BROADBAND AND ECONOMIC DEVELOPMENT: A MUNICIPAL CASE STUDY FROM FLORIDA

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In this paper, we explore whether broadband investment by municipalities has an effect on economic growth. To do so, we employ an econometric model to compare economic growth between counties in the State of Florida. Our econometric model shows that Lake County – a small county in central Florida – has experienced significantly greater growth in economic activity relative to comparable Florida counties since making its municipal fiber-optic network generally available to businesses and municipal institutions in the county. Our findings are consistent with other analyses that postulate that broadband infrastructure can be a significant contributor to economic growth.

1. Introduction

The future of a community is often directly related to that community's public infrastructure. Good schools, adequate roads and transportation, access to affordable health care, and quality of life factors such as parks and cultural venues play a role in whether communities will attract new businesses and residents, and be vibrant. Economic research shows that public infrastructure investment is a powerful driver of business productivity, investment, and economic growth (Aschauer, 1989; Blum, 1982; Button *et al.*, 1995; Gramlich, 1994; Nadiri and Mamuneas, 1994. Seitz, 1995; Seitz and Licht, 1995).

Several countries around the world have undertaken substantial direct government investment in broadband infrastructure, often treating it like other areas of public infrastructure. The South Korean government has utilized direct investment, guaranteed loans, and construction on consignment programs (in which private firms build facilities with the government acting as a sort of guarantee of service) to build the world's leading broadband capability (Speta, 2004). The Korean Information Infrastructure Project invested $7.3 billion from 1995–2002 and has plans to invest an additional $17.8 billion by 2010.[1] Korea now leads the world with a 24.9% household broadband penetration rate, compared with 13.0% in the United States.[2]

[1] Nae-Chan Lee, *Broadband Internet Service: Korea's Experience*, (Feb. 2002), at http://www.mic.go.kr/eng/res/res_pub_db/res_pub_sep_brd/Broadband_Internet_in_Korea_2002.pdf. Based on relative population, the equivalent national investment in the United States would be $153 billion.

The United States has historically relied on private investment to build and construct its communications infrastructure. However, the United States has subsidized this private investment over the decades through a number of support and subsidy programs, including federal and state universal service programs. These subsidy flows are often justified by reference to social equity grounds, an implicit recognition of the importance a communications infrastructure has on economic development.

In the last few years, the desire to deploy broadband ubiquitously throughout the United States has led national and local political leaders to argue for a more direct governmental role by federal, state, and local governments.[3] President Bush has stated that all corners of the United States must have "universal, affordable" broadband service by 2007, so that no community forgoes the "great opportunity" afforded by broadband services.[4] Community leaders are concerned that communities without broadband service will wither and be left behind as firms and jobs move to regions – either elsewhere in the USA or abroad, where instant, high-bandwidth connectivity is available and affordable. For example, Federal Communications Commission (FCC) Michael J. Copps has observed:

> Providing meaningful access to advanced telecommunications for all our citizens may also spell the difference between stagnation and economic revitalization. One study estimates that universal broadband access could add half a trillion dollars to the U.S. economy every year. Even that may be conservative. Broadband is already becoming key to our nation's systems of education and commerce and jobs and, therefore, key to America's future. It's going to be front-and-center in America's Twenty-first century transformation. Bet on it.[5]

Many municipalities have begun to directly invest in constructing broadband infrastructure, just as cities build schools, pave roads, and construct hospitals.[6] Justification for such construction is nearly always tied to the pro-growth potential of broadband services, and frequently tied to the failure of private firms to provide adequate broadband services, if any, to the

[2] Organization for Economic Cooperation and Development, *OECD Broadband Statistics* (May 2005, http://www.oecd.org/document/60/0,2340,en_2649_37409_2496764_1_1_1_37409,00.html

[3] UTOPIA, a consortium of 14 Utah cities, states "[t]elecommunications infrastructure today is just as vital for economic growth as transportation systems were in the past. ... Cities have always been in the infrastructure business." Utah Telecommunications Open Infrastructure Agency, *White Paper: Utah's Public-Private Fiber-to-the-Premises Initiative* (Nov. 2003), http://www.utopianet.org/downloads/Utopia_White_Paper.pdf ("UTOPIA White Paper") at 7–8. For examples of current city networks and proposals, *see* MuniWireless, http://www.muniwireless.com/archives/cat_hot_cities.html.

[4] The White House, *A New Generation of American Innovation* (April 2004), http://www.whitehouse.gov/infocus/technology/economic_policy/200404/innovation.pdf, at p. 11. President Bush said in a June 24, 2004 speech: "Imagine if you're the head of a chamber of commerce of a city, and you say, 'Gosh, our city is a great place to do business or to find work. We're setting up a wi-fi hot zone, which means our citizens are more likely to be more productive than the citizens from a neighboring community.' It's a great opportunity." The White House, *President Bush: High Tech Improving Economy, Health Care, Education* (June 2004), http://www.whitehorse.gov/news/releases/2004/06/020040624-7.html.

[5] Remarks of Michael J. Copps, Commissioner, Federal Communications Commission, FCBA Denver Chapter (Jan. 11, 2002) http://ftp.fcc.gov/Speeches/Copps/2002/spmjc202.html

[6] Some "municipal broadband" projects are a direct outgrowth of other public infrastructure activities, such as the provision of low-income health services. *See, e.g.*, FMEA, *The Case for Municipal Broadband in Florida* (March 2005) at 9 (describing project in Jacksonville, Florida in which municipal broadband network provides medical help to inner city, asthmatic children).

community.[7] These municipal investment projects have been criticized, however, as money-losing, inefficient and potentially wasteful use of taxpayer resources.

In this paper, we explore whether direct municipal broadband investment in broadband infrastructure creates positive economic gains for the community as a whole, beyond those that private investment supplies. Theoretical research suggests that it might, particularly in economically disadvantaged communities (Robinson, 1977; Martin 1999; Martin and Rogers 1995; Hesham 2000). Our empirical approach is necessarily limited, given the lack of detailed data on this relatively recent phenomenon. There exists, however, sufficient data to perform a straightforward test of the impact of municipal broadband on economic activity, even though the results should be qualified as "preliminary evidence." Broadband deployment by the public or private sector is an important policy issue in nearly every industrialized nation and, to our knowledge, this paper represents the first systematic effort to quantify its impact on economic activity.[8]

Our findings provide support for the position that municipal broadband infrastructure stimulates economic growth. Since 2001, when the municipal fiber-optic network launched in Lake County, Florida, the county has experienced a significant burst of economic activity relative to its peers. If these external benefits of broadband services cannot be captured by private firms, which they most likely cannot, then public investment in broadband infrastructure may be warranted.

2. Details of methods and findings

In this paper, we quantify the effect on economic development resulting from a community's investment in a broadband network. One difficulty in doing so is the general lack of sufficient economic and demographic data to analyze changes in a community's economic fortunes. Broadband service is a relatively recent phenomenon, and local economic data is often unavailable. However, we were able to find sufficient information on economic activity both before and after the deployment of municipal broadband infrastructure for counties in the State of Florida. We use this data in an econometric model to quantify the effect of the municipally-owned broadband network on economic growth.

Our attention focuses on Lake County, Florida. We choose Lake County as the subject of our study for a number of reasons. First, in 2001, the City of Leesburg began offering private businesses across Lake County access to one of Florida's most extensive, municipally-owned broadband networks, with fiber-optic connections to hospitals, doctor offices, private businesses, and 44 schools.[9] Thus, the age of the system allows for data collection in the pre-availability and post-availability periods. Second, some detailed data on economic activity is available on Florida counties. The Florida Department of Revenue provides month-by-month, county-by-county reports since January 1998 of retail sales data, which we utilize as a proxy for economic

[7] *See* UTOPIA White Paper at 9 ("Private enterprise has not deployed true broadband to homes and small businesses in a widespread way.").

[8] Community specific studies of the impact of municipal communications networks are available from Strategic Networks Group (sngroup.com)

[9] The municipality began construction and use of the network in 1992, but its use was limited to services for government agencies.

activity.[10] As a result, we have three years of monthly retail sales data before Lake County's general offering of its broadband network, as well as nearly three years of data after this expanded use of its network (excluding the expansion period 2001).

Lake County is, in some ways, a rather typical Florida county. Located on the edge of the Orlando Metropolitan Statistical Area, Lake County contains some suburban and some rural areas, but does not contain any major urban center (its population density is 220.9 per square mile, compared to Florida's overall density of 296.4). The 2000 census reported that Lake County's per capita income was slightly below Florida's average. Retail sales per capita have historically been below the state average ($7,781 in 1997, compared to $10,297 statewide). Advocates on both sides of the issue of municipal broadband entry routinely state their desire that non-urban localities like Lake County receive the same broadband options that downtown, urban residents may have.

2.1 The empirical model

Economic growth is an obvious measure of economic development, so we begin with a simple model of economic growth.[11] Let y be a measure of economic activity. The formula for compound growth is

$$y_t = y_0(1+g)^t \tag{1}$$

where y_0 is the initial value of economic activity, g is the growth rate, and t is time. Taking the natural logarithm of both sides (and ignoring seasonality), Equation (1) can be expressed in econometric form as

$$\ln(y_t) = \beta_0 + \beta_1 t + \varepsilon \tag{2}$$

where $\beta_0 = \ln(y_0)$, $\beta_1 = \ln(1+g)$, and ε is the econometric disturbance term. The coefficient β_1 measures the instantaneous rate of growth in economic activity; the compound rate of growth is $[\exp(\beta_1) - 1]$. The starting level of y is simply $y_0 = \exp(\beta_0)$. In Equation (2), β_1 is assumed to be constant over t.

This simple growth model can be expanded to measure the marginal impact on growth of a change in the productive capacity of an economy occurring during the period T*. Say there are two economies of interest, A and B, which have the same growth rate in period T (which is prior to period T*). The growth rate equations in T are simply

$$\ln\left(y_t^A\right) = \beta_0^A + \beta_1 t + \mu \tag{3a}$$

$$\ln\left(y_t^B\right) = \beta_0^B + \beta_2 t + \nu \tag{3b}$$

[10] Retail sales data is commonly used to measure economic activity, particularly among government economic development organizations. Retail sales is also highly correlated with Gross Domestic Product – an obvious measure of economic activity – with a correlation coefficient of 0.94 (computed using data from the FRED database of the St. Louis Federal Reserve Bank, research.stlouisfed.org).

[11] An alternative approach would be to specify a structural model economic activity; such models generally are multi-equation systems. However, we do not have the data required for such a model, and even if we did, we would run the risk of masking the effects of the broadband network, since many of the regressors in such a model are also indicators of economic activity (e.g., the size of the labor force and investment expenditures). See, e.g., Feder (1983) and Ram (1986).

where $\beta_1 = \beta_2$ but β_0^A may or may not equal β_0^B.[12] Assume, however, that in time period T* a new, growth-stimulating technology is deployed in economy B. In period T*, we have the two growth equations

$$\ln(y_t^A) = b_0^A + b_1 t + \mu' \tag{4a}$$

$$\ln(y_t^B) = b_0^B + b_2 t + \nu' \tag{4b}$$

where no particular relationships between b_i and β_i are assumed (the latter from Equations 3a and 3b). If the technology positively impacts growth, then we have $b_2 > b_1$ (i.e., growth is higher in economy B). If the technology has no effect on growth, then we have $b_2 = b_1$. While it is unlikely that a new technology will reduce growth, a reduction in growth renders $b_2 < b_1$. From both a directional and size perspective, the marginal contribution to growth of the new technology is measured by $b_2 - b_1$, with the percentage change being equal to $(b_2 - b_1)/b_1$.

Note that comparing b_2 to β_1 (measuring the temporal change in growth) does not indicate the contribution of the technology to growth, since general economic conditions may alter the growth rates between periods (b_1, the growth rate absent the technology, may not equal β_1). The impact of the technology can only be assessed (in this model) by comparing the economic growth rate of the technology-affected economy B to growth in the unaffected, but otherwise identical, economy A. The need to focus on relative growth is a requirement of the model, because we are comparing the economic performance of one community (Lake County, Florida) with its peers (other Florida counties). We chose this method given the limitations in available data and the nature of the question at hand.

2.2 Estimation procedures

With data on y^A and y^B, the parameters β_0, β_1, b_0, b_1, and b_2 can all be estimated using appropriate econometric techniques, thereby quantifying the marginal impact of the technology on economic growth. In this study, we are using county level data, so the economies in the empirical model are counties.

Our framework could be utilized to measure the economic significance of any particular event or technology (if sufficient data were available). Of concern to us is the availability of a municipal-owned broadband infrastructure. Our empirical framework assumes that the two economies, A and B, are nearly identical in growth in the pre-technology period T. Thus, we need to select a group of counties to represent the "A" economy, while Lake County is the "B" economy. Assembling a group of *identical* counties is obviously not possible, so we are limited to a group of very similar counties. Since growth is our measure of development, it follows that the most sensible way to choose peer counties is to select based on similarities in growth rates and economic activity patterns. From a theoretical perspective, the members of this control group should have at least two relationships to Lake County in period T: 1) the growth rates (β_1 and β_2) should be equal and 2) the economic activity levels should be highly correlated [that is, a high correlation coefficient between y or $\ln(y)$]. Equality of growth rates satisfies Equations (3a) and (3b), while the high correlation among counties ensures that the

[12] If the economies differ in the level of y, then the coefficients will be different.

control group economies have behaved nearly identically over time.[13] So while there may be different demographic and business profiles among the counties, these differences have not led to systematic differences in the observed growth and economic activity among the counties.[14] If both statistical criteria are met, the county economies that qualify for the control group will be nearly identical in their economic activity levels over the time period, with the exception of the event or technology change that we are studying. Selecting the control group in this way is necessary from a theoretical perspective, given the chosen growth-based model.

2.3 Data

With the conceptual framework in mind, our empirical approach proceeds as follows. First, we collect county-level data on *gross sales*, available online through the Florida Department of Revenue on a monthly basis from January 1998 through November 2004.[15] *Gross sales* is a common measure of economic activity, and so we use gross sales in this study as the dependent variable of the regression analysis (y).[16]

We define the two periods as follows: a) T is January 1998 through December 2000 and b) T* is January 2002 through November 2004. We exclude the transition year 2001, the year in which the municipal network in Lake County was first used widely to offer broadband services to local businesses over its municipal network. Exclusion of the transition year is common practice in "event" studies such as this one, since it allows for greater temporal separation between the two periods (T and T*) and avoids temporal instabilities (Andersen *et al.*, 2001; Fairlie, 2002; Ralle and Tonjas-Bernatte, 1990). Creating a time gap between the two periods also helps minimize any time dependence between the two periods, rendering better estimates of the effects of interest. Further, our statistical analysis reveals that the annual growth rates within T and T*, as defined, are generally equal; we are unable to reject equality of the annual growth rates for years 1998, 1999 and 2000 (period T), and for the years 2002, 2003, and 2004 (period T*).[17] Annual growth in 2001, however, differs from the growth rates in both periods. So, excluding 2001 ensures homogeneity of growth rates within the two periods.[18]

[13] It is possible that identical growth rates could arise from economies that behave very differently over time. For example, growth in Lake and Franklin counties are very close (0.0080 and 0.0085), but their correlation coefficient is very small (0.165). The ρ constraint ensures the selection of only very similar economies by adding an additional dimension of likeness. Grouping markets or economies by evaluating correlations of particular variables across markets and economies is used in a variety of contexts. See, e.g., an application to antitrust market definition in Stigler and Sherwin (1985).

[14] In fact, diversity in demographic and business profiles of the control group may provide us more robust and general conclusions as to the economic impact of the new technology. For instance, a subject county and control group of only rural counties would, at best, only be able to support a conclusion that the technology would benefit rural communities.

[15] http://www.myflorida.com/dor/taxes/distributions.html.

[16] According to the Center for Economic and Business Research ("CEBR") at the University of South Florida, this data on Gross Sales "is intended as a measure of economic activity" (cedr.coba.usf.edu).

[17] This test is conducted using a homogenous growth rate for all counties that is estimated uniquely for each year. Equality is then evaluated using the Wald test.

[18] Equality cannot be rejected for the per-capita data, but including 2001 does not materially alter the results. For consistency, we exclude 2001 from the analysis using per-capita data. Including 2001 from the level data does not impact much the size of the difference.

2.4 Selection of peer Florida counties

As a second step, we use a statistical procedure to select a group of Florida counties to which we compare Lake County. This group of peer counties represents the "A" economy of our empirical model, which we call the *control group*. This peer-county sample is selected by first estimating (by ordinary least squares) the growth rate (g_i) of sales (y_i) for *each* of the 67 counties in Florida over the period January 1998 through December 2000 (period T) using the equation

$$\ln(y) = \beta_0 + \beta_1 t + \sum_{m=1}^{11} \lambda_m M + \varepsilon, \tag{5}$$

where M_m are m monthly dummy variables, each having a unique coefficient λ_m (i.e., the seasonality effects). There are 11 (m) monthly dummy variables, with December being excluded to avoid the dummy trap. Next, we compute the simple correlation coefficients (ρ_i) of ln(y) between Lake County and each of the other 66 counties.

For selecting the control group of counties, we employ a simple two-factor joint selection rule: 1) choose counties with a growth rate g_i within the 80% confidence interval of Lake County's growth rate and 2) choose counties with $\rho_i > 0.80$.[19] Both criteria must be satisfied for a county to qualify for the control group. The symmetric boundary around Lake County's growth should produce a mean (and median) growth rate for the control group (statistically) equal to the growth rate for Lake County, and statistical equality between Lake County and the others individually (with an acceptable degree of statistical confidence).[20] This procedure renders twelve comparable counties, five of which have municipal networks that provide at least some broadband services over (some part) the time period analyzed (APPA, 2005). For this reason, we exclude these counties. The final panel contains eight counties (Lake, plus seven comparable counties). The counties, along with some relevant descriptive statistics, are listed in Table 1.

The data used in this study is time series data, and the particular properties of time series data can affect the quality of the estimated coefficients. We are concerned primarily with the presence or absence of serial correlation and stationarity (Gujarati, 1999: 401, 710–24).[21] In the presence of serial correlation, the estimated coefficients of the model will be unbiased and consistent, but inefficient. Non-stationary data could lead to spurious results, which are highly undesirable (Gujarati, 1995; Granger, 1999).

We address both issues with appropriate statistical tests. For serial correlation, we compute the Durbin-Watson statistic (DW) for both the periods T and T*. Positive first-order serial correlation is indicated if the computed DW is less than 0.69. All the DW statistics exceed these

[19] These boundaries were chosen so that a reasonably large group of comparables could be constructed. Increasing (decreasing) either of the thresholds will reduce (increase) the number of comparable counties. Generating a very large group of comparables runs the risk of having unlike counties in the control group, so the goal is to keep the thresholds "tight" (i.e., a small confidence interval around g and ρ values close to 1.0) while maintaining a sufficiently large control group.

[20] The Wald test indicates that the growth rates in all the counties are statistically equal (F = 1.15, Prob = 0.33), and the test also reveals the growth rate in Lake County is not different from that of the mean or median of the control group.

[21] A central concern with the application of the constant growth model used here is the potential for spurious results due to non-stationary data. Gujarati (1995: 719).

Table 1. Members of the panel dataset

County	g_i	ρ_i	DW_i		PP_i	
			T	T*	T	T*
Lake	0.0080	1.00	1.11	1.88	−3.85	−15.07
Broward	0.0088	0.90	1.75	1.84	−5.33	−57.18
Charlotte	0.0072	0.84	1.76	1.81	−3.11	−13.91
Madison	0.0078	0.84	2.25	1.57	−5.68	−9.28
Palm Beach	0.0085	0.89	1.44	1.83	−4.28	−38.67
Sarasota	0.0072	0.90	1.40	1.73	−4.44	−5.64
Seminole	0.0077	0.82	1.79	1.93	−6.26	−11.73
Suwannee	0.0074	0.90	2.02	1.80	−5.42	−4.25
Average (exc. Lake)	0.0078	0.87	...	...	...	...

values, so serial correlation is not a problem.[22] To evaluate the stationarity of the series, we apply the Phillips-Perron test (PP) for a unit root.[23] The null hypothesis of the PP test is "y has a unit root," and the critical value is about −2.92 with rejection indicated if the PP statistic is smaller (more negative) than the critical value.[24] We can reject the null hypothesis of the PP test for all series in both periods (the PP statistics are less than the critical values), so we conclude our y series are stationary and consequently that our findings are not the result of spurious regression.

The summary information in Table 2 illustrates that we have selected excellent candidates for the control group; the growth rates for the control counties are practically and statistically identical to Lake County (0.008 versus 0.0078, on average) and the $\ln(y)$ series are highly correlated (0.87, on average). None of the series is serially correlated and each is stationary. For the period January 1998 through December 2000, the behavior of gross sales over time for the panel of counties is nearly identical, thereby satisfying the principal assumptions of the empirical growth model.

3. Results

With our control group in place, we now turn to the estimation of Equations (4a) and (4b). We can estimate the relevant parameters and test for differences in growth rates by jointly estimating eight equations, one for each county in the panel, with each having the general form:

$$\ln(y_{it}) = (b_0 + a_i) + b_1 t + \delta d \cdot t + \sum_{m=1}^{11} \lambda_{mi} M_{mt} + \varepsilon_{it} \tag{6}$$

where b_0 is a common intercept, a_i is a fixed effect for county i, M_m are m monthly dummy variables, and d equals 1 for Lake County (0 otherwise). Seasonal effects are unique to each county, but b_1 is assumed to be equal across the control group counties. Growth for Lake County

[22] The regressors influence the size of the computed DW statistic, and the use of the time-trend as the explanatory variable will push the value of DW toward 0. Since the time-trend is the only explanatory variable, the lower bound of the DW statistic (often called d_l) is the appropriate critical value for the test of serial correlation (thereby ignoring the typical indeterminate zone of the DW statistic). For details, see Pindyck and Rubinfeld (1991; 144).

[23] The Phillips-Perron unit root test is robust to serial correlation. Since we are testing for serial correlation, it seems appropriate to employ a test that renders reliable results regardless of the outcome of the DW test.

[24] We also performed a battery of panel unit root tests on the entire panel, and these tests all indicated stationarity.

Table 2. Summary of regression results (t-statistics in parenthesis)

	Jan-98 through Dec-00	Jan-02 through Nov-04
β_1	0.00763 (21.38*)	...
δ	0.00042 (0.73)	...
$\beta_2 = \beta_1 + \delta$	0.00805	...
b_1	...	0.00419 (5.80*)
δ	...	0.00424 (7.63*)
$b_2 = b_1 + \delta$	...	0.00843
Obs.	36	35
Members	8	8
Panel Obs.	288	280

*Statistically significant at the 5% or better.
[a]Bootstrap critical value for b_1 is 2.84 and for δ is 2.74.

is $b_1 + \delta$; note that $b_2 = b_1 + \delta$ (from Equations 4a and 4b). The hypothesis test $\delta = 0$ is a direct test for the statistical significance of a change in the growth rate for Lake County in the T* period. Since we expect the disturbance terms (ε) to be correlated across the counties, all equations are estimated jointly using Seemingly Unrelated Regressions (SUR). Standard errors are estimated using the Panel Corrected Standard Error methodology (Beck and Katz, 1995). We also bootstrap the critical values, since SUR has been shown in some cases to understate the estimated standard errors (Rilstone and Veall, 1996).[25]

The results of the SUR estimation are summarized in Table 2. The coefficients for the fixed effects and monthly dummy variables are suppressed, since they add no useful information to our empirical inquiry. Results are presented for both the T and T* periods. The null hypothesis of the Breusch-Pagan test, "no correlation of the residuals," is easily rejected, indicating that the residuals are correlated (Breusch and Pagan, 1980). As for the estimates of interests, both b_1 and δ are statistically-significant at the 5% level or better in the two-tailed test, regardless of whether asymptotic or bootstrapped critical values are used.

As shown in Table 2, there is no statistical difference in the growth rates of the peer group and Lake County in the T period (i.e. $\beta_1 = \beta_2$). This result is by design. Alternately, the estimated economic growth rate since 2002 (the T* period) in Lake County (b_2) is more than 100% larger than the control group of Florida counties (b_1). The estimate of b_1 indicates that monthly economic growth in the relevant time period was about 0.419% per month for the control group, compared to the estimated growth rate for Lake County of 0.843% per month. The estimated coefficient δ, which measures the difference in growth between Lake and the control counties, is statistically significant and different from zero, which allows us to *reject* the hypothesis that the growth in Lake County remained equal to that of the control group counties in T*. Indeed, the positive and statistically significant coefficient on the coefficient δ implies

[25] We use 999 simulations and choose the 0.05(999+1)/2 and 0.095(999+1)/2 quantiles of the sorted statistics as critical values (i.e., the statistics associated with the 5% significance level in a two-tailed test) following MacKinnon (2002).

Table 3. Members of the panel dataset, per-capita data

County	g_i	ρ_i	DW_i		PP_i	
			T	T*	T	T*
Lake	0.0047	1.00	1.09	1.88	−4.97	−6.88
Charlotte	0.0052	0.84	1.78	1.81	−3.51	−4.44
Highlands	0.0040	0.85	2.05	2.11	−4.49	−4.24
Hillsborough	0.0038	0.85	1.22	1.36	−7.21	−6. 06
Manatee	0.0045	0.86	2.60	2.15	−6.05	−7.18
Sarasota	0.0055	0.90	1.40	1.72	−4.70	−5.91
Seminole	0.0054	0.82	1.79	1.93	−6.97	−6.94
Suwannee	0.0054	0.90	2.03	1.69	−6.30	−4.98
Average (exc. Lake)	0.0048	0.86	...	...	...	...

that Lake County experienced a positive and meaningful increase in economic growth since January 2002 in comparison with the other Florida counties in the control group. This finding is consistent with the hypothesis that Lake County's broadband network stimulated economic growth.

Of potential interest is that during the period covered by the data, Lake County experienced relatively rapid population growth. This growth may be either a result of, or exogenous to, the broadband network. In order to test whether our results are the function of population growth in Lake County or the control group, we replicate the estimation algorithm using per-capita data (i.e. we divide y by county population). By expressing the data in per-capita terms, we account for the possibility that any difference between county sales growth was caused not by the municipal network but by an exogenous population change, such as the creation or expansion of a housing development, the closing of a military base, or some other population affecting event within the county. As an initial matter, we note that population growth in a county could, in fact, be a positive consequence of broadband availability. To the extent Lake County's broadband network impacts the economy, it is also likely to impact population. In fact, population growth is often used as an index of economic development in empirical studies, so it is probably incorrect to assume that population growth is exogenous (independent) of the change we are interested in studying (Carlino and Mills, 1987; Deller *et al.*, 2001).

Setting this concern aside, we felt it would be interesting and useful to repeat our analysis using per-capita data, dividing gross sales by total population in the county.[26] Expressing the data in per-capita terms assumes that population growth is not affected by the availability of the municipal broadband network. As a result, the analysis requires us to select again a control group based on per-capita data. This selection identifies a slightly different control group of Florida counties, but most of the members in the per-capita control group are also in our first control group.

Panel members are listed in Table 3 along with the relevant descriptive statistics. As Table 3 shows, our control group selection rule again selects seven counties to compare with Lake County. Demographic information for all counties in both of our control groups can be found in Appendix A. By design, growth rates are similar and correlation coefficients are high.[27]

[26] The population data is annual, and we assume constant for all months in the year. Population data is from http://www.state.fl.us/edr/population.htm.

[27] Growth in Lake County is not statistically different from the mean growth of the control group in period T.

Table 4. Summary of regression results, per-capita data (t-statistics in parenthesis)

	Jan-98 through Dec-00	Jan-02 through Nov-04
β_1	0.00491 (13.59*)	...
δ	−0.00022 (−0.38)	...
$\beta_2 = \beta_1 + \delta$	0.00469	...
b_1	...	0.00278 (4.67*)
δ	...	0.00240 (3.13*)
$b_2 = b_1 + \delta$	...	0.00518
Obs.	36	35
Members	8	8
Panel Obs.	288	280

*Statistically significant at the 5% or better.
[a]Bootstrap critical value for b_1 is 2.72 and for δ is 2.87.

Table 4 summarizes the estimated parameters of Equation (6) using per-capita data. Again, the null hypothesis of the Breusch-Pagan test is rejected, so the residuals of the regressions are correlated and SUR estimation is beneficial.

This per-capita regression renders similar results to the levels data. Since 2002, per-capita economic activity in Lake County grew at nearly twice the rate (0.518% per month) of the control group of Florida counties (0.278% per month). These results are statistically significant at the 5% level or better, so we can reject equal growth rates with a high degree of statistical confidence. (These monthly growth rates are lower than the rates in Table 2 because population is growing.) As before, growth in Lake County is larger than growth in the control group counties; the δ coefficient indicates an 86% increase in relative growth. Since δ is statistically different from zero, we can again reject the null hypothesis that Lake County's growth is the same as the control group in period T*. This result implies that even if we assume all population growth is independent of the broadband network, Lake County experienced a higher growth rate since 2002 relative to the control group of comparable Florida counties. In other words, the higher economic growth we observe in Lake County since 2002 is not explained simply by relative population changes.

4. Conclusions and policy implications

In this paper we employ a simple econometric model of growth to assess the impact on economic activity of an extensive, fiber-optic broadband network deployed by a municipal government. Our estimates indicate a sizeable effect on economic growth. Our findings are consistent with other analyses postulating that broadband infrastructure may be a significant contributor to economic growth. The United States government's Bureau of Economic Analysis has stated that broadband infrastructure confers positive, public benefits on the economy. Our results also provide support for the idea that there are large external benefits from communications networks.[28]

It is important to understand that Lake County's peers no doubt had at least some private broadband network in their communities during the period evaluated, but these privately-owned networks *did not* produce the sizeable growth we observe in Lake County. This difference may be the result of the difference in deployment incentives. A municipally-owned broadband infrastructure (like Lake County's) is generally built to fulfill the public benefit of broadband, rather than simply to increase the profits of private firms. Thus, it is reasonable to hypothesize that private network providers, since they would not collect all the benefits that a community would reap from a broadband infrastructure as profits, would not necessarily deploy infrastructure as extensively or pervasively (FMEA, 2005: 6–10).[29] Flexibility and better customer service may also contribute to differential impacts. Advocates of municipal broadband investment have stated that "municipalities owe a duty to maximize the economic development of the communities they serve" and that, with regard to broadband and economic development, "the public and profit interests sufficient diverge to require action by the local government (FMEA, 2005: 9–10)."

Moreover, our findings suggest that efforts to restrict municipal broadband investment, efforts which are increasingly common in the United States, could deny communities an important tool in promoting economic development. Municipalities build schools, roads, hospitals, parks, marinas and convention centers in order to attract businesses, create jobs, and improve the quality life in their communities. Broadband investment is seen by many as another form of infrastructure that could offer those and other community benefits. Sixteen states currently restrict or regulate the manner in which municipalities may build or construct telecommunications, cable, or broadband networks. The United States Supreme Court recently declined to rule that these state regimes, which range from explicit prohibitions to milder regulation, were preempted by the Telecommunications Act of 1996.[30] Currently, three bills are pending before the 109th Congress that would expressly permit (S. 1294), regulate (S. 1504), or simply eliminate (H.R. 2726) future municipal broadband projects. If further municipal investment is hindered or prohibited, the economic development boost Lake County seems to have received from its broadband investment would be denied to other communities.

Further, it has been argued that municipalities invest in broadband infrastructure to serve a diffuse public purpose (a better-educated public, more business opportunities, etc) that private communications providers acting alone may ignore, since these external benefits cannot be captured as profits. Economic theory indicates that in the presence of large benefits that are impossible to capture as profits, which broadband Internet probably produces, public participation (as ownership or subsidy) may be desirable, since private entities will under-supply the good (Vickers and Yarrow, 1991).[31] Under-supply by the private sector leads to no supply at all in many communities, leaving either the government to supply the service or for constituents to

[28] Bureau of Economic Analysis, *Input-Output Accounts Data: 1999 Annual 1-O Table Two Digit*, available at www.bea.gov. A study funded by Verizon Communications points to numerous external benefits of broadband deployment. See Crandall and Jackson (2003).

[29] The FMEA argues "broadband networks provide benefits that may not be recognized by the private sector").

[30] *Nixon v. Missouri Municipal League*, 124 S. Ct. 1560, 541 U.S. _ (2004).

[31] Vickers and Yarrow (1991) ("In competitive market conditions (and in the absence of other market failures), externality effects are small, so private profit and social welfare objectives are closely aligned, and private governorship is likely to have the advantage[]. On the other hand, public ownership may have the advantage if externalities are larger (at 114))."

go without the service. To achieve the U.S. Government's goal of universal availability by 2007, municipalities may need to play an even-more significant role in the provision of broadband services.

Finally, we reiterate the limitations of our analysis, since time and data limitations allow for only preliminary empirical investigation. Our findings are but one, and perhaps the first, element, in what it sure to be a growing portfolio of evidence. Certainly, as advanced communications networks become more widespread and as time passes, we expect more sophisticated analysis of this important and timely public policy issue.

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References

Andersen, T.G., Bollerslev, T. and Das, A. 2001. Variance-ratio Statistics and High-frequency Data: Testing for Changes in Intraday Volatility Patterns. *Journal of Finance* 56, 305–327.

APPA (American Public Power Association) 2005. Annual Directory and Statistical Report. Washington, DC: APPA.

Aschauer, D.A. 1989. Is Public Expenditure Productive? *Journal of Monetary Economics* 23, 177–200.

Beck, N. and Katz, J.N. 1995. What to Do (and Not to Do) with Time Series Cross-Section Data. *American Political Science Review* 89, 634–647.

Blum, U. 1982. Effects of Transportation Investments on Regional Growth: A Theoretical and Empirical Investigation. *Papers and Proceedings of the Regional Science Association* 49, 169–184.

Breusch, T.S. and Pagan, A.R. 1980. The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics. *Review of Economic Studies* 47, 239–254.

Button, K.J., Leitham, S., McQuaid, R.W. and Nelson, J.D. 1995. Transport and Industrial and Commercial Location. *Annals of Regional Science* 29, 189–206.

Carlino, G.A. and Mills, E.S. 1987. The Determinants of County Growth. *Journal of Regional Science* 27, 39–54.

Crandall, R.W. and Jackson, C.J. 2003. The $500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet Access. In: Shampine, A.L. (ed.), *Down to the Wire: Studies in the Diffusion and Regulation of Telecommunications Technologies*. Haupauge, NY: Nova Science Press.

Deller, S.C., Tsai, T.H., Marcouiller D.W. and English, D.B.K. 2001. The Role of Amenities and Quality of Life in Rural Economic Growth. *American Journal of Agricultural Economics* 83, 352–365.

Fairlie, R.W. 2002. Drug Dealing and Legitimate Self-Employment. *Journal of Labor Economics* 20, 538–567.

Feder, G. 1983. On Exports and Economic Growth. *Journal of Development Economics* 12, 59–73.

FMEA (Florida Municipal Electric Association) 2005. *The Case for Municipal Broadband in Florida*. Tallahassee, FL: FMEA.

Gramlich, E. 1994. Infrastructure Investment: A Review Essay. *Journal of Economic Literature* 32, 1176–1196.

Granger, C.W.J. 1999. *Empirical Modeling in Economics: Specification and Evaluation*. New York: Cambridge University Press.

Gujarati, D. 1995. *Basic Econometrics*. New York: McGraw-Hill.
Hesham, M.A. 2000. Multi-firm City Versus Company Town: A Micro Foundation Model of Localization Economies. *Journal of Regional Science* 40, 755–771.
MacKinnon, J.G. 2002. Bootstrap Inference in Econometrics. *Canadian Journal of Economics* 35, 615–645.
Martin, P. 1999. Public Policies, Regional Inequalities and Growth. *Journal of Public Economics* 73, 85–97.
Martin, P. and Rogers, C.A. 1995. Industrial Location and Public Infrastructure. *Journal of International Economics* 39, 335–362.
Nadiri, I. and Mamuneas T. 1994. The Effects of Public Infrastructure and R&D Capital on the Cost Structure and Performance of US Manufacturing Industries. *Review of Economics and Statistics* 76, 189–198.
Pindyck, R.S. and Rubinfeld, D.L. 1991. *Econometric Models & Economic Forecasts*. New York: McGraw-Hill.
Ralle, P. and Tonjas-Bernatte, J. 1990. Indexation des Salaires; la Rupture de 1983. *Economie et Prévisión* 92/93, 187–219.
Ram, R. 1986. Government Size and Economic Growth: A New Framework and Some Evidence from Cross-Section and Time Series Data. *American Economic Review* 76, 191–203.
Rilstone, P. and Veall, M. 1996. Using Bootstrapped Confidence Intervals for Improved Inferences with Seemingly Unrelated Regression Equations. *Econometric Theory* 12, 569–80.
Robinson, R. 1977. Dependency, Government Revenue, and Economic Growth. *Studies in Comparative International Development* 12, 3–28.
Seitz, H. 1995. The Productivity and Supply of Urban Infrastructures. *Annals of Regional Science* 29, 121–141.
Seitz, H. and Licht, G. 1995. The Impact of Public Infrastructure Capital on Regional Manufacturing Production Cost. *Regional Studies* 29, 231–240.
Speta, J.B. 2004. Commentary: Policy Levers and Demand Drivers in Korea Broadband Penetration. *Journal of Korean Law* 4, 1–18.
Stigler, G.J. and Sherwin, R.A. 1985. The Extent of a Market. *Journal of Law and Economics* 28, 555–585.
Vickers, J. and Yarrow, G. 1991. Economic Perspectives on Privatization. *Journal of Economic Perspectives* 5, 111–132.

Appendix. Demographic profile of control group counties

Table A1. Demographics of control group counties

County	Control group	Population, 2003 est.	Persons per square mile, 2000	Per capita income, 1999	Percent below poverty, 1999	Retail sales per capita, 1997
Lake		245 877	220.9	$20 199	9.6%	$7781
Broward	1	1 731 347	1346.5	$23 170	11.5%	$12 174
Charlotte	1	153 392	204.2	$21 806	8.2%	$8035
Highlands	2	91 051	85.0	$17 222	15.2	$8239
Hillsborough	2	1 073 407	950.6	$21 812	12.5	$12 018
Manatee	2	286 804	356.3	$22 388	10.1	$9110
Madison	1	18 766	27.1	$12 511	23.1%	$3653
Palm Beach	1, 2	1 216 282	573.0	$28 801	9.9%	$11 561
Sarasota	1, 2	346 793	570.3	$28 326	7.8	$12 011
Seminole	1, 2	386 374	1184.9	$29 591	7.4%	$10 333
Suwannee	1, 2	36 695	50.7	$14 678	18.5%	$6348
Florida		17 019 068	296.4	$21 557	12.5%	$10 297

Source: US Census Bureau, State and County QuickFacts, http://quickfacts.census.gov.