation, as the technology adoption curves provided in Figure 1 suggest.

Figure 1, Selected Technology Adoption Curves

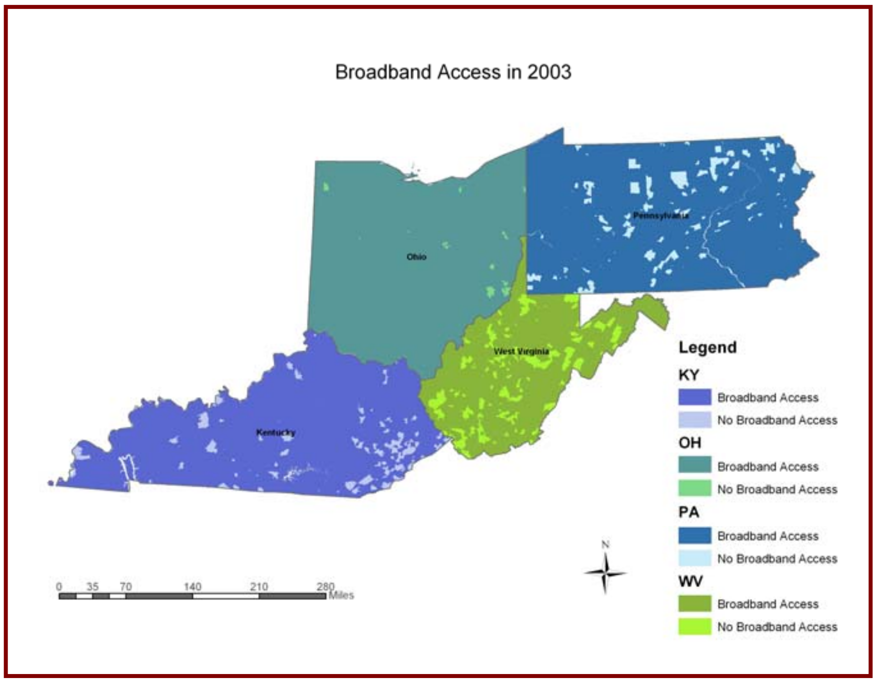


Source: Lilien, Rangaswamy and Van den Bulte [1999]; Owen, 2002; FCC

Given the rapidity with which broadband technologies have been embraced, it is not surprising that the emergence of these technologies has spawned a number of policy issues. These issues are made more complex by the diversity of broadband technologies. The two most widespread forms of broadband are (1) digital subscriber lines (DSL) supplied by local exchange telecommunications carriers and (2) two-way digital communications supplied by cable television providers over coaxial cable networks. Local exchange carriers also provide dedicated broadband lines to higher capacity users and there are rapidly emerging wireless technologies through which remote digital users can be connected to traditional Internet facilities.[4]

In most large urban markets, each competing technology is available to both business and residential customers, sometimes from a variety of competing sellers. Most other metropolitan populations have access to, at least, one of the available broadband technologies. However, in the very rural areas, where population densities are notably low, broadband access is often nonexistent. This is, in fact, the case for a measurable portion of West Virginia's population.[5] Broadband access within the region is depicted graphically in Figure 2.

Figure 2, Regional Broadband Access



[4] Throughout this report we employ the Federal Communications Commission definition of Broadband, both technologically and regionally. The FCC reports a zip code as possessing residential broadband service if at least one household receives service with at least 200Kbps of asymmetric data transmission. We are excruciatingly aware of the criticisms of these definitions. For example, mailing a small packet of CD's will meet this definition (Odlyzko, 2003). We are also quite certain that no better definition has emerged. As will be apparent in our recommendations, effective changes to the utility provided by broadband may play a role in future policy developments.

[5] As of December 2004, the Federal Communications Commission estimates that seventeen percent of West Virginia zip codes have no broadband access. Moreover, services are often confined to small geographic areas in zip codes where broadband is available. In all, as of December 2002, 6.7% of West Virginia's residents lived in zip codes not served by broadband telecommunications. (Federal Communications Commission. *High-Speed Services for Internet Access: Status as of June 30, 2004*).

Within the public policy arena, advocates of public intervention in the provision of broadband services appear to be prompted by two separate, but not mutually exclusive, motivations. These include: (1) a desire to intensify the level of competition for broadband subscribers in areas where services are currently offered by a limited number of providers; and (2) a desire to see some form of broadband services made available to potential rural users who currently have no broadband access. It is this latter concern which motivates the current analysis.

Within West Virginia, broadband advocates have proposed an array of policies for extending access into rural communities where it is currently unavailable. The suggested set of policy alternatives includes (but is probably not limited to): (1) state investment in telecommunications infrastructure; (2) the creation of some form of universal service fund to subsidize either the public or private extension of broadband networks; (3) municipal provision of broadband infrastructures through public-private partnerships; and (4) compelling incumbent broadband providers to extend existing networks more rapidly through the use of existing regulatory procedures.

Evaluating these (sometimes) competing policy alternatives is far beyond the scope of the current analysis. Instead, the current study effort focuses on one lone task. We seek to evaluate the scope and magnitude of the benefits rural users can anticipate if broadband telecommunications reaches their communities. By providing these estimates, we hope to better inform subsequent discussions of specific telecommunication policy alternatives.

2. *Economic Benefits to Rural Users*

There are three specific sources of potential economic benefits in the event that broadband services are extended to rural communities where they are currently unavailable. These include: (1) Increased utility to rural residential users; (2) external network benefits that would accrue network-wide; and (3) increased productivity for rural business users. Each of these benefit areas is discussed theoretically within the current section. Actual benefit estimates are provided in Sections 4 and 5.

Utility for Residential Users Virtually every household in West Virginia has Internet access through traditional wireline telephony.[6] Nevertheless, tens of thousands of households within the state opt to pay a monthly premium in order to obtain faster access via broadband. FCC statistics on broadband usage combine residential and small business usage.[7] However, assuming 108 thousand purely residential users and a monthly premium of $20, the total annual incremental payments for broadband access is nearly $26 million. Clearly broadband provides additional utility to residential users. Residential applications requiring broadband capacity include on-line gaming, music and video downloads, and voice over internet protocol (VoIP).

Network Externalities Very often, in a network setting, the utility of the network to existing users increases as additional new users choose to participate in the same network. For example, in traditional wireline telephony the value of the network to existing users is largely a function of how many other people they can contact by phone. Adding a new household to the network provides existing households and businesses with a new opportunity to communicate with additional residents. Thus, there are benefits to the existing users attributable to the new household's decision to purchase phone service. Because existing users are neither paying for the new household's service nor participating in the decision process, the benefits to the current users are referred to as "external" benefits that are attributable to the network production process or simply positive "network externalities."

[6] In 2001, the FCC reports that 94.5% of West Virginia roughly 756,000 households have home telephony. (Federal Communications Commission, Telephone Subscribership in the United States, 2002).

[7]This combined total of DSL and cable broadband subscribers for West Virginia was 151,163 as of December 2004. Federal Communications Commission. *High-Speed Services for Internet Access: Status as of December 31, 2004*)

In the case of positive externalities (as in the illustration above), economics suggests that unfettered markets will under-produce the good or service in question. Accordingly, the appropriate policy response is for the government to intervene in a way that will increase the amount of the good or service that is purchased in each time period. For example, in the case of traditional telephone service, the government has elected to subsidize service for new users through a Universal Service Fund paid for by existing users.[8]

Within the current context, the question is whether or not existing residential telecommunications users are made better off when a new user elects to purchase broadband services. For existing wireline users, the answer is almost certainly "no". For existing broadband users, the answer is less clear. Those residential users who use broadband access for entertainment purposes may, in fact, benefit as broadband usage increases. Gamers gain new opponents and those users who trade music and/or video images may enjoy increased choices as broadband network usage grows. Further, the much discussed but hitherto unobserved "killer apps" (high-end broadband applications) that may yield dramatic increases in utility may be unprofitable (and, therefore, absent) until a much higher proportion of households subscribe to broadband. Thus, growth in user utility is likely to correspond positively with increasing total network reach. Ultimately, it is probably imprudent to fully and permanently dismiss the matter of network externalities. Unfortunately there is currently no means of estimating the magnitudes of any existing effects, so that the current analysis must rest with the qualitative discussion provided above.

Increased Firm Productivity Broadband telecommunications services represent a potential input into the productive processes through which firms produce goods and services. For some firms, the availability of broadband will offer little or nor advantage. For other firms, broadband communications may yield sizable increases in productivity and corresponding increases in the quantity of firm outputs. The importance of broadband access depends on a variety of factors.

[8] The majority (53 percent) of Universal Service Fund payments go directly to carriers through the High Cost Support Program. It should be noted that the positive externalities used to justify this fund were never quantified, thus creating the strong potential to overprice this payment. Other universal service mechanisms include subsidies targeted at low income subscribers, subsidized service for schools and libraries, and subsidies for rural health care providers.

These include (1) the price the firm receives for its outputs; (2) the price of broadband service; (3) the prices of other necessary inputs; and (4) the extent to which broadband may complement or be a substitute for other productive inputs.

Broadband provides communications capacity that translates into speed and the ability to transmit previously impractical data volumes. Both facets can be important within the production process. Consider for example financial institutions. Well before the widespread availability of DSL or cable broadband, financial services providers routinely subscribed to dedicated lines in order to accommodate both data volumes and the service requirements of their customers. With the growing availability of less expensive broadband services, firms in other industries are now able to perform similar tasks, albeit with differing aims and without dedicated lines.

Readers should, however, take care not to confuse the productive influence of the Internet with the efficiency potentials offered by *high speed* Internet access. The emergence of Internet (digital) communications, in and of itself, radically changed production processes for a wide array of users. Moreover, for at least some of these users, the higher speeds afforded by broadband will not necessarily yield productive increase beyond what has been attained through narrow band Internet access. It is also important to consider where within the production (or distribution) process communications speed is necessary. For example, a firm that hosts client web-sites may desire broadband so that it can communicate more effectively with client customers. The clients themselves may not require high speed service to retrieve orders or other customer information.

3. Rural Households and the Demand for Broadband

Nationally, there has been a strong growth in the demand for residential broadband service. Statistics suggest that approximately 41 percent of residential users in the U.S. access the Internet via a broadband connection. High speed usage has also increased in West Virginia. The total number of lines increased from just over six thousand in December of 2000 to more than 127 thousand in June of 2004 and of these lines, the vast majority (124 thousand) are used by either residential or small business customers.[9]

Regional access to broadband communications has been explored by a number of analysts.[10] In order to add to this existing research and develop results that are specific to West Virginia, we first analyzed data on broadband availability and demographic and economic data describing the residents of more than 4,300 zip codes in Kentucky, Ohio, Pennsylvania and West Virginia. Though a number of factors are statistically related to the presence of broadband, only educational attainment and the relative size of age groups provide any statistically meaningful explanation of the presence of broadband. Combining 2003 broadband data with the largely static data from the 2000 census we found an increase in a region's proportion of 5-24 year olds by one percent increases a region's probability of having access to broadband communications by 50 percent, while reducing the proportion of adults without a high school diploma by one percent increases the probability of a zip code having broadband by almost 65 percent. In contrast, an increase in median household income of roughly $1,000 per year only increases the probability the zip code will have broadband access by 0.4 percent, and a reduction in median house age of 100 years, will increase the probability of broadband access by less than 1 percent. Most surprisingly, population density played a small role in broadband availability. Adding 1,000 persons per square mile in the sample area was associated with an increased probability of broadband access of less than 4 percent.[11]

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[9] Federal Communications Commission. *High-Speed Services for Internet Access: Status as of June 30, 2004.*

[10] See, for example, Grubesic (2003) or Grubesic and Murray, (2004).

[11] We employed a multinomial probit for each of the years of broadband regressed on 2000 Census. The goodness of fit measure (McFadden's R-squared) dropped by half over the five years tested, strongly suggesting the link between regional characteristics and broadband availability is weakening.

Our results very clearly suggest that demand conditions have played a critical role in determining whether or a not a region enjoys access to broadband. This having been said, the demographic and economic characteristics of would-be purchasers are declining in their predictive power. This is almost certainly due to its rapid rollout in less affluent and more rural regions reducing the correlation between rurality, and its associated characteristics and access to broadband.

Turning our attention specifically to West Virginia, at least in the aggregate, there does not appear to be a substantial amount of unmet residual demand within the State.[12] As a part of the study process, CBER surveyed 600 West Virginia households.[13] A comprehensive summary of the survey results is provided here as Appendix B. There are, however, several points worth highlighting. First, of the 600 households, roughly half (299) connect to the Internet. This is notably less than the 66 percent penetration rate observed nationally.[14] This is likely a function of the state's demographic characteristics - an older and less educated population with below-average rates of computer ownership - rather than a function of access to the Internet.[15] However, for those West Virginians who do use the Internet at home, the split between traditional dial-up usage and broadband closely mirrors the national average (42 percent State-wide versus 41 percent nationally). On the whole, residential broadband users appear to more educated and more affluent than their dial-up counterparts. A modest set of demographic and economic statistics is included within Table 1.

Presumably, if there is substantial unmet demand for broadband services it would rest among dial-up users who would prefer to purchase broadband services. However, of the 173 dial-up users surveyed, 37 percent <u>did not know</u> whether or not they currently have access to

[12] There are certainly individual households that would very much welcome the extension of broadband networks in to areas where service is currently unavailable.

[13] This survey was a random sample of 600 West Virginia households. It is possible that the willingness of those surveyed to participate could have influenced the results by picking up individuals who were already more interested in this topic.

[14] Federal Communications Commission. *High-Speed Services for Internet Access: Status as of June 30, 2004.*

[15] Our analysis of more than 4,300 zip codes in Kentucky, Ohio, Pennsylvania and West Virginia found that age distribution and educational attainment were the two dominant factors in broadband access, with either effect rendering income virtually irrelevant.

broadband service (cable, DSL, or wireless).[16] Moreover, of the group of dial-up users who could confirm that they have access to some form of broadband service, only 32 percent had any knowledge of the prices for available services. Finally, only six of the 173 current dial-up customers indicated that they are willing to pay more for broadband than they currently pay their dial-up Internet service provider and for those six, the additional monthly premium they were willing to pay was less than $10.

Table 1 – Characteristics of Internet Users

	Dial-Up Users	*Broadband Users*
Median Household Income	29,794	33,049
Median Per-Capita Income	16,180	18,157
Median Age	39	39
% of Population did not finish High School or Equivalent	24.5%	21.2%
% of Population with High School or Equivalent	39.5%	37.0%
% of Population with Some Higher Education	21.1%	23.3%
% of Population with a Bachelors Degree	9.0%	11.1%
% of Population with a Graduate Degree	5.9%	7.4%

Source: US 2000 Census. All values are for the zip code of residence.

Given that a substantial portion of dial-up users could not say whether or not they have access to broadband services, and of those who could there was little awareness of price, it is challenging to statistically model the relationship between availability, pricing, and subscribership as has been done elsewhere.[17] While a substantial number of West Virginia households have embraced broadband, those who have not appear to be relatively disinterested in the topic. This is not, however, an outcome that is likely to persist indefinitely.

[16] Across the entire survey 51.5 percent of respondents did not know whether or not they have access to broadband services.

[17] There have been numerous attempts to model residential demand for broadband services. Perhaps, one of the most comprehensive efforts is that of Rappoport, Kridel, Taylor and Alleman (2004).

Modeling demand relationships is difficult when a large number of consumers are unaware of available prices. However, we were able to glean information regarding the relationship between broadband access and several other factors. [18] To do so, we first modeled the choice to access the Internet (either through dial-up or broadband), finding results very similar to earlier studies of Internet usage. We also modeled the choice of dial-up or broadband among those who access the Internet.[19] The results of the second stage process are reported in Table 2.

Table 2, Dial-up or Broad for Internet Broadband Access
(Ordered Logit Estimates)

Variable	**Coefficient**
Have Broadband at Work	-0.242714**
Number of Adults in Family	0.781561***
Number of Kids in Family	0.595455***
Age of Youngest Family Member	-0.012353
Percent Population > 25 with BA degree	-4.766761
Median Age	-0.045488
Median HH income	0.0000835***
Broadband Price (actual, but not necessarily known)	0.004993
c1	1.209799
c2	2.214068
Pseudo R2	0.11
Liklihood Ratio Statistic (8 d.f.)	65.19842***
Akaike Information Criterion	1.94107

***** 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.**

[18] Our survey revealed that a trivial proportion of dial-up users and virtually no residents without Internet access knew the prices of broadband. Thus, our ideal strategy of estimating a nested logit model (where broadband vs. dialup was a second, or nested choice following the decision to access the Internet at home) was complicated by the absence of pricing knowledge. We are forced to make one of two assumptions. We could choose the unappealing option to ignore price as a decision variable for Internet access in our statistical model or use the actual price for each zip code, assuming that this price matters in the decision even though respondents did not know what the price may be. This is not a new problem, and was highlighted earlier this year by Chaudhuri and Flynn [2005]. Also, the leading analysis of this problem (Rappoport, Kridel, Taylor and Alleman [2004]) mixed both survey and regional pricing data (much as we have done) to estimate access elasticities. We consider this a question best resolved in later research. Insofar as access elasticity matters, neither approach yields different results in these data. Access elasticity is not different from zero.

[19] An early and errant model specification included a dichotomous variable indicating whether or not the residence is in a zip code where broadband is available, as well as the variable denoting whether or not the respondent knew if broadband is available. Not surprisingly, both variables were highly significant. Consequently, the authors can say with virtual certainty that very few households accidentally subscribe to broadband services in areas where they are unavailable.

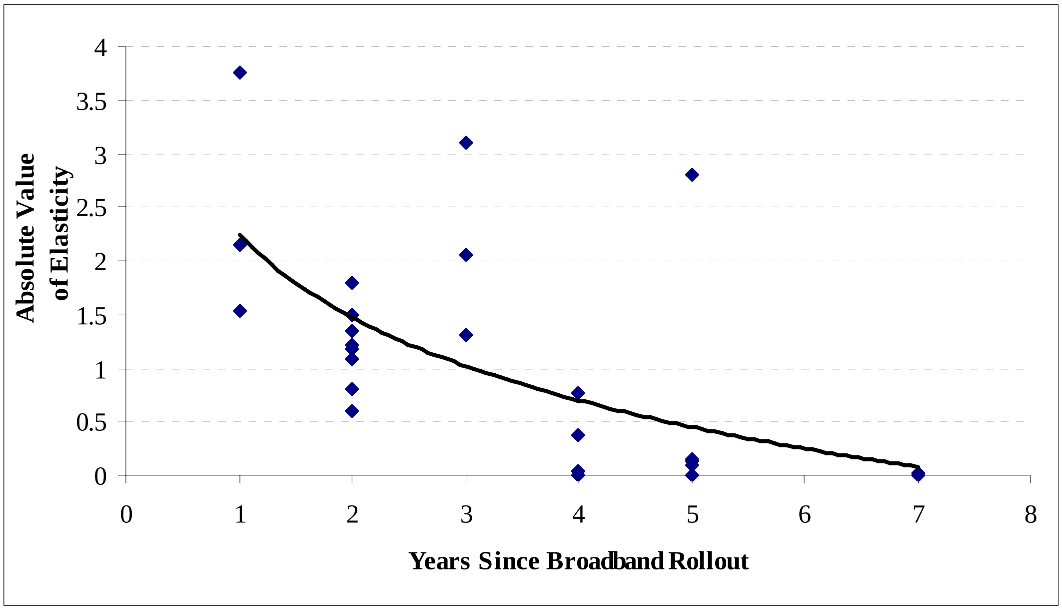
As expected, the price of broadband service is not a statistically significant predictor of the decision to subscribe to broadband service. Somewhat surprisingly, however, both the measure of household education and the age of residents also failed to attain statistical significance at a ninety percent level of confidence. The results do suggest that, for the sample group, higher incomes are positively correlated with the probability that the household selects broadband instead of wireline service. Also, it appears that at least some households are willing to substitute broadband service at work or school in place of home access.

Perhaps two of the most interesting results involve the coefficient estimates for the variables denoting the number adults and the number of children residing within the household. Both coefficients are positive and highly significant. We believe this is likely a reflection of the opportunity cost of slow Internet access in relatively busy households. Moreover, if the result was driven by the demands of the children, we would have expected the children's age variable to be significant, but it is not. Instead, it appears to be the opportunity costs to the adults that drives this relationship.[20] This finding is certainly consistent with Rappaport, Kridel and Taylor (2002) who also find the opportunity cost of time to be positively correlated with broadband subscription rates.

The West Virginia survey results strongly suggest that, given the currently observable set of prices, broadband pricing plays little or no role in residential consumption decisions. Thus, the current price elasticity of demand appears to be very nearly zero. This outcome is completely consistent with residential behaviors observed in other parts of the nation. Figure 2 depicts various estimates of residential demand elasticities plotted over time. Collectively, these estimates tell a compelling story. Even without any appreciable change in real prices, residential elasticities appear to be trending toward zero. This is a clear extension of the observed trend across all the existing studies of access elasticity over the past decade.

[20] We have no direct evidence from the survey questionnaire that opportunity costs of time are higher in households with children. However, we shall only entertain criticism of this interpretation from readers with children.

Figure 3, Residential Access Elasticities Over Time



As broadband services are extended and the number of applications (and other users) has increased, residential broadband access is increasingly being viewed as essential by an ever increasing number of households. There is no *a priori* reason to expect that this would not be the case in West Virginia as potential users become familiar with available applications and obtain the skills necessary to execute those applications. Once again, however, we must offer the caveat that this result applies only for the currently observable set of broadband prices.

4. Broadband and the Productivity of Rural Businesses

As described in Section 2, the availability of broadband telecommunications services has the potential to improve the productivity of commercial users. The ultimate impact of improved telecommunications services depends on the nature of firm-specific production functions, as well as the price of other productive inputs and the prices of the products or services that the firm sells. Nationally, there is evidence that extending broadband service to commercial users has contributed to firm efficiency, particularly among smaller producers.[21] This having been said, the current study team and the Steering Committee which guided it felt it necessary to explore commercial impacts specific to West Virginia. The study team found these impacts to be significant for the Finance and Services sectors, but not for the economy as a whole.

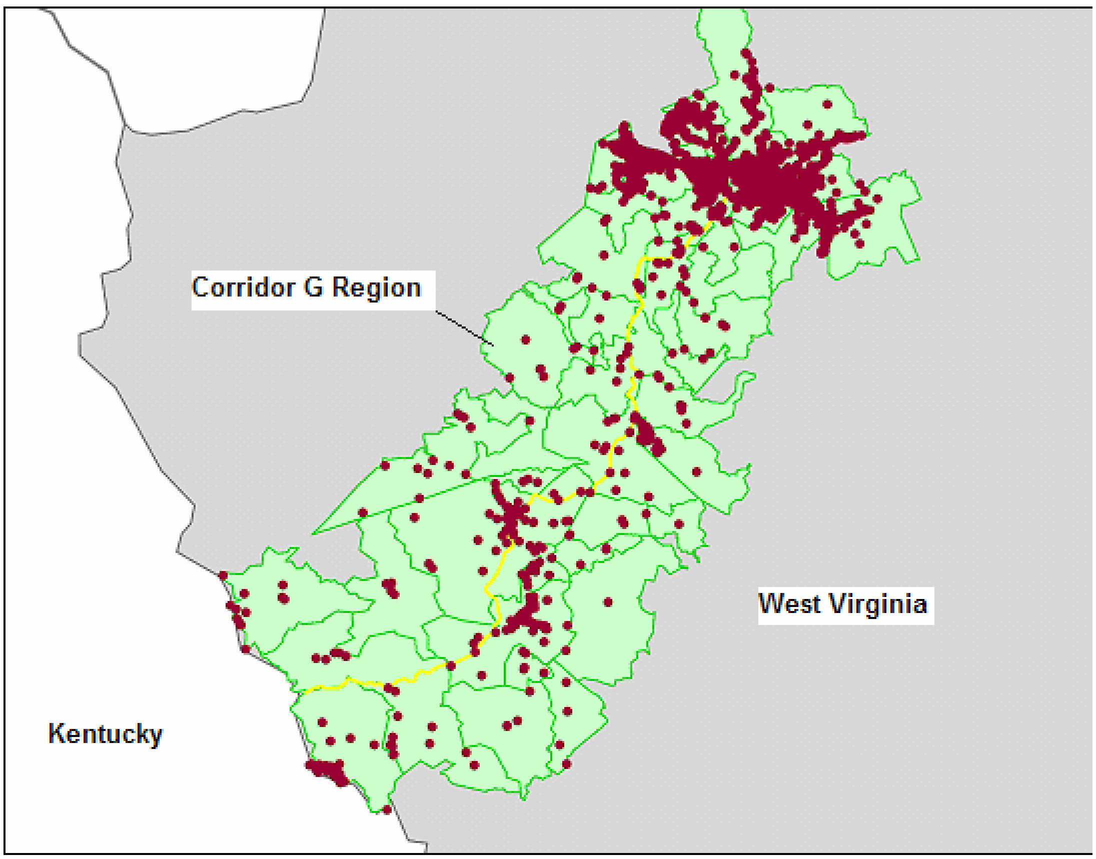
To the extent that broadband contributes to efficiency, we should observe a number of identifiable impacts. Firms with broadband access should be more productive in terms of the amount of output they are able to produce with fixed quantities of other inputs. In turn, productivity improvements attributable to broadband should allow firms to better reward the other productive inputs. This means (potentially, at least) higher returns to capital inputs – hence greater investment — and higher wages for workers. Finally, if broadband genuinely adds a competitive advantage, competition should lead to an outcome in which areas without broadband service will fail to sustain or attract firms in industries where these services are important.

To actually quantify these potential impacts, the study team undertook three empirical activities. First, we modeled the relationship between output per worker and access to broadband services as a means of identifying productivity impacts. Second, we attempted to correlate wage differentials to broadband access across industrial sectors. Finally, we examined firm locations in relationship to broadband availability. The results of each activity are summarized within the remainder of the current section.

[21] Not only does the evidence suggest that broadband access is important to small firms, there is also empirical evidence that this access is particularly important to firms that operate from multiple locations. BJK Associates "Broadband for Rural Small Businesses" 2001.

An Empirical Evaluation of Broadband and Firm Productivity Within this initial process, we directly estimated the role of broadband availability at the firm level through the use of data developed in an earlier study on firm productivity and highway infrastructure. This allowed us to test the role of broadband on the productivity of almost 8,000 firms located in West Virginia and Kentucky along US 119 (Appalachian Development Highway System Corridor G).[22] Firm locations are depicted in Figure 4.

Figure 4, West Virginia Firm Locations Along Corridor G



The data describe individual establishments located in zip codes that are within 15 miles of US 119. The region begins with zip codes contiguous to the West Virginia capitol building, passes through some of the most rural parts of West Virginia into Kentucky, terminating in Pikeville, KY. For each firm, (in year 2000) the data detail employment, revenues, firm legal

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[22] Hicks, Michael J. The Impact of Appalachian Corridors on Small Business, *Transportation Research Board* National Academy of Sciences, *Proceedings, Transportation and Economic Development 2001.*

structure, size, 4-digit SIC Code, number of reported SICs and the suite of census data. We measure productivity as the revenues per worker within the firm. Of particular interest is actual proximity measured by road distance to US 119, the infrastructure measurement in the earlier study.

The earlier research identified a modest role for highway infrastructure as a means of explaining firm productivity. We have added the availability of residential broadband to that specification.[23] To evaluate the relationship between firm productivity and broadband we estimated the relationship between revenue per worker and firm and regional characteristics (including broadband access). A more detailed explanation of this model appears in the Technical Appendix. However, Table 3 summarizes estimation results.

Table 3. Estimated Firm Productivity

Variable	*Logit*[24]	*OLS*
C	8.475339***	9.150856***
Distance to Corridor G (feet)	-0.250432†	-0.147382
Distance to Corridor G squared	0.013835†	0.007741
Broadband*Age of Firm	-0.174906*	-0.147507*
Broadband	0.11164	0.077964
Age of Firm	0.510805**	0.372638*
Age of Firm Squared	0.059398	0.088066**
Urban Zip	0.0444	0.296379**
Population	0.042774†	0.085633***
Number of Households	-0.043865	-0.307219**
Number of SIC Codes	0.709776***	0.242038*
Privately Owned	-0.023441	-0.076569**
West Virginia	-0.099375*	-0.059841
Per Capita Income	0.647904***	0.418935***
Adjusted R-squared	0.046	0.46
S.E. of regression	0.561837	0.561735
Log likelihood	-2325.072	-2325.072

***** 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.**

[23] The data describing broadband availability reflect the presence or lack of DSL, cable modem service or wireless broadband access anywhere within a specific zip code. While it is unlikely that this variable is perfectly correlated with the availability of broadband services to commercial customers, it remains the best measure available.

[24] These techniques are extreme value Logit and ordinary least squares. The two techniques are employed due to different statistical assumptions, which we discuss in the appendices.

Both models yield similar results. In particular, proximity to the Appalachian Development Corridor matters, with an additional mile increasing productivity by roughly one quarter of a percent, with this an increasing function.[25] Older firms in urban areas that produce goods or services in more than one Standard Industrial classification, and those that are located in more affluent areas, are more productive. Publicly traded firms in the sole Kentucky county we examined had higher levels of productivity (possibly due to a high percentage of the zip codes being urban).

The Table 3 results suggest that the availability of broadband, by itself, is not statistically significant as an explanation of firm productivity. This outcome may be attributed to a combination of three possible causes. First, the dissemination of broadband, as well as any productivity-related impacts was limited in 2000, the year from which the data were drawn. Second, as will be further discussed, the spatial distribution of firms within the Corridor G setting makes it impossible to disaggregate the data to the industry levels that would have, perhaps, yielded more revealing results.[26] Finally, the data do not reflect those instances in which firms secured dedicated broadband access from Verizon, the dominant local exchange carrier within the region and thus are likely to underestimate the number of firms who had access to broadband.

These results do provide one extraordinarily important finding. While broadband access by itself was not a contributor to firm productivity, its interaction with the age of the firm was an important explanation for differences in firm productivity. This result points to an important, and often overlooked characteristic of firm location dynamics and broadband: simply, most firms made their location choices prior to the development of broadband. The mean age of the firms in

[25] However, this finding was sensitive to specification (Logit only) and was not statistically different from zero at the ten percent level. This finding suggests that earlier research performed on the Appalachian Development Corridor which did not include accounting for broadband access may need to be re-evaluated in light of this finding. See Hicks, Michael J. The Impact of Appalachian Corridors on Small Business, *Transportation Research Board National Academy* of Sciences, *Proceedings, Transportation and Economic Development 2001.*

[26] We performed some limited disaggregation, however the data supported little of this. We did find the service sector most affected by broadband presence. No financial services firms located in zip codes without residential access. We discuss this implication in our later analyses.

this sample is 18.2 years, so that most firms made chose a location more than a decade before telecommunications became available. We find in this sample of firms that age and broadband access interact to explain a significant proportion of productivity differences across firms. Specifically, for each firm located in a broadband accessible zip code, productivity increases by between 14 and 17 percent over a similarly aged firm locating outside a region with broadband access. Younger firms are locating where broadband is available and are generally more productive.

This is a nontrivial impact for an individual firm, and certainly would likely matter in firm location decision. Indeed, this finding provides the most direct available estimate of firm level productivity due to access to broadband that we have encountered in the literature. However, the aggregate impact is small, even for data that is quite stale in terms of broadband access. In 2000, along a relatively remote and poor area of West Virginia the incremental benefit in terms of production associated with extending broadband to firms who did not have access to residential service would have been under one million dollars annually.

In order to better understand the age/broadband interaction we also tested to determine whether or not the average productivity of firms that located without regard to broadband, and that of those that were broadband sensitive in our sample were statistically different. While firms that located only in areas with residential broadband enjoyed a roughly 3 percent higher productivity, the difference was not statistically significant. However, the differences in the other distributional characteristics of the productivity values were quite telling.

While the average productivity of firms located within and outside broadband accessible areas was not different, there was a very clear presence of more very highly productive firms which were located within broadband accessible regions. This suggests a tendency for very productive firms to locate in places with broadband. Further, among the firms that located in places without broadband, there was more clustering around the mean, with far fewer modestly higher productivity firms. In the view of the study team, these differences stand as tentative evidence of the effects that broadband access may have on firm location decision and productivity now, or within the foreseeable future. However, analysis which evaluates the role broadband has played dynamically in regional growth may lead to better insights into the both the history and potential future roles of access to broadband on aggregate economic activity.

Broadband access and Worker Wages While the initial investigation of productivity found important, if modest productivity impacts directly attributable to broadband access, it is further possible to both identify and quantify any such impacts through their secondary impact on wages. Specifically, firms that are more productive are be able to pay workers higher wages. Moreover, if markets for labor are effectively competitive, wage premiums to more productive labor will not be voluntary. Thus, if broadband contributes to firm productivity, we should observe higher wages in those areas where broadband services are available. In order to explore this potential relationship, we used the population distribution from the 2000 Census to allocate population within the county. The reported annual changes in population are distributed evenly across the county each year. This forms the core of the data used to evaluate the aggregate and sectoral wage impacts of broadband access from 1995 through 2003.[27] This model was estimated for selected two-digit SIC sectors individually for the states of West Virginia, Kentucky, Ohio, and Pennsylvania and collectively within a multi-state specification. The model accounts for past levels of wages, regional impacts, the most recent recession, the technology sector decline and the availability of broadband telecommunications.[28]

Because of their product offerings and service production processes, we were particularly interested in the potential impact of broadband on the wages within the Services and Finance sectors. This interest was further bolstered by two important studies on the role of information technology at the industry level. Stiroh (2001) examined the role of information technology on individual industries at the two digit level, finding the impact of IT on services dominating much of the aggregate impact. Interestingly, Stiroh did not examine either finance or IT producing sectors as the very obvious consumption and production of IT in these sectors unambiguously suggested he would find an impact. A second study of IT relating to productivity growth in the UK found that finances and services explained virtually all the aggregate impact of IT (Correa,

[27] Clearly broadband was unavailable prior to 1998, but this time period permitted us to include a greater number of lagged dependent variables in our model, as might be appropriate. Also 2003 is the most current data available.

[28] We estimated county level broadband access as a percentage of residents in that county living in a zip code with broadband access each year.

2003). Thus, if we are to find impacts of broadband it would behoove us to examine those sectors already identified as having exhibited productivity gains due to IT. Productivity gains to IT within and industry should serve as a necessary, but not sufficient condition to the presence of productivity benefits attributable to a more limited IT component – broadband. As a test of this assumption we also tested the total wages as a comparison of the models, in all cases the real wage values are in logarithmic form for ease of interpretation. Results for the cross-state aggregation are provided in Table 4.

Table 4. Multi-State Wage Model Results

Variable	*All Jobs Coefficient*	*Finance Coefficient*	*Services Coefficient*
(intercept)	8.828665***	0.083758	-2.728118
(broadband)	0.000788	-0.030047	-0.044281
t-1 (broadband)	0.002651	-0.005857	-0.008073
(spatial autocorrelation)	5.96E-05***	1.001739	1.813129***
t-1 (spatial autocorrelation)	-8.72E-06**	-0.075115†	-0.006296
X1 (recession)	-0.012982**	0.002515	-0.066457**
X2 (2001 dummy)	0.005634*	0.008551	0.007212
(autocorrelation)	0.551523***	0.450772***	0.542878***
Adjusted R-squared	0.97	0.87	0.82
S.E. of regression	0.027961	0.107073	0.106839
Durbin-Watson stat	1.99	1.86	2.12

***** 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.**

The results of these regressions suggest that in a geographically aggregated setting, broadband access does not explain any observable wage differentials. This is true for the cross-industry specification, as well as those estimations specific to the Financial and Services sectors. The dominant factors were the spatial or regional influence and wages in the previous period. This is a consistent finding in almost all spatial models of economic growth. The 2001 recession also led to wage reductions in aggregate and on the Services sector, but did not affect wages in the Financial sector with any statistical significance. The magnitude of the recession impacts was extremely modest, with impacts of between 0.02 and 6.6 percent for all wages and in Services. This is consistent with most other estimates we have seen (albeit with modestly higher impact in services). We also attempted to identify broadband impacts that are specific to rural communities, defined here, as counties lying outside Metropolitan Statistical Areas (MSAs). Again, however, there was no impact attributable to broadband access on aggregate wages or wages in the Services or Finance sectors for the multi-state specification.

We anticipated state-level differences in the commercial impacts of broadband availability. Accordingly, the next step was to test our model on aggregate and sectoral wages in Services and Finance on a state-by-state basis. As with the multi-state study area and the non-MSA counties, aggregate wages within individual states were not affected by broadband access. However there were state level impacts of broadband access for Services and the Financial sectors in Ohio, Pennsylvania and West Virginia, but not in Kentucky. The results for the Services sector appear in Table 5.

Table 5. State-Specific Service Sector Wage Model Results

	KY	**OH**	**PA**	**WV**
(intercept)	-0.78876	0.985071	1.637126***	2.78389*
(broadband)	0.023672	0.056003†	0.049734***	0.073141*
t-1(broadband)	-0.01931***	-0.02725*	-0.00592	-0.01336
(spatial autocorrelation)	1.218585	1.077958***	0.354074**	0.280402
t-1(spatial autocorrelation)	-0.02126	-0.43343**	0.09451	-0.22494*
X1 (recession)	-0.04118*	-0.02784†	-0.02631***	-0.02236
X2 (2001 dummy)	-0.01386	-0.01689†	0.011614	0.019167
(autocorrelation)	0.513412***	0.425024***	0.887119***	0.463508***
Adjusted R-squared	0.767133	0.889928	0.941056	0.911554
S.E. of regression	0.116849	0.072853	0.057312	0.077218
Durbin-Watson stat	2.21743	2.111413	1.834619	2.033289

***** 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.**

In the Service sector in Pennsylvania and West Virginia there is support for the hypothesis that broadband access positively influences wages. In Pennsylvania, we observed an increase in wages of roughly 4.9 percent associated with the presence of ubiquitous broadband in a county. For West Virginia the associated impact was roughly 5.2 percent, with as much as a 5.6 percent increase in Ohio, though the level of statistical significance is weak. We found no impacts in Kentucky.[29] The magnitudes of these findings warrant considerable attention, given the increasingly prominent role of the Service sector in new job creation.

These impacts translate into an estimated $1,308 in increased service sector wages attributable to broadband. If historical relationships were applied throughout the state, in Pennsylvania the presence of broadband would raise individual Service sector wages by roughly $110 million per year if broadband was brought to those zip codes where it currently does not exist. In West Virginia, broadband was observed, although less strongly, to be associated with a Service sector wage differential of roughly $1,519 per worker. This translates into a statewide impact of broadband on service sector wages of more than $314 million. The gains associated with extending broadband to all zip codes would account for a roughly $32.6 million one time, non-transient increase in service sector earnings. As in Pennsylvania and West Virginia, Ohio's service sector workers located in broadband accessible regions earn roughly $1,287 more per year. However, given the extensive broadband coverage in Ohio, extending broad to unserved areas would account for only about $27 million in wage benefits to the service sector.

These impacts are important, and within the scale of other recent technologies quite large, however one major cautionary note is warranted. Given current technologies and production processes, the overwhelming majority of these impacts have already been realized since broadband access is widespread throughout Ohio, Pennsylvania and West Virginia. As aforementioned, as of 2003 only 6.7 percent of West Virginians lived in zip codes without any access to broadband. In Pennsylvania that figure was 1.4 percent, and only 0.6 percent of Ohio residents live in zip codes without broadband access. Again, given current technologies and applications, as yet unattained impacts are modest. In West Virginia, extending broadband access to areas where broadband is unavailable would add $32.6 million to service sector incomes. Similarly, in Pennsylvania the statewide impact of ubiquitous broadband access on service sector wages would be roughly $110 million, and an additional $27 million for Ohio.

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[29] Closer examination of Kentucky reveal that the 2001 change to NAICS may have led to a 16% increase in the FIRE sector, most likely a redefinition of existing firms, primarily from services. This anomaly precludes better analysis.

We find a similar result in the impact of broadband on wages in the Financial sector. In West Virginia, workers in broadband-served areas enjoy an almost 11.2 percent wage differential. In Pennsylvania the difference is a little more than 4.4 percent. However, the coefficient estimate does not experience common levels of statistical significance (See Table 6). Workers in Pennsylvania's Finance, Insurance and Real Estate sector experienced a roughly $1,348 earnings increase that is attributable to broadband. The additional income in this sector that would be attributable to ubiquitous broadband availability would be roughly $25.6 million statewide.

The impact in West Virginia is proportionately much larger with an estimated 11.2 percent increase in Finance sector wages associated with broadband access. If historical relationships were applied throughout the state, this would translate into $2,250 per worker or $12.2 million in state-wide earnings that could be realized from an extension of broadband to areas not yet served. In Ohio the per worker impact is similar to that of West Virginia, but due to the widespread coverage of broadband access the total impact across the state is roughly $15.5 million.

Table 6. State-Specific Finance Sector Wage Model Results

	KY	OH	PA	WV
(intercept)	2.770219	4.712759**	0.779468*	1.055483†
(broadband)	0.052901	0.118629*	0.04974†	0.112331**
t-1(broadband)	0.024332*	0.007191	-0.0395**	-0.01054
(spatial autocorrelation)	0.211818†	-0.42393	1.010244*	0.542992**
t-1(spatial autocorrelation)	-0.14596	-0.0988	-0.25727*	0.035854
X1 (recession)	-0.02137**	0.023879	0.014683	-0.02594
X2 (2001 dummy)	0.035887†	0.078294**	-0.02214	0.075596**
(autocorrelation)	0.366064***	0.437868***	0.529745***	0.328048***
Adjusted R-squared	0.828521	0.877696	0.935132	0.6867
S.E. of regression	0.101404	0.097225	0.095452	0.125138
Durbin-Watson stat	1.855819	1.90528	1.927908	1.84888

***** 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.**

Our selection of the Service and Finance sectors for analysis in this section was motivated by our hypothesized transmission mechanism between broadband use and firm productivity. While we were unable to isolate this productivity impact in our first suite of estimates, we attributed this to the absence of some very specific industries within the service and FIRE sectors. This test of the more aggregate measures suggests that broadband access has played a non-trivial role in the productivity growth within these sectors. We were unable to isolate impacts in other sectors, or aggregate incomes in our study region. Thus it is likely that, at this time, the measurable productivity impacts of broadband access are limited to these two sectors.

Our findings in these estimations also speak broadly to problems of endogeneity, or the direction of causation between incomes and broadband access that naturally plague studies of this type. While we have attempted to ameliorate this problem in our estimates through the technical application of the statistical technique of two-stage least squares, the strongest evidence that endogeneity is not an issue within our findings are in the results themselves. Since we find that broadband impacts are confined to two economic sectors (as opposed to impacts that are economy-wide), it is not inconsistent with the data to assume that broadband access within these sectors that is driving wages rather than the reverse.

We note that these models portray both time and spatial autocorrelations and the recession as theory and other empirics suggest are correct. This provides us comfort in the quality of the model in explaining the role of broadband on wages in two sectors where the transmission of productivity impacts is well documented.

Finally, we note that the wage benefits associated with broadband deployment may represent enticing opportunities for welfare gain. We note that as of 2002 most of these benefits had already been achieved.

Firm Locations Ultimately, if access to broadband telecommunications confers a significant competitive advantage to resident firms, and assuming effective competition, producers who lack this access will not survive. Accordingly, we expect to observe that certain economic activities are confined to areas where broadband is available and absent where it is not.

Table 7 provides data describing firm locations for a number of relatively disaggregated industries. These industries represent specific commercial activities that only take place where broadband services are available. Again, the empirical results described above suggest that the limitations imposed by a lack of broadband access have yet to become evident in aggregate regional or state-wide economic outcomes. Though, as we mentioned earlier, the productivity advantage explained by the interaction between age and Internet access should begin to matter to firms.

Table 7. Firm Locations in West Virginia

Sample of Industries Absent in Zip Codes without Residential Broadband Access
Cable & other pay television broadcasting
Communication services, n.e.c.
Electric services
Travel agencies
Process control instruments
Measuring & controlling devices, n.e.c.
Surgical appliances & supplies
Jewelry, precious metal
Silverware & plated ware
Dolls
Sporting & athletic goods, n.e.c.
Periodicals
Veterinary Services for Livestock
Automobile parking
Automobile parking
Motion picture production and allied services
Motion picture theaters
Legal services
Forestry Services
Coal mining services
Crude petroleum & natural gas
Oil & gas exploration services
Oil & gas field services, n.e.c.
Nonmetallic minerals services, except fuels
General contractors--residential bldgs, other than single-family
Operative builders
General contractors--industrial buildings & warehouses
Highway & street construction contractors, exc elevated highways
Commercial Banks
Credit Unions

This list of industries in instructive in that it is apparent that the difference in industrial structure of regions with and without broadband require more analysis. From this list it is clear that some firms (commercial banks, travel agencies and cable TV) will require broadband for their routine operations. It is less clear to us why, for example, automobile parking requires broadband access. However, we are certain that in the time required to fully undertake a study of the transmission mechanism between broadband access and firm productivity that new technologies, applications or processes not yet defined may well render such a study moot.

What we believe this analysis tells us with some certainty, is that there was not (as of 2000) unassailable evidence that firm location decisions are heavily effected by the presence of residential broadband. However, it is an almost certainty that any productivity advantages offered by the presence of broadband may influence location decisions for firms in some industries. A more definitive finding regarding firm location and access to residential broadband will require further analysis.

5. *Summary and Conclusions*

The importance of affordably priced, widespread broadband telecommunications has sparked a huge amount of excitement among those who have glimpsed this technology's potential for transforming both commercial activities and the quality of residential life. Accordingly, for some, ubiquitous availability of broadband service and competitively-induced reductions in broadband prices cannot come quickly enough. As a result, there are numerous proposals for governmental intervention aimed at hastening the extension of broadband to areas where it is currently unavailable and at intensifying the level of competition in the provision of these communication services. Indeed, if there is anything that is ubiquitous, at this point, it is the excitement that broadband has spawned.

Unfortunately, many policy discussions are conducted in an environment where there is a paucity of factual information describing the potential benefits attributable to broadband telecommunications. This challenge is certainly not unique to West Virginia. However, recognizing the problem, West Virginia policy-makers commissioned the empirical investigation reported herein. Regardless of how one views the current study's methods or conclusions, the policy-makers who sponsored this work should be lauded for both their prudence and ambition.[30]

The economic impacts of broadband availability vary between commercial and residential users. Commercial users are interested in the technology's potential to increase productivity and reduce costs. Residential users are motivated by the way broadband increases the utility of household applications that are often related to entertainment.[31] Hence, the current analysis elected to treat residential and commercial benefits separately.

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[30] This concern was well expressed by Stanton [2004] that "The public policies currently being debated [regarding broadband] do not acknowledge this smaller [digital] divide nor do they acknowledge the emerging technologies for broadband access that will make it easier for remote areas to have high speed Internet connections. These factors will change the broadband policy debate." pg. 9.

[31] This was noted by Robert Gordon [2002] that ". . . American corporate business already has fast connections, and even college freshmen have lightning-fast access to the Internet from their dorm rooms. Whatever impact on business productivity made possible by universal adoption of broadband in the American corporate and institutional world has already occurred. A rush to install broadband connections in the American household would not have a direct impact on business productivity, since its major effect would be to allow faster downloading of video, music and games." pg. 47.

In terms of commerce, there is evidence that available broadband is important to specific business activities, mostly observable at present within the Services and Financial sectors, which depend more on the speed of broadband Internet access to perform multiple and frequent transactions essential to their operations. Moreover, firms within the industries where broadband access is viewed as a competitive advantage generally will not locate in areas where this access does not exist. On a state-wide basis, any extant lack of broadband access has not generated observable negative economic outcomes. This largely owes to the fact that broadband services (in some form) are already available to the vast majority of firms within the state. Moreover, while it is true that extending the current broadband networks might yield measurable benefits to additional commercial users, the magnitude of these incremental benefits pales when compared to the benefits already achieved without any policy intervention. Thus, while commercial concerns within individual communities may stand to gain from further network extensions, the state economy, as a whole, would see few changes.[32] The overall West Virginia economy is far more likely to be impacted by improvements in service speeds and/or pricing in those areas where broadband communications are already available.

With regard to households, there is growing national evidence that broadband telecommunications services have (or, at least, will) become the "fourth utility." There is, however, consistent evidence that residential adoption rates are largely a function of education and age structure. This correlation very probably helps to explain the relative lack of concern evidenced by many of the households who participated in the survey conducted as a part of the current study effort.[33] The current set of dial-up Internet users would appear to represent the set of users that is most likely to yield new broadband subscribers. Yet of this group nearly one-third could not say definitively whether or not their household currently has access to broadband

[32] The benefits to communities should also receive extensive scrutiny before serious public sector investment is undertaken. Broadband, and other information technology may be a necessary, but are not a sufficient condition for rural economic growth (see Fox and Porca 2001; Glasmeier and Howland, 2001; and Malecki [2001] in Drabenstott, Mark and Katharine Sheaff. "Exploring policy options for a new rural America--a conference summary." Federal Reserve Bank of Kansas City, 2001.

[33] Whitacre (2001) notes when discussing efforts to close a 'digital divide' that "The most important [policy] form deals with working on the underlying characteristics between rural and urban areas, including attempts to increase education and income levels in rural areas." pg 15.

services and the vast majority are making the decision to continue their dial-up services without even exploring the prices of any available broadband alternatives. These findings certainly do not instill any sense of urgency.[34] While the effects of income on subscription rates could be quickly overcome through public policy, the impact of educational deficiencies on broadband subscription rates will be much more difficult to remedy. Therefore, extending broadband networks into the most remote reaches of the state is likely to yield relatively few new users.

Barely 10 years ago the Internet was little more than a novelty familiar only to the technologically elite. In fewer years than it takes a new-borne child to reach kindergarten this technology emerged as one of the most powerful economic forces ever observed and it did so largely without public sector guidance. Today, at least domestically, there are very few (if any) lines of commerce that are not measurably different because of the emergence of Internet services. The impacts of the Internet on public sector activities and on home life have been no less profound.

Though networks now support millions of users and thousands of new applications, overall available capacity is plentiful. The past decade has seen increases in our computational and communications capacities that have outstripped demand-side growth. Moreover, the breathtaking growth in technological capacity, combined with competition has produced substantial declines in the pricing of both equipment and services. Indeed, in the final days of this nearly year long study, SBC communications announced a suite of broadband services would be made available of as little as $14.95 a month.[35] While the current pace of technological progress may not be sustainable, there is little doubt that myriad improvements to equipment, software, and services are still forthcoming.[36] Care must be taken to avoid

[34] This finding is echoed by a 2003 Congressional Budget Office study which concludes "Yet if the market for broadband is working tolerably well, as CBO's analysis concludes, it is likely that consumer demand and market developments —uninfluenced by subsidies—will draw resources toward the production of a bundle of goods and services that will grant an even higher level of well-being." Does the Residential Broadband Market Need Fixing? Congressional Budget Office, December 2003.

[35] Searcy, Diane "New Low Price for Broadband" Wall Street Journal, Wednesday, June 1, 2005. At this price, dial-up service would seem to be on its way out.

[36] The Journal Report: Technology, May 23, 2005.

investment in technology that could become quickly outmoded. This cautionary note should be especially relevant to governments seeking investments that will constrain future choices without the discipline of markets.[37]

Far from ignoring what amounts to a technological revolution, West Virginians have participated in it. There is no evidence that availability to commercial users within the state has been an impediment to the adoption of broadband. There is also no indication that the roll-out of these services elsewhere has been timelier or less troublesome. While it is true that 12 percent of zip codes within the state have no broadband access, this figure does not compare unfavorably with a number of rural states in the Midwest and western United States. Moreover, 30 percent of West Virginia zip codes have three or more providers, while 54 percent have at least two. Finally, in West Virginia, residential use of the Internet is measurably below the national average (50 percent versus 66 percent). However, of those households who do subscribe to some form of Internet service, broadband usage (42 percent) is more comparable to the national average of 41 percent.

In summary, broadband access in West Virginia is not as extensive as it is in more affluent and more densely populated states. Still, there is no substantive evidence of any widespread deficiency. There are, no doubt, isolated instances in which either commercial or residential users have unmet demands. The problem does not, however, appear to be wide-spread. Accordingly, the magnitude of the potential benefits from more extensive service offerings, particularly to residential users, appears to be relatively small.

[37] And, though economic analysts from Adam Smith onwards have provided breathtaking underestimates of adoption rates of new technologies, government planners not infrequently make economists appear remarkably prescient.

6. Postscript

The analyses described in the above text represent a very preliminary examination of a nascent and rapidly changing technology. We have concluded that West Virginia is enjoying economic benefits associated with the currently available technologies that are similar in nature and magnitude to the benefits accruing to the nation as a whole. For this reason, we have suggested that direct, broad-based State intervention in broadband markets is not warranted at this time. This does not mean that there is no need for an active State broadband policy. To the contrary, the magnitude of the successes enjoyed to date underscores the potential benefits from public policies that actively preserve current gains and encourage future progress. Specifically, we believe the state should consider the following courses.

- **An Investigation of the Links Between Broadband and Healthcare** The State of West Virginia heavily subsidizes both the public and private provision of healthcare services. Increasingly, broadband is used in the transmission of medical data and billing information. Understanding the linkages between healthcare and rural broadband availability could substantially increase the State's future ability to control healthcare costs and improve the quality of services.

- **Development of a Monitoring Program** Again, the current analysis suggests that State policies have been effective given current technologies, but in an area where change is so abundant, the State should continuously monitor market conditions and outcomes to ensure that success is continued.

- **Data Development** Early criticisms of the current analyses largely rest on the accuracy and timeliness of the FCC data used in many portions our work. Better data describing the specific broadband services that are available at precise geographic locations (including price data) would lead to more universally accepted analytical outcomes.

- **National Policy Analysis** There will likely be national telecommunications legislation within the foreseeable future and this legislation will almost certainly consider regulatory changes in the provision of broadband. West Virginia would be well advised to investigate these potential regulatory changes now in order to determine which potential changes are desirable from a West Virginia perspective and which are not.

- **<u>Continued Advocacy on the Behalf of Communities</u>** We see no evidence that broadband availability is a Statewide problem requiring broad-based government intervention. There are, however, any number of communities in which a localized lack of broadband availability is viewed as an impediment to economic development. Very often State agencies have taken on the role of advocate as the communities negotiate with potential providers. This is very likely a useful State function.

Respectfully Submitted by:

Mark Burton

Michael Hicks

June 2005

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APPENDIX A: THE DATA

TO

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

FINAL REPORT

JULY 2005

MARK L. BURTON

MICHAEL J. HICKS

Introduction

This Appendix describes the data collected as part of the preceding study. Since much of the data is publicly available we provide only selected summary statistics. Our intent is to highlight strengths and weaknesses of the data, and explain the potential impact of on our study of varying definitions of the data. We begin with a general description of the study, temporally and regionally. We then describe the data collected and analyzed as part of the analysis of consumers, followed by a similar description for the commercial analysis. Much of the data was evaluated in both studies, and so as to avoid redundancies we will only note how the data was employed in the later studies, providing the bulk of the discussion for the first application of the data. We also include descriptions of how calculations for each transformation of data or aggregation scheme were performed.

The Study Design

This study evaluates consumer and commercial benefits to broadband, through analysis of a variety of data from Kentucky, Ohio, Pennsylvania and West Virginia. The region of particular interest is West Virginia, thus the surrounding areas have been chosen to provide greater robustness to a number of the hypotheses examined in the course of the preceding study. The time period we analyzed stretched from 1990 through 2005, but was obviously different for data of varying vintage. In each case we were constrained by the availability and definition of data (or cost of acquiring better data). This is an unavoidable dilemma in research of this nature.

The study itself had a number of analytical components from maps, to advanced econometric models. We gathered data from the *Federal Communications Commission* (FCC), the *Bureau of Labor Statistics* (BLS), the *Census* and the *Bureau of Economic Analysis* (BEA). We compared these data to other sources such as the West Virginia Public Service Commission and a number of advocacy groups, industry data and those collected and evaluated from other sources. We also collected our own data through a telephonic survey of West Virginia households.

The data we have employed is the best available. We are familiar with both the shortcomings and strengths of the data, and the manner in which the geographic definitions have been made. In the final analysis, if these data prove insufficient to the reader in providing a basis for evaluating the questions we have attempted to answer (as distinct from our ability to answer these questions) then no economic, environmental, political or social study will be acceptable.

The Consumer Study

We begin our consumer study in terms of regional access to broadband telecommunications. We employ the regions created by state legislators (counties) and the subsets created by the U.S. Postal Service (zip codes). We note that zip codes include population, infrastructure and geological considerations. The most important of these is population as zip codes are designed to better manage mail traffic to households and businesses. Zip codes change (though rarely) and the largest impact in recent changes to zip codes have been in the dense suburban areas of Ohio and Pennsylvania. Zip codes are used to provide regional analysis of broadband coverage, and also provide Census estimates of key demographic and economic information.

Broadband Access

The Federal Communications Commission has collected data since 1998 on broadband access by zip code in the United States. These data have been criticized for both the technical and geographic content. The FCC defines broadband as data transfer, in one direction at 200 kbs. One Commissioner challenges this definition as "so 1997." And, while we admire this air of technological savoir faire, the alternative definitions do no better in defining what is "state of the art" nor what is likely to be extant eight years hence. What is clear is that this definition marked a point of departure from traditional dial-up internet connections to something different. It still does, and so in whatever failures this definition provides, it at least allows a clear demarcation between those without any access to technology better than dial-up.[1] Among the better informed analysis of these problems (Odlyzko, 2003) notes that the Postal Service meets the current (and virtually all proposed) definitions of broadband as a box of CD's mailed overnight potentially meet any speed and data based definition. The many new or alternative technological definitions which rely on symmetric data transfer or greater speeds are subject to the same criticisms. The studies are not better, merely different.

The FCC defines regional access at the zip code level. Thus, access of a 200 kbs asymmetric data transfer by a single household, or by every household, meets the FCC definition of access. This definition is clearly adequate for most of the study region. However, for the very rare zip codes with highly spatially unbalanced populations, this

[1] One advocacy group noted that this definition was contrived by Telecom friendly members of Congress to protect regional monopolies by distorting the reality of broadband. They further argued that 200kbs could be achieved by enhanced dial-up. We wonder, if this is the case, why then the ILEC's don't simply offer the enhanced dial-up to the remaining unserved zip codes (at a trivial cost) and thus report to the FCC that everyone in the US now has broadband access.

definition permits the misinterpretation that all residents enjoy broadband access. We discourage such a lazy interpretation, but caution the critic as well, these data are substantially correct.

As researchers with considerable experience with data we are satisfied that these data represent the phenomenon of internet access as adequately as most other regional or technological data. By comparison we feel compelled to note that all data has errors. Indeed, the breathtakingly high levels of the shadow economy (10-27% of West Virginia’s Gross Domestic Product), which distorts the poverty measures; the arbitrariness of the rural/urban divide; and the bias generated by poor literacy in reporting Census data are examples of data concerns.

As our postscript suggests, we believe there is need for data collection and analysis, and that this will become more urgent as technology continues to change the benefits derived by consumers and businesses for different types of information technology and the services generated by these difference. However, the evidence to date strongly suggests that the FCC broadband data is very effective in its effort to portray the “dial-up” versus “high speed” divide both technologically and geographically.

Census Data

The 2000 Census represented the most ambitious national Census in history, and the data obtained from this effort is remarkably descriptive. These data are collected at the Census Tract level and aggregated through multi-state regions. The data are intended to be “as of” March, 2000, but are released over several a considerable period of time. Direct data on residential broadband access or internet use is limited to the Current Population Survey. We have reviewed studies of these data for the 2000 Census. We chose not to directly model these data for two reasons. First, the interesting questions surrounding these data have largely been answered and second, there are no geographical links to the data so we cannot isolate any proximal study region.

The data from the 2000 Census we employ in this study are some of the typical characteristics, which we divide by internet access (see Table 1, pg 12 of this report). While these data are almost universally viewed as the gold standard in data quality, conditions such as literacy levels may bias some of the reported data.

We report only limited ranges of these data, since simple access was not among the direct study questions in this report. We refer the reader to a number of potential studies of geographic and demographic features of broadband access noted in the text. Among these are Grubesic [2002]; Grubesic and Murray [2003] and Chaudhuri and Flamm [2005].

The Survey Data

The survey instrument employed in this analysis was an extensive questionnaire regarding internet knowledge and use, matched to individual (and regional) data. The survey consisted of 600 random calls to households, with 200 each collected in each of West Virginia's three Congressional districts. The choice to separate the survey in this way was motivated by the Steering Committee's desire to observe regional variation in the data collection process. The survey itself enjoyed a response rate in excess of 30 percent, which is unusually good for a questionnaire of this length. The responses provide a sample of the State's population which is enjoys significance better than the 2.5 percent level. The questions employed in our analysis are reported in the text. Table A-2 provides summary statistics to these data.

Table A-2 Summary Statistics of Selected Survey Data

Variable	Mean	Median	Maximum	Minimum	Std. Dev.
Number of Adults in Family	1.87	2	5	1	0.730078
Number of Kids in Family	0.48	0	6	0	0.931837
Age of Youngest Family Member	8.23	12	12	1	4.350707
Median Age	39.05	39.6	46.3	22	3.261337
Percent Population > 25 with BA degree	0.091	0.087	0.279612	0	0.048993
Median HH income	30,201.14	29,112	62,445	0	7,454.883
Have Broadband at Work	1.226667	1	3	0	1.159395
Broadband Price (actual, but not necessarily known)	35.34531	35	50	10	8.130141

Summary

The data employed in the residential demand estimates represent the best available for this type of analysis. These data form the bulwark of research regarding broadband (and many other questions) and are well accepted by researchers and informed policymakers. However, these data are not perfect, and in an attempt to improve upon known shortcomings we collected our own primary data on internet usage, price, and household demographics. We also recommend more attention to data collection occur (see Section 8 of the report).

Firm Productivity Study

Three separate estimation strategies were employed to evaluate firm productivity impacts of broadband. The first of these was a firm level estimate of broadband's productivity impact employing microdata from West Virginia and Kentucky. The second analysis consisted of a series of estimates of panel data consisting of county level data on all counties in Kentucky, Ohio, Pennsylvania and West Virginia from 1990 through 2003. This model permitted the estimate of broadband impacts on industry productivity as measured through the impact on worker wages in these industries. We review the data to support these modeling efforts in turn. The third process involved a simple comparison of firms located in the Corridor G region based upon the presence of broadband access. The goal of this analysis was to evaluate the relative productivity of firms based solely on their location decision with respect to residential broadband.

Firm Level Productivity Estimates of Broadband

The first of these matched the FCC's 2000 broadband access data with an existing microdata set of firms employed in an earlier study of firm productivity and highway access along the Appalachian Development Corridor G (RTE 119).[2] This study matched

[2] Hicks, Michael J. The Impact of Appalachian Corridors on Small Business, Transportation Research Board National Academy of Sciences, Proceedings, Transportation and Economic Development 2001. See

firm and regional specific data with GIS estimates of actual route and Euclidean distance to Corridor G.

By matching the FCC data to the firm specific and regional data we were able to estimate the impact of broadband on firm productivity (the average product of labor, which is defined as the Revenues per worker in an establishment). See summary statistics in Table A-2.

Table A-2 Selected Corridor G Data

	Mean	Median	Maximum	Minimum	Std. Dev.
Distance to Corridor G (feet)	28,587.55	19,855.18	138,529.7	330.488	25079.23
BROADBAND	0.972421	1	1	0	0.163775
Age of Firm	18.15707	12	196	0	20.66663
URBAN Zip	0.685366	1	1	0	0.464405
POPULATION	11713.94	10329	25012	114	7890.45
Number of Households	5,044.238	4663	10476	49	3,222.29
West Virginia Dummy	0.809843	1	1	0	0.392455
Per Capita Income	19,105.24	17867	36812	7157	5,575.244

The specific methods of calculating the distance to Corridor G, and the productivity arguments are offered in the original work, and again in the technical appendix on firm productivity appended to this report.

The Broadband Access and Worker Wage Study

Analysis of worker wages leads to an imputation of labor productivity since at the county level labor markets are typically quite competitive. Competitive labor markets will thus generate wage responses due to productivity increases.

In order to estimate this response, we aggregate broadband coverage from the FCC zipcode data to the county level. We used the zip code populations, to estimate the proportion of the county's population (from the 2000 Census) with broadband access for each year from the earliest FCC data through 2003.

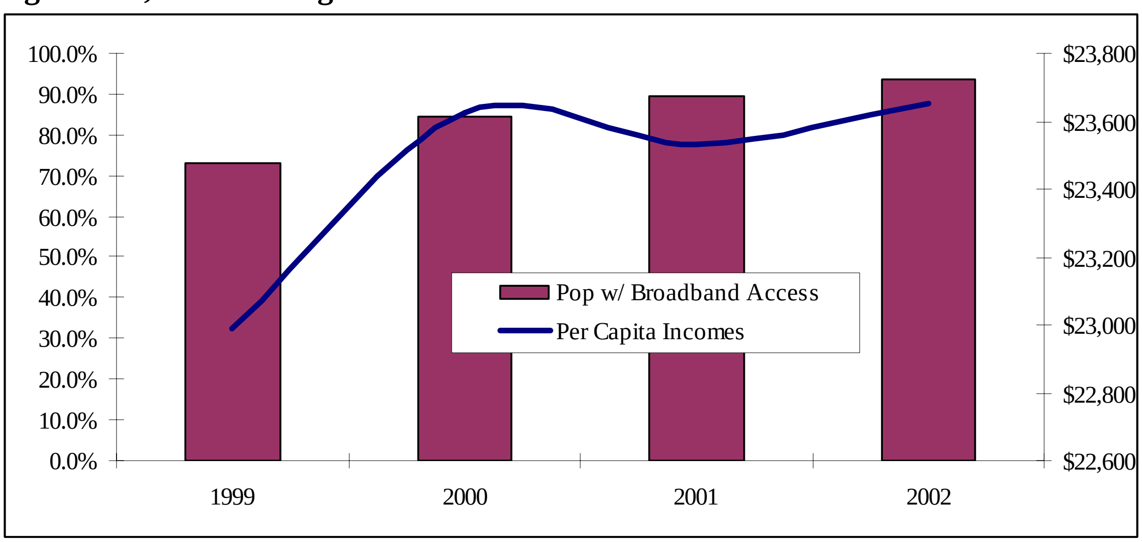
also The Impact of Appalachian Highway Corridors on the Scope of Small Business Activity, ATI 99-15 Rahall Appalachian Transportation Institute.

Further, we created a spatial weighting matrix W, for a series of spatial autocorrelation functions which appear in the estimation. The spatial weight matrix is simply the average of some variable X, in each of the contiguous counties to the county in question. Hence, the spatial weighting matrix is known as a first order contiguity matrix in this setting.

The remaining data on incomes, population, employment were collected from the *Department of Commerce's, Bureau of Economic Analysis, Regional Economic Information Systems*, and placed into 2002 dollars (for nominal values) using the consumer price index, all consumers.

The binary variables in these estimates included a recession dummy, which was coded for the year in which the National Bureau of Economic Research declared a recession in the United States. The 2001 binary variable was included to account for the drop off in investment following the dot.com bust. These data are far too extensive to display in this setting. Selected data appear in Figure A-1.

Figure A-1, Selected Regional Data



The Firm Location Analysis

The final productivity estimate we attempted was to evaluate the role of firm location decisions with respect to broadband. To accomplish this, we manually eliminated all firms with SIC codes which occurred simultaneously in zip codes with either broadband or without broadband access. An excerpt of this data appears in Table 7 (page 27) of the main study document.

Summary

The firm level productivity data and the regional productivity data are compiled from public sources, and are available from the Federal Communications Commission, the Department of Commerce and the National Bureau of Economic Research. These data represent the best available time series data on broadband, income, population, inflation and recessions for the United States.

Contact:

Michael J. Hicks
hicksm@marshall.edu
Michael.hicks@afit.edu
Center for Business and Economic Research
Marshall University
1 John Marshall Drive
Huntington, WV 25755

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

MARK L. BURTON

MICHAEL J. HICKS

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

$$\mathrm{y} = [0,1,2]$$

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

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

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.

Contact:

Michael J. Hicks
hicksm@marshall.edu
Michael.hicks@afit.edu
Center for Business and Economic Research
Marshall University
1 John Marshall Drive
Huntington, WV 25755

APPENDIX C: TECHNICAL ANALYSIS OF FIRM PRODUCTIVITY ANALYSIS

TO

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

FINAL REPORT

JULY 2005

MARK L. BURTON

MICHAEL J. HICKS

Introduction

The final analyses provided in this study were estimates of firm productivity associated with broadband. The first of these studies was a firm level analysis, followed by regional industry level analyses and finally a firm location model (which was descriptive, not econometric). We review the first two of these models in this appendix.

Benefits to Commerical Users

To evaluate the relationship between firm productivity and broadband we estimated the following general function:

$$\frac{Y}{N} = f\left(\Gamma, Broadband, \Phi, \Omega\right)$$

Where the revenue per worker in each firm is a function of access to highway infrastructure Γ, broadband telecommunications access, and the control variables of regional characteristics Φ, and firm specific characteristics, Ω. We also permitted higher order values of some variables (to estimate non-linear relationships) and interactions between selected variables. The basic construct of the model is derived from Hicks [2001] but with addition of the broadband variable and interaction term. For readers interested in a more detailed treatment of production technologies, we recommend the earlier research.

The estimation of this model required some specific statistical assumptions which we feel are useful to highlight. First, the model was estimated using both a limited dependent variable model (LDV) and ordinary least squares (OLS) techniques. The limited dependent variable model was estimated using a statistical assumption which placed less emphasis on extreme productivity values.[1] This is important since there are potential data concerns apparent in some higher ranges of productivity estimates. Also, we excluded firms that did not have employees (e.g. sole proprietorships) and those with implausibly low levels of productivity per worker (less than $10,000 per year). This could be to data errors, or the misreporting of temporary employees as full time equivalents. These data cleaning efforts are designed to eliminate from consideration known data errors and situations where we may capture data on a very non-traditional firms in which a sole proprietor may operate the business formally from home, without employees. This type of operation may, or may not, be sensitive to broadband, but warrants separate consideration. Examples of the industries we eliminated in this process were consultancies, legal services and real estate brokers. In no instance did we eliminate all the firms in an industry, and our final sample after these selection processes was in excess of 2,700 firms. Estimation results are provided in Table 3 (page 18) of the text. Selected diagnostics accompany these results. This model was subjected to a

[1] Formally, this is the extreme value distributional assumption where we assume $f(x) = \exp(x-e^x)$.

Hausman endogeneity test, demonstrating no levels of endogeneity at any level of statistical significance.

The Broadband and Worker Wage Analyses

In estimating the impact on worker wages of broadband, we are implicitly considering the traditional models of worker productivity and workers wages in a competitive setting.[2] The empirical model construct takes the form:

$$Y_{i,t} = \alpha + \gamma_1 \Omega_{i,t} + \gamma_2 \Omega_{i,t-1} + \rho_1 W_i Y_{i,t} + \rho_2 W_i Y_{i,t-1} + \beta \mathrm{X}_i + \lambda Y_{i,t-1} + u_i + e_t$$

where

$$W_i = \begin{pmatrix} w_{11} & \cdots & w_{1n} \\ \vdots & \ddots & \vdots \\ w_{m1} & \cdots & w_{mn} \end{pmatrix}$$

where *Y* is real incomes in county *i*, in time *t.* Following the equality operator, α denotes the common intercept, and γ the estimated coefficients for Ω the current and lagged proportion of broadband access in county *i*. The following terms ρWY denote the spatial autocorrelation function and its lagged value. The spatial autocorrelation term is the value of the dependent variable for the surrounding regions weighted by the distance to county *i*. In this example we employ W, as a first order contiguity matrix for Y. The remaining coefficients include a recession binary variable X, a 2001 dummy and the autocorrelation function for Y. The fixed effects dummy u, and the disturbance term e complete the basic form of our model. This model was estimated for selected two-digit SIC sectors individually for the states of West Virginia, Kentucky, Ohio, and Pennsylvania and collectively within a multi-state specification.[3]

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[2] Virtually all macroeconomic models, and regional wage models treat the marginal productivity of labor as the labor demand curve. We do as well, believing that labor markets, especially during this time period were quite competitive at the county level.

[3] As noted in the text, in each specification, we were concerned with the possible influence of endogeneity. Accordingly we adopted the preferred correction for this problem - a two-stage least squares estimator Selection of instruments is always challenging, and in this case we employed population, real per capita

In each case we were motivated by concerns for the question of endogeneity (or direction of causation) to employ an instrumental variable technique. Our two stage least squares estimates provide a method for a consistent estimate (in the just-identified instrument case or our model).[4] This also permits improvements in the robustness of the estimate when the independent variables may suffer measurement errors (as noted in Appendix A). All variances were calculated using White's [1980] heteroscedasticity invariant-variance covariance matrix. Also, we tested for the presence of a unit root in these series, which were uniformly rejected, which we believe due to the relatively brief sample period. Results for the aggregate and state level sectoral estimates are provided in Tables 4, 5 and 6 in the text.

Our findings in these estimations also speak broadly to problems of endogeneity, or the direction of causation between incomes and broadband access that naturally plague studies of this type. While we have attempted to ameliorate this problem in our estimates through the technical application of the statistical technique of two-stage least squares, the strongest evidence that endogeneity is not an issue within our findings are in the results themselves. Since we find that broadband impacts are confined to two economic sectors (as opposed to impacts that are economy-wide), it is not inconsistent with the data to assume that broadband access within these sectors that is driving wages rather than the reverse.

Summary

The two econometric models offered in this section are derived from basic economic theory applied to the question of broadband. In the first model, we were able to clearly identify the role of broadband as it interacts with firm age to provide a productivity advantage. In the second model we were able to isolate impacts of broadband access on workers wages in two sectors: Services and FIRE, as suggested by

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income and the number of residents with broadband access. We rejected COV(z,e) for z estimators at the .10 percent level.

[4] We employ population, number of residents with broadband access and per capita income as our instruments. See Green, Willim H 91997) Econometric Analysis, Prentice Hall. New York.

considerable earlier research. This finding, combined with the two stage least squares technique largely suggests that broadband is affecting wages in some sectors, and that our models do not suffer from the very real potential problem of reverse causation.

Contact:

Michael J. Hicks
hicksm@marshall.edu
Michael.hicks@afit.edu
Center for Business and Economic Research
Marshall University
1 John Marshall Drive
Huntington, WV 25755