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Economic Implications of FTTH Networks: A Cross-Sectional Analysis

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Abstract
Individuals and businesses are becoming ever more reliant on advanced telecommunications technologies that provide increased bandwidth capabilities. Because fiber-to-the-home (FTTH) enables the technology necessary to facilitate such things as sophisticated computer-aided design and advanced system integration, drastic improvements in efficiency of technology-intensive business processes and communication are expected. In an effort to empirically assess the economic impact of FTTH at the community level, this study employed a quantitative design using cross-sectional data collected for 16 experimental communities as well as for 16 matched control cities. The findings of this research are seemingly reflective of potential economic improvements that could arise if FTTH is present in a community. Specifically, annual employment rate, mean annual household income, and educational attainment were found to be significantly higher in experimental cities as compared to control cities. These results offer some insights regarding policy-making efforts at the federal, state, and local levels.

Keywords
Telecommunications infrastructure, fiber-to-the-home, economic development, optical fiber networks

Introduction

Individuals and businesses are becoming ever more reliant on advanced telecommunications technologies that provide increased bandwidth capabilities. This dependence makes the resilience of the technological infrastructure critical. From an economic standpoint, telecommunications technologies (namely, optical fibre networks) have emerged as key newsworthy topics in recent years particularly because of their potential benefits to both consumers and business. Fibre-to-the-home (FTTH) is one such technology. Because FTTH enables the technology necessary to facilitate such things as sophisticated computer-aided design and provides the capacity for advanced system integration and visualisation techniques, drastic improvements in efficiency of technology-intensive business processes and communication are expected.

FTTH implementations are increasing within the US and abroad at an exponential rate. Deployments in US communities, first executed in 1998, increased from 21 in 2002 to almost 1,000 communities in April of 2006 (Render, Vanderslice and Associates, 2006). More current data suggest that greater than 15 per cent of homes in the US have been passed with fibre, while a little more than 4 per cent penetration has occurred with regard to actual homes connected (Render, 2010). Worldwide, there was a 15 per cent increase in FTTH subscribers in just the first half of 2009 (FTTH Council, 2009).

Studies of the economic implications of telecommunications infrastructures are not new (Cronin, Parker, Colleran, and Gold, 1991; Hardy, 1980; Jipp, 1963; Telecommunications Industry Association [TIA], 2003), but the state-of-the-art capabilities, the future-proof elements of FTTH infrastructure, and the trend of installation of these networks with little to no empirical evidence to support economic return calls for empirical investigations in this area. This paper reports on a study that provides such an investigation.

The subsequent sections of this manuscript include a review of the literature, hypotheses development, a description of the methodology employed, data analysis and results, and discussion and conclusions based on the findings.

Review of the Literature

Telecommunications has long been established in the literature as an important input or contributor to economic development, and is theoretically comparable to the function of traditional infrastructures in economic growth (Cronin, McGovern, Miller and Parker, 1995; Williams, 1991). Historically, research has concluded

that substantial economic progress has resulted from investments in, and the subsequent development of, traditional infrastructure networks such as rivers, roads, and transcontinental railroads (Moss and Townshend, 2000). An influential study conducted by Aschauer (1989), for example, involved the investigation of the relationship between private sector output and public infrastructure investment. Aschauer (1989) employed a classical production function approach and found the return to infrastructure could be as high as 70 percent per year. Later studies (Kavanagh, 1997; Talley, 1996) argue that such outcomes are likely biased due to problems of spurious correlation and methodological errors resulting in an ambiguous illustration of the direction of causation. Because of these methodological problems, critics claim that such studies fail to provide the proper basis for sound policy recommendations regarding infrastructure. In spite of this, however, there seems to be a consensus among researchers that sufficient evidence exists to indicate a positive and statistically significant effect of infrastructure on long-run economic growth (Nijkamp and Poot, 2004). A recent study conducted by Mizutani and Tanaka (2010) suggests similar results. In analysing data from 46 prefectures in Japan, the authors found that public infrastructure investments can indeed contribute to productivity in the private sector.

Most of the literature pertaining to telecommunications focuses solely on the impact of the telephone, a specific communications medium, on economic growth. Research conducted in the 1960s, 1970s and 1980s suggested that the introduction and diffusion of telephones enhanced economic development. It is important to note, however, that the majority of these preliminary studies (Hardy, 1980; Jipp, 1963; Marsh, 1976) used simple correlation methodologies that are flawed because of their inability to infer causation and determine directional influences. Notably, however, Cronin, Parker, Colleran, and Gold (1991) conducted a time series analysis of 31 years of US data (1958-1988, inclusive). The Granger causality test and the Modified Sims test were used to provide substantial evidence confirming that increases in economic output lead to investment in telecommunication infrastructure and increases in telecommunication investments have a positive economic impact (Cronin et al. 1991). Lee (1994) found similar results using Korean data sets. Additional empirical investigations provide some evidence of a causal link between telecommunications infrastructure and aggregate output (Nadiri and Nandi, 1997; Wang, 1999), although none of these studies specifically address broadband infrastructure investments.

Literature pertaining to the economic impact of broadband options such as DSL and cable is elemental in informing this research. Much of the initial research in

this area consisted of case studies of isolated US communities with municipal broadband in place, all of which found positive economic returns from the installations of the publicly-owned infrastructures (Ford and Koutsky 2005; Kelley 2003; Strategic Networks, 2003). Later studies have more of a quantitative orientation. For example, a study conducted by Lehr, Osorio, Gillett, and Sirbu (2005) found that, between 1998 and 2002, broadband communities experienced increases in job growth and number of businesses, predominantly in the information technology sector. No statistically significant impact was found, though, when studying the impact of broadband on wages. Similarly, Kolko (2010) conducted an empirical examination for the Public Policy Institute of California and found a positive relationship between broadband development and employment between the 1999 and 2006 time period, but did not find a statistically significant effect of broadband on other economic outcomes such as average pay per employee and median household income. Furthermore, Crandall, Lehr, and Litan (2007), found positive results when studying the impact on employment and output at the state level, while Qiang, Rossotto, and Kimura (2009) conducted an econometric analysis across 120 developed and developing countries (1980-2006) and found a positive and significant effect of broadband on the economy. More recently, after using robust tests to address issues of reverse causality, Czernich, Falck, Kretschmer and Woessmann (2011), found a positive relationship between broadband (defined as anything above 256 kbit ⁄ s) and economic development across a panel of OECD countries.

Although the preponderance of literature is seemingly suggestive of an overall positive impact of broadband on economic development at various levels of inquiry, the results of these studies and others in this domain need to be viewed in light of their methodological limitations pertaining to data availability, measurement, and issues of time lag (Flamm, Friedlander, Horrigan and Lehr, 2007; Holt and Jamison, 2009).

This article extends research on the economic implications of broadband by specifically focusing on FTTH. Substantial differences in bandwidth capacity exist between fibre and more traditional broadband options such as DSL or cable. Prior work in this stream of literature has not addressed broadband implications with such specificity. There are two potential explanations for this. First, data on FTTH penetration is not specifically gathered by the Federal Communication Commission (FCC) or any other governmental body, so it is not possible to use this metric as an element of any empirical analysis on this topic. Importantly, even metrics of general broadband penetration are only available at the state level or above. This is often listed as a limitation in extant literature pertaining to the economic implications of broadband (see Lehr et al., 2005). Secondly, although

much research has considered the lag issue with respect to technological innovations, theoretical evidence and a unified body of literature do not exist to aid in determining the precise time lag before an impact is realised. This time period may range from only a few months in some instances to many years in others, as this is contingent upon the level of sophistication and complexity that is inherent in the introduction/implementation of technological innovations and resources dedicated to educating end users (Devaraj and Kohli, 2002). Although these issues contribute to the potential difficulties in studying the economic implications of this phenomenon (and others), it does not lessen the importance of beginning to look at the ways in which FTTH impacts local economies.

Beyond this, contributions to the literature are made through the inclusion of several economic variables not used in previous empirical work in this area (i.e. retail sales as a measure of business sales revenue; poverty status and specified consumer expenditures as measures of household income). This, along with the use of a carefully crafted matching technique, will allow for more precision in determining impact.

Hypotheses Development

According to an investigation conducted by O'Mara (1999) that sought to unveil the strategic considerations of 40 information-age firms seeking to relocate, telecommunications infrastructure was frequently mentioned as an important criterion for site selection. Furthermore, McManus, Carr, Snyder and Ford (2005) concluded that telecommunications infrastructure is a necessity for manufacturing firms seeking to effectively compete in a global economy. In their exploratory study involving electronic firms, one-half indicated that telecommunications infrastructure was a primary consideration in their most recent location decision. Additional academic literature seems to be consistent with these studies, as much research links the presence of advanced technological infrastructure with business location preferences (see, for example, Read and Youtie, 1996). Moreover, the presence of technology-intensive firms seems to be synonymous with the existence of advanced telecommunications infrastructure (Gorman, 2000; Walcott and Wheeler, 2001). With information-oriented firms comes the need for a labor pool that is skilled in such technical areas. Interestingly, at least three of the twenty highest paying jobs in the private sector, as reported by *Bizjournal* (cited Thomas, 2008), were specific to the information technology and computer science fields. It is therefore expected that the presence of FTTH will have a positive effect on:

H_1: the number of business establishments;
H_2: labor compensation rates, as measured by annual payroll;

> H_3: employment, as measured by annual number of employees (H_{3a}) and annual employment rate (H_{3b});
> H_4: household income, as measured by average annual household income (H_{4a}), poverty status (H_{4b}), and specified consumer expenditures (H_{4c}).

Furthermore, in studying the economic impact of traditional broadband, Lehr et al. (2005) used rental rates as an indicator of economic conditions. Rent is a coincident indicator of economic health and very responsive to immediate economic conditions (Council of Economic Advisers, 2000). As such, rental rates are fluid responders to labor market conditions. Thus, the following hypothesis is set forth:

> H_5: the presence of FTTH has a positive effect on property values, as measured by median housing rent.

A report from the OECD indicates that information and communication technology (ICT) is a proven determinant of economic expansion resulting from better efficiency in business processes and increased access to foreign markets (Organisation for Economic Co-operation and Development [OECD], 2003). Because the advanced capabilities of the FTTH infrastructure could potentially further enhance these opportunities in the form of foreign exports or local sales, it is suggested that business sales revenue will increase. As such, the following hypothesis is offered:

> H_6: the presence of FTTH has a positive effect on business sales revenue, as measured by retail sales.

Methodology

A quantitative design using cross-sectional data allowed for the comparison between communities that were theoretically comparable in every significant characteristic except the presence of FTTH. Data was collected for 16 experimental communities as well as for 16 matched control cities. The experimental cities consist of communities that began offering FTTH services between 1998 and 2002.[1] The geographical dispersion of these experimental cities is presented in Figure 1.

[1] The FTTH Council and Telecommunications Industry Association published an updated listing of US Optical Fibre Communities each year. The listing was prepared by Render, Vanderslice & Associates, LLC in 2006.

Figure 1: Geographical dispersion of FTTH communities.
Adapted from National Park Service (2010)

One control city was chosen for every experimental city. Since this design involved collecting data at and pertaining to a single point in time, the analysis relied on differences between the experimental and control cities at the 2005/06 time period (deVaus, 2001). In an effort to carefully 'match' cities and to increase the internal validity of the results, control cities were paired with experimental ones based on several variables. Specifically, geographic location, population size, cost of living, housing value, crime change, and urban influence code were used as matching variables in this cross-sectional model. The source, definition, and level at which the data were obtained is included in Table 1, while a listing of the matching cities is presented in Table 2. The paired comparisons revealed that there were no significant differences between samples with regard to the variables that were used to match the cities, thereby demonstrating comparability of the matched experimental and control cities (see Table 3).

Table 1: Matching Variables

Matching variables	Source	Level
Population size	Bureau of the Census	City
Cost of living (versus the national average)	Economic Research Institute	City
Housing value	Claritas	City
Crime rates (change)	Uniform Crime Reports (Federal Bureau of Investigation)	County
Urban influence code	US Department of Agriculture	County

Source: Author's own construction

Table 2: Matching Cities

State	Community	Matching city
California	Roseville	Arden –Arcade CDP
Colorado	Colorado City	Fowler
Colorado	Rye	Cheraw
Iowa	Cambridge	Colo
Iowa	Guthrie Center	Stuart
Iowa	Huxley	Madrid
Iowa	Slater	Prairie City
Kansas	Almena	Scandia
Kansas	Hill City	Plainville
Kansas	Norton	Philipsburg
Kansas	Osborne	Oberlin
Minnesota	Alberta	Beardsley
Minnesota	Chokio	Morton
Minnesota	Morris	Montevideo
Oregon	Woodburn	Pendleton
Pennsylvania	Kutztown	Shillington

Source: Author's own construction

Table 3: Results of Paired Samples Test: Matching Variables

Variables	Paired differences					
	Mean	Std. deviation	Std. error of the mean	95% confidence interval of the difference		t
Cost of living (E) – cost of living (C) [percentage]	0.108	5.175	1.435	-3.020	3.235	0.075
Housing value (E) – housing value (C) [in dollars]	-4118.308	68778.624	19075.758	-45680.814	37444.199	-0.216
Crime change (E) – crime change (C) [change from 1998 to 2005]	-90.188	690.518	172.630	-458.139	277.764	-0.522
Urban influence code (E) – urban influence code (C)	-1.000	2.366	0.592	-2.261	0.261	-1.690
Population (E) – population (C)	860.062	2272.714	568.178	-350.981	2071.106	1.514

Source: Author's own construction

The impact of FTTH infrastructure on several indicators of economic health was investigated. The sources for these variables, definitions, and level at which this data was obtained are included in Table 4.

Table 4: Sources for Dependent Variables

Dependent variables	Source	Level
Number of establishments	Claritas	City
Annual payroll	Census Bureau	Zip code
Annual number of employees	Census Bureau	Zip code
Annual employment rate	Claritas	City
Mean annual household income	Claritas	City
Poverty status (by families)	Claritas	City
Total specified consumer expenditures:		
Consumer buying power	Claritas	City
Retail sales	Claritas	City
Median housing rent	Economic Research Institute	City

Source: Author's own construction

The US Census Bureau, the Economic Research Institute, Claritas, and a thorough review of relevant literature were used as sources to establish this listing of indicators.

Data Analysis and Results

Table 5 provides the correlation analysis of the variables included in this cross-sectional design. According to our hypotheses, for every dependent variable, the 'FTTH sample' is supposed to have a higher mean than its paired non-FTTH counterpart. Thus, we used one-tailed paired samples *t*-tests to test our cross-sectional design. The results of these tests are presented in Table 6.

Table 5: Pearson Correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. number of establishments (E)	1.00															
2. number of establishments C)	0.99**	1.00														
3. average annual payroll (E)	0.99**	0.99**	1.00													
4. average annual payroll (C)	0.44	0.45	0.39	1.00												
5. annual number of employees (E)	0.99**	0.99**	0.99**	0.44	1.00											
6. annual number of employees (C)	0.99**	0.99**	0.99**	0.48	.099**	1.00										
7. annual employment rate (E)	-0.12	-0.13	-0.06	-0.50	-0.11	-0.15	1.00									
8. annual employment rate (C)	-0.07	-0.09	-0.05	0.03	-0.07	-0.10	0.39	1.00								
9. mean annual household income (E)	0.67**	0.66**	0.71**	0.20	0.68**	0.65**	0.46	0.25	1.00							
10. mean annual household income (C)	0.50*	0.50*	0.49	0.49	0.50*	0.51*	0.01	0.33	0.44	1.00						
11. poverty status (E)	0.15	0.14	0.19	-0.04	0.14	0.10	0.46	0.03	0.29	0.24	1.00					
12. poverty status (C)	-0.24	-0.25	-0.26	0.08	-0.25	-0.26	0.35	0.43	-0.05	0.38	0.29	1.00				
13. total specified consumer expenditures (E)	0.99**	0.99**	0.99**	0.41	0.99**	0.99**	-0.09	-0.07	0.70**	0.50*	0.16	-0.26	1.00			
14. total specified consumer expenditures (C)	0.99**	0.99**	0.99**	0.43	0.99**	0.99**	-0.09	-0.06	0.70**	0.50*	0.17	-0.25	0.99**	1.00		
15. retail sales (E)	0.99**	0.99**	0.99**	0.40	0.99**	0.99**	-0.07	-0.07	0.70**	0.49	0.16	-0.27	0.99**	0.99**	1.00	
16. retail sales (C)	0.99**	0.99**	0.99**	0.39	0.99**	0.98**	-0.06	-0.05	0.71**	0.48	0.18	-0.26	0.99**	0.99**	0.99**	1.00

Table 5: Pearson Correlations (continued)

Variable	17	18	19	20	21	22	23	24	25	26	27	28
17. median housing rent (E)	1.00											
18. median housing rent (C)	0.41	1.00										
19. cost of living (E)	0.78**	0.25	1.00									
20. cost of living (C)	0.43	0.37	0.74**	1.00								
21. housing value (E)	0.48	0.25	0.79**	0.79**	1.00							
22. housing value (C)	0.37	0.41	0.63*	0.89**	0.82**	1.00						
23. crime change (E)	-0.47	-0.51	-0.45	-0.67*	-0.56*	-0.87**	1.00					
24. crime change (C)	-0.39	-0.33	-0.61**	-0.72**	-0.80**	-0.90**	0.84**	1.00				
25. urban influence code (E)	-0.80**	-0.03	-0.76**	-0.41	-0.54*	-0.38	0.35	0.05	1.00			
26. urban influence code (C)	-0.70**	-0.10	-0.65**	-0.55	-0.58*	-0.52	0.45	0.49	0.88**	1.00		
27. population (E)	0.18	0.21	0.54*	0.76**	.91**	0.89**	-0.64**	-0.87**	-0.32	-0.41	1.00	
28. population (C)	0.18	0.21	0.54*	0.76**	0.91**	0.89**	-0.65**	-0.86**	-0.31	-0.41	0.99**	1.00

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

Note: 1-28 are matched pairs with (E) representing Experimental Cities and (C) representing the Control cities.

Source: Author's own construction

Table 6: Results of Paired Samples Test

Paired Samples	Paired Differences					
	Mean	Std. deviation	Std. error of the mean	95% confidence interval of the difference		t
				Lower	Upper	
Pair 1: number of establishments (E) – number of establishments (C)	-17.188	109.043	27.261	-75.293	40.918	-0.630
Pair 2: average annual payroll (E) - average annual payroll (C) [in $1,000s]	193557.533	821295.744	212057.649	-261260.890	648375.957	0.913
Pair 3: annual number of employees (E) – annual number of employees (C)	958.938	3880.321	970.080	-1108.740	3026.615	0.989
Pair 4: annual employment rate (E) – annual employment rate (C) [percentage]	4.144	7.590	1.898	0.100	8.189	2.184*
Pair 5: mean annual household income (E) – mean annual household income (C) [in dollars]	4436.125	9687.363	2421.841	-725.906	9598.156	1.832*
Pair 6: poverty status (E) – poverty status (C) [percentage]	1.219	3.798	0.950	-0.805	3.243	1.284
Pair 7: total specified consumer expenditures (E) – total specified consumer expenditures (C) [in $1,000s]	20774.188	73087.479	18271.870	-18171.381	59719.756	1.137
Pair 8: retail sales (E) – retail sales (C) [in dollars]	1.204E8	3.606E8	9.014E7	-7.170E7	3.126E8	1.336
Pair 9: median housing rent (E) – median housing rent (C) [in dollars]	-163.692	314.385	87.195	-353.674	26.289	-1.877*

** p<0.01
* p<0.05

Source: Author's own construction

Table 6 demonstrates that the annual employment rate (E $\bar{x}$ = 63.58%, C $\bar{x}$ = 59.44%, t = 2.184, sig. = 0.023) and mean annual household income (E $\bar{x}$ = $53,720.06, C $\bar{x}$ = $49,283.94, t = 1.832, sig. = 0.044) are significantly higher in experimental cities as compared with control cities. And, although average annual payroll (E $\bar{x}$ = $255,257,670, C $\bar{x}$ = $61,700,130, t = 0.913, not significant [ns]), annual number of employees (E $\bar{x}$ = 6466.00, C $\bar{x}$ = 5507.06, t = 0.989, ns), total specified consumer expenditures (E $\bar{x}$ = $189,214.44, C $\bar{x}$ = $168,440.25, t = 1.137, ns), and retail sales (E $\bar{x}$ = $34,300,000,000, C $\bar{x}$ = $22,200,000,000, t = 1.336, ns), were found to be higher in the experimental cities, results were nonsignificant.

Results also indicate that the percentage of the population not living in poverty (E $\bar{x}$ = 94.22%, C $\bar{x}$ = 93.00%, t = 1.284, ns) is marginally higher in experimental cities. Furthermore, the number of establishments (E $\bar{x}$ = 520.75, C $\bar{x}$ = 537.94, t = -0.630, ns) and median housing rent (E $\bar{x}$ = $1150.31, C $\bar{x}$ = $1314.00, t = -1.877, sig = 0.043), were lower in experimental cities than in control cities. Overall, the results demonstrated support for hypotheses H_{3b}, H_{4a} and H_7, while failing to significantly support the remaining hypotheses.

Discussion and Conclusion

Upon consideration of the quantitative results, methodological limitations, and further review of relevant literature, implications for researchers, ideas for future research, and several potential pragmatic implications for policy-makers emerged.

Implications for Future Practice and Research

Several implications for future practice and research are presented in the text that follows.

Motivational Factors that Influence FTTH Initiatives

Understanding the motivational factors that influence the implementation of FTTH at the community level is important and is needed to provide proper insight regarding deployment policy decisions. It is feasible that the ability of fibre to impact the economic health of a community is not only reflected in more measurable symbols of economic health, but is also thought of as a public relations or promotional tool that symbolises how progressive a community might be. Literature suggests that the construction of social reality associated with a particular phenomenon is enhanced as a result of media attention and other forms

of symbolic modeling and mechanisms (Bandura, 1986; Pearl, Bouthilet and Lazar, 1982).

The information technology literature supports this premise, as a number of Information Systems (IS) researchers (Markus, 1983; Nidumolu, Goodman, Vogel and Danowitz, 1996) consider a political perspective whereby the underlying motivation for the introduction and implementation of a technology is often because of the political and symbolic value it suggests. Could this *political perspective* be a significant potential motivator of FTTH initiatives?

Further, a majority of cities included in this investigation were located in rural areas and were struggling economically during the period prior to the introduction of fibre. From an economic development perspective, these impoverished communities could have been using fibre as a survival, recovery, or defensive mechanism to combat eroding economies (Min, Sukhumaran and Varghese, 2001).

Future research, therefore, is needed to explore whether the installation of FTTH was really used as a defensive mechanism to extinguish a theoretical fire, or as more of a proactive way of ensuring that a community withstood the technological test of time. Further, do the motivational factors have anything to do with the outcome? Does the motivation behind the introduction of FTTH influence the way that FTTH is promoted, positioned or marketed?

Social Implications of FTTH

It is possible that the impact of fibre is also captured, measurable, and evident in indicators of the social health of a community. In the city of Lafayette, Louisiana, the Chamber of Commerce speculated that the FTTH system would promote cultural enrichment and other benefits (Blanchard, 2005). For example, the city of Lafayette held its annual game camp in the summer of 2008, allowing for students to develop and market their own video game (Moore, 2008). In a world where fibre optic technologies are becoming prevalent, educational opportunities such as this are becoming increasingly common.

Additionally, FTTH provides the technological infrastructure necessary to support smart home technologies and other socially beneficial applications such as telemedicine, management of personal finances and distance learning (Aldrich, 2003). It will thus be interesting for future research to consider the social implications of FTTH in an effort to more fully understand the potential benefits of such community-wide initiatives.

Temporal Issues and Critical Mass

Historically, the issue of time lag has been recognised as a critical element of consideration when investigating the relationship between information technology investment and firm performance across a variety of industries (Devaraj and Kohli 2000, 2002; Peffers and dos Santos 1996; Pinsonneault and Kraemer, 1993). The economic impact of infrastructures is not contemporaneous and, as such, previous research suggests that there is a lag between the time of ICT investment and when the positive effect on productivity can be detected (see Dedrick, Gurbaxani and Kraemer, 2003 for a review). Further, time lag has been documented as an explanation for overall inconsistent findings across many studies that have investigated this topic. Thus, it seems necessary for future research to address the lag effect, especially once additional and sufficient time has passed.

Related to these temporal issues is the idea of achieving a critical mass. A necessary precondition for ensuring a sustainable acceptance and subsequent adoption of fibre is the achievement of a critical mass, a phenomenon that suggests that economic growth will only be realised after a certain level of telecommunications infrastructure penetration has been reached (Capello and Nijkamp, 1996; Shapiro and Varian, 1999). Notably, there is no current consensus regarding what a critical mass is, although some research indicates this would be achieved with approximately 40 percent penetration (Röller and Waverman, 2001). The issue remains largely unresolved primarily because of the inconsistencies in methods of measurement and the difficulties inherent in empirically assessing critical mass (Allen, 1988; Capello and Nijkamp, 1996).

Policy Implications

Most current policies pertaining to FTTH and economic development are informed by research reports, typically prepared by governmental agencies, industry associations, or consulting firms. Such reports run the risk of bias and the absence of complete objectivity, as authors are often visible and vocal advocates. And while these reports indicate that FTTH and/or other broadband options positively impact economic development (see, for example, Oden et al., 2002), these reports are often made available without the typical process of academic scrutiny and review. Thus, the results of the current study can offer some preliminary and substantive guidance for policy-makers at the national, state, and local levels.

In distilling the previous discussion and results of this study, policy implications related to educational strategies and data availability emerged.

Educational Strategies

The lack of consumer knowledge regarding how to effectively use the bandwidth capacity that fibre offers can hinder the ability of businesses to effectively use it and, hence, impact the 'perceived usefulness' of this technology (Davis, 1989). As such, the identification and communication of appropriate and effective ways to utilise this technology to improve business processes is an important consideration. According to Capello and Nijkamp (1996), the organisational aspect needs to be regarded as a strategic factor when considering adoption issues. These authors further claim that this consideration is necessary in order to fully exploit network externalities by firms and, thus, by means of the economic multiplier effect, by communities. Therefore, the development of policies with a strong focus on the various business applications of fibre could produce a positive and lasting effect on local economic development. Furthermore, the presence of fibre in a community can serve to attract technology-intensive firms to the area, thereby increasing job demands. Public funds could be utilised within the community to train potential employees of such firms.

Data Availability

It is apparent that much of the publicly reported data regarding the adoption and use of telecommunications services are collected at the national level (Flamm et al., 2007). Better measurements representing overall economic health (e.g. gross domestic product [GDP]) are more readily available at this level as well. While there is value in studying this phenomenon at the national level, there is incremental value and additional benefit in studying it at the local level, as the ongoing debate surrounding FTTH deployment resides at this level and remains a local policy issue.

Flamm et al. (2007, p. 21) suggests that "national level data sets do not provide data at a suitable granular level of detail" for studies of this nature. Some measure of GDP at the community level, for example, would be helpful in providing a comprehensive snapshot of current economic conditions within a local area. Measures of economic diversity and Per Capita Income per Year at the community level could assist in overcoming these inadequacies of measurement.

Also inherent in these issues surrounding data collection are measures specifically related to FTTH. For example, although penetration is measured at the community level by either public or private providers of FTTH, there is no consensus as to how to calculate this metric and, thus, a clear indicator of FTTH diffusion does not exist. Policies focused on developing a standardised metric for these

calculations would allow for more reliable estimates of the economic implications of such infrastructure.

Conclusion

Although the results of this investigation did reveal some significant and positive impacts of FTTH on local economies in the US, it is important to view these results in light of the discussion presented herein. The most optimal data were sometimes difficult to find or impossible to obtain, but this challenge must be viewed in light of the apparent need to explore the implications of FTTH. Furthermore, it is important to note that, although diligent efforts were undertaken in choosing comparable cities, there are some things that may be happening in a particular city that would be unknown or impossible to capture in an objective manner. For example, there could be some issue of politics in the city council, a unionisation effort, or some other factor that may influence economic development that would be difficult to measure and isolate. Even with the most diligent and sophisticated matching techniques, there is always some variation that exists. This, however, does not discount the usefulness of such schemes in empirical research such as this.

As detailed earlier in this manuscript, there is exponential growth in FTTH deployments on an annual basis, warranting research such as this to provide at least some level of guidance to policy-makers and city leaders contemplating these initiatives. There remain a number of unanswered questions regarding the impact of this advanced technological infrastructure. As such, the community of researchers and policy-makers continue discussions on this very important issue.

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Appendix A: Definitions of Matching Variables (as provided by respective sources)

Cost of living: The cost of purchasing goods and services, as determined by the demand and supply of goods, services, and property. Typically, these costs are determined by a standard package of terms. The cost of living is measured by the Consumer Price Index (CPI) which measures the change in consumer prices, as determined by the Bureau of Labor Statistics' monthly survey. Many pension and employment contract changes are tied to changes in consumer prices to protect against inflation and reduced purchasing power. CPI components include the costs of housing, food, transportation, and electricity.

Housing value: The data on value (also referred to as 'price asked' for vacant units) were obtained from answers to long-form questionnaire Item 51, which was asked on a sample basis at owner-occupied housing units and units that were being bought, or vacant for sale at the time of enumeration. Value is the respondent's estimate of how much the property (house and lot, mobile home and lot, or condominium unit) would sell for if it were for sale.

Crime rate: Crime rate is a measure of the rate of occurrence of crimes committed in a given area and time.

Urban influence code: The urban influence code takes into account city size and adjacency to larger places, as this is reflected in various county-level measures, such as population change, educational attainment, managerial/professional employment, and earnings.

Appendix B: Definitions of Dependent Variables (as provided by respective sources)

Number of establishments: Employees per establishment ratios from the Census Bureau's County Business Patterns files provide the basis for estimating business establishments for the private sector categories. Industries (Government and Non-Profit), or the Public Sector, includes Public Administrations, Museums, Educational, and Social Services. All the rest of the Industries are the Private Sector.

Annual payroll: Payroll includes all forms of compensation, such as salaries, wages, commissions, dismissal pay, bonuses, vacation allowances, sick-leave pay, and employee contributions, to qualified pension plans paid during the year to all employees. For corporations, payroll includes amounts paid to officers and executives; for unincorporated businesses, it does not include profit or other compensation of proprietors or partners. Payroll is reported before deductions for social security, income tax, insurance, union dues, etc. This definition of payroll is the same as that used by the Internal Revenue Service (IRS) on Form 941.

Annual number of employees: Annual number of employees includes all civilians 16 years old and over who were either (1) 'at work' - those who did any work at all during the reference week as paid employees, worked in their own business or profession, worked on their own farm, or worked 15 hours or more as unpaid workers on a family farm or in a family business; or (2) were 'with a job but not at work' - those who did not work during the reference week but had jobs or businesses from which they were temporarily absent due to illness, bad weather, industrial dispute, vacation, or other personal reasons. Excluded from the employed are people whose only activity consisted of work around the house or unpaid volunteer work for religious, charitable, and similar organizations; also excluded are people on active duty in the United States Armed Forces. The reference week is the calendar week preceding the date on which the respondents completed their questionnaires or were interviewed. This week may not be the same for all respondents.

Annual employment rate: All civilians 16 years old and over who were either at work during the census reference week or who had a job, but were not at work during the census reference week.

Mean annual household income: The data on income were derived from answers to long-form questionnaire Items 31 and 32, which were asked of a sample of the population 15 years old and over. 'Total income' is the sum of the amounts reported separately for wage or salary income; net self-employment income; interest, dividends, or net rental or royalty income or income from estates and trusts; social security or railroad retirement income; Supplemental Security Income (SSI); public assistance or welfare payments; retirement, survivor, or disability pensions; and all other income. Receipts from the following sources are not included as income: capital gains, money received from the sale of property (unless the recipient was engaged in the business of selling such property); the value of income 'in kind' from food stamps, public housing subsidies, medical care, employer contributions for individuals, etc.; withdrawal of bank deposits; money borrowed; tax refunds; exchange of money between relatives living in the same household; and gifts and lump-sum inheritances, insurance payments, and other types of lump-sum receipts. Mean income is the amount obtained by dividing the aggregate income of a particular statistical universe by the number of units in that universe. Thus, mean household income is obtained by dividing total household income by the total number of households.

Poverty status: Households are classified below the poverty level when the total income of the family or of the nonfamily householder is below the appropriate poverty threshold. The poverty threshold is based on the number of children under 18 years old and the number of family members in the household. The poverty thresholds are revised annually to allow for changes in the cost of living as reflected in the Consumer Price Index. Poverty thresholds were applied on a national basis and not adjusted for regional, state or local variations in the cost of living. The percentage reported herein is representative of those that are not in poverty.

Total specified consumer expenditures (consumer buying power): The Consumer Buying Power database is created using statistical models estimated from the Bureau of Labor Statistics' Consumer Expenditure Surveys (CEX) and the most current consumer expenditures surveys – CES data available. Current consumer buying power – CBP data employs the most recent annual consumer expenditure surveys (1997-2001). Claritas has an archive of the consumer expenditures – CEX data over many years, but uses the latest five years to update the consumer buying power – CBP data model coefficients each year. The methodology now includes an independent set of national-level consumer expenditures estimates and projections. Developed by Global Insight, formerly Wharton Econometric Forecasting Associates (WEFA), national consumer expenditure models are created as controls to update the national spending levels for Consumer Buying Power line items. The CBP Expenditures Categories are as follows: apparel, education, electronic devices, food at home, furniture, major appliances, medical expenses, personal care, miscellaneous items, miscellaneous household items, and other miscellaneous.

Retail Sales: Retail sales is defined as supply. In other words, supply is the estimated total retail sales for a retail store type or merchandise line item.

Median Housing Rent: An amount paid to rent a residential home.