Broadband Impacts on State GDP: Direct and Indirect Impacts

Herbert G. Thompson, Jr.
McClure School of Information and Telecommunication Systems
Ohio University
Athens, Ohio 45701
Email: thompsh3@ohio.edu

and

Christopher Garbacz
Flora, MS 39071
Email: cgarbacz@yahoo.com

Abstract

Questions and opinions about the economic impact of Broadband Internet abound. This form of telecommunication service is growing rapidly and its economic impact is likely to vary considerably around the globe. This study focuses on the direct and the indirect economic impact of broadband service penetration using US state-level data. Direct effects are estimated by regressing broadband penetration rates on state GDP *per capita*. Our direct findings, which find little or even a negative impact associated with broadband services, are similar to those of Crandall et al. (2007). However, as with other telecom services, the availability of broadband services may have indirect benefits on economies, such as reducing inefficiency and improving productivity of other inputs. In other words, although broadband may not, as yet, show a direct impact on expanding state GDP, it could be responsible for allowing a state economy to be less inefficient than it would otherwise be with less of this service. To measure the indirect effect, we use the model developed in (Thompson and Garbacz, 2007) which employs a stochastic-frontier production function approach where broadband penetration is modelled as an inefficiency reducing factor. We find that increasing the broadband network significantly reduces inefficiency in state economies.

Introduction

Broadband deployment in the United States may lead to substantial economic growth over the next few years. Crandall and Jackson (2001) estimate that the direct impact may be in the $500 billion range. Obviously telecom innovations in general may be important economic drivers both at home and abroad. Studies have been hampered by the relative newness of the phenomenon and the resulting paucity of data. Only recently has the picture come into better focus as more data has become available. Some other recent studies (e.g. Shideler, Badasyan and Taylor, 2007) have used disaggregated data, which focus on the impact in one area in the US. More work on estimating the impact of the Internet (although not necessarily broadband) has been undertaken using across country data, which allows for a larger data-base (Thompson and Garbacz, 2007).

Most of the studies on the impact of expanding telecommunication networks on business efficiency and economic growth have suggested a strong positive link, although there is as yet an unresolved issue of the direction of causality and some have raised issues of data problems. Data aggregation and the complexity of linkages, such as balancing infrastructure investments for improved use and functionality, may obscure some relationships.

High levels of all other telecommunications services interconnecting markets, people and their institutions are nothing new in the developed world. Near universal service levels of telecommunications penetration have existed there for decades. Countries with rudimentary telecommunications systems, generally find themselves at lower levels of economic development. Evidence suggests that the economic impact of expanding telecommunications infrastructure in regions such as sub-Saharan Africa is formidable, in addition to the positive returns from improved political stability coupled with economic institutional reforms (Waverman *et al.* 2005). However, there remain many unanswered questions concerning the value to business of growing penetration of broadband Internet access when compared to the benefits of other telecom networks.

Direct and Indirect Impact of Broadband

The expected impacts of broadband Internet on economic growth and development have thus far been modelled much that same as the previous studies viewed the effect of other telecommunication services. Generally, telecom services are assumed to show an immediate effect similar to other infrastructure investments, followed by the services available from these investments. These include the benefits of business information access, reduction in transactions costs, and similar benefits associated with the elimination of the costs of time and distance.

There has been remarkably little detailed discussion about how high-speed Internet service has the potential to significantly improve an economy other than through massive investment. Broadband proponents emphasize the potential business productivity gains from e-commerce, improved supply coordination, improved management efficiency, the cost-saving benefits of telecommuting and the like. Impact generally on markets includes the potential benefits of improved retailing efficiency, saving to households from reduced commuting, growth in home entertainment markets, and greater access to quality health care and education. Some, including Crandall et al, (2007), mention that the indirect effects of broadband, the so-called network externalities or 'spill-over' effect will have the most significant economic impact, but that we will not see these for some time yet as they may take time to disperse through an economy. Among the indirect or externality effects of broadband, as with other telecom services, would be general productivity improvements such as total factor productivity (TFP), an anomalous yet important source of economic growth usually associated with knowledge and technology dissemination and application.

Direct Broadband Impact – Literature, Model and Results

Recent studies tend to focus on broadband impact on employment levels directly, with a lesser interest in the general measures of income and growth (GDP). In one study using Kentucky data, disaggregated at the industry level, (Shideler, Badasyan and Taylor, 2007), found that broadband deployment positively affects total employment and the employment in many industries. However, the found negative effects in some industries. They did not study the direct effect on income or output.

Crandall et al. (2007) provide the most recent published estimates on the impact of broadband at the state level. Using yearly changes in employment they find that broadband leads to a 0.2 to 0.3 percent increase in employment in a state for a 10 percent increase in broadband lines. Particular industry groups are more affected than others. Apparently manufacturing, finance, education and health care have larger employment gains, whereas, paradoxically, some of the 'information intensive' industries showed a weaker employment effect. However, they find no statistically significant effect on state GDP. This appears to be counter-intuitive. This last surprising result leads us to investigate the issue further.

Following Crandall et al, (2007), Garbacz and Thompson (2008) developed a simple econometric model to determine the direct impact of broadband on GDP at the state level for the United States (panel from 2000-2006) and several sub-periods.. This model employed some new variables, a weighting factor and controls for unmeasured differences between the states and over time that Crandall *et al*. (2007) did not include.

This model had the following form:

STATEGDP = f (BROADBAND, LABOR, EDUCATION, DENSITY, BLACK & TAX).

All of these variables, as well as some used in the next model, are defined and their sources presented in Table 1. It is reasonable to assume that the impact will not occur immediately, since there is a learning curve, so we lag the broadband data one year in one of the models. This allows us to compare with the model with level data, and with the endogeneity control methods employed by Crandall et al. (2007). Their 2SLS model to account for endogeneity of broadband gives results approximately the same as their OLS model, so the endogeneity problem may not be significant. We also found the results of lagged and level broadband to have the same sign and not exhibit serious endogeneity bias.

The results of the Garbacz and Thompson (2008) OLS model in log form are reproduced in Table 3. Again, a weighting factor (population), fixed state and time dummies are employed. The BROADBAND coefficient in the model for 2001-2006 is statistically significant and negatively related to GDP, but has an elasticity of only 0.018. So a ten percent increase in BROADBAND would result in a 0.18 percent decrease in real GDP. This translates to a yearly decrease in GDP for the United States of about $18.66 (lagged) to $29.03 billion (level) per year at the sample mean. For the years from 2004-2006 the BROADBAND coefficient is not statistically different than zero, which means it has no impact on GDP. Fixed (state and time) effects were quite powerful, indicating perhaps the impact of capital and other factors we cannot incorporate directly into the model.

All other estimated coefficients are statistically significant and have the correct sign with the possible exception of BLACK. However, the positive sign on BLACK may reflect to some extent the movement of transfer payments from the federal government to states with large black populations that tend to receive more of these payments. But the elasticity is small. EDUCATION and TAX have important impacts as expected. LABOR makes a substantial contribution to the model, as does DENSITY (but with a negative impact).

Our results as well as Crandall, *et al* (2007) suggest that the standard direct impact econometric model has great difficulty in delineating the GDP impact of broadband. This is probably because of data limitations and because of the way that broadband is embedded in network investment, or that the direct effects may not yet have manifested themselves **as yet** in output measures. However, these approaches do not attempt to measure the many indirect effects or benefits, such as TFP impacts. These effects may at a later time be reflected in GDP growth, but they may currently account for why some states are more efficient in their use of resources, relative to others. This may argue for a more sophisticated approach that attempts to measure inefficiency-reducing factors such as total factor productivity, and are discussed in the next section.

Indirect Broadband Impact: Model and Results

In earlier work Thompson and Garbacz (2007) explore more completely the role of certain factors in growth and development, and at the same time avoid some of the methodological shortcomings of previous studies. They employed the latest advances in the stochastic-frontier production function approach and derive a model that allows for the determination of the factors most responsible for shifting out the production frontier (the production function for the most efficient economies in a sample), while at the same time identifying what factors may be responsible for why some economies fall short of that frontier. Both measures of institutional freedom and the extent of the information (telecommunications) network are possible explanations of relative inefficiency. Country panel data allowed them to capture the most recent growth in new telecommunications services in this structure.

Thompson and Garbacz (2007) found that penetration rates of telecommunications services measures of economic institutional freedom, using the Heritage Foundations' Economic Freedom Index (EFI), and both significantly improve the productive efficiency of the world as a whole, in the subset of low income countries, most particularly for the countries comprising sub-Saharan Africa and Latin America. There is also some evidence that information networks are playing a role in the significant Asian economic development. By contrast, the developed nations of the OECD, which have had near universal service levels of telecommunications and free-market institutions over this period, already operate at or near their productive frontier and show virtually no response to changes in telecommunication penetration. These findings strongly support the results of other recent studies and recommend continued efforts to expand telecom networks and improved economic institutions in Africa and other developing regions.

In the present paper, we set out to apply this model to the impact of broadband penetration on the states of the United States. Data used in estimating this model was same data used in the direct impact model, with the exception of a proxy for capital stock, and exclude some variables not normally found in a traditional production function (to be consistent with previous work). State capital stock data is not measure directly by government sources. They do, however, track Gross Operating Surplus (GOS) at the state level. GOS is a composite measure of private profits and surplus revenue of government enterprises. Assuming that rates of return to capital is determined in US capital markets; this measure should be proportional to the capital stock at the state level. The state tax rate variable serves as proxy for the business environment in different states and is thought to capture effects similar to the EFI variable appropriate in a cross-country study. Because of the lack of capital stock proxy data, 2006 data was not used. Otherwise, the data and sources are contained in Table 1 and summary statistics in Table 2. This allows for a panel of states with appropriate data to be constructed over a five-year period.

A detailed discussion of the history of the applications and properties of the Stochastic Frontier Production Function (SF) studies of telecommunication’s impact on productive inefficiency can be found in Thompson and Garbacz, 2007. A summary of the important differences for this model from previous telecom impact models include: (1) summarizing important evidence on the endogeneity impact argument; (2) addressing questions concerning the separability of modern, digital-based telecom capital; and (3) decomposing the TFP effect into of telecom network effects and business environment indicators.

As with the primary findings in the cross-country Thompson and Garbacz, 2007 study, we hypothesize that inputs to the frontier production function (measure of labor, capital and education) should have positively signed parameters, and the variables explaining technical inefficiency should have negative signs if they act to reduce production inefficiency. Specifically, in this study, if increased broadband penetration at the state level reduces productive inefficiency, the parameter estimate should be negative and statistically significant. Tax rates, on the other hand, should have a positive sign if, as generally assumed, higher taxes result in more productive inefficiency.

For estimation of the stochastic-frontier production function a version Battese and Coelli (1995) was employed, which imposes reasonable restrictions on the model, allows the use of panel data and permits the simultaneous estimation of the frontier production function variables with the productive inefficiency variables. Theoretical and empirical support for the single-stage, simultaneous estimation relative to the 2-step approach is given in Wang and Schmidt (2002). Estimation is performed using Frontier 4.1, Model 2, developed and referenced by Coelli (1996).

Specifically, this model estimates a production frontier of the following form:

$$Y_{it} = x_{it}\beta + (V_{it} - U_{it}), \quad (1)$$

where i = 1,…,N states, and t = 1,…,T time periods. Y is the output variable (State GDP in 2000 constant dollars) for each country and time period. The x is a vector of production inputs of capital, labor, education, and a linear time trend. The β are the unknown input parameters for the frontier production function. This formulation could be adjusted to reflect the multiplicative form of the production function. Natural logs of all quantifiable variables are used in the model. The V are randomly distributed error terms, and are assumed to be independent of U, which are the non-negative error terms that are designed to account for technical inefficiency in production – and have a half-normal distribution. The U can then be explained in the following formula:

$$U_{it} = z_{it}\delta + w_{it}, \qquad (2)$$

where z is a vector of explanatory variables for technical inefficiency (tax rate and broadband penetration rates), and δ is a vector of parameters to be estimated. The *w* are assumed to be randomly distributed errors. Again, we do not use the two-step approach implied by this formulation.

The ability of the model to estimate and explain a stochastic production frontier is indicated by the variation in the parameters $\sigma^2 \equiv \sigma^2 u + \sigma^2 v$ and $\gamma = \sigma^2 u/\sigma^2$. The value of γ may be interpreted as an inefficiency indicator. As γ approaches zero, overall variation in the errors of the production function can be attributed to random elements. Alternatively, as γ approaches one, more of the estimation errors can be attributed to technical inefficiency. An efficiency measure, with ability to identify and rank the efficiency of production for different states and time periods is developed by the program and is the ratio of the actual production level to the estimated production frontier level.

The decision was made not to use state effects variables in this specification for several reasons. First, and most importantly, the inclusion of state effects eliminates the explanatory power of the variables included in the inefficiency function, which are the focal point of this study - and a problem noted by Coelli in correspondence**.** Secondly, state effects variables imply that important changes in unmeasured effects occur between states, but not over time within a state. Third, the decision to allow capital, labor, and human capital to vary across the sample introduces some additional control for heterogeneity in the data. Finally, using the production function specification, a sample of states in the generally homogeneous United States will provide additional control for data heterogeneity.

Results of the Model of Indirect Impact

The parameters for the simultaneously estimated production frontier and inefficiency functions for the states can be found in table 4. We estimate two models. The production function estimates across the models are similar and appear to be reasonable. Labor has a coefficient of 0.36, Capital is at 0.68 and Human Capital is 0.43 to 0.47. Trend is a small negative. Average efficiency is 0.69 to 0.79.

Now refer to the inefficiency component. BBPEN has a statistically significant negative impact on inefficiency. In the level model the impact is a reduction of inefficiency of about 0.024. This is a substantial impact given that average efficiency is calculated at about 69%. The impact would be to increase average efficiency to about 3.6% for a 10% increase in BBPEN. TAX has a negative impact indicating that an increase in the tax rate at the state and local level would reduce inefficiency. This would suggest that there is a public infrastructure effect. However, the impact is small. The lagged model does not reveal any inefficiency in the model, based on a Chi Square test.

A comparison of these state-level results with those of the earlier cross-country study provides an insightful contrast (see Table 5 for a subset of the results from Thompson and Garbacz, 2007). A comparison of the state results with the OECD sample of countries results should find some values that are similar. However, the study finds that on the production function side that the OECD has a larger capital effect, a smaller labor effect, no education effect and a higher average efficiency. On the productive inefficiency side the OECD results show that there is no Internet (or a positive) but the EFI effect is high and as expected. In fact, the state results are more similar to that of the World sample as a whole. Perhaps the variation across world economies more closely models the variation across states, relative to that across OECD countries. This could be result of similar variation in the industrial base, product specialization, population densities, and other characteristics across states.

Summary and Conclusions

Examination of the model results for the Direct and Indirect impact of broadband on state GDP, including results from previous studies, provide some important insights into the broadband deployment policy debate. First, broadband expansion does not demonstrate direct, positive impact on state income, although there is some evidence that employment in certain industries is expanded. This would tend to imply that true economic growth will likely result eventually. It is also clear that the connection between increased broadband deployment and employment growth is poorly understood, and that the mechanisms are not obvious. Why is some industry employment strongly impacted, while others are not? This is especially puzzling, given that non-information intensive industries appear to be more strongly affected than information-based industries. There may be a substitution effect between broadband and employment that should be carefully explored.

A better understanding of broadband's impact may lie in exploring the network externality effects associated with its use. Productive inefficiency may well vary across the industries explored in these earlier studies and are affected disproportionately by broadband's productivity enhancement. Ideally, a more disaggregated dataset (at the industry level) examined by methods capable of revealing relative inefficiency may provide many answers and suggestions as to where broadband may be more effective as a policy tool.

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Table 1*

Variable Definitions

GDP		Direct Model: Gross Domestic Product per capita at the state level. Constant 2000 dollars. Indirect Model: State GDP: Source: BEA
BBPEN		Broadband lines per 1000 in the population - with speeds of 200 kbps or greater. Source: FCC
LABOR		Direct Model: Labor force participation per capita. Indirect Model: Labor force participation. Source: Bureau of Labor Statistics
EDUCATION		Proportion of the population 25 years or older with a high school degree. Source: Census
DENSITY		Percentage of population living in urban areas. Source: 2000 Decennial Census
BLACK		Proportion of the population black. Source: Census
CAPITAL		Gross Operating Surplus in 1000 US Constant dollars; BEA
TAX		State and local tax rate. Lagged one year. Source: Tax foundation

* Because of unavailable data, the following states are not included in the Direct Models: Hawaii, District of Columbia. In addition, the states if North Dakota and Vermont were exclude from the Indirect models due to missing capital data.

Table 2

Summary Statistics

Variables	Mean	Standard Deviation	Minimum	Maximum	Number of Observations
GDP *per capital*:	$34,477	$6,283	$22,384	$59,988	294
GDP (1,000 USD)	$216,330	$246,741	$18,114	$1,457,090	235*
BBPEN (2001-2006):	95.6	63.6	0.002	304.5	294
BBPEN (2001-2005):	76.2	43.7	0.002	193.7	235
LABOR (percent):	38.3%	3.5%	30.3%	46.9%	294
LABOR (in thousands)	2,300	2,312	184	12,381	235
EDUCATION (2001-2006):	86.1%	3.9%	77.2%	92.7%	294
DENSITY:	71.3%	14.7%	38.2%	94.4%	294
BLACK:	10.1%	9.5%	0.30%	37.2%	294
CAPITAL	$76,475	$88,644	$7,803	$538,937	235
TAX:	10.3%	1.2%	6.5%	14.0%	294

*Note: Figures for Capital and other variables used only in the Indirect Model are for a slightly different sample, and for the years 2001-2005. There was no measureable difference in tax rates or education in the two samples.

Table 3

Direct Effects Model Elasticities

(Standard Errors in Parentheses)

Variables	**Broadband Level Models**			**Broadband Lagged Models**		
		2001-2006	**2004-2006**		**2001-2006**	**2004-2006**
BBPEN		-0.028*	0.020		-0.018*	-0.002
		(0006)	(0.035)		(0.003)	(0.027)
LABOR		0.929*	0.915*		1.007*	0.932*
		(0.075)	(0.109)		(0.075)	(0.108)
EDUCATION		0.475*	0.368		0.464*	0.388
		(0.122)	(0.262)		(0.119)	(0.262)
TAX		-0.471*	-0.372*		-0.441*	-0.366*
		(0.037)	(0.058)		(0.037)	(0.695)
BLACK		0.123*	0.042*		0. 126*	0.044*
		(0.011)	(0.010)		(0.011)	(0.010)
DENSITY		-0.331*	0.185*		-0. 319*	0.189*
		(0.072)	(0.049)		(0.070)	(0.049)
Adj. R2		0.980	0.960		0.981	0.960
Obs.		294	147		294	147

Table 4

State Indirect Effects Model Results

Production Function:	**Variables**	**BB-Level**	**BB-Lagged**
β_0	CONSTANT	0.346	-0.199
		(7.996)	(1.138)
β_1	LABOR	0.356***	0.357***
		(0.020)	(0.021)
β_2	CAPITAL	0.682***	0.684***
		(0.020)	(0.020)
β_3	EDUCATION	0.432***	0.472***
		(0.083)	(0.086)
β_4	TIME TREND	-0.016***	-0.001**
		(0.004)	(0.003)
Inefficiency Function:			
δ_0	CONSTANT	0.325	-0.044
		(7.895)	(1.025)
δ_1	BBPEN	-0.024***	-0.006***
		(0.003)	(0.002)
δ_2	TAX	-0.062***	-0.053**
		(0.017	(0.017)
σ^2		0.003***	0.003***
		(0.0003)	(0.0003)
γ		0.872	0.014
		(14.647)	(1.065)
Log – Likelihood		339.123	331.978
Mean Efficiency		0.692	0.786
Chi Sq	One-sided test	19.70***	5.0408
Sample size		235	235

Table 5

International Internet Results (Thompson and Garbacz, 2007)

Parameter	Variable	WORLD	AFRICA	OECD**
Production Function				
β_0	Constant	4.810***	6.245***	3.280***
		(40.063)	(3.765)	(3.772)
β_1	Labor	0.373***	0.445***	0.241***
		(31.310)	(21.135)	(2.961)
β_2	Capital	0.581***	0.546***	0.721***
		(54.042)	(18.371)	(8.601)
β_3	Education	0.112***	-0..004	0.013
		(3.826)	(-0.385)	(0.134)
β_4	Time Trend	-0.005	-0.110***	0.022
		(-1.411)	(-7.142)	(1.248)
Inefficiency Function				
δ_0	Constant	0.304***	1.611***	0.023
		(3.466)	(2.529)	(0.038)
δ_1	Internet	-0.061***	-0.127***	0.117***
		(-12.437)	(-21.776)	(2.763)
δ_2	EFI	-0.0671***	-0.226***	-0.517***
		(-2.473)	(-8.310)	(-4.137)
σ^2		0.158***	0.114***	0.019***
		(7.176)	(11.335)	(5.113)
γ		0.803***	0.999***	0.061
		(24.514)	(>999)	(0.177)
Log –Likelihood		-51.954	-80.531	102.303
Mean Efficiency		0.7835	0.2380	0.9052
Observations		837	243	180