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The Local Economic Growth Impact of Broadband Infrastructure 1998 to 2008

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THE LOCAL ECONOMIC GROWTH IMPACT OF BROADBAND INFRASTRUCTURE 1998 TO 2008

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DEDICATION

Dedicated to my husband Ronald Finnerty, who, come hell or high water, was going to see this through with me.

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I came to this research fully supported. I will take a moment now to thank those important to this endeavor.

I would like to thank Dr. Robert Scherer, the Chair of this committee. You stepped up to chair me when no one else would and offered me a simple piece of advice “find a model.” These words are something I apply to my everyday living. Dr. Joel Elvery, I have shared three classes with you including the 800-level statistics class. Needless to say, you have seen the sum of my 24 years of academic progress. Thank you for sticking it out. Dr. Haifeng Qian, I ambushed you the moment you started working at Cleveland State University. Thank you all for considering and joyfully accepting committee membership.

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THE LOCAL ECONOMIC GROWTH IMPACT OF BROADBAND INFRASTRUCTURE 1998 TO 2008

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ABSTRACT

This dissertation presents estimates of the relationship between early investment in broadband infrastructure and a number of local economic indicators using a data set of communities (by zip code) across the U.S. Data is matched from the FCC (Form 477) on broadband infrastructure availability with demographic and other socio-economic data from the U.S. Population Censuses and Business Trends Surveys. Spatial econometric techniques are utilized. Even after controlling for community-level factors known to influence broadband availability and economic activity, it was found that between 1998 and 2008, communities in which broadband was available by 1999, compared to those that did not, experienced a greater difference in the growth of 1) rents, 2) salaries, 3) employment, and 4) overall establishments. In addition, broadband contributed to the share of different industry structures lending support to the GPT hypothesis. This research replicates and extends Lehr et al. (2005).

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CHAPTER I

INTRODUCTION

1.1 Research Background

Over 60 years of economic growth literature has revealed that technology is the only explicable determinant of long-run growth with the accepted economic assumptions of diminishing returns and scarce resources (Aghion & Howitt, 2009). Technology allows more work to be done with the same resources or less. One type of technology that has shown great returns in economic growth literature is Information Communication Technologies (ICTs). This includes broadband, which is attractive to local economic development for a number of reasons. Broadband has served as a method of business attraction and retention, particularly in information-intensive "high tech firms." It is the physical infrastructure for a whole new way of doing business – electronic commerce (e-commerce). Broadband is showing signs of being a General Purpose Technology (GPT) that offers unique growth-inducing qualities. There is no plan for a nation-wide broadband intervention (ARRA, 2009; FCC, 2009) offering a novel place-based infrastructure opportunity to drive a competitive advantage for local communities that invest early. To provide evidence of the growth potential for broadband infrastructure expansion, justifying public expenditures, this dissertation examines the past 10 years of broadband performance.

Researchers have hypothesized about broadband's ability to support regional economic development, as early as 1998. Wieman (1998) stated, "broadband information infrastructure is now as important to a growing array of high-tech firms as railroads were to nineteenth century steel and textiles mills." Moss & Townsend (2000) found that, "the geographical concentration of the Internet backbone development also suggests that regions that do not host Internet Network Access Points (NAPs) are going to be unable to compete for high-tech industries with those that are bandwidth rich." A survey of Seattle's high-tech executives found that telecommunication infrastructure is important in selecting a location for business expansion (Sommers & Carlson, 2000) and that the need for bandwidth skewed growth into two locations of the U.S.: New York and San Francisco (Gorman, 2002). Hackler (2006) adds, "for cities that desire stronger tax bases and more jobs, telecommunications infrastructure may be an untapped local advantage that can attract high-tech industry. Telecommunications is no longer an ignorable issue." Blakely & Leigh (2010) remind policymakers about the desirability of high-tech companies and infrastructure requirements. They state, "high-tech targeted industry attraction provides higher wages and tax revenue that they generate for the city. To attract high-tech industry, a locale must create conditions that will allow new high-tech firms to take root." Recently researchers have noted that speed is growing in importance, "broadband infrastructures with a high transmission capacity are seen as a key precondition for the development of an information society, and therefore, their supply and availability have become important issues in public policies” (Eskelinen, Frank, & Hirvonen, 2004). One of these conditions is broadband infrastructure, which has been linked to growth in many industries but particularly in the “high-tech” knowledge intensive industries (Kolko, 2010; Lehr, Osorio, Gillett, & Sirbu, 2005). Besides the potential business attraction advantages, broadband is the foundation for e-commerce.

In only a decade the amount of internet users worldwide has grown to over 2.26 billion users, which constitutes about 32.7 percent of the world’s population (www.internetworldstats.com, 2011). U.S. business internet participation achieved ubiquity by 2002, faster than any previous technology -- electricity, telephony, the steam engine or the automobile (Forman, Goldfarb, & Greenstein, 2002). Per the U.S. Census Bureau’s E-stats report (2010), e-commerce grew faster than the total economic activity in three of the four major economic sectors covered by the report (U.S. Census Bureau, 2010). E-commerce has made a large impact on sales in certain industries: $2.1 billion for manufacturing, $1.2 billion for merchant wholesalers, and $142 billion for retailers (U.S. Census Bureau, 2010). Demands on speed grow daily. In 2005, the website www.youtube.com came online after an $8 million dollar venture capital infusion. A year later the site was purchased by Google for $1.65 billion (www.logicbank.com, 2007). The site experienced 13 million hours of video uploads in 2010 and 700 billion playbacks (www.youtube.com, 2011). Videos on the website are an average of 10mbits in size, which requires more advanced bandwidth than previous internet applications (www.websiteoptimization.com, 2010). This growth would not be possible without broadband infrastructure.

Unlike industry-specific technology, broadband may be a GPT that promotes growth in other sectors by being an input into production (Basu & Fernald, 2007). Studies estimate that broadband supports a high multiplier as demonstrated in Table 1.

Table 1: Prospective Broadband Input-Output Studies

Study	**Geography**	**Direct Effects**	**Indirect Effects**	**Induced Effects**	**Total Effects**
Atkinson et al. (2009)	U.S.	1	1.47	1.13	3.6
Crandall et al. (2003)	U.S.	1	1.17	NA	2.17
Katz & Suter (2009)	U.S.	1	1.47	1.13	3.6
Katz et al. (2010)	Germany	1	0.45	0.48	1.93
Liebenau et al. (2009)	UK	1	1.76	NA	2.76
Strategic Networks (2003)	Canada	1	1.03	1.4	3.42

The input spurs complementary investments and innovations that increase jobs in other sectors. Input-output estimations suggest that for every "direct" job created in the deployment or support of broadband infrastructure an additional 0.45 to 1.76 "indirect" jobs are created throughout the rest of the economy.

The U.S. was the undisputed world leader in broadband statistics in 2000 (Pew Center on the States, 2010). However, the U.S. dominance in broadband is over. Table 2 demonstrates the current U.S. rankings compared to other countries from statistics reported by the Organization for Economic Co-operation and Development (OECD, 2010).

Table 2. U.S. Broadband International Ranking (34 countries)

Broadband Statistic	**U.S. Ranking**
Average advertised download speed	23rd
High speed Price	23rd
Broadband penetration: Subscribers per 100 inhabitants	14th
Percentage of fiber connections in total broadband subscriptions	10th
Source: OECD, 2010	

The U.S. is 23rd in average download speeds, ranked 14th-23rd in favorable pricing, and ranked 10th -14th in population-controlled penetration rankings. This is true even though the U.S. outpaces every country in the actual level of broadband subscribers: the U.S. had 83 million subscriptions compared to 33 million in the next largest country (Japan). The U.S. had 136.6 million wireless broadband subscriptions compared to 96 million (Japan). Furthermore, the distance between the U.S. and the leader is often vast.

Table 3 demonstrates that the U.S. has 27 broadband subscribers per 100 people compared to the leader at 37.8 (Netherlands). However, the most troublesome statistics is the percentage of fiber connections, which is 5% in the U.S.

Table 3. U.S. Broadband International Ranking Comparison

Broadband Statistic	**U.S.**	**Leader**
Speed: Average advertised download speeds	1.4Mbits	107Mbits (Japan)
Prices: Average Monthly for Very High Speed	$122.45	$29.12 (France)
Penetration: Subscribers per 100 inhabitants	27	37.8 (Netherlands)
Percentage of fiber connections	5%	55% (Japan)
Source: OECD, 2010		

The lack of fiber supply leads to cost and speed implications with the U.S. coming in at 14th through 23rd in various price rankings, and 23rd in advertised speed of 1.4Mbits compared to the leader at 107Mbits (Japan). Overall, the lag in national level broadband may offer a unique opportunity for regions and municipalities to capture an unprecedented technological competitive advantage through additional broadband investment.

The length and specific time period of this study is also of interest. Most studies are two to four years in length with the exception of the Czernich, Falck, Kretschmer, & Woessmann (2009) study of 25 countries which offers limited information at the local level. Table 4 demonstrates that studies that examine economic impact do not capture a longer timeframe.

Table 4. Evaluative Broadband Research

Scale	Author (Year)	Study Period
Multi-country	Koutroumpis (2009)	2003-2006
	Czernich et al. (2009)	1996-2007
State	Crandall et al. (2007)	2003-2005
Local	Kelley (2003)	2002
	Ford & Koutsky (2005)	1998-2000
	Strategic Networks (2003)	2001-2003
	Shideler et al. (2007)	2003-2005
	Lehr et al. (2005)	1998-2002
	Mack et al. (2011)	2001,2006

A longer study time period is necessary because the expectation is that the largest portion of economic effects will be derived from industries that utilize the new technology to innovate (Bresnahan & Trajtenberg, 1995) and there is evidence of a five to 15 year post-investment lag in growth (Basu & Fernald, 2007). The timing of the study from 1998 to 2008 is also of interest because there is a possibility that this technology infrastructure may produce resilient local economic growth despite adverse exogenous shocks.

Broadband infrastructure links to short-term growth in community level economic indicators (Lehr et al., 2005). However, there is no evidence to indicate if these benefits sustain once other communities experience broadband infrastructure provision. Also, the technology may not be resilient against economic shocks such as those experienced in the United States in the early 2000s. There is a call in the literature for further examinations, over longer period of time, to inform public policy decisions. Lehr et al. (2005) state "Local policy-makers in particular may wish to understand whether the economic advantages conferred by broadband are temporary (i.e. growth in the early "have" communities came at the expense of the early "have nots") or longer-lasting (i.e.

broadband stimulated growth of the overall economic pie). If the advantages are temporary, then the benefits to be gained from local public investments to speed broadband availability will be muted once neighboring communities catch up." On the other hand, if broadband affects the base growth rate of the local economy, then the benefit from getting it sooner will continue to compound into the future." Mack, Anselin, & Grubesic (2011) state, "Over a decade after the privatization of the Internet and the subsequent explosion in Internet use, relatively little is known regarding the linkages between firm location and ICT infrastructure. The majority of studies attempting to evaluate this relationship remain largely theoretical and speculative in nature."

Figure 1 presents the conceptual model for this dissertation.

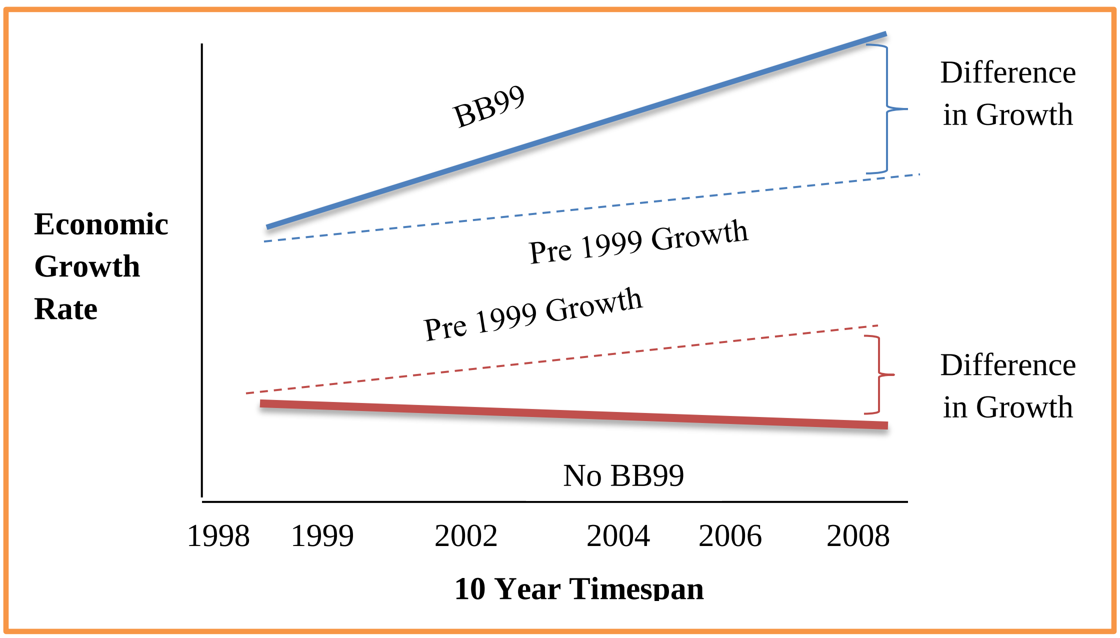


Figure 1. Conceptual Model

Economic growth theories and ICT infrastructure literature are utilized to build the foundation for examination followed by the testing of the conceptual model. The expectation of Figure 1 is that locations that had broadband in 1999 experienced economic growth, which outpaced communities that did not have broadband prior to

December 1999, even though broadband reached an ubiquitous coverage by 2003 in urban areas. The purpose of this study, and anticipated contributions to research provided by empirically testing the conceptual model, will now be reviewed.

1.2 Purpose of Research

This dissertation seeks to inform economic development policy about a potential investment opportunity. Local economic development programs address a community's loss of jobs, tax base, high unemployment, and blight (Blakely & Leigh, 2010). These programs that promise job gains, are also popular methods to help public officials win re-election (Wolman & Spitzley, 1996). Table 5 demonstrates the priorities of policymakers in in a survey of 15 states.

Table 5. Economic Development Priorities in 15 States

	Average Rank*
Retain and expand existing businesses	4.3
Diversify economic base	2.3
Raise skill level of workforce	1.7
Increase international trade	1.6
Develop entrepreneurs and new businesses	1.2
Attract firms to locate in state	1.1
Expand business opportunities in depressed areas	0.9
Expand tourism	0.8
Build or rebuild infrastructure	0.7
Promote high-technology industries	0.4
Provide employment for welfare recipients	0

*Scale: 0-5, with 0 as no ranking and 5 as the most important.

Source: Bradshaw & Blakely (1999)

The table illustrates that infrastructure, generally, was virtually in last place as a tool for development in the late 1990's despite the growth inducing potential. However, if broadband promotes business retention and expansion, it would fit in with the top goal stated by economic developers. When Google announced a bid for a gigabit city, there were over 110 applications from municipalities across the country. Therefore, the momentum for broadband is beginning to change (Savov, 2011).

This research examines local growth indicators to help inform policy about the economic development qualities of broadband infrastructure. This dissertation replicates and then extends Lehr et al. (2005) addressing unexplored gaps in economic growth ICT literature in regards to broadband infrastructure. Specifically, this research extends the above literature stream by empirically testing the continued growth relationship between pre-1999 broadband infrastructure provision and local economic growth factors from 1998 to 2008 by location and various industry sectors to observe GPT trends. Unlike cross-country studies that utilize the gross domestic product (GDP) as the primary dependent variable, the indicators of local economic growth include: 1) employment, 2) wages, 3) rents, 4) establishments, and 5) broadband's contribution to the share of different industries.

1.3 Broadband Definition and Characteristics

Broadband has three primary definitions or characteristics: 1) it is a telecommunication service, 2) it is an infrastructure, and 3) it is an industry and type of work.

As a telecommunication service, the term broadband commonly refers to "data services that are fast, always available, and capable of supporting advanced applications requiring substantial bandwidth" (FCC, 2005). More specifically, it is "an advanced telecommunications service that has the capability of supporting, in both downstream and upstream directions, a transmission speed in excess of 200 kilobits per second (kbps)" (FCC, 2004). Because 200 kbps is relatively low, this definition of broadband does not meet current consumer demands nor does it represent the speeds necessary for international competition. The reason for these low broadband specifications by the FCC is based on two factors: 1) meeting politically appealing goals of ubiquity to un-served areas and 2) the premise that the appearance of more supply drives more utilization (Aron & Burnstein, 2003; Pew Center on the States, 2010).

Broadband is also an ICT infrastructure (Koutroumpis, 2009). It is part of the telecommunications capital for a given country (Timmer & Van Ark, 2005; Van Ark, Inklaar, & McGuckin, 2003). The direct capital impacts of broadband in the U.S. economy are measured through NAICS codes 513310, Wired Telecommunications Carriers; 517510, Cable and Other Program Distribution; 518111, Internet Service Providers, and partially in construction NAICS 23 (www.naicscode.com, 2002).

For the purposes of this paper, the definition of broadband is a blend between service capacity and infrastructure where broadband is a telecommunication infrastructure that supports at least 200 kbps of service in one direction.

1.4 Broadband U.S. Policy Issue

The U.S. is falling behind annually in the provision of high-speed broadband services as demonstrated in the introduction section. In Figure 2, Stevenson (2008) describes that a modem, providing 56K of service, is telephone copper line technology. The ISDN through VDSL services are upgraded telephone lines and cable lines, and FTTx is any method of fiber deployment. The high-speed broadband infrastructure that most consumers use from their premises is an upgraded copper cable or telephone line.

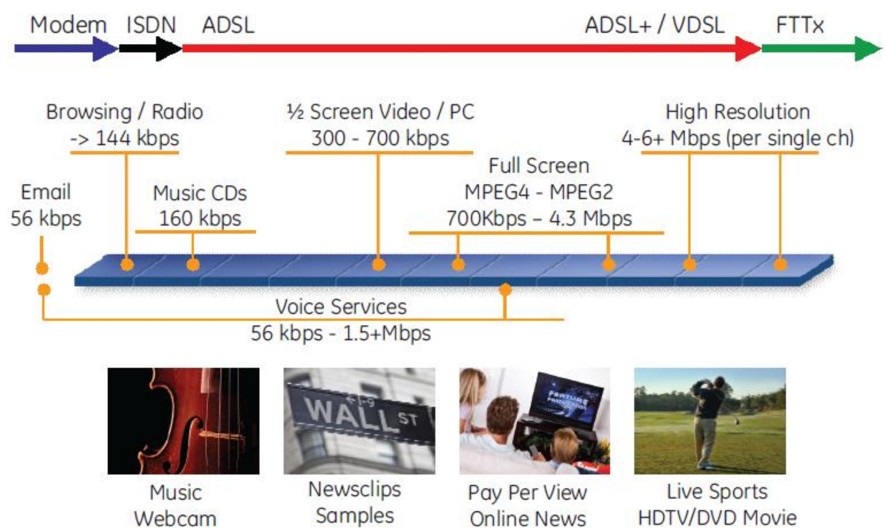


Figure 2 Broadband Technology Speed Ranges
Source: Stevenson (2008)

The U.S. is declining in speed and price for three primary reasons: a lack of Fiber to the Premises (FTTP) connections; the inability of carriers to recoup the cost of deployment (Aron et al., 2003) and; the general unwillingness to pay the high price for upper level services (Stevenson, 2008). FTTP is also known as Fiber to the Home (FTTH), Fiber to the "x" (FTTx), and "last mile" connections. These lines eventually connect to a national and international fiber backbone, also called the "long haul" network.

Carriers like AT&T, Qwest Communications International, Global Crossing and Williams Communications have spent billions of dollars building networks that transmit data over long distances between cities, not within the cities. The long haul system has excess capacity otherwise known as the fiber glut (Ames, 2001). Figure 3 is an approximate depiction of the long haul fiber network (www.qwest.com, 2011). The figure is an approximation because, as of 2011, there was no formal mapping of current fiber network other than what the carriers choose to release for advertising purposes. The broadband long haul network can be compared to an interstate system with no well-developed local road systems to get off the freeway.

Figure 3 Long Haul Fiber Network Approximate Depiction
Source: www.qwest.com (2011)

Fiber is a much more powerful medium than copper. The entire world's long-distance activity can be performed with two or three strands of fiber, and there are thousands of strands in the ground (Ames, 2001). One strand of fiber is capable of transmitting over 1,000 times as much bandwidth with distances over 100 times further than the copper lines found in telephone and cable wiring (Fiber Optic Association, 2005).

Per the OECD statistics, only five percent of the U.S. broadband connections are through fiber infrastructure (OECD, 2010) and only 12 percent of commercial establishments connect via a fiber network (Stevenson, 2008). The U.S. Broadband Speed Map (Figure 4) and the Map Key modified from Pew Center on the States (Table 6) demonstrate the current state of broadband in the country and reveal that in 2010, there was still plenty of room for improvement across the nation. The colors correspond to different speed capabilities with only the green shade approaching competitive international broadband speeds.

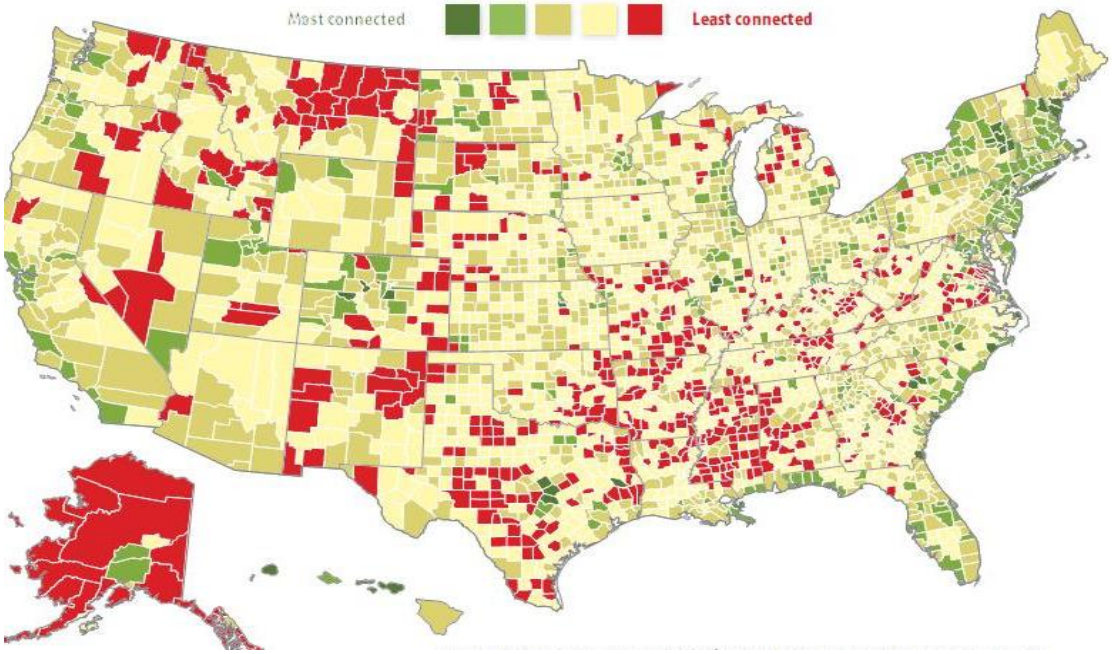


Figure 4 U.S. Broadband Speed Map

Source: Pew Center on the States (2010)

Table 6. Map Key			
Color	Downstream	Type	Download Time 3mb Song
Red	56K	Dial up	7 Minutes
Yellows	200-768K	Old minimum high speed	15 Seconds-2 Minutes
Greens	5-100M	Fiber or close to node	¼ of a second to 4 seconds

Compared to the United States, many countries are specifically targeting increases in speed either in lieu of, or in conjunction with, equity-orientated policies. The American Recovery and Reinvestment Act stipulates expansion to rural areas (ARRA, 2009) while the FCC (2009) "National Broadband Plan," written in 2008, sets forth goals that include connecting at least 100 million U.S. homes to affordable speeds of 100 megabit down and at least 50 megabits up. Funding was set aside for contractors to lay regional solutions. Formal mapping of fiber networks is also part of the "National Broadband Plan."

Table 7 demonstrates the broadband strategy by select countries. The areas focused on rural investment are italicized. The United States is more focused on rural equity than on a national plan for increased speed through fiber connections.

Table 7. Targets of the Broadband Initiatives in Selected Countries

Countries	**Timeframe**	**Speeding Up Existing Links or *Expanding Connectivity to Rural Areas***
Australia	2018	Broadband of 100 Mbps to 90 percent of homes, schools and businesses. *The other 10 percent of people would get a wireless upgrade.*
Canada	2009-2012	Extend broadband to all un-served communities beginning in 2009–2010.
Finland	7 years (2009-2015)	Ultrafast broadband to every household in Finland, with download speeds of at least one Mbps by 2010, ramp-up to 100 Mbps by 2016..
France	5 years (2008-2012)	Ultra broadband networks to four million households through FTTH access by 2012.
Germany	10 years (2009-2018)	Broadband access at 50 Mbps or above to 75 percent of the homes by 2014. *Germany to have broadband at 1 Mbps by the end of 2010 to all homes.*
Ireland	2 years (2009-2010)	*To provide broadband coverage and services to the remaining un-served with minimum download speeds of 1.2 Mbps.*
Japan	2 years (2009-2010)	*Broadband infrastructure rollout plan for the rural areas.*
Portugal	2 years (2009-2010)	Connect 1.5 million homes and businesses to the new fiber networks. A goal of 50 percent home broadband penetration.
Singapore	5 years (2009-2013)	60 per cent of homes and offices to have access ultra high-speed and pervasive Next Generation National Broadband Network by 2013
Republic of Korea	5 years (2009-2013)	Upgrade to 1 Gbps by 2012; subscriber capacity on 3G broadband services to be increased to 40 million.
Spain	4 years (2009-2012)	*To have greater reach of broadband in rural and isolated areas.*
U.S.	2 years (2009-2010)	*To provide broadband service to un-served areas and improve service to underserved areas*

Source: Qiang (2010)

Carriers deploy broadband related to the economic characteristics of the community. These include income and population density (Flamm, 2004; Grubesic & Murray, 2004; Prieger, 2003), the education level of the geographic area, cost-related variables, user age, the presence of children (Clements & Abramowitz, 2006), competition from alternative broadband platforms (Grubesic, 2003), and local loop unbundling (which allows competitors to utilize existing infrastructure) (Lee & Marcu, 2008). Some municipalities that do not display the required economic characteristics, and have publicly owned utilities, have pursued a route of self-determination, utilizing public dollars to lay the FTTx infrastructure. However, these have not been without issues like legal battles and underhanded marketing tactics by broadband suppliers (American Public Power Association, 2004).

To recap, broadband fiber carriers are not investing because of the inability to recoup the cost of laying new infrastructure. Unlike other countries, there is no national plan for laying a robust FTTx infrastructure. The result is a decline in U.S. capabilities as a total nation that presents a unique opportunity for economic development through broadband at the local level.

Prior to public investment in broadband infrastructure for economic development purposes, the question remains, "does broadband offer continuing growth benefits to a location?" Growth may be temporary for two reasons: 1) infrastructure provides a temporary bump in employment that declines as construction is completed; or 2) that subsequent broadband investment in other locations erodes the economic advantage conferred by early investment. However, locations may receive continued growth opportunities if the technology results in continued innovation, and growth, through different industries per the GPT hypothesis.

1.5 Contributions of the Study

This research makes the following contributions:

1. Answers the call by researchers for more quantitative studies in regards to the longer term economic impacts of broadband;
2. New information on whether a technology infrastructure like broadband provides continuing economic growth on a local level;
3. New 10-year findings of the broadband impact on additional industry sectors in support of the GPT hypothesis;
4. Confirmation of a link between broadband and local economic development indicators;
5. Completes an aspect of the Lehr et al., (2005) study follow-up recommendations;
6. Adds a spatial econometric method of analysis to control for spatial autocorrelation.

1.6 Organization of the Paper

This dissertation first addresses the theoretical and empirical literature prior to model and hypothesis development. Then, the research design and methodology are discussed. The research findings are followed by policy and future research recommendations.

Specifically, Chapter I introduces the relevance, reasoning, and research question addressed by this dissertation.

Chapter II contains a literature review of economic growth theory, GPT theory, empirical findings of ICT literature, and empirical findings of broadband economic impact policy research.

Chapter III proposes a model and hypothesis development of the relationship among broadband and (1) rent; (2) salary; (3) employment; (4) establishments; (5) and broadband's contribution to the share of different types of industries.

Chapter IV is a review of the research design and methodology, including data limitations and manipulation, analysis procedures, and results.

Chapter V presents the research findings and a summary of results.

Chapter VI concludes with a discussion of the research findings, policy implications, contributions of the research, study limitations, and future research suggestions.

Finally, a bibliography containing citations for all references is provided, along with an appendix of tables, descriptive statistics, and statistical output. A list of tables and figures is also provided after the table of contents.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction to Literature Review

A complete review of literature addressing economic growth or the technical aspects of broadband is beyond the scope of this dissertation. However, several research streams offer a foundation to explore broadband, including a brief overview of economic growth theory, GPT theory, empirical ICT literature, and broadband economic growth literature.

2.2 Economic Growth Theory

Aghion & Howitt (2009) recently published a comprehensive presentation of economic growth theory and models. The first model is referred to as the neoclassical growth model formulated by Solow (1956) and Swan (1956), which showed "how economic policy can raise an economy's growth rate by inducing people to save more. The model also predicts that such an increase in growth cannot last indefinitely. In the long run, the country's growth rate will revert to the rate of technological progress, which neoclassical theory takes as being independent of economic forces, or *exogenous*" (Aghion & Howitt, 2009). The neoclassical model does not permit the analysis or rationalization of these technological forces that provide growth and counteract diminishing returns to productivity inherent in the model (Aghion & Howitt, 2009). After many years, new models, called endogenous growth theories, attempted to analyze and explain technological progress. Table 8 demonstrates the various endogenous growth models (Aghion & Howitt, 2009).

Table 8. Endogenous Growth Theories		
Theory	Notes	Variables Used
AK Model	Save portion of GDP that will find its way to finance a higher rate of technological progress	Savings rate, fiscal policy, and trade policy
Product Variety I	Innovation creates new product varieties utilizing the same inputs (capital and labor)	R&D, education, product variety, and patents
Product Variety II Schumpeterian	Quality-improving innovations render old products obsolete: creative destruction	Education, patents, firm exit and entrance
Source: (Aghion & Howitt, 2009)		

Endogenous growth theory seeks to measure technological change as a part of the economic process where profit maximizing firms seek to utilize research and development, and educated/skilled labor as intentional "economic" activities (Aghion & Howitt, 2009). However, none of these specifically addresses broadband or ICTs. A current form of technology considered popular in explaining recent accelerated growth are "general purpose technologies" (Aghion & Howitt, 2009).

2.3 General Purpose Technologies (GPT)

The U.S. experienced an accelerated growth in Total Factor Productivity (TFP) across a broad base of industries from 2000 to 2004 despite a number of adverse macroeconomic shocks (Stiroh & Botsch, 2007). The GPT hypothesis offers a method to examine growth in a period of market decline.

Historical examples of other GPTs include the steam engine, electricity, and most recently ICTs. General purpose technologies have the following characteristics: 1) pervasive use through many industries; 2) productivity reduction at first introduction; and 3) the invention of new products and processes (Bresnahan & Trajtenberg, 1995). However, GPTs can be complicated to adopt so growth is not a guarantee. Jovanovic & Rousseau (2005) suggest that for growth to occur GPTs require the following: 1) complementary innovations and learning that sometimes reduce short-run productivity; 2) a “skill premia” or highly-skilled labor; and 3) “creative destruction” with firm entry and exit that may result in a temporary decline in the stock market. General purpose technologies lead to fundamental changes in the production process for firms that use the new technology (Helpman, 1998), which spurs complementary investments/innovations (Basu & Fernald, 2007). Therefore, growth occurs in two ways under the GPT theory: first, temporary and permanent jobs in the ICT-intensive sectors that install and maintain the technology; and second, new permanent job growth in ICT-using industries that innovate with the GPT (Fernald & Ramnath, 2004).

As predicted by GPT theory, complementary investments that utilize or innovate with the GPT take time. Therefore, growth created by these investments lags the direct GPT ICT investment. Basu & Fernald (2007) state that “the U.S. industry data suggest that ICT capital growth is associated with industry TFP accelerations with long lags of five to 15 years." In a comparison study between the E.U. and U.S., the U.S. dominance in TFP growth between 2000 to 2005 is due to heavier U.S. ICT production and expansion in the 1990s (Van Ark, 2006; Van Ark et al., 2003; Timmer & Van Ark, 2005; Van Ark, O'Mahony, & Timmer, 2008).

Broadband is displaying similar characteristics of other ICTs as a GPT. Most notably, the growth of TFP in IT-using industry sectors, between 2000 and 2004, supports the theory that broadband investments in the 1990s resulted in a broad base of industry growth in the early 2000s. A review of ICT economic impact research is presented next, followed by broadband specific evaluative research.

2.4 Information and Communication Technology Literature

The ICT growth literature offers a window into the broadband potential. The literature supports the theory that telecommunications infrastructure produces significant growth results across many scenarios and with more controls and techniques over time. However, models analyzing national growth experiences offer little support for the impact of local economic development interventions. In addition, much of this literature, focus on the impact of telephones, which are relatively easy to use, compared to the complex complementary investments required to use broadband. In addition, previous ICT literature may concentrate on developing countries, which may react differently to investment than a developed country. Lastly, ICT literature is a part of infrastructure research. This stream of research requires many controls to determine causality. Röller & Waverman (2001) describe the challenges in infrastructure examinations which face two issues: 1) reverse causality; and 2) spurious correlations. Reverse causality suggests that locations that invest in infrastructure may have already been growing, spurring demand for more infrastructure, versus the infrastructure spurring more growth. In addition, growth is highly correlated with income, education, and population typically indicative of urban locations. Despite these challenges, the generally significant and positive impact of ICTs contributes to the hypothesis that broadband will support positive and significant growth effects.

2.4.1 GDP Growth Impact

In the first study of its kind, Hardy (1980) examined 60 countries, from 1960 to 1973, in order to measure the role of the telephone on economic development. The regressions show a positive, significant impact of telephone lines per capita on GDP per capita. However, a separate estimation for developed and developing countries shows that the results are not significant. Later authors hypothesize that the lack of significance was due to missing fixed effects and controls for reverse causality (Röller & Waverman, 2001).

Madden & Savage (1998) built a supply-side growth model to measure telecommunication penetration from 1991 to 1994 for 11 transitional European countries. Main phone lines were a key element to growth in these countries. The author’s improvements still result in a positive and significant relationship between telecommunications and growth. They also test for the direction of causality and find technology penetration precedes growth.

Röller & Waverman (2001) jointly estimated a micro-model for telecommunications investment within a macro-production function across 21 developed OECD countries from 1970 to 1990, and found that telecommunications contributed between 0.59 of the 1.96 percent per year in GDP growth rate. They also found that a critical mass of investment resulted in higher growth amounts.

K. S. Sridhar & V. Sridhar (2004) performed a simultaneous equation analyses for developing countries. When controlling for the effects of capital and labor, the authors found that there was a significant impact of cellular services on national output. However, the impact was lower for developing countries suggesting a lack of convergence between economies.

Datta & Agarwal (2004) examined 22 OECD countries utilizing panel data and a dynamic fixed effects method of estimation to control for the omitted variable bias of single cross-section regression. The results show that telecommunications is both statistically significant and positively correlated with growth in real GDP per capita growth for these countries. However, the results find that telecommunications investment is subject to diminishing returns.

Duggal, Saltzman, & Klein (2007) utilized a nonlinear production function to measure both public and private U.S. infrastructure from 1975 to 2001. The authors found increasing returns to scale for the U.S. economy, implying that information technology was the largest contributing component to growth during the 1990's expansion.

Ding & Haynes (2006) tested two different methods in analyzing the telecommunications infrastructure and economic growth of 29 Chinese regions from 1986 to 2002. The authors found that, although both produced positive and significant results, the generalized method of moments (GMM) estimation is more likely to produce consistent and efficient estimates than OLS and fixed-effect estimation.

Jalava & Pohjola (2008) compared the returns to electricity and ICT in Finland, one of the world's ICT leaders. The authors found that ICT's contribution to GDP growth from 1990 to 2004 was three times as large as electricity's contribution in the period from 1920 to 1938.

In conclusion, studies of the effects of ICT infrastructure on GDP tend to be positive and significant.

2.4.2 Industry-level Economic Impact

According to the GPT hypothesis, growth will occur in ICT-using, not just ICT-intensive and producing industries. However, timing is important since the majority of telecommunications modernization to support broadband occurred between the mid-1990s through 2004. The ICT research only studies general GDP impacts. Understanding the impact on industries may also assist in making informed public policy decisions. In the case of broadband, the goal may be to develop IT-intensive sectors to change the existing portfolio of industries. However, if broadband affects other industry segments, the investment may leverage the existing mix of industries.

Greenstein & Spiller (1996) utilized a cross-section time-series method between 1986 and 1992, to examine the impact of telecommunication infrastructure on two NAICS codes: finance, insurance and real estate (FIRE), and manufacturing. The results indicate that a doubling of fiber optic cable results in a 10 percent increase in the FIRE sector. However, manufacturing was not significant. This result is counter to the E-stats report that suggests manufacturing has received the largest share of growth through e-commerce due to Electronic Data Interface (EDI) technology (U.S. Census Bureau, 2010). However, the time period of 1986 to 1992 may be too early to analyze these results.

Yilmaz, Haynes, & Dinc (2001) reported by sector and found that the magnitude and statistical significance of aggregate growth varies across sectors. Telecommunications infrastructure investment has the strongest positive impact on the service-related sectors: wholesale trade, FIRE, retail trade and other services. The impact was non-significant or negative for agriculture, mining, construction, and manufacturing. Once again, the time period of the study from 1984 to 1997 does not fully capture broadband's continuing implications on the economy.

Another quality of technology is adoption, signifying use, which also impacts growth. However, adoption is more difficult to measure than infrastructure and is a limitation of this study as well. Yilmaz & Dinc (2002) attempted to measure adoption. The authors examined 48 states to determine if there was a relationship between service sector output growth and telecommunication infrastructure. The study found that some states were using their infrastructure more efficiently as determined by infrastructure input to service sector output.

Early industry level analysis suggests there is a positive relationship between telecommunications and the FIRE and service sectors. Another body of literature that compares capital investment to total factor productivity (TFP) is also helpful in the industry-level discussion of broadband.

2.5 Total Factor Productivity Empirical Examinations

Total Factor Productivity (TFP) literature differs from the previous macroeconomic GDP evaluations by measuring how well the economy uses all of its factors of production. Fernald & Ramnath (2004) state that “TFP growth allows us to increase the amount of output we produce—and, hence, how much we have available to consume today or invest for the future—without having to increase the resources (mainly capital and labor) used.”

Capital investments themselves spur growth. The TFP literature subtracts growth from capital investments, leaving a residual, also called the “Solow residual,” which offers information of the growth that happened due to technological progress (Aghion & Howitt, 2009). This particular stream of literature utilizes ICT and IT interchangeably and includes computer, software, and communication capital.

The U.S. experienced a productivity resurgence that began in 1995 directly related to ICT producing sectors (Stiroh & Botsch, 2007). The first wave of TFP growth in the mid-1990s has been directly attributed to ICT capital’s five percent contribution of total capital stock (Jorgenson, 2001). However, TFP growth continued from 2000 to 2004, but not in non-ICT-producing sectors (Oliner, Sichel, & Stiroh, 2007). Corrado, Hulten, & Sichel (2009) attributed gains in the early 2000s in the finance and business services, while Triplett & Bosworth (2004) found that all of the post-2000 gains traced to the service sector. Since the mid-1990s, countries with especially dynamic economic growth have tended to be highly specialized in ICT-producing (intensive) and ICT-using industries (Van Ark & Inklaar, 2005).

Stiroh & Botsch (2007) offered three hypotheses for the lack of connection between TFP growth and the ICT sector. First, cautious hiring practices that created a jobless recovery may be hiding ICT’s impact. Second, ICT is now so pervasive that an ICT-intensity indicator by industry may not be useful. Third, the recent gains could reflect the delayed impact of earlier ICT investment potentially supporting the GPT theory.

Basu and Fernald (2007) agreed that growth between 2000 and 2004 occurred outside of ICT-intensive industries but for a different reason. They state, “in standard neoclassical growth theory, the use of ICT throughout the economy leads to capital deepening, which boosts labor productivity in ICT-using sectors—but does not change TFP in sectors that only *use* but do not produce ICT. TFP growth in *producing* ICT goods shows up directly in the economy’s aggregate TFP growth. From the perspective of neoclassical economics, there is no reason to expect an acceleration in the pace TFP growth outside of ICT production.” The authors continue, “The assumption that complementary investments are needed to derive the full benefits of ICT is supported both by GPT theory and by firm-level evidence. Since (intangible) capital accumulation is a slow process, the full benefits of the ICT revolution show up in the ICT-using sectors with significant lags.”

In pursuit of the GPT hypothesis, the authors sought to measure growth in ICT-using sectors based on a lag from investment in ICT-producing sectors. The authors report the share ICT (computer, software, and communication infrastructure) contribution to value-added revenue in a number of industries with communications and the business services sectors garnering the largest amounts. However, from 1990 to 2004 the total ICT share increased in sectors not traditionally associated with ICT use: mining, manufacturing, construction. In the same time period there was a decrease in the finance and retail trade sectors. They found that gains in U.S. TFP in the late 1990s were positively associated with five to 15 year lags in ICT capital growth, which the authors hypothesize is due to the dispersion of business output into unmeasured investment in complementary capital (Basu and Fernald, 2007; Basu, Fernald, & Oulton, 2004).

The TFP literature stream suggests an economic impact from direct telecommunication capital expenditures. However, there is an expectation of a lagged growth effect in industries that utilize the technology resulting in a second wave of productivity growth potentially higher than the first wave of capital investment.

2.6 Broadband Growth Literature

The following literature directly compares broadband to the growth of economic indicators. However, some are national which offer support for broadband but have limited use in explaining the local economic impact. The national and sub-national research is broken into two sections.

2.6.1 Broadband Growth: National-level Literature

Table 9 presents the evaluative broadband growth literature at the national, or country-level, which usually have GDP or GNP as the dependent variable.

Table 9. Broadband National-level Empirical Literature

Study	Dependent	Independent	Findings
Czernich et al., 2009	GDP	Broadband penetration 10 percent increase	0.9-1.5 increase annual per-capita growth
Koutroumpis (2009)	GNP	Broadband penetration	0.4 percent to GNP

Koutroumpis (2009) utilized a structural econometric model within a production function framework to endogenize telecommunications' investment, which controls for the two-way relationship between infrastructure and growth. The author found that for 15 E.U. countries between 2003 and 2006, broadband penetration correlated with growth.

The effect was the most profound above a “critical mass” of infrastructure. This simultaneous equation has become a common method to controlling for reverse causality. However, the method is not possible for this study due to data availability issues at the community level.

Czernich et al. (2009) estimated the effect of broadband infrastructure on economic growth for a panel of 20 OECD countries from 1996 to 2007. The authors utilized an instrumental-variable model and found that a 10-percentage point increase in broadband penetration raised annual per-capita growth by 0.9-1.5 percentage points. The authors also reported that GDP is 1.9 and 2.5 percent higher than before its introduction.

2.6.2 Broadband Growth: Sub-national Literature

The following studies serve as the model basis for this dissertation. Table 10 presents the sub-national broadband economic impact research.

Table 10. Sub-national Broadband Empirical Literature

Study	Dependent	Independent	Findings
Crandall et al. (2007)	Employment	Broadband lines/Pop	An increase of 0.01 lines per capita is almost 0.6 percent growth in employment between 2003 and 2005
Mack et al. (2011)	IT-intensive industries	Number of broadband providers by zip	1 percent increase Broadband contributed 1 to 2.5 percent to the growth of IT-intensive industries in six MSAs.
Kelley (2003)	Revenue	Fiber to an industrial park	Cedar Falls: $32M(1996) to $101M(2002); Waterloo: $58M(1996) to $53M(2002)
	Population		Cedar Falls: 5.3 percent and Waterloo: 3.4 percent
	Establishment Growth		Growth from 2003 to 2004: 15 new businesses
SN Group (2003)	Jobs	Municipal fiber network	The contributed 62.5 new jobs

Table 10. Sub-national Broadband Empirical Literature Cont.			
Study	**Dependent**	**Independent**	**Findings**
Ford Koutsky (2005)	Lake County Gross Sales	Municipal fiber	Lake County experienced 100 percent more revenue growth
Shideler et al. (2007)	Employment by industry	Percent of KY county areas with broadband service as of January1, 2004	Broadband was a positive and significant variable contributing to growth in sectors: mining, construction, information and administrative, support, and waste management and remediation services
Lehr et al. (2005)	Rent	Broadband infrastructure 1999	Positive and significant variable broadband contributed 6.6 percent to rent.
	Salaries		Not significant
	IT Intensive sectors		Positive and significant variable broadband contributed .6 percent to share of IT sectors
	Employment		Positive and significant variable broadband contributed 1 percent
	Establishments		Positive and significant variable broadband contributed 4.8 percent

Crandall, Lehr, & Litan (2007) estimated 48 U.S. states' data to determine the relationship between broadband penetration, output, and employment from 2003 to 2005 by sector at the state level. They found for every one percentage-point increase in statewide broadband penetration, employment increased by 0.2 to 0.3 percent per year. They extrapolated a one percentage point increase in broadband penetration would equate to about 300,000 jobs nationwide. The authors found that broadband lines per population (adoption) had a positive and significant effect on the following 2-digit NAICS codes: 61-education, 62-health care, and 52-financial services, and 31-manufacturing. None of these NAICS fall into the business services sectors supporting the GPT hypothesis that growth will be broad-based. Employment in other sectors had no significant relationship to broadband. However, state output of goods and services was not statistically significant potentially due to noise at higher levels of aggregation.

Mack et al. (2011) performed a spatial econometric estimation technique of six MSAs to determine if locales with lower levels of ICT infrastructure were at a disadvantage for ICT firm retention development. The author found that a one percent increase broadband contributed one to 2.5 percent growth of IT-intensive industries in six U.S. metropolitan statistical areas. Mack et al. (2011) explains that spatial econometrics is important for this type of geographic based data. Linear regression models estimated via ordinary-least squares (OLS) may use untransformed count data from business sources violating the normality assumption. In addition, previous literature has found a spatial autocorrelation with the provision of broadband (Grubesic, 2003). The authors state that estimates that do not control for autocorrelation will produce biased and inconsistent estimators. Broadband may also experience endogeneity between other economic indicators producing inconsistent coefficient estimates. For instance, Holt & Jamison (2009) found an endogenous relationship between broadband provision and two variables; GDP growth and broadband demand. Even with the additional methods, the authors found that a one percent increase in the number of broadband providers in a metropolitan area produced a one to two and one half percent growth in the number of knowledge intensive firms. Additional information about the spatial econometric method will follow in the “Research Results” section.

Kelley (2003) is an empirical, but not statistical analysis, of the Cedar Falls, Iowa municipal broadband network linked to an industrial park. Cedar Falls garnered growth benefits compared to the experiences of a neighboring city without a fiber network, Waterloo, Iowa. The industrial park experienced a growth in 15 new businesses in a year. From the period of 1996 to 2002, Cedar Falls experienced a revenue growth of $32M to $101M compared to Waterloo which declined from $58M to $53M in the same period. The Cedar Falls population grew 5.3 percent compared to Waterloo at 3.4 percent. Since there are no controls for other community characteristics or previous patterns of growth, it is impossible to determine the direction of causality with this study.

Ford & Koutsky (2005) performed an econometric analysis of Lake County, Florida that offered businesses access to a municipal fiber optic network. The authors matched Lake County to seven other counties in Florida without a municipal fiber network based on similar growth and socio-economic patterns. Lake County experienced 100 percent more revenue growth -- a doubling -- compared to other similar counties.

Strategic Networks Group (2003) examined the impact of a $750,000 municipal broadband fiber network from 2001 to 2003 in Dundas County, Ontario, Canada. The findings indicate growth of 62.5 new jobs, a $2.8 million commercial/industrial expansion, and $140,000 in increased revenues. In addition, 54.2 percent of fiber accessing businesses grew compared to 27 percent of the dial-up access businesses and 5.6 percent of non-internet using companies. The industries that grew the most in employment were accommodation, food and beverage, manufacturing, transportation, finance and insurance, and communication. Therefore, growth occurred in many types of industries, not just those typically considered information intensive. However, like Kelly (2003) it is not possible to determine causality without the presence of additional controls.

Shideler, Badasyan, & Taylor (2007) performed a regression analysis on the impact of broadband deployment on employment across 20 two-digit industrial sectors in Kentucky. The broadband measurement was a penetration percentage in each county. The following industries had a positive and significant employment relationship including; 21-mining, 23-construction, 22-utilities, 55-management of companies and enterprises, and 56-administrative, support, waste management, and remediation service. Of these industries, only the management of companies and enterprises sector is a business services sector. The accommodation and food services' sector shows a weak negative relationship, providing a counter-point to Strategic Networks Group (2003) reported success in that sector. The square of broadband deployment is negative and significant in all of the above industries, suggesting diminishing returns. Broadband's contribution to total employment growth ranged from 0.14 to 5.32 percent.

Lehr et al. (2005) measured broadband against state and zip code level measurements across the U.S. to determine if there was a correlation between broadband availability and growth at the state and community-level in 1) employment, 2) wages, 3) rents, 4) the number of businesses overall, and 5) businesses in IT-intensive sectors from 1998 to 2002. This is the foundational research piece for this dissertation's methods section. It was determined that the state level was too high of a level of aggregation to identify results. At the zip code level, broadband contributed 6.6 percent to rent, .6 percent to the share of IT sectors, one percent to employment growth, and 4.8 percent to establishment growth. This research was selected because it is the most expansive and thorough examination at the community level. The authors' method controls for spurious correlations by including variables that drive supply and demand of broadband in the previously reviewed literature. This includes controls for urban versus rural, income, education, and share of ICT intensive firms. In their regressions, one surprising exception was population density, which was consistently non-significant and dropped from their measurements. The authors actively control for reverse causality by using a variable that captures previous performance of the dependent growth variables as a control. The authors utilized the Forman et al. (2002) definition of ICT-intensive industry sector NAICS codes at the 3-digit level: 551, 511, 221, 523, 512, 513, 514, 334, and 483. The study calls for further studies, over a long period of time, with additional variables, and with different methods.

The sub-national level of research uses different approaches to examining the broadband impact. The broadest scope of the research is from Lehr et al. (2005) across all zip codes in the United States. This is followed by the Shideler et al. (2007) examination of employment by industry in Kentucky counties. Although Mack et al. (2011) is an even more limited examination of six MSAs, it offers a window into the need for spatial econometrics for this type of data. Together the three serve as the basis for the methods employed in this dissertation.

2.7 Integration of Literature Review and Model Development

Based on the preceding literature review, ICTs had an impact on overall GDP growth in developed and developing countries. At a national level, a country may experience increases in gross domestic product (GDP) with no growth in jobs, wages, or businesses. In addition, national level studies do not focus on the local economic development. Therefore, the standard national ICT literature offers very little for community-level analysis except signs of growth. However, at the zip code level, there is evidence of a positive and significant relationship between broadband and growth in rent, employment, and establishments. However, growth, especially community-level growth, is not guaranteed due to the short-term characteristic of network construction, the potential for diminishing returns, and the need to have complementary industries/investments that will utilize the infrastructure efficiently. There is no information on whether a region that invested in broadband continues to experience growth as other places deploy infrastructure. In addition, current research has not captured a lengthier picture of timing and industry relationships with broadband infrastructure.

According to the GPT literature, for those zip codes that had broadband prior to 1999 there may be a gap of five to15 years from the point of investment until IT-using firms show a positive relationships. The community-level longitudinal method of this research will observe changes by industry and location over time. Lastly, spatial econometrics, a method common in regional science and economic geography, is an additional method of analysis that will be employed in this study.

CHAPTER III

MODEL DEVELOPMENT AND HYPOTHESES

3.1 Research Question and Hypotheses

Broadband infrastructure has been linked to short-term growth in community-level economic indicators. However, there is no evidence to support whether these benefits persist offering a competitive advantage even as other communities experience broadband infrastructure provision as well. There is also no evidence of whether or not broadband was able to continue benefitting communities despite multiple shocks to the economy. There is also limited evidence of broadband's impact on different timing and types of industries. To help inform local broadband policy, the principal research question posed is "Did locations that had broadband prior to 1999 experience a greater difference in local economic growth indicators compared to communities that did not have broadband prior to 1999?"

The model in Figure 1, presented in the first chapter of this paper, demonstrates the goal of observing growth in locations between a group of zip code communities that had broadband in 1999 to those that did not have broadband in 1999. The expectation is that the communities that had broadband will experience a higher growth rate in the measured economic growth variables than those that did not. In this study, the Lehr et al. (2005) time period of 1998 to 2002 is replicated and then followed by the 1998 to 2008 study period.

3.1.2 Hypotheses Related to Broadband Infrastructure and Local Economic Growth

The first four hypotheses posit that there is a positive relationship between broadband infrastructure in 1999 and local economic growth factors. The majority of growth literature measures national GDP and not community level measurements of growth. Local economic development programs address a community's loss of jobs, tax base, high unemployment, and blight (Blakely & Leigh, 2010). Policy interventions that offer the potential for job gains are popular methods to help public officials win re-election (Wolman & Spitzley, 1996). These measures also boost the local tax base that support more services (Blakely & Leigh, 2010). Therefore, establishing a connection between broadband and growth is important to make informed policy decisions.

Because there is no single economic indicator at the community level (Lehr et al., 2005), a variety of community-level economic metrics will be utilized to measure growth including median gross rent, salary, employment, and establishments.

3.1.2.1 Hypothesis Related to Broadband Infrastructure and Growth in Rents

Lehr et al. (2005) is the only study that measured growth in rents associated with ICT or broadband. Rents are used as a proxy for home values. The authors found a significant relationship between rent growth and broadband. Lehr et al. (2005) rationalize that increased rents equate to increased affluence. With the longer period of time of this study, it is expected that broadband will contribute to growth in rents because broadband attracts or grows information intensive businesses (Lehr et al., 2005; Mack et al., 2011) that tend to have higher wages (Jovanovic & Rousseau, 2005) which may create demand for more expensive housing. Based on the previous research, the relationship between broadband and rents is as follows:

Hypothesis 1: Locations that had broadband by 1999 experienced a greater difference in the median housing rent growth compared to communities that did not have broadband prior to 1999 for the period between 2000 to 2009.

3.1.2.2 Hypothesis Related to Broadband Infrastructure and Salary Growth

Lehr et al. (2005) is also the only research paper that measured wage growth compared to ICT or broadband and found no significant relationship between the two variables. Higher wages equate to increased tax revenues. Local economic development policymakers seek to increase the tax revenues to fund other programs (Blakely & Leigh, 2010; Hackler, 2006) and to create jobs that are popular for re-election bids. Research links broadband to an increase in IT-intensive firm growth (Lehr et al., 2005; Mack et al., 2011). Theoretically, IT-intensive jobs require a skill-premia that equate to higher paying jobs (Jovanovic & Rousseau, 2005). However, Lehr et al. (2005) did not produce statistically significant results for a relationship between broadband and salary growth between 1998 and 2002. Lastly, if broadband is a GPT it may take time for the growth to occur as IT-using industries implement complementary investments that fundamentally change production processes as well as “creative destruction” with firm entry and exit (Helpman, 1998; Jovanovic & Rousseau, 2005; Basu & Fernald, 2007). Based on having a longer study period, the expected relationship between broadband and salaries is as follows:

Hypothesis 2: Locations that had broadband by 1999 experienced a greater difference in growth of the ratio of average salaries compared to communities that did not have broadband prior to 1999 for the period of 1998 to 2008.

3.1.2.3 Hypothesis Related to Broadband Infrastructure and Employment

The following section discusses the impacts broadband has had on jobs. In addition to the increase in taxes (Blakely & Leigh, 2010; Hackler, 2006), job growth is tangible and popular evidence that policymakers are serving the electorate (Wolman & Spitzley, 1996). The ratio of employment between study time periods is the common measurement used in this paper’s foundational literature (Crandall et al., 2007; Lehr et al., 2005; Shideler et al., 2007). Lehr et al. (2005) found that broadband contributed one percent to employment growth. Crandall et al. (2007) found that an increase of 0.01 percent of broadband lines equated to a 0.60 percent growth in employment between 2003 and 2005. Shideler et al. (2007) found that broadband’s contribution to total employment growth ranged from 0.14 to 5.32 percent.

Based on the reported impacts, the hypothesized relationship between broadband and employment is expected to be positive and significant resulting in the following hypothesis:

Hypothesis 3: Locations that had broadband by 1999 experienced a greater difference in growth of the ratio of overall employment compared to communities that did not have broadband prior to 1999 for the periods of 1998 to 2008.

3.1.2.4 Hypothesis Related to Broadband Infrastructure and Establishment Growth

Business formation is another matter of economic development interest due to industrial diversification and tax revenue growth (Blakely & Leigh, 2010; Hackler, 2006). The IT-intensive firm hypothesis suggests that growth will be in specific types of industries (Forman et al., 2002). However, GPT theory suggests growth may occur across a broad base of industries (Stiroh & Botsch, 2007). Therefore, all establishment creation and growth will be researched. Lehr et al. (2005) is the only research paper that measured overall firm creation at the local level. The authors found that from 1998 to 2002, broadband increased business formation growth by one-half of one percent (0.00483).

Based on the literature, the relationship between broadband and establishments is as follows:

Hypothesis 4: Locations that had broadband by 1999 experienced a greater difference in growth in the ratio of establishments compared to communities that did not have broadband prior to 1999 for the periods of 1998 to 2002 and 1998 to 2008.

3.1.2 Hypotheses Related to Broadband Infrastructure and Industry Composition

Policymakers seek to not just grow jobs, but to develop industries that offer higher wages to support the local tax base and assist in re-election bids (Blakely & Leigh, 2010; Wolman & Spitzley, 1996) In addition, a diversified portfolio of industries can protect a location from changes in any one industry. The authors referred to this examination as industry mix. The literature has shown that broadband has the potential to impact more than just IT intensive industries, supporting the GPT theory, but that these effects may not occur immediately. For instance, an IT-intensive firm that develops fiber optic cabling may show faster, and shorter term, growth results than an IT-using firm that needs to develop new systems to implement the technology. Studies have found that the effects may be delayed between five to 15 years following the technology investment (Basu & Fernald, 2007). In order to examine potential timing effects of broadband, this analysis studies the periods of 2002, 2004, 2006, and 2008. The broadband coefficient is interpreted as the amount that broadband contributed to the share of an industry type, with establishments as the measurement.

The industry composition hypotheses section seeks updated information directly related to IT-intensive and IT-using industries. A group of researchers identified that certain industries tend to utilize IT in innovative ways spurring growth (Blakely & Leigh, 2010; Forman et al., 2002). Broadband was regressed on the IT-intensive industries as well as manufacturing, FIRE, and service sectors. The one difference is that Lehr et al. (2005) utilized the model in Forman et al. (2002) as the basis for selecting IT-intensive 3-digit NAICS codes. Between 1998 to 2002, the Lehr et al. (2005) study period, there were no changes at the 3-digit level. In later years, there are many changes. The IT-intensive 3-digit NAICS are followed throughout the years. However, for FIRE, manufacturing, and service, the analysis removes the IT-intensive NAICS in those sectors and then analyzes the remaining 2-digit industry NAICS codes, respective of each industry, to capture the many changes that occurred particularly in 2004 and 2007.

3.1.2.1 Hypotheses Related to Broadband Infrastructure and the I.T. Industry

IT-intensive industries are isolated for three reasons in the literature. First, communities seek to diversify their industrial portfolio with emerging trends (Hackler, 2006). Second, IT is particularly important because the jobs tend to be higher skilled and therefore higher paying (Jovanovic & Rousseau, 2005) which builds the tax base (Blakely & Leigh, 2010; Hackler, 2006). Table 11 demonstrates the only two authors that measured broadband and its positive and significant contribution to growth of IT-intensive industries.

Table 11. Broadband & IT-Intensive Industry		
Author	**Industry**	**Contribution**
Mack et al. (2011)	Sum of 2-digit Knowledge Industries (NAICS 51; 52; 54; 55; and 62)	1 percent to 2.5 percent
Lehr et al. (2005)	Sum of Knowledge Intensive Industries (551, 511, 221, 523, 512, 513, 514, 334, and 483)	0.05 percent

Lehr et al. (2005) utilized the Forman et al. (2002) model to identify 3-digit NAICS codes that utilize information technologies to innovate and found the sum of these industries experienced firm growth of 0.05 percent. Mack et al. (2011) performed a similar regression at the 2-digit NAICS level and found that broadband contributed to a 1 percent to 2.5 percent growth in the number of knowledge-intensive firms. For this research the IT-intensive variables will use Lehr at al. (2005)'s 3-digit codes 551, 511, 221, 523, 512, 513, 514, 334, and 483. To ensure any changes at the 3-digit NAICS codes, the IT-intensive variable is as follows 2-digit 55 and 51 along with 523, 221, 334, and 483.

Based on the literature, the relationship between broadband and IT firm creation is as follows:

Hypothesis 5a: Broadband in 1999 positively contributed to the share of establishments in IT-intensive sectors compared to communities that did not have broadband prior to 1999 for 2002, 2004, 2006, and 2008.

3.1.2.2 Hypotheses Related to Broadband Infrastructure and the FIRE Industry Sector

A link has been identified between telecommunications infrastructure with growth in the FIRE industry sector (Greenstein & Spiller, 1996; Yilmaz et al., 2002). There is anecdotal evidence that broadband provides growth in FIRE industries (Strategic Networks Group, 2003). However, a statistical relationship of this link has not been established. In 1998, the 3-digit analysis includes 521, 522 524,525,531,532, 533. However, the subsequent years measure the 2-digit 52-finance and insurance and 53-real estate with the 3-digit code 523 removed and inserted into the IT-intensive analysis.

Based on the literature, the relationship between broadband and manufacturing is as follows:

Hypothesis 5b: Broadband in 1999 positively contributed to the share of establishments in the FIRE sector compared to communities that did not have broadband prior to 1999 in the periods of 2002, 2004, 2006, and 2008.

3.1.2.3 Hypotheses Related to Broadband Infrastructure and the Manufacturing Industry Sector

There is conflicting information about the link between telecommunications infrastructure and the manufacturing industry sector. Two industry level studies of the telecommunications and manufacturing relationship resulted in no significance (Greenstein & Spiller, 1996; Yilmaz et al., 2002). From 1990 to 2004, the total ICT share increased in sectors not traditionally associated with ICT use including mining and manufacturing (Basu and Fernald, 2007; Basu et al., 2004). The Census' E-stats report suggests manufacturing has received the largest share of growth, of all industry sectors, through e-commerce due to Electronic Data Interface (EDI) technology (U.S. Census Bureau, 2010). Hatch & Clinton (2000) reported that between 1990 and 2000 the only two industrial sectors to experience a decline in employment was mining and manufacturing. If broadband was influential in supporting manufacturing it may be important in minimizing the decline to locations that had broadband. The manufacturing analysis includes the 2-digit NAICS codes of 21-mining, 31-food manufacturing, 32-wood manufacturing, and 33-metal manufacturing with 334 removed and inserted into the IT-intensive analysis.

Based on the literature, the relationship between broadband and the FIRE industry sector is as follows:

Hypothesis 5c: Broadband in 1999 positively contributed to the share of establishments in the manufacturing sector compared to communities that did not have broadband prior to 1999 in the periods of 2002, 2004, 2006, and 2008

3.1.2.4 Hypotheses Related to Broadband Infrastructure and the Service Industry Sector

The fastest growing industry sector in the 1990s was the services sector including hotels, personal services, business services, automotive, motion pictures, amusement and recreation, health, legal, educational, social, museums, membership orgs, engineering, research, accounting, management. The transition to the 1997 NAICS created different categories to determine where this growth was occurring in a changing economy. Two of the service industries are considered IT-intensive, and already captured in the pIT98 control variable. The service sector has no expectation for IT-intensive industries. The variable includes the two digit NAICS of 54- professional, scientific, and technical services, 61-educational services, 62-health care and social assistance, 71-arts, entertainment, and recreation, and 72- accommodation and food services.

Based on the literature, the relationship between broadband and the service industry sector is as follows:

Hypothesis 5d: Broadband in 1999 positively contributed to the share of establishments in the service sector compared to communities that did not have broadband prior to 1999 in the periods of 2002, 2004, 2006, and 2008

The following section presents the methods, variable operationalization, and conceptual models used in this dissertation.

CHAPTER IV

RESEARCH DESIGN AND METHODOLOGY

4.1 Overview

Chapter IV describes the research methodology used to test the hypothesized relationships developed in Chapter III. First is a discussion of the research design followed by a review of the data with its limitations and an explanation of the control variables. Next, is the analytical process that replicates Lehr et al. (2005)'s variables and OLS method, an application of spatial econometrics to the 1998 to 2002 time period are presented. Lastly, the use of additional variables and spatial econometrics for the 1998 to 2008 time period are described.

4.2 Study Design

The purpose of this research is to perform a longitudinal study that differentiates geographic areas based on broadband infrastructure availability in 1998 (the initial broadband observation period) and then measures changes in community-level economic indicators during the chosen time period. This research replicates and extends the Lehr et al. (2005) seminal piece with follow-up periods of 2002, 2004, 2006, and 2008, permitting a decade of analysis from the year before the 1999 treatment period.

The community-focus of the study increases the chance of statistically significant results. Nobel Laureate Robert Solow noticed that “we see computers everywhere but in the productivity statistics” (Triplett, 1999). This became known as the “Information Productivity Paradox.” Reasons for the paradox include too high a level of aggregation where ICTs were still a relatively small share of the total capital stock subject to noisy aggregate industry or economy-wide data (Crandall et al., 2007). The community level has provided more statistically significant results than at the state level (Lehr et al., 2005) and has the advantage of many more observations. Although it is common to measure communities by metropolitan statistical areas (MSAs), due to data restrictions, communities are measured at the zip code level to match with the FCC’s reporting of broadband availability by zip code and the census business zip code pattern database. In addition to data reporting, the MSA level would not offer as much variance in broadband provision by 1999.

Research has found that broadband infrastructure produces a positive economic benefit in the short-term. However, there is no measurement of a continuing growth advantage once other communities have their own infrastructure. In addition, general purpose technology theory hypothesizes that a GPT will affect all industries with a secondary period of growth following intense capital investment for industries that use the new GPT. It is now possible to control for new infrastructure and measure the economic indicators over a longer period of time

4.3 Data Collection

This research utilizes five publicly available datasets. Table 12 depicts the variables utilized at the zip code level and sources from which they were obtained.

Table 12: Variables and Data Sources			
Type of Data	**Description**	**Availability**	**Source**
Business Metrics	Employment, business establishments, wages (payroll), industry sector and industry business size mix. Reported at zip code level.	Collected annually.	U.S. Census Bureau -ZIP Code Business Patterns (ZCBP)
Geographic Controls	Used to indicate how urban or rural a zip code is, based on its population and proximity to metropolitan areas.	Computed every 10 years; most recent coding from 2003.	U.S. Department of Agriculture - Urban Influence Code (UIC).
Broadband Metrics	Reports number of high-speed Internet providers by zip code, and number of lines in service by state.	Collected every 6 months (end of June and December) since 12/1999.	U.S. Federal Communications Commission - Form 477 Database.
Socioeconomic Indicators / Controls	Used for labor, family income, rent, and educational attainment	Collected every ten years.	U.S. Census Decennial Census 1990,2000
Rent Dependent	Media gross rent for dependent variable.	Average of figure from annual running 5-year collection 2006-2010	American Community Survey

The business metrics of employment, establishments, and salaries were derived from the annually collected U.S. Census Bureau's ZIP Code Business Patterns (ZCBP). The business information for the industry examination was derived from the same source wherein it is listed as 6-digit NAICS codes by zip code and amount of establishments. As stated in the hypothesis section, this data was reduced from six to three digits by zip, aggregated by industry for analysis, and in some cases, the 2-digit NAICS codes were used to capture changes that occurred across the study period. The U.S. Department of Agriculture's Urban Influence Code (UIC) is documented one through three for urban and four through ten as rural. The designation of urban versus rural is based on drive time from a central business district. A zip code that entails a drive time under thirty minutes is categorized as urban and one that exceeds a thirty minute drive time is categorized as rural (U.S. Department of Agriculture, 2003). The current median gross rent dependent variable is derived from the three-year average figure of the annually collected American Community Survey and is reported at the census tract level. The socioeconomic control variables, also at the census tract level, are gathered every ten years. The data is all normalized to the 2000 zip codes boundaries unlike other databases. One challenge faced during this study involved moving the variables from the census tract level up to the zip code level. This was overcome by creating a centroid inside the census blocks and measuring population weight thus creating an allocation factor. If the allocation factor equaled one then the entire block group is considered to be in the zip code. Otherwise, a proportion was assigned to the block group and served as a calculation for socio-economic control variables[1]. Once these variables are adjusted to the zip code level, the next issue is that these figures are median, not gross numbers. The population weight calculation is also utilized to calculate the median figures. The broadband variable has been collected every six months by the FCC since 1999.

4.4 Broadband Variable

[1] To calculate these a weighted average was utilized. The basis for this calculation, and its methods, derives from the Missouri Census Data Center http://mcdc2.missouri.edu/.

The primary variable of interest is dBB99. In 1999, the FCC required service providers that had at least 250 high-speed connections within a single state, to report zip codes that had at least one line of high-speed service to at least one customer as of December 31, 1999; this is the source of the variable dBB99 . It is thus a broadband "infrastructure" variable and not a variable that is a measure of the utilization and innovation through the use of broadband. While not ideal, it still is a useful and pertinent measure of the impact broadband can have on economic growth.

Table 13 lists the initial broadband figures. Broadband in 1999 provides enough contrast between the "haves" versus "have nots" to make a useful comparison. Ideally, an earlier broadband metric would have been more advantageous because a large proportion of the zip codes that first appear in the 1999 data collection had broadband availability.

Table 13. Early Broadband

	Total Urban Zips	Urban BB99	Urban Percentage W/ BB99	Rural	Rural BB99	Rural Percentage W/ BB99
Dec-99	22,774	11,884	52 percent	19,129	5,629	29 percent

There are limitations to the broadband metric dBB99. The FCC's 1999 definition of "high-speed" broadband was any line with a speed higher than 200 kilobits per second (kbps) in at least one direction (Lehr et al. 2005). This is slow and barely even considered broadband by today's standards. However, this is still an important differentiator because 200 kilobits of service, unlike the telephone's 56 kilobits of dial-up services, requires an infrastructure investment.

In addition, the minimum reporting threshold of a carrier with 250 lines in a state undercounts rural areas served by small independent carriers. However, a community is considered to have broadband if a bill is sent anywhere in the zip code. This may overestimate geographically larger zip codes found in rural areas (Crandall et al., 2007; Flamm, 2004; Lehr et al., 2005; Grubesic & Murray, 2004). In summary, the data set is not perfect but it does provide a meaningful metric for measuring broadband.

The broadband metric "dBB99" is based on availability and is defined as "1" if the zip code had broadband by the end of 1999, and "0" otherwise. The source of this variable is a simplified metric where an asterisk is used to denote when a community has one to three lines of infrastructure.

As stated in the first sentence of this dissertation, technology is the only explicable determinant of long-run growth with the accepted economic conditions of diminishing returns and scarce resources (Aghion & Howitt, 2009). However, there are other factors that spur growth in the short and mid-term that, when controlled for, offer more reliable evidence. In addition, the goal of this dissertation is to build off Lehr et al. (2005), which means replicating their variables and approach. New control variables are introduced through each equation in an attempt to separate the effects of broadband from the existing economic characteristics of the community as measured by zip code. These variables are discussed in the next section.

4.5 Control Variable Definition and Operationalization

Appendix A presents the list and definition of all variables. Appendix B presents their summary statistics. In the following sections, each variable's inclusion and operationalization will now be discussed in greater detail.

4.5.1 Growth Control Variables

Due to data limitations, Lehr et al. (2005) uses previous growth in the dependent variable as a control measure of future growth as a strategy for the reverse causality issue common to infrastructure studies. The following section will discuss all of the control variables and the additional methods of analysis.

These variables are calculated as a percent change of the dependent variable. The respective years are presented as an extension of each variable. For instance, gemp9498 is the percent change in employment between 1994 and 1998 using the following equation:

$$(Y(t)-Y(0))/Y(0)*100 \qquad \text{(Eq1)}$$

Where Y(t) measures the dependent variables new year minus older year (Y0) over older year multiplied times 100.

4.5.1.1 Growth Rate of Number of Employees (gemp9498)

While growth rate in the number of employees is not typically used as a growth control variable in this instance it is used as one as the objective is to get a baseline of employment growth, by location, prior to the treatment period. It is plausible that previous growth predicts future growth. As stated previously, infrastructure is subject to reverse causality (Koutroumpis, 2009) and there are challenges in zip-code level data collection (Lehr et al., 2005). This variable is expected to be a positive and significant coefficient for explaining employment growth similar to the Lehr et al. (2005) study.

4.5.1.2 Growth Rate and Share of the Number of People (25+) with College Degrees or Higher 1990-2000 (grColl90)

Education, particularly a bachelor’s degree or higher, is a commonly applied control variable in growth literature. Knowledge is a form of technology that is an important part of endogenous growth theory (Romer, 1994) and is difficult to directly measure. Proxies for knowledge include college degrees or patents resulting from research and development. However, for this particular literature stream, researchers measure knowledge through the number of bachelor's degree or higher holders in a location (Lehr et al., 2005; Crandall et al., 2007; Shideler et al., 2007; Koutroumpis, 2009). The education variable in Koutroumpis (2009) was positive and significant while in Crandall et al. (2007) it was not significant. Shideler et al. (2007) found that the variable was negative and significant in the construction industry sector. However, it was positive and significant with information, real estate rental and leasing, professional/scientific/technical, management of companies and enterprises, and arts/entertainment/recreation. In Lehr et al. (2005) the variable was not significant for wage, but it was positive and significant for IT-intensive firms.

4.5.1.3 Growth Rate of Number of Establishments 1994-1998 (grEst9498)

The growth rate in the number of establishments serves as a baseline control for reverse causality. To improve the strength of the estimation for the "ratio of establishments" parameter, a measure of establishment growth ratio is taken between 1998 and 1994. This variable is utilized to control for the growth in overall establishments and it exhibited a positive and significant relationship in Lehr et al. (2005).

4.5.1.4 Growth Rate of the Median Family Income 1990-2000 (grfin90s)

Income, or wage, is a common control variable for growth. However, the direction of the relationship is different. In Crandall et al. (2007) this variable was not significant in explaining growth in jobs or GDP. However, Mack et al. (2011) found a positive and significant relationship. Income is also a primary determinant for broadband adoption (Flamm, 2004; Grubesic & Murray, 2004; Prieger, 2003). This variable is utilized to control for median housing rent and has a positive and significant relationship with broadband (Lehr et al., 2005).

4.5.1.5 Growth Rate of the Civilian Employed Labor Force 1990-2000 (grlab90s)

Labor force is a common variable often substituting for population controls in many studies. It is expected to be a positive and significant contributor to growth in line with previous research (Koutroumpis, 2009; Mack et al., 2011). This variable controls for median housing, rent, wage, and total establishment growth (Lehr et al., 2005).

4.5.1.6 Growth Rate of the Share of Establishment in IT Intensive Sectors 1998-2000 (grIT9800)

The previous growth rate in the share of establishments in IT intensive sectors is not a typical control variable. Lehr et al. (2005) is the only study that has used this control. The authors find that the previous growth rate of the share of IT-intensive sectors contributed eight percent to the growth in IT-intensive sectors from 1998 to 2002.

4.5.1.7 Growth Rate in Average Salary, (grSalary9498)

Lehr et al. (2005) utilized previous growth in salary, from 1994 to 1998, as a control for future growth in salary. Their research paper found that previous growth in this variable contributed to a 12.5 percent reduction in the average salary growth rate from 1998 to 2002. Therefore, this is an important control variable.

4.5.2 Log of the Base Figure of Dependent Variable Control Variables

The premise of including the base year of each measurement period is similar to growth from previous years. Lehr et al (2005) utilized this method in in their rent model where the natural log of the year 1990 (lmrent90) was used to control for the 2000 rent dependent variable. This same principle is extended to all equations. For instance, when measuring the natural log of salaries between 1998 to 2002, the natural log of salary (lsal98) is a control variable for the equation. The variables include lmrent90, lmrent00, lsal98, lest98, lemp98, pit98, pfire98, pmanu98, and pserv98 in the respective equations. Since Lehr et al. (2005) only added this in rent equations, these variables will not be used when replicating Lehr et al. (2005) for salary, employment, establishment, and IT-industry mix.

4.5.3 Share of the Base Figure of Dependent Variable

The existing industry mix, before the 1999 treatment period, affects growth outcomes. Broadband has short-term effects in the initial deployment and then long-term effects as companies adopt the new technology. Lehr et al. (2005) hypothesized that IT-intensive firms were likely to experience the majority of the growth. Therefore, locations that were heavy in IT-intensive firms receive the most growth benefits of broadband.

However, not all locations may be on equal footing. Hatch & Clinton (2000) reported on job growth through the 1990s and found that some industries grew while others declined. To control for these influences, the following variables were created utilizing the pre-treatment year of 1998 to capture the post-treatment effects of broadband with the following equation:

$$(Yi/Ye)*100 \qquad \text{(Eq1)}$$

Where Y_i measures the sum of the NAICS code assigned to specific industry divided by the sum of all establishments in the zip code Y_e in 1998.

4.5.3.1 Share of Establishment in IT Intensive Sectors 1998 (pIT98)

The previous share of establishments in IT intensive sectors is not a typical control variable. Lehr et al. (2005) found that the previous share of IT-intensive sectors in 1998 contributed 86 percent to the share of IT-intensive sectors from 1998 to 2002. This variable is calculated as the sum of knowledge intensive establishments (551, 511, 221, 523, 512, 513, 514, 334, and 483) per zip code divided by the sum of all industries by zip code.

4.5.3.2 Share of Establishments in Finance, Insurance, and Real Estate in 1998 (pfire98)

Although the finance, insurance, and real estate industries experienced moderate growth, previous studies have located a potential link between these industries and information technology. This variable is calculated as the sum of finance, insurance, and real estate establishments (521, 522, 524, 525, 531, 532, 533) per zip code divided by the sum of all industries by zip code.

4.5.3.3 Share of Establishments in Manufacturing and Mining Sectors 1998 (pManu98)

Hatch & Clinton (2000) reported that the only two industrial sectors to experience a decline in employment was mining and manufacturing by up to 25 percent. Locations that are heavy in these sectors do not grow at the same pace as locations that were heavy in the sectors that experienced growth. This variable is calculated as the sum of manufacturing establishments (211, 212, 213, 311, 312, 313, 314, 315, 316, 321, 322, 323, 324, 325, 326, 327, 331, 332, 333, 335, 336, 337, and 339) by zip code divided by the sum of all industries by zip code.

4.5.3.4 Share of Establishments in Service Industries in 1998 (pServ98)

Hatch & Clinton (2000) reported that the service sector experienced the largest gains in employment. This sector includes hotels, personal services, business services, automotive, motion pictures, amusement and recreation, health, legal, educational, social, museums, membership orgs, engineering, research, accounting, management. The transition to the 1997 NAICS created different categories to determine where this growth was occurring in a changing economy. Two of the service areas considered IT-intensive are already captured in the pIT98 control variable. The rest are derived from the two digit NAICS of 54- Professional, Scientific, and Technical Services, 61-Educational Services, 62-Health care and Social Assistance, 71-Arts, Entertainment, and Recreation, and 72- Accommodation and Food Services. This variable is calculated as the sum of service establishments (541, 611, 621, 622, 623, 624, 711, 712, 713, 721, and 722) per zip code divided by the sum of all industries by zip code.

4.5.4 Dummy Control Variables

The following variables are a binary operationalization of “0” or “1” according to the attributes described in each section.

4.5.4.1 (dUrban)

In 2003, the USDA created an urban and rural designation based on commuting to an urban center. A designation of one to three by their categorization is urban. Anything over three would be considered rural. According to the FCC, a total of 17,513 zip codes had broadband in 1999. Applying the UIC designation to the broadband zip codes creates 11,884 urban and 5,629 rural. Therefore, 52 percent of urban and 29 percent of rural zip codes had broadband. This allows for meaningful analysis of the 1999 broadband infrastructure data. The variable is a "1" if it is urban and "0" if the zip is rural.

4.5.4.2 New Infrastructure (dBB02, dBB04, dBB06, dBB08)

The next set of variables control for the zip codes that adopted broadband after 1999.. The assumption is that the locations that moved from not having broadband to having broadband will control for skew in the data. This is a departure from Lehr et al. (2005). The dummy variable for new broadband penetration is operationalized as a "1" if the zip has infrastructure in each respective year, or "0" if it does not; dBB02 for having broadband in 2002, dBB04 for 2004, dBB06 for broadband in 2006, and dBB08 for broadband in 2008. The dBB02 is applied in the 1998 to 2002 models. All of the variables are included in the 1998 to 2008 calculations. For the industry mix calculations, the year associated with the respective calculation is used. For instance, when calculating industry share from 1998 to 2002 the equation will use dBB99 and dBB02.

4.5.5 Population Control Variable (lpop2K)

The population variable is the natural log of the population per zip code divided by total population in year 2000. Local economic growth literature has found a relationship with density and growth. However, Lehr et al. (2005) reported that it was non-significant and removed it from their final equations. This dissertation has found that the log of population in 2000 is significant in every model except rent. This variable, similar to the urban/rural dummy variable, controls for the possible growth due to differences in population density.

4.6 Dependent Variable Operationalization

The next sections presents the dependent variables and their operationalization. Appendix A has a full list of all variables and their definitions. Appendix B has the summary variables.

4.6.1 General Growth Operationalization

There is no single economic indicator at the community level (Lehr et al., 2005). The most common macroeconomic growth measurement, Gross Domestic Product (GDP), is not reported below the state level. State level studies have not been producing statistically significant results (Crandall et al., 2007; Lehr et al., 2005). Table 14 recaps the dependent variables used for the general growth equations.

Table 14. Dependent Variable Operationalization for General Growth Equations

Variable	Definition
lmrent00	Median Gross Rent from Census 2000 (Ln)
lmrent09	Median Gross Rent from the American Community Survey's 2006-2009
lnrent0009	Ratio of Median Gross Rent from the American Community Survey's 2006-2009 average and Median Gross Rent in Census 2000 (Ln)
$lsal_{t1,2}$	Ratio of Average Salaries of 2002/1998 and 2008/1998 (Ln)
$lemp_{t1,2}$	Ratio of Employment 2002/1998 and 2008/1998 (Ln)
$lest_{t1,2}$	Ratio of Establishments 2002/1998 and 2008/1998 (Ln)

The growth dependent variables were calculated as follows;

$$\ln(Y(t)/Y(0)) = g(t) = a + X\beta + \gamma BB + e \qquad \text{(Eq1)}$$

where $a = \ln A + r^* = r^*$ if $A=1$.

Where Y(0) corresponds to economic variables in 1998 and Y(t) to economic variables corresponds in the year of interest. When using equation 1, γ is interpreted as an increment to the growth rate of the dependent variable due to availability of broadband. Lehr et al. (2005) used the log level figure of rent. Calculations are performed to capture the log level as well as the growth in rent.

4.6.2 Industry Mix Operationalization

This research will measure broadband's contribution to the share of select industries in a community. The goal of the dependent variables is to detect broadband's contribution to industry. Since there may be a delay in when broadband positively contributes to different types of IT-using industries, the data is captured and presented every two years. Table 15 introduces the select industry dependent variables.

Table 15. Dependent Variables for the Industry Share Equations

Variable	Description
pit_t	Share of IT establishments in 2002, 2004, 2006, 2008
$pfire_t$	Share of finance, insurance, real estate establishments in 2002, 2004, 2006, 2008
$pmanu_t$	Share of manufacturing establishments in 2002, 2004, 2006, 2008
$pserv_t$	Share of service establishments in 2002, 2004, 2006, 2008

The equation for creating the variable is as follows:

$$(Y_{i,t})/Y_{e,t})*100 \qquad \text{(Eq1)}$$

Where Y_i is the sum of each respective industry (i) divided by all establishments in each zip code (e) and t is 2002, 2004, 2006, or 2008.

4.7 Assumptions

The primary assumption of this paper is that the unobserved broadband impact, for communities that had broadband prior to 1999, is reflected in the economic growth of each geographic region. However, this study controls for the community level economic characteristics in order to separate the impact of broadband infrastructure on economic growth indicators as proxy of economic growth. The paper also assumes that the observed rate of economic growth will differ from the optimum growth rate in any given period because of unanticipated shocks to the economy (Lehr et al., 2005; Shideler et al., 2007).

4.8 Tests of Significance and Inference

The spatial analysis is used to determine how much the variance of the coefficient estimate is being inflated by multicollinearity as well as heteroskedastic standard errors. Spatial econometrics was chosen for this research because it is a method utilized in geographic research where spatial dependence exists between the observations (Grubesic, 2006). Based on the definition of spatial dependence, the variables of interest may be dependent on the behavior of other locations, particularly in close proximity (Anselin, 1988; LeSage, 1999). Spatial dependence may occur when the boundaries of the area under observation do not completely reflect the underlying social and economic characteristics of the location. This issue violates the OLS assumption of uncorrelated error terms and independent observations creating bias in the estimates (Anselin, 1988). There is clear evidence of spatial dependence in this dataset validating the selection of this method.

Additional concerns stem from the diverse nature of zip codes across the nation causing a wide distribution of values. For instance, an increase of 10 employees in a zip code of 50 employees equates to a growth rate of 20 percent. However, the same growth would appear as a 0.5 percent growth rate in employees in a zip code of 2000 employees.

To ensure that no single observation heavily influences the results, a test was run with studentized residuals that excluded any residual value that exceeded "2" in absolute value. However, the removal of outliers did not alter the coefficients so the standardized residuals were used in the final equations.

4.9 Analytical Approach

The strategy for analysis will take two basic approaches demonstrated in Table 16.

Table 16. Analysis Approach	
Replicate Lehr et al. (2005)	**New Methods**
Ordinary Least Squares	Spatial Econometrics with Additional Controls

First, this paper replicates the Lehr et al. (2005) OLS approach and control variables from 1998 to 2002. This paper then departs from the Lehr et al. (2005) by adding new control variables. In the case of rent, Lehr et al. (2005) utilized a log level, versus growth, dependent variable. A growth version of the variable is added for better interpretation of the results. Spatial econometric techniques control for the likely spatial dependency issues found in economic data studied across geography. These methods will now be discussed in greater detail following the introduction of the conceptual models.

4.9.1 Growth Conceptual Models

The following sections present the conceptual models for the growth equations for rent, salaries, employment, and establishments. Each "EQ" matches the column in the hypothesis testing as well as the related Appendix D regression tables.

4.9.1.1 Dependent Variable: Rent

Table 17 present the conceptual equations utilized in examining the rent dependent variable. There are three approaches to obtaining an estimate of the effect of broadband including the replication of Lehr et al. (2005) (1A1).

Table 17. Rent Conceptual Equations			
Dependent Variable			**Control Variables**
EQ	**Period**	**Name**	
1A1	2000	Lmrent00	$= \beta_1 dBB99 + \beta_2\ dUrban + \beta_3\ grfin90s + \beta_4 lmrent90 + \beta_5\ grlab90s$
1A2	2009	Lmrent09	$= \beta_1 dBB99 + \beta_2\ dUrban + \beta_3\ grfin90s + \beta_4 lmrent00 + \beta_5\ grlab90s$
1A3	2000-2009	lmrent0009	$= \beta_1 dBB99 + \beta_2\ dUrban + \beta_3\ grfin90s + \beta_4 lmrent90 + \beta_5\ grlab90s$

Additional control variables used in this paper are then added (1A2). Lastly, a calculation using spatial error calculation is presented (1A3). To obtain current data on rent, the study utilizes the median gross rent average from the American Community Survey from 2006-2009 (lmrent09). This variable, like other socioeconomic data, is moved from tract to zip code level using an allocation factor technique described in section 4.2.

Lehr et al. (2005) studied the change in a log level coefficient of rent from the census between 1990 and 2000. This study replicates this method. In addition, growth in rent between 2000 and 2009 (lmrent0009) is also estimated using the same control variables. In this equation, rent is dependent on whether or not there was broadband in 1999 along with the following controls, additional broadband investments, median gross rent from the base year, the growth rate in median family income from 1990-2000, the growth in civilian employed labor force from 1990 to 2000, and whether a location is urban or rural. Rent serves as a proxy for all housing values. Due to data collection issues, median rent will only be calculated over one time period similar to Lehr et al. (2005).

4.9.1.2 Dependent Variable: Salary

Table 18 presents the equations used to measure broadband in 1999's impact on salary. The first equation replicates Lehr et al. (2005) (2A1). The following equations depart from Lehr et al. (2005) by adding control variables and by using the spatial error model to measure 1998 to 2002 (2A2) and 1998 to 2008 (2A3).

Table 18. Salary Conceptual Equations			
Dependent Variable			Control Variables
EQ	**Period**	**Name**	
2A1	1998-2002	Lsal9802	$= \beta_1$dBB99 + β_2dUrban + β_3 grlab90s + β_4 grcol90s + $\beta_5$pcol2k + $\beta_6$grsal9498 + $\beta_7$pit98
2A2	1998-2002	Lsal9802	$= \beta_1$ dBB99 + β_2dUrban + $\beta_3$lpop2k + $\beta_4$lsal98 + $\beta_5$grlab90s + $\beta_6$grcol90s + $\beta_7$pcol2k + $\beta_8$grsal9498 + $\beta_9$pit98 + β_{10}pfire98 + β_{11} pserv98 + β_{12} pmanu98
2A3	1998-2008	Lsal9808	$= \beta_1$dBB99 + β_2dUrban + $\beta_3$lpop2k + $\beta_4$lsal98 + $\beta_5$grlab90s + $\beta_6$grcol90s + $\beta_7$pcol2k + $\beta_8$grsal9498 + $\beta_9$pit98 + β_{10}pfire98 + β_{11} pserv98 + β_{12} pmanu98

The ratio of salary growth is dependent on whether or not a location had broadband in 1999; additional broadband investments; the growth rate of the average salary from 1994 to1998; the growth rate in the number of people (25+) that had a college degree or higher from 1990 to 2000; the share of the population (25+) with a college degree or higher in 2000; the growth in the civilian employed labor force from 1990 to 2000; whether or not a location is urban or rural; the log of the population of the zip code; the log of the base year variable; the share of establishments in IT intensive sectors in 1998; the share of establishments in manufacturing sectors in 1998; the share of establishments in the FIRE sector in 1998; and the share of establishments in service sectors in 1998.

4.9.1.3 Dependent Variable: Employment

Table 19 presents the conceptual equations used to measure broadband in 1999's impact on employment growth.

Table 19. Employment Conceptual Equations			
Dependent Variable			Control Variables
EQ	Period	Name	
3A1	1998-2002	Lemp9802	$= \beta_1$dBB99 + β_2 dUrban + $\beta_3$gremp9498
3A2	1998-2002	Lemp9802	$= \beta_1$dBB99 + β_2dUrban + $\beta_3$lpop2k + $\beta_4$pit98+ $\beta_5$gremp9498 + $\beta_6$lemp98+ $\beta_7$pfire98+ $\beta_8$pserv98 + $\beta_9$pmanu98
3A3	1998-2008	Lemp9808	$= \beta_1$dBB99 + β_2dUrban + $\beta_3$lpop2k + $\beta_4$pit98+ $\beta_5$gremp9498 + $\beta_6$lemp98+ $\beta_7$pfire98+ $\beta_8$pserv98 + $\beta_9$pmanu98

The first equation (3A1) replicates Lehr et al. (2005). The following equations depart from Lehr et al. (2005) by adding control variables and by using the spatial error model to measure growth between 1998 to 2002 (3A2) and 1998 to 2008 (3A3).

The ratio of employment is dependent on whether or not the location had broadband in 1999; additional broadband investments; the growth rate of the number of employees from 1994 to 1998; whether or not the location was urban or rural; the log of the population of the zip code; the log of the base period variable; the share of establishments in manufacturing sectors in 1998; the share of establishments in the FIRE sector in 1998; and the share of establishments in service sectors in 1998.

4.9.1.4 Dependent Variable: Establishments

Table 20 presents the conceptual equations used to measure broadband in 1999's impact on overall establishment growth. The first equation (4A1) duplicates Lehr et al. (2005). The following equation departs from Lehr et al. (2005) by adding control variables and by using the spatial error model to measure between 1998 to 2002 (4A2) and 1998 to 2008 (4A3).

Table 20. Establishment Conceptual Equations			
Dependent Variable			Control Variables
EQ	**Period**	**Name**	
4A1	1998-2002	Lest9802	$= \beta_1$ dBB99 + β_2 dUrban + β_3 grlab90s + $\beta_4$grest9498
4A2	1998-2002	Lest9802	$= \beta_1$ dBB99 + β_2dUrban + $\beta_3$lpop2K + $\beta_4$lest98 + $\beta_5$grlab90s + β_6 pfire98 + $\beta_7$pserv98 + $\beta_8$pmanu98 + $\beta_9$pit98 + β_{10}grest9498
4A3	1998-2008	Lest9808	$= \beta_1$ dBB99 + β_2dUrban + $\beta_3$lpop2K + $\beta_4$lest98 + $\beta_5$grlab90s + β_6 pfire98 + $\beta_7$pserv98 + $\beta_8$pmanu98 + $\beta_9$pit98 + β_{10}grest9498

The ratio of establishment growth is dependent on whether or not the location had broadband in 1999; additional broadband investments, the growth rate of the number of employees from 1994 to 1998; whether or not the location was urban or rural; the log of the population of the zip code; the log of the base period variable; the share of establishments in manufacturing sectors in 1998; the share of establishments in finance, insurance, and real estate sectors in 1998; and the share of establishments in service sectors in 1998.

4.9.2 Industry Share Conceptual Models

Due to the amount of conceptual models for the industry analysis, Appendix C presents the tables, similar to previous growth equation section. Because there may be timing issues facing different industries, equations are performed in two years increments. Lehr et al. (2005) only measured the IT-intensive sector. There is one extra equation duplicating the authors' calculations. For the other variables, the pattern remains virtually the same with only a change in the two variables to control for the dependent variable. The calculations add control variables and use the spatial error model to calculate broadband's contribution to the share of industries in 2002 (A1), 2004 (A2), 2006 (A3), and 2008 (A4).

The growth of each sector is dependent on whether or not a location had broadband in 1999; additional broadband investments; the share of establishments in IT-Intensive sectors in 1998; the growth rate in the number of people (25+) with college degree or higher from 1990 to 2000; whether or not a location is urban or rural; the log of the population of the zip code; the growth rate in the share of establishments in each respective sector from 1998 to 2000; and when not already included, the controls for the share of establishments in manufacturing sectors in 1998; the share of establishments in the FIRE sector in 1998; and the share of establishments in service sectors in 1998.

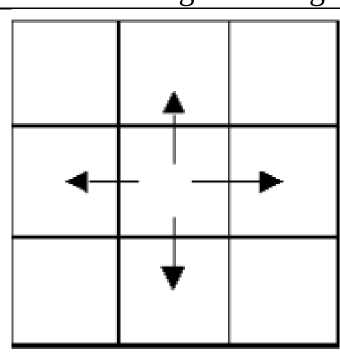
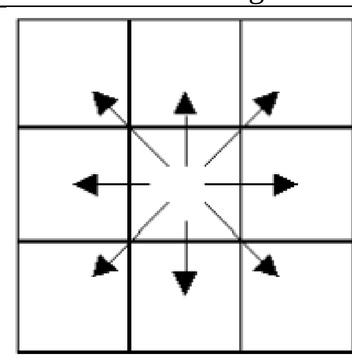
4.10 Spatial Analysis

There are two primary ways spatial structure may be modeled econometrically to manage autocorrelation issues; the spatial lag or the spatial error model (Anselin, 1988; Mack et al. 2011). Anselin (1988) describes that the spatially dependent variables could be a dependent variable, an explanatory variable, or a regression error term, depending on the nature of the spatial externalities. The author developed a technique to address the presence of spatial autocorrelation by adding a spatially lagged variable. A specialized open source spatial regression tool, GeoDa, has been developed to address these issues. The software includes diagnostics for spatial autocorrelation, a maximum likelihood estimation of the spatial lag, and a spatial error model (Anselin, 2004).

The first diagnostic is the Global Moran I. This is the initial test to identify if there is spatial dependency. Following the Moran I, the Lagrange Multiplier (LM) test determines the relevant model based on five LM test statistics: LM-Lag, Robust LM-Lag, LM-Error, Robust LM-Error, and LM-SARMA. If none of the LM statistics is significant, a spatial regression model is unnecessary because the OLS result is considered appropriate. However, a significant LM Lag statistic calls for the spatial lag model. A significant LM-Error points to the spatial error model. For this study, statistics are measured at a significance level of $p \leq .05$.

To create the variable that is included in the regression, GeoDa takes a weighted average of the neighboring locations. There are three options to create a spatial weights matrix: 1) contiguity-based, 2) distance-based, and 3) neighborhood-based spatial weights. The distance-based spatial weight matrix is useful for calculating the distance between points and the neighborhood based spatial weight matrix, as used in Mack et al. (2011), allows the user to specify the exact amount of neighbors. A contiguity-based spatial weight matrix functions best for polygon shaped entities. Table 21 visually demonstrates the contiguity-based weights option.

Table 21. Contiguity-based Option

Rook's Case	**Queen's (Kings) Case**
Immediate Contiguous Neighbors	Second Order Contiguous Units
	

Since zip codes are irregular, and this is a study of the continental U.S. and not just a few cities, the contiguity-based weights option is the most appropriate choice. The rook criterion concentrates on a full boundary segment while the queen option includes all neighborhoods that do not have a full boundary segment. Due to the irregular shapes of the zip codes, the Queen's case will be the option utilized for this study.

Anselin (1988) states that the spatial issue can affect the dependent, independent, and error terms. A spatial lag of the dependent variable or a lag of the error term may be required, as determined by testing, to measure observations. Anselin (1988) specifies the spatial lag model as follows:

$$y = \rho W y + X\beta + u \qquad \text{(Eq1)}$$

where *y* represents the dependent variables, X, the vector of independent variables, β, as the regression coefficients, *u* as the independent and identically distributed random error terms, and *W* is the exogenous spatial weights matrix that specifies the assumed spatial structure or connections between the observations. The *Wy* is the spatially lagged dependent variable to account for spatial dependence. The parameter ρ refers to spatial correlation or a spatial dependence parameter. The value of ρ is equal to zero in a traditional linear regression model.

Anselin (1988) also specified the spatial error model for unknown causes of autocorrelation as follows:

$$y = X\beta + \varepsilon \text{, with } \varepsilon = \lambda W\varepsilon + u \qquad \text{(Eq 2)}$$

where *y* represents the dependent variables, *W* is the spatial weight, *X* encompasses the explanatory variables, ε is the spatially autocorrelated error terms, μ is the independent and identically distributed errors, and λ and β are parameters. In all cases, both the spatial lag and spatial error specifications were calculated. Section 5.3 discusses the model selection process.

In summary, the goal is to improve upon the basic OLS utilizing methods known to control for the unique data issues related to broadband implementation and spatial economic analysis. Section V describes the research results followed by Section IV discussion and conclusions.

CHAPTER V

RESEARCH RESULTS

5.1 Overview

The data analysis for this research study can be categorized into two broad stages; 1) the study replicates the ordinary least squares method of analysis and variables utilized in Lehr et al. (2005), 2) then control variables are added and the spatial econometrics model is applied. In the case of the variable "rent", this study presents an additional growth equation. The following sections discuss data issues, the diagnostic tests administered to detect them, and then methods followed for data adjustments.

5.2. Sample Size Adjustment

An overview of the summary statistics table in Appendix B demonstrates that the variables do not all have equal "n" sizes requiring data manipulation to create a unified, and ultimately, reduced sample size. There are two main contributors to the drop in sample size: a difference in "n" sizes amongst two databases and a "zero" value in a set of calculated variables. The database containing business metrics contains approximately

41,000 zip codes while the census-tract level has about 32,000 for the variables of interest to this study. In addition, the census database had over 100 zip codes that do not appear in the remaining business zip codes. The data was normalized so that only zip codes shared between the two primary databases remain.

The next drop in sample size occurs in the calculation of the industry level control variables grit9800, grfire9800, grmanu9800, and grserv9800. The growth equation used for these variables is {(new year-old year)/old year}. When a "zero" value is in the denominator, 1998, the calculation produces a null or missing value. A final match between all variables from all databases produces a final sample size of 14,907.

Hair, Black, Babin, Anderson, and Tatham (2006) provide a four-step decision tree and "rules of thumb" for missing data. The two selected remedies were a multiple imputation of the mean resulting in a sample size of 23,665 and a complete case analysis of the most strictly limited dataset of 14,907 zip codes. The results of the two methods were compared to identify changes in the coefficients. Although both results are not specifically reported in this dissertation there were differences. The changes to the broadband coefficient from multiple imputation to complete case analysis are as follows; rent from 2000 to 2009 changed from being significant to non-significant, salary from 1998 to 2002 changed from non-significant to significant, three IT-intensives coefficients changed from non-significant to significant, and there is a slight reduction in magnitude across most variables. In the complete case analysis, the best fit for the spatial statistics model also became more apparent. Therefore, the more representative higher "n" size is abandoned for the smaller complete case analysis. The original variable and the new subset summary statistics are presented side by side in the Appendix B.

5.3 Multicollinearity

Every model, except the replication of Lehr et al. (2005), has a high degree of multicollinearity. The subsequent models, which add many more control variables, exhibit degrees of multicollinearity over 100 for the 1998 to 2008 calculations. Regressions can suffer from collinearity to some degree as long as the collinearity is not perfect (Wooldridge, 2006). To ensure that the multicollinearity has not significantly altered the coefficients, the non-significant new broadband variables were removed from the general equations. This dropped the multicollinearity down to 30 but did not dramatically alter the direction, significance, or magnitude of the coefficients in the general equations. Therefore, the new broadband variables were excluded from this analysis. Although 30 is still considered high, it is tolerated to maintain consistency across the models.

5.3 Spatial Diagnostics and Model Selection

One of the changes made to the base OLS model is the addition of spatial econometrics. The reason for the addition is that ordinary least squares estimations with spatial data often violate the classic regression assumption of independence of observations. This can bias the estimation of the standard errors of parameters, and offer misleading significance tests (Anselin, 1988). In order to identify the types of spatial dependency, GeoDa has six tests. The first test is the Moran's I. If the Moran’s I test is significant then there is spatial autocorrelation. Every single model in this research has a significant Moran I justifying the need and use of spatial analysis and the GeoDa open source software.

There are five Lagrange Multiplier tests which may indicate a preference for the spatial lag model or spatial error model. Every single model in this research has a significant LM test for both the lag and the error model at the level of $p<0.05$. Anselin (2004) specifies "While it is tempting to focus on traditional measures, such as the R^2, this is not appropriate in a spatial regression model. The value listed in the spatial lag output is not a real R^2, but a so-called pseudo-R^2, which is not directly comparable with the measure given for OLS results. The proper measures of fit are the Log-Likelihood, AIC and SC." Table 22 presents the diagnostics to determine which model is the best fit for the regression.

Table 22. Spatial Diagnostics- Improved Fit Determination

Name	**Positive Number Indication**	**Negative Number Indication**
Log Likelihood (LL)	Increases	Decreases
Akaike Info Criterion (AIC)	Decreases	Increases
Schwarz Criterion (SC)	Decreases	Increases

Appendix F presents an analysis of the movement in the Log Likelihood, the Akaike Info Criterion, and the Schwarz Criterion as well as the resulting best fit used for each equation.

5.4 Growth Hypothesis Testing

Tables I through VIII present the estimates of the primary variable of interest, broadband infrastructure in 1999. The first section analyzes growth in rent, salary, employment, and establishments. The following section analyzes broadband's contribution to four industries: information technology, FIRE, manufacturing, and service industries.

The first four hypotheses posit that there is a positive relationship between broadband infrastructure in 1999 and local economic growth factors: rent, salary, employment, and establishments. Each table presents the 1999 broadband coefficient.

The first column, titled "Lehr", presents the Lehr et al. (2005) findings. Then, the second column is a replication of the Lehr et al. (2005) variables using the same ordinary least squares method (A1). The third and fourth column add in new control variables and utilize the spatial econometric method for the periods of 1998 to 2002 (A2) and 1998 to 2008 (A3). Rent uses slightly different time periods which are discussed in the rent section. These identifiers of A1 through A4 correlate with the regression tables located in the Appendix D.

5.4.1 Hypothesis 1: Broadband in 1999 and Rent

Table 23 demonstrates the impact of broadband in 1999 on rent for locations that had the infrastructure compared to those that did not.

Table 23. Rent Coefficients

	Lehr	**1A1**	**1A2**	**1A3**	**1A4**
		Replicate	**2000**	**2009**	**2000-2009**
dBB99	6.6%***	10.1%***	5.0%***	0.7%	0.7%
Obs	22,390	14,907	14,907	14,907	14,907
R^2	0.763	0.583	0.781	0.799	0.134
Significance ***p<0.01, **p<0.05					

Hypothesis 1 posits that locations that had broadband by 1999 experienced a greater difference in median housing rent growth between the period 2000—2009 compared to communities that did not have broadband prior to 1999. The Lehr et al. (2005) equation measuring broadband's impact on rent from 1990 to 2000 is replicated

(1A1) and then the spatial error model (1A2) is run. This is followed by the log level examination of 2000 to 2009 (1A3). In Lehr et al. (2005) the authors did not measure rental rate growth; this study looks at that measure for the years 2000—2009 (1A4).

Lehr et al. (2005) reported that broadband contributed to a 6.6% increase in rental rates between 1990 to 2000. The replication using OLS has a coefficient of 10.1% (1A1). However, the application of the spatial error model reduces the magnitude to 5.0% (1A2). The following decade shows that broadband was non-significant and did not contribute to rent (1A3) and rent growth (1A4). Based on the models, the rents in communities that had broadband in 1999 did not receive an additional advantage compared to those that did not have broadband in 1999.

5.4.2 Hypothesis 2: Broadband in 1999 and Salary

Hypothesis 2 posits that locations that had broadband by 1999 experienced a greater difference in growth of the ratio of average salaries between the period of 1998 and 2008 compared to communities that did not have broadband prior to 1999.

Table 24 demonstrates the impact of broadband in 1999 on salary for locations that had the infrastructure compared to those that did not.

Table 24. Salary Coefficients

	Lehr	**2A1**	**2A2**	**2A3**
		Replicate	**1998-2002**	**1998-2008**
dBB99	-0.3%	-0.3%	2.1%***	4.3%***
Obs	22,390	14,907	14,907	14,907
R^2	0.077	0.078	0.124	0.156
Significance ***p<0.01, **p<0.05				

One of the largest changes in significance, direction, and magnitude of the coefficients, both from Lehr et al. (2005) and over time, occurs with salary. Lehr et al. (2005) finds that broadband infrastructure in 1999 is not statistically significant. In replicating Lehr et al. (2005), this research also finds that broadband did not provide a statistically significant contribution to salary growth (2A1). However, with the addition of control variables and the use of the spatial econometric methods, the coefficients become significant and positive. The findings support the hypothesis that having broadband infrastructure in 1999 contributed to an increase in salary growth of 2.1% between 1998 and 2002 (2A2) and a 4.3% increase between 1998 and 2008 (2A3).

5.4.3 Hypothesis 3: Broadband in 1999 and Employment

Table 25 demonstrates the impact of broadband in 1999 on employment.

Table 25. Employment Coefficients

	Lehr	**3A1**	**3A2**	**3A3**
		Replicate	**1998-2002**	**1998-2008**
dBB99	1.0%	1.4%***	3.2%***	6.0%***
Obs	22,390	14,907	14,907	14,907
R^2	0.027	0.024	0.082	0.101
Significance ***p<0.01, **p<0.05				

Hypothesis 3 posits that locations that had broadband by 1999 experienced a greater difference in growth in the ratio of overall employment between the period of 1998 and 2008 compared to communities that did not have broadband prior to 1999.

Lehr et al. (2005) did not find a significant relationship between broadband and employment. In replicating the 1998 to 2002 period using OLS, this dissertation finds a positive and significant relationship. Broadband contributes 1.4% to employment growth between 1998 through 2002 (3A1). With additional controls and spatial econometrics, the impact increases to 3.2%. The results for the period of 1998 to 2008 (3A3) supports the hypothesis that broadband contributes to an increase of 6% in employment growth.

5.4.4 Hypothesis 4: Broadband in 1999 and Establishments

Hypothesis 4 posits that locations that had broadband by 1999 experienced a greater difference in growth of the ratio of establishments between the period of 1998 and 2008 compared to communities that did not have broadband prior to 1999.

Table 26 demonstrates the impact of broadband in 1999 on establishments.

Table 26. Establishments Coefficients

	Lehr	**4A1**	**4A2**	**4A3**
		Replicate	**1998-2002**	**1998-2008**
dBB99	0.5%	1.1%***	1.5%***	3.4%***
Obs	22,390	14,907	14,907	14,907
R^2	0.063	0.190	0.220	0.277
Significance ***p<0.01, **p<0.05				

Lehr et al. (2005) stated that broadband contributed one-half of a percent to establishment growth between 1998 to 2002. However, the authors utilized a 90 percent probability level, below this research's 95 percent threshold. When utilizing the same variables and the ordinary least squares method, this research produces positive and significant results of 1.1% (4A1). The magnitude of the coefficient increases to 1.5% (4A2) after adding control variables and applying spatial econometrics. The results support the hypothesis that broadband in 1999 contributed to an increase of 3.4% in the ratio of establishment growth between 1998 and 2008 (4A3).

5.4.5 Growth Hypothesis Testing Conclusion

The results of this research indicate that locations that had broadband in 1999 had a greater difference in growth compared to communities that did not from 1998 to 2008. Rent was sensitive to different models and, with the final selected method, became non-significant. However, salaries, establishment, and employment indicate a positive and significant relationship from 1998 to 2002 as well as the time period of interest 1998 to 2008.

5.5 Industry Mix Hypothesis

To determine if broadband has an impact on other industries, supporting the GPT hypothesis, broadband was regressed on the following sectors: information technology, manufacturing, FIRE, and service.

For the IT intensive analysis, the first column, titled “Lehr” presents the Lehr et al. (2005) findings. Then, the second column is a replication of the Lehr et al. (2005) variables using the same ordinary least squares method (A1). The remaining columns add in the extra variables and utilize the spatial econometric technique. Lehr et al. (2005) did not analyze manufacturing, FIRE, and service industries. Therefore, the columns for those industries only represent all variables and the spatial econometric method for the periods of 2002, 2004, 2006, and 2008. The column identifiers correspond to the respective regression tables located in the Appendix E.

5.5.1 Hypothesis 5a: Broadband in 1999 and I.T. Industry Share

Hypothesis 5a posits that locations that had broadband by 1999 experienced a greater share of IT intensive establishments compared to communities that did not have broadband prior to 1999 for the periods of 2002, 2004, 2006, and 2008.

Table 27 demonstrates the impact of broadband in 1999 on IT establishments for locations that had the infrastructure compared to those that did not.

Table 27. IT Industry Mix Coefficients						
	Lehr	**5A1**	**5A2**	**5A3**	**5A4**	**5A5**
		Replicate	**2002**	**2004**	**2006**	**2008**
dBB99	0.6%	20.3%***	8.1%**	22.6%***	26.8%***	40.8%***
Obs	22,390	14,907	14,907	14,907	14,907	14,907
R^2	0.763	0.649	0.652	0.468	0.405	0.750
Significance ***p<0.01, **p<0.05						

Lehr et al. (2005) found that broadband in 1999 contributed to an increase in the share of IT intensive sector establishments by an additional one half percent between 1998 and 2002 at the 90 percent probability level. This research finds a positive and significant result of 20.3% (5A1) in using OLS and replicating Lehr et al. (2005). With additional controls and spatial econometrics, the results support the hypothesis that broadband positively contributed to the share of IT-intensive industries by 8.1% in 2002 (5A2), 22.6% in 2004 (5A3), 26.8% in 2006 (5A4), and 40.8% in 2008 (6A4). The next section explores the impact on the FIRE industry sector.

5.5.2 Hypothesis 5b: Broadband in 1999 and Finance, Insurance, Real Estate (FIRE) Industry Share

Table 28 demonstrates the impact of broadband in 1999 on FIRE establishments.

Table 28. FIRE Industry Mix Coefficients				
	6A1	**6A2**	**6A3**	**6A4**
	2002	**2004**	**2006**	**2008**
dBB99	37.4%***	19%***	91.9%***	102.9%***
Obs	14,907	14,907	14,907	14,907
R^2	0.533	0.554	0.445	0.448
Significance ***p<0.01, **p<0.05				

Hypothesis 5b expects that locations that had broadband by 1999 experienced a greater share of establishments in the FIRE sector compared to communities that did not have broadband prior to 1999 for the periods of 2002, 2004, 2006, and 2008.

The results support the hypothesis that broadband contributed a 37.4% increase in the share of FIRE industries in 2002 (6A1), 19% in 2004 (6A2), 91.9% in 2006 (6A3), and 102.9% in 2008 (6A4). The next section explores the impact on the manufacturing industry sector.

5.5.3 Hypothesis 5c: Broadband in 1999 and Manufacturing Industry Share

Hypothesis 5c posits that locations that had broadband by 1999 experienced a greater share of establishments in manufacturing sectors compared to communities that did not have broadband prior to 1999 for the periods of 2002, 2004, 2006, and 2008.

Table 29 demonstrates the impact of broadband in 1999 on manufacturing establishments.

Table 29. Manufacturing Industry Mix Coefficients

	7A1	**7A2**	**7A3**	**7A4**
	2002	**2004**	**2006**	**2008**
dBB99	37.6%***	10.5%	65.8%***	69.7%***
Obs	14,907	14,907	14,907	14,907
R^2	0.677	0.721	0.515	0.482
Significance ***p<0.01, **p<0.05				

The results indicate that broadband's contribution to the share of establishments in the manufacturing sectors as significant, positive, and with a large magnitude in most years. Broadband positively contributed to the share of manufacturing by 37.6% in 2002 (7A1), 10.5% in 2004 (7A2), 65.8% in 2006 (7A3), and 69.7% in 2008 (7A4).

5.5.4 Hypothesis 5d: Broadband in 1999 and Service Industry Share

Hypothesis 5d expects that locations that had broadband by 1999 experienced a greater share of establishments in the service sector compared to communities that did not have broadband prior to 1999 for the periods of 2002, 2004, 2006, and 2008.

Table 30 demonstrates the impact of broadband in 1999 on service establishments.

Table 30. Service Industry Mix Coefficients				
	8A1	**8A2**	**8A3**	**8A4**
	2002	**2004**	**2006**	**2008**
dBB99	94.4%***	62.0%***	268.0%***	269.2%***
Obs	14,907	14,907	14,907	14,907
R^2	0.652	0.677	0.498	0.585
Significance ***p<0.01, **p<0.05				

The result of broadband's contribution to the share of firms in service sectors is significant, positive, and has a large magnitude in all years. Broadband positively contributed to the share of service industries by 94.4% in 2002 (8A1), 62% in 2004 (8A2), 268% in 2006 (8A3), and 269.2% in 2008 (8A4). The next section concludes the implications of growth and industry mix results.

5.5.5 Industry Mix Hypothesis Testing Conclusion

The results of the industry mix research indicate that locations that had broadband in 1999 supported a wide range of industries in every year examined for IT-intensive, FIRE, manufacturing, and service sectors. This offers an additional foundation to the broadband-GPT hypothesis. However, the GPT theory suggests that broadband's positive contribution to IT-using industries will lag investment five to 15 years (Basu &

Fernald, 2007). In this case, the research does not indicate any delay. This may be because the broadband 1999 variable is not early enough to capture the time lag between investment and subsequent growth. Although this dissertation's result supports the hypothesis that broadband makes a positive contribution to both IT-intensive and IT-using sectors, further research is recommended in the next section.

CHAPTER VI

DISCUSSION

6.1 Discussion and Implications

Economic growth research posits that technology is the only explicable determinant of long run growth (Aghion & Howitt, 2009) and, that amongst technologies, GPTs contribute to greater and longer term growth impacts compared to other forms of technologies (Bresnahan & Trajtenberg, 1995). The internet achieved ubiquitous business use faster than previous GPTs such as electricity, telephone, automobile, and the steam engine (Forman, et al., 2002) signaling that broadband may offer greater returns to investment than other types of technologies and economic interventions (Basu & Fernald, 2007; Fernald & Ramnath, 2004). There is evidence across this research to support the impact of broadband on local economic growth. Even after controlling for reverse causality, spurious correlation, and spatial dependence, broadband investment in 1999 remains significant and positive in the growth of salaries, employment, and establishments. The only exception is the rent variable, which provided non-significant results from 2000 to 2009. Broadband also has evidence of supporting different industry sectors acting as a GPT that enables different types of local portfolios.

The effects of broadband on growth are resilient despite exogenous economic shocks. Between 2000 and 2004, the United States experienced the dot.com crash in the early 2000s; the September 11, 2001 Twin Tower attacks; a corporate accounting scandal in 2002 and a period of rising oil prices that adversely affected the stock market (Stiroh & Botsch, 2007; Oliner et al., 2007); and a housing crash between 2006 and 2008 (Snyder, 2011). While this dissertation does not specifically control for these events, the time period captures the potential impacts on growth and support of different industry shares.

The proliferation of the internet is placing pressure on existing broadband supply (OECD, 2010; Pew Center on the States, 2010) and the United States has no current national initiative to expand infrastructure (ARRA, 2009; FCC 2009). This lack of plan creates a potentially unique local economic development opportunity that would create more jobs, increase salaries (and therefore the tax base), and the formation of new establishments across different industrial mixes.

6.2 Policy Recommendations

From a policy recommendation perspective, certain localities may be at an advantage in deploying a broadband initiative including locations that already have a history of public utility interventions or locations with institutions for long-term planning and a history of public-private partnerships.

Based on the published case studies, smaller cities with municipal telecommunications, tend to be the leading examples of local broadband interventions (Strategic Networks Group, 2003; Ford & Koutsky, 2005; Kelley, 2003). Because the expense of laying the infrastructure may not be recouped quickly enough for a profit motive, these smaller locations have demonstrated the ability to perform a policy intervention without the need for an instant return on investment.

Locations that lack public telecommunications, but have institutions in place for long-term planning or a history of strong private-public partnerships, may be able to pursue a broadband intervention. A recent initiative through Google offers a new example of a private-public partnership. The company allowed different cities to compete for the first "fiber town" or "gigabit city" (Kahn, 2010). Kansas City, Kansas won the Google project over 1,100 other cities with their 126-page application that detailed how the city would use the fiber (Savov, 2011). With Google and Kansas City taking the lead, cities will have an example of the do's and don'ts in pursuing a robust local broadband strategy.

6.3 Contributions to the Literature

This dissertation specifically answers the call for additional quantitative research into the relationship between broadband and local economic impacts (Greenstein and Spiller, 1996; Lehr et al. 2005; Mack et al. 2011) and indicates broadband's ability to sustain once other communities experience infrastructure provision (Lehr et al. 2005; Mack et al. 2011). In addition, the research directly addresses a potential area of investment that is typically lower on the list of possible investments for economic development professionals (Bradshaw & Blakely, 1999) contributing to a growing discussion about broadband policy at the federal and local levels (FCC, 2009). The overall contributions include the large scale local level analysis, the length and time period, controls for reverse causality, additional controls that fit the scope of the research to determine the relationship between broadband and growth, the reporting of IT-using, not just IT-producing, and the use of spatial autocorrelation controls.

A large-scale local level analysis is a contribution to the literature. The conversation about broadband's potential for local economic growth has mostly been limited to case studies with limited generality to other locations (Ford & Koutsky, 2005; Kelley, 2003; Strategic Networks Group, 2003). Higher levels of aggregation at the state level (Crandall et al., 2007) and national level (Czernich et al., 2009; Koutroumpis, 2009) offers limited interpretation to the likely impacts of a local intervention. The two most relevant studies are Shideler et al (2007) which examined the industry effects in Kentucky counties, Mack et al. (2011) which examined six MSAs, and Lehr et al, (2005) which examined all zip codes. However, each of three studies had missing components listed in the following sections.

The length of time and period of this paper is a contribution. Previous studies are typically in the early 2000's and only over two to four years. The one exception is the Czernich et al. (2009) country level examination from 1996 to 2007. However, as stated previously, the country level does not offer much in the way of application to local economic development interventions. The other shorter periods do not capture the recent past, which has been economically and socially tumultuous with the dot.com bust, September 11th, rising oil prices, an accounting scandal, and the housing bubble.

The inclusion of controls for reverse causality is a contribution. Only two broadband studies used measures to control for this challenge. This is an issue because previous growth may be the source of future growth and is a likely cause of the infrastructure investment itself. Koutroumpis (2009) used a simultaneous equation to control for supply and demand effects that are not available at the local level. All other studies had no controls with the exception of Lehr et al. (2005). Although not consistent across all models, the authors used previous growth and a level variable as controls. In this study, earlier growth and level versions of the dependent variable control for this issue over every model. For example, when measuring growth in salary from 1998 to 2008, the base level of salary in 1998 and the growth between 1998 and 2000, are used as control variables. These variables are significant in every model and may be helpful in additional broadband or infrastructure studies.

This research also adds new controls to eliminate a spurious correlation. It may be that broadband is just moving in the same direction as growth but that the two are not actually related. This research replicated the use of Lehr et al. (2005)'s control variables of family income (grfin90s), share of Bachelor's degrees or above (pcol2k), growth in Bachelor's degrees (grcol90s), the growth in the labor force (grlab90s), and the urban versus rural dummy variable (durban99). All but the growth in bachelor's degree (grcol90s) remain significant in the growth equations. In the share equations, all of the variables are significant. Other variables were added including new broadband penetration after 1999, population, and also industry controls. The broadband variables were largely non-significant and were removed to reduce multicollinearity. However, the population variable (lpop2k) was non-significant in only rent and in some industry share equations. The industry variables (pit98, pmanu98, pFIRE98, and pserv98) are of interest because it is expected that locations that had a mix of industries that were declining or growing would affect the overall performance of a location. All industry variables are significant in many of the models especially the IT-intensive and manufacturing. The significance experienced by these new variables may indicate their usefulness in future broadband studies.

Examining IT-using, versus IT-intensive industries, is another contribution to the examination of broadband. The reason for this is that localities may pursue broadband for the purpose of attracting higher paying blue collar IT jobs (Hackler, 2006) and that a GPT will support growth in the industries that use and innovate with the technology, not the industries that actually produce the technology (Basu & Fernald, 2007; Fernald & Ramnath, 2004). A link has been identified between telecommunications infrastructure with growth in different industries including FIRE (Greenstein & Spiller, 1996; Yilmaz et al., 2002) and manufacturing (Basu and Fernald, 2007; Basu et al., 2004; U.S. Census Bureau, 2010). Despite service being the fastest growing set of industries in the 1990s (Hatch & Clinton, 2000) there is no previous evidence of a connection between service and broadband. However, this study found that broadband contributed to different industry mixes, including service, which may be examined in the future to identify how broadband impacts different industrial portfolios.

Another contribution of this paper is controls for spatial dependency. One community's actions may affect the actions of another community. This violates a statistical rule of independent observations. One reason for this gap in the literature is that the methods and tools to manage this issue are isolated to a relatively small, albeit growing, stream of regional science literature. Mack et al. (2010) is the only previous broadband study that used this method but their study was on six MSAs versus the larger setting of this study. A significant Moran I indicated that this data had strong spatial dependency issues and this research used spatial econometric tools to manage these issues.

6.4 Limitations

The impact of broadband is still revealing itself. Unfortunately, the FCC did not start collecting data until 1999 impairing the ability to identify a true early implementation advantage. In addition, the FCC reporting has limited the ability to examine locations by municipal jurisdiction. A city or county can make policy decisions and access the flow of federal, state, and other funding methods necessary for a broadband intervention. However, studying areas outside of governmental boundaries is common in local economic development research. Mack et al. (2010) studied the MSA level, a popular measurement, which also has no administrative form of government.

The time period of the research has its limitations. The data demonstrates a clear association between broadband and longer-term positive economic outcomes. Even through ten years is longer than other studies, it may not typically be considered "long-term" in economic research.

The results are probative in regards to causality due to challenges inherent to infrastructure and growth research. Locations that had broadband in 1999 may have had other growth inducing policies. Additional research would be required to determine that the results reflect the effects of broadband on those communities versus possible fundamental differences in the communities that implemented broadband earlier.

Normalizing the differences in variable sample sizes, as well as methods of moving the census tract data to the zip code level, altered some of the results and is the most logical cause of differences between Lehr et al. (2005) and this dissertation. Since

Lehr et al. (2005) is not explicit in their data manipulation methods, this will remain an unknown. The complete case analysis is heavily weighted towards analyzing locations that had a diverse mix of industry structure in 1998. Prior to removing the zip codes with zero values, the mean value for the broadband dummy variable is 0.50 which implies that 50% of the zip codes, out of an initial data size of 31,714 zip codes, had broadband prior to 1999. However, after removing all of the zero values to produce the unified reduced sample size of "14,907" the mean of the broadband variable rose to 0.82 or 82%. The greatest reduction in sample size came from the calculation of the industry growth variables due to a zero value in the 1998 industry figure. The removal of zero values did reduce the representativeness of the data. Because of this, the policy recommendations are more relevant to places that already had a diverse industry mix compared to those that did not.

6.5 Future Research

There are a number of directions for additional broadband research. A cause for concern with this is the industry impact analysis. The magnitude of some coefficients may indicate the need for different approaches to understanding the relationship between broadband and different industries. In addition, the results do not offer support for expected timing differences between IT-intensive and IT-using industries. For instance, locations may be interested in deepening or diversifying their industry portfolio. This calls for an analysis of broadband's effect on shifting portfolios. In addition, a deeper understanding of employment growth by industry, with establishment size as a measure, is also possible.

Causality with infrastructure research continues to be an issue. An additional analysis of fundamental differences in the communities that implemented broadband and controls for other economic development investments by community, may assist in isolating the broadband on growth effect.

Better measures of broadband would also be more useful. For instance, data on broadband adoption and or the level of service would be improvements to just the presence of infrastructure. However, this will remain an issue because speed and use are rapidly evolving every year. There may also be an interest in broadband's impact on workforce-related indicators such as self-employment and the share of white-collar workers.

Time, improved data, and additional case study experiences, like that of Kansas City, will continue to build the broadband story. However, based on this research, there is evidence of a positive relationship worthy of the policymaker's attention.

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APPENDICES

Appendix A: Variable Key

Table 31. Variable Key	
Variable	**Description**
dBB99	Dummy variable; broadband in 1999;1 for BB, 0 for no BB
dUrban	Urban/rural dummy variable: 1 if Urban, 0 if Rural
grcol90s	Growth in Bachelor's degree or higher between 1990 and 2000
gremp9498	Employment growth between 1994 and 1998
grest9498	Establishment growth between 1994 and 1998
grfin90s	Growth in family income between 1990 and 2000
grlab90s	Growth in labor force between 1990 and 2000
grfire9800	Growth of share of finance, insurance, real estate firms, 1998 and 2000
grit9800	Growth of share of IT firms between 1998 and 2000
grmanu9800	Growth of share of manufacturing firms between 1998 and 2000
grserv9800	Growth of share of service firms between 1998 and 2000
grsal9498	Salary growth between 1994 and 1998
lemp98	Employment in 1998 (ln)
lemp9802	Growth rate in employment between 1998 and 2002 (ln)
lemp9808	Growth rate in employment between 1998 and 2002 (ln)
lest98	Employment in 1998 (ln)
lest9802	Growth rate in establishments between 1998 and 2002
lest9808	Growth rate in establishments between 1998 and 2002
lmrent00	Median gross rent figure 2000 (ln)
lmrent0009	Growth of median gross rent between lmrent00 and lmrent69 figures
lmrent09	Median gross rent figure, ACS 2006 to 2009 (ln)
lmrent90	Median gross rent figure 1990 (ln)
lpop2k	Total population in 2000 (ln)
lsal98	Salary in 1998 (ln)
lsal9802	Growth rate of salary between 1998 and 2002 (ln)
lsal9808	Growth rate of salary between 1998 and 2008 (ln)
pcol2k	Share of population with Bachelor's degree or higher in 2000
pfire02	Share of Finance, Insurance, and Real Estate firms in 2002
pfire04	Share of Finance, Insurance, and Real Estate firms in 2004
pfire06	Share of Finance, Insurance, and Real Estate firms in 2006
pfire08	Share of Finance, Insurance, and Real Estate firms in 2008
pfire98	Share of Finance, Insurance, and Real Estate firms in 1998
pit02	Share of IT firms in 2002

Table 31. Variable Key Cont.	
Variable	**Description**
pit04	Share of IT firms in 2004
pit06	Share of IT firms in 2006
pit08	Share of IT firms in 2008
pit98	Share of IT firms in 1998
pmanu02	Share of manufacturing firms in 2002
pmanu04	Share of manufacturing firms in 2004
pmanu06	Share of manufacturing firms in 2006
pmanu08	Share of manufacturing firms in 2008
pmanu98	Share of manufacturing firms in 1998
pserv02	Share of service firms in 2002
pserv04	Share of service firms in 2004
pserv06	Share of service firms in 2006
pserv08	Share of service firms in 2008
pserv98	Share of service firms in 1998

Appendix B: Summary Statistics

Table 32. Summary Statistics							
	Full Sample					Sub-Sample (N=14,907)	
Variable	**N**	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**
dBB99	31714	0.6	0.5	0.0	1.0	0.82	0.38
dUrban	31558	0.5	0.5	0.0	1.0	0.36	0.48
grcol90s	31369	56.1	234.0	-100.0	25400.0	50.15	80.53
gremp9498	27024	32.6	555.7	-100.0	55760.0	41.35	732.47
grest9498	30510	20.7	316.0	-100.0	32100.0	17.51	145.84
grfin90s	31396	74.2	541.1	-86.7	50600.0	74.71	442.43
grfire9800	16706	-13.1	46.1	-100.0	481.8	-13.35	45.28
grit9800	16706	10.3	43.3	-100.0	901.2	10.30	42.44
grlab90s	31393	19.3	98.9	-100.0	9898.0	17.69	44.78
grmanu9800	16706	-16.3	46.4	-100.0	350.8	-16.40	45.68
grsal9498	27025	62.9	1109.8	-100.0	151936.0	76.04	1485.03
grserv9800	16706	-14.1	42.5	-100.0	543.3	-14.16	41.66
lemp98	27844	6.3	2.2	0.0	12.0	7.79	1.49
lemp9802	26538	0.0	0.4	-3.3	4.1	0.04	0.24
lemp9808	24391	0.1	0.5	-3.7	5.7	0.10	0.36
lest98	30981	4.0	1.9	0.0	8.9	5.38	1.15
lest9802	30755	0.0	0.3	-2.1	3.2	0.04	0.13
lest9808	30595	0.1	0.4	-2.4	4.6	0.08	0.24
lmrent00	31402	6.2	0.4	0.5	7.6	6.30	0.36
lmrent0009	31402	0.3	0.2	-7.4	2.9	0.30	0.18
lmrent09	31714	6.5	0.4	-2.1	7.6	6.60	0.36
lmrent90	31723	5.8	0.4	0.6	6.9	5.89	0.39
lpop2k	31714	7.9	1.8	0.0	11.6	9.15	1.14
lsal98	27847	9.4	2.4	2.2	16.2	10.94	1.66
lsal9802	26539	0.2	0.4	-3.6	4.1	0.17	0.28
lsal9808	25801	0.4	0.6	-3.7	6.3	0.41	0.41
pcol2k	31404	12.4	8.8	0.0	100.0	14.83	10.02
pfire02	31446	4.3	4.9	0.0	39.9	8.07	3.78
pfire04	31079	4.6	5.1	0.0	42.7	8.62	3.68
pfire06	31244	4.4	5.2	0.0	50.2	8.21	4.33
pfire08	31446	4.4	5.2	0.0	33.3	8.34	4.19
pfire98	31133	4.4	4.8	0.0	37.2	8.24	3.32
pIT02	31446	2.0	2.7	0.0	62.2	3.60	2.59
pIT04	31079	1.4	2.1	0.0	45.7	2.45	2.03
pIT06	31244	1.3	2.0	0.0	56.5	2.38	2.01
pIT08	31446	1.7	2.4	0.0	53.4	3.08	2.44
pIT98	31133	1.9	2.6	0.0	67.5	3.46	2.34
pManu02	31446	2.8	4.1	0.0	41.5	5.34	4.27
pManu04	31079	3.0	4.2	0.0	60.0	5.51	4.26
pManu06	31244	2.6	3.9	0.0	49.1	4.80	4.21
pManu08	31446	2.6	3.9	0.0	46.6	4.85	4.20
pManu98	31133	3.4	4.6	0.0	62.1	6.21	4.47

Table 32. Summary Statistics Cont							
	Full Sample					Sub-Sample (N=14,907)	
Variable	**N**	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**
pServ02	31446	13.8	15.2	0.0	78.3	26.10	10.73
pServ04	31079	14.7	15.6	0.0	80.8	27.59	9.92
pServ06	31244	13.7	15.6	0.0	81.0	25.71	11.97
pServ08	31446	14.2	16.2	0.0	79.4	27.03	12.21
pServ98	31133	14.3	14.8	0.0	77.3	26.69	8.83

Appendix C: Industry-Level Conceptual Model Tables

Table 33. IT-intensive Industry Sectors Conceptual Equations			
Dependent Variable			**Control Variables**
EQ	**Period**	**Name**	
5A1	2002	Pit02	$= \beta_1$ dBB99 + β_2 dUrban + $\beta_3$grcol90s + $\beta_4$pcol2k + $\beta_5$pit98 + $\beta_6$grit9800
5A2	2002	Pit02	$= \beta_1$ dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pit98 + $\beta_7$grit9800 + β_8 pfire98 + $\beta_9$pserv98 + β_{10}pmanu98
5A3	2004	Pit04	$= \beta_1$ dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pit98 + $\beta_7$grit9800 + β_8 pfire98 + $\beta_9$pserv98 + β_{10}pmanu98
5A4	2006	Pit06	$= \beta_1$ dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pit98 + $\beta_7$grit9800 + β_8 pfire98 + $\beta_9$pserv98 + β_{10}pmanu98
5A5	2008	Pit08	$= \beta_1$ dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pit98 + $\beta_7$grit9800 + β_8 pfire98 + $\beta_9$pserv98 + β_{10}pmanu98

Table 34. FIRE Conceptual Equations			
Dependent Variable			**Control Variables**
EQ	**Period**	**Name**	
6A1	2002	pfire02	$= \beta_1$dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + β_6 pfire98 + β_7 grfire9800 + β_8 pserv98a + β_9 pmanu98a + β_{10} pit98
6A2	2004	pfire04	$= \beta_1$dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + β_6 pfire98 + β_7 grfire9800 + β_8 pserv98a + β_9 pmanu98a + β_{10} pit98
6A3	2006	Pfire06	$= \beta_1$dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + β_6 pfire98 + β_7 grfire9800 + β_8 pserv98a + β_9 pmanu98a + β_{10} pit98
6A4	2008	Pfire08	$= \beta_1$dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + β_6 pfire98 + β_7 grfire9800 + β_8 pserv98a + β_9 pmanu98a + β_{10} pit98

Table 35. Manufacturing Conceptual Equations			
Dependent Variable			**Control Variables**
Type	**Period**	**Name**	
7A1	2002	pmanu02	= β_1 dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pmanu98+ β_7 grmanu9800 + β_8 pserv98a + β_9 pfire98 + β_{10} pit98
7A2	2004	Pmanu04	= β_1 dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pmanu98+ β_7 grmanu9800 + β_8 pserv98a + β_9 pfire98 + β_{10} pit98
7A3	2006	Pmanu06	= β_1 dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pmanu98+ β_7 grmanu9800 + β_8 pserv98a + β_9 pfire98 + β_{10} pit98
7A4	2008	Pmanu08	= β_1 dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pmanu98+ β_7 grmanu9800 + β_8 pserv98a + β_9 pfire98 + β_{10} pit98

Table 36. Service Conceptual Equations			
Dependent Variable			**Control Variables**
Type	**Period**	**Name**	
8A1	2002	pserv02	= β_1dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pserv98 + β_7 grserv9800 + $\beta_8$pfire98 + β_9 pmanu98 + β_{10}pit98
8A2	2004	Pserv04	= β_1dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pserv98 + β_7 grserv9800 + $\beta_8$pfire98 + β_9 pmanu98 + β_{10}pit98
8A3	2006	Pserv06	= β_1dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pserv98 + β_7 grserv9800 + $\beta_8$pfire98 + β_9 pmanu98 + β_{10}pit98
8A4	2008	Pserv08	= β_1dBB99 + β_2 dUrban + $\beta_3$lpop2k + $\beta_4$grcol90s + $\beta_5$pcol2k + $\beta_6$pserv98 + β_7 grserv9800 + $\beta_8$pfire98 + β_9 pmanu98 + β_{10}pit98

Appendix D: Growth Regression Tables

Rent Regressions

Table 37. 1A1 Rent Replicate Lehr (lmrent00)				
Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	3.371	0.033	102.525	0.000
dBB99	0.101	0.005	19.502	0.000
dUrban	-0.245	0.004	-56.023	0.000
grfin90s	0.000	0.000	9.468	0.000
lmrent90	0.491	0.005	90.281	0.000
grlab90s	0.002	0.000	47.747	0.000
R^2 0.583				

Table 38. 1A2 Rent Replicate Lehr Spatial (lmrent00)				
Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	4.689	0.033	143.545	0.000
dBB99	0.050	0.004	13.474	0.000
dUrban	-0.158	0.005	-30.547	0.000
grfin90s	0.000	0.000	2.578	0.010
lmrent90	0.268	0.005	49.300	0.000
grlab90s	0.001	0.000	30.547	0.000
LAMBDA	0.718	0.005	139.332	0.000
R^2 0.781				

Table 39. 1A3 Rent Level (lmrent09)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	1.435	0.037	38.800	0.000
dBB99	0.007	0.004	1.625	0.104
dUrban	-0.054	0.004	-12.897	0.000
lmrent00	0.818	0.006	140.815	0.000
grfin90s	0.000	0.000	2.394	0.017
lpop2k	0.003	0.002	1.851	0.064
grlab90s	0.000	0.000	3.072	0.002
LAMBDA	0.307	0.009	33.930	0.000
R^2 0.799				

Table 40. 1A4 Rent Growth (lmrent0009)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	1.435	0.037	38.800	0.000
dBB99	0.007	0.004	1.630	0.103
dUrban	-0.054	0.004	-12.895	0.000
lpop2k	0.003	0.002	1.846	0.065
grfin90s	0.000	0.000	2.394	0.017
lmrent00	-0.182	0.006	-31.309	0.000
grlab90s	0.000	0.000	3.066	0.002
LAMBDA	0.307	0.009	33.937	0.000
R^2 0.134				

Salary Regressions

Table 41. 2A1 Salary Growth Replicate Lehr (lsal9802)				
Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	0.134	0.008	17.447	0.000
dBB99	-0.003	0.006	-0.466	0.641
dUrban	-0.046	0.005	-9.041	0.000
grlab90s	0.001	0.000	13.304	0.000
grcol90s	0.000	0.000	-1.443	0.149
pcol2k	0.003	0.000	13.307	0.000
grsal9498	0.000	0.000	2.291	0.022
pit98	-0.005	0.001	-5.356	0.000
R^2 0.078				

Table 42. 2A2 Salary Growth 1998-2002 (lsal9802)				
Variable	Coefficient	Std.Error	z-value	Probability
W_lsal9802	0.098	0.010	10.095	0.000
CONSTANT	0.202	0.024	8.522	0.000
dBB99	0.021	0.007	3.246	0.001
dUrban	-0.052	0.005	-9.841	0.000
lpop2k	0.053	0.003	16.167	0.000
lsal98	-0.054	0.002	-23.472	0.000
grlab90s	0.001	0.000	9.826	0.000
grcol90s	0.000	0.000	0.038	0.969
pcol2k	0.004	0.000	13.298	0.000
grsal9498	0.000	0.000	2.185	0.029
pit98	0.001	0.001	1.217	0.223
pmanu98	-0.004	0.001	-6.411	0.000
pserv98	0.000	0.000	1.016	0.310
pfire98	-0.002	0.001	-2.578	0.010
R^2 0.124				

Table 43. 2A3 Salary Growth 1998-2008 (lsal9808)				
Variable	Coefficient	Std.Error	z-value	Probability
W_lsal9808	0.192	0.009	21.115	0.000
CONSTANT	0.441	0.034	12.897	0.000
dBB99	0.043	0.009	4.511	0.000
dUrban	-0.057	0.008	-7.553	0.000
lpop2k	0.087	0.005	18.242	0.000
lsal98	-0.088	0.003	-26.829	0.000
grlab90s	0.002	0.000	12.457	0.000
grcol90s	0.000	0.000	-0.709	0.478
pcol2k	0.006	0.000	14.906	0.000
grsal9498	0.000	0.000	2.666	0.008
pit98	0.005	0.001	3.140	0.002
pmanu98	-0.005	0.001	-5.727	0.000
pserv98	-0.001	0.000	-1.789	0.074
pfire98	-0.004	0.001	-4.365	0.000
R^2 0.156				

Employment Regressions

Table 44. 3A1 Employment Growth Replicate Lehr (lemp9802)				
Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	0.050	0.005	9.294	0.000
dBB99	0.014	0.005	2.640	0.008
dUrban	-0.070	0.004	-16.562	0.000
gremp9498	0.000	0.000	5.118	0.000
R^2 0.024				

Table 45. 3A2 Employment Growth 1998-2002 (lemp9802)				
Variable	Coefficient	Std.Error	z-value	Probability
W_lemp9802	0.148	0.010	15.365	0.000
CONSTANT	-0.017	0.021	-0.825	0.409
dBB99	0.032	0.006	5.645	0.000
dUrban	-0.064	0.004	-14.883	0.000
lpop2k	0.055	0.003	18.405	0.000
lemp98	-0.058	0.002	-25.540	0.000
gremp9498	0.000	0.000	4.868	0.000
pit98	0.004	0.001	4.282	0.000
pmanu98	-0.004	0.000	-8.626	0.000
pserv98	0.001	0.000	2.375	0.018
pfire98	-0.001	0.001	-1.818	0.069
R^2 0.082				

Table 46. 3A3 Employment Growth 1998-2008 (lemp9808)				
Variable	Coefficient	Std.Error	z-value	Probability
W_lemp9808	0.268	0.009	29.647	0.000
CONSTANT	0.014	0.031	0.449	0.654
dBB99	0.060	0.008	7.252	0.000
dUrban	-0.091	0.006	-14.511	0.000
lpop2k	0.088	0.004	20.455	0.000
lemp98	-0.090	0.003	-27.580	0.000
gremp9498	0.000	0.000	5.793	0.000
pit98	0.004	0.001	3.075	0.002
pmanu98	-0.007	0.001	-9.200	0.000
pserv98	0.000	0.000	-0.134	0.893
pfire98	-0.004	0.001	-4.712	0.000
R^2 0.101				

Establishment Regressions

Table 47. 4A1 Establishment Lehr Replication (lest9802)				
Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	0.025	0.003	9.043	0.000
dBB99	0.011	0.003	4.120	0.000
dUrban	-0.044	0.002	-20.522	0.000
grlab90s	0.001	0.000	50.358	0.000
grest9498	0.000	0.000	10.708	0.000
R^2 0.190				

Table 48. 4A2 Establishment Growth 1998-2002 (lest9802)				
Variable	Coefficient	Std.Error	t-Statistic	Probability
W_lest9802	0.249	0.009	28.192	0.000
CONSTANT	-0.074	0.011	-6.667	0.000
dBB99	0.015	0.003	5.138	0.000
dUrban	-0.033	0.002	-15.206	0.000
lpop2k	0.030	0.002	18.546	0.000
lest98	-0.033	0.002	-19.738	0.000
grlab90s	0.001	0.000	42.058	0.000
grest9498	0.000	0.000	10.042	0.000
pit98	0.001	0.000	2.130	0.033
pmanu98	-0.001	0.000	-4.493	0.000
pserv98	0.000	0.000	0.272	0.786
pfire98	-0.001	0.000	-4.545	0.000
R^2 0.220				

Table 49. 4A3 Establishment Growth 1998-2008 (lest9808)				
Variable	Coefficient	Std.Error	z-value	Probability
W_lest9808	0.373	0.008	46.986	0.000
CONSTANT	-0.141	0.018	-7.696	0.000
dBB99	0.034	0.005	7.165	0.000
dUrban	-0.055	0.004	-15.303	0.000
lpop2k	0.053	0.003	19.704	0.000
lest98	-0.054	0.003	-19.636	0.000
grlab90s	0.002	0.000	47.005	0.000
grest9498	0.000	0.000	11.751	0.000
pit98	0.002	0.001	2.527	0.012
pmanu98	-0.003	0.000	-6.493	0.000
pserv98	0.000	0.000	-2.272	0.023
pfire98	-0.003	0.001	-5.657	0.000
R^2 0.277				

Appendix E: Industry Mix Regressions

Information Technology Intensive Industry Sectors

Table 50. 5A1 IT Share Replicate Lehr (pit02)				
Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	-0.062	0.044	-1.398	0.162
dBB99	0.203	0.035	5.809	0.000
dUrban	-0.006	0.029	-0.211	0.833
grcol90s	0.000	0.000	-1.612	0.107
pcol2k	0.022	0.001	15.545	0.000
pit98	0.877	0.006	150.100	0.000
grit9800	0.014	0.000	45.878	0.000
R^2 0.649				

Table 51. 5A2 IT Share 2002 (pit02)				
Variable	Coefficient	Std.Error	z-value	Probability
W_pit02	0.096	0.007	14.275	0.000
CONSTANT	-1.129	0.138	-8.162	0.000
dBB99	0.081	0.038	2.134	0.033
dUrban	0.024	0.031	0.775	0.438
lpop2k	0.076	0.014	5.302	0.000
grcol90s	0.000	0.000	0.249	0.804
pcol2k	0.013	0.002	7.855	0.000
pit98	0.863	0.006	140.663	0.000
pmanu98	-0.003	0.003	-1.026	0.305
pserv98	0.004	0.002	1.924	0.054
pfire98	0.028	0.004	6.782	0.000
grit9800	0.014	0.000	45.505	0.000
R^2 0.652				

Table 52. 5A3 IT Share 2004 (pit04)				
Variable	Coefficient	Std.Error	z-value	Probability
W_pit04	0.114	0.008	14.214	0.000
CONSTANT	-1.046	0.134	-7.832	0.000
dBB99	0.226	0.037	6.150	0.000
dUrban	-0.015	0.030	-0.496	0.620
lpop2k	0.030	0.014	2.148	0.032
grcol90s	0.000	0.000	-0.143	0.887
pcol2k	0.028	0.002	17.448	0.000
pit98	0.520	0.006	88.297	0.000
pmanu98	0.010	0.003	3.099	0.002
pserv98	0.008	0.002	4.819	0.000
pfire98	0.024	0.004	6.099	0.000
grit9800	0.007	0.000	23.811	0.000
R^2 0.468				

Table 53. 5A4 IT Share 2006 (pit06)				
Variable	Coefficient	Std.Error	z-value	Probability
W_pit06	0.163	0.008	19.947	0.000
CONSTANT	-0.741	0.139	-5.332	0.000
dBB99	0.268	0.038	7.015	0.000
dUrban	0.000	0.031	-0.015	0.988
lpop2k	-0.010	0.014	-0.720	0.471
grcol90s	0.000	0.000	0.078	0.938
pcol2k	0.025	0.002	14.976	0.000
pit98	0.465	0.006	75.894	0.000
pmanu98	0.013	0.003	3.969	0.000
pserv98	0.008	0.002	4.332	0.000
pfire98	0.035	0.004	8.333	0.000
grit9800	0.006	0.000	19.650	0.000
R^2 0.405				

Table 54. 5A5 IT Share 2008 (pit08)				
Variable	Coefficient	Std.Error	z-value	Probability
W_pit08	0.026	0.006	4.378	0.000
CONSTANT	-3.606	0.111	-32.423	0.000
dBB99	0.408	0.031	13.341	0.000
dUrban	0.097	0.025	3.936	0.000
lpop2k	0.312	0.012	26.992	0.000
grcol90s	0.000	0.000	2.003	0.045
pcol2k	0.009	0.001	6.538	0.000
pit98	0.913	0.005	184.644	0.000
pmanu98	-0.013	0.003	-4.959	0.000
pserv98	0.009	0.001	6.197	0.000
pfire98	-0.012	0.003	-3.732	0.000
grit9800	0.002	0.000	7.406	0.000
R^2 0.750				

Finance, Insurance, Real Estate

Table 55. 6A1 FIRE Share 2002 (pfire02)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	-3.790	0.235	-16.120	0.000
dBB99	0.374	0.063	5.952	0.000
dUrban	0.419	0.056	7.421	0.000
lpop2k	0.540	0.024	22.233	0.000
grcol90s	0.001	0.000	2.895	0.004
pcol2k	0.013	0.003	4.512	0.000
pit98	0.038	0.010	3.905	0.000
pmanu98	-0.032	0.006	-5.717	0.000
pserv98	0.019	0.003	6.270	0.000
pfire98	0.728	0.007	103.975	0.000
grfire9800	0.016	0.001	30.756	0.000
LAMBDA	0.221	0.010	23.127	0.000
R^2 0.553				

Table 56. 6A2 FIRE Share (pfire04)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	-2.743	0.229	-11.974	0.000
dBB99	0.190	0.062	3.073	0.002
dUrban	0.383	0.053	7.225	0.000
lpop2k	0.509	0.024	21.433	0.000
grcol90s	0.002	0.000	9.066	0.000
pcol2k	0.021	0.003	7.560	0.000
pit98	0.025	0.010	2.539	0.011
pmanu98	-0.034	0.005	-6.218	0.000
pserv98	0.010	0.003	3.493	0.000
pfire98	0.726	0.007	105.751	0.000
grfire9800	0.011	0.000	23.109	0.000
LAMBDA	0.128	0.010	12.908	0.000
R^2 0.554				

Table 57. 6A3 FIRE Share (pfire06)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	-8.015	0.299	-26.762	0.000
dBB99	0.919	0.080	11.521	0.000
dUrban	0.532	0.073	7.318	0.000
lpop2k	1.013	0.031	32.784	0.000
grcol90s	0.003	0.000	9.086	0.000
pcol2k	0.032	0.004	8.444	0.000
pit98	0.081	0.013	6.457	0.000
pmanu98	-0.046	0.007	-6.453	0.000
pserv98	0.021	0.004	5.431	0.000
pfire98	0.607	0.009	68.128	0.000
grfire9800	0.012	0.001	17.341	0.000
LAMBDA	0.248	0.009	26.393	0.000
R^2 0.445				

Table 58. 6A4. FIRE Share 2008 (pfire08)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	-7.999	0.290	-27.625	0.000
dBB99	1.029	0.079	13.106	0.000
dUrban	0.726	0.066	10.957	0.000
lpop2k	1.044	0.030	34.754	0.000
grcol90s	0.003	0.000	9.780	0.000
pcol2k	0.027	0.003	7.689	0.000
pit98	0.068	0.012	5.568	0.000
pmanu98	-0.056	0.007	-8.183	0.000
pserv98	0.024	0.004	6.257	0.000
pfire98	0.574	0.009	65.981	0.000
grfire9800	0.009	0.001	14.568	0.000
LAMBDA	0.102	0.010	10.187	0.000
R^2 0.448				

Manufacturing

Table 59. 7A1 Manufacturing Share 2002 (pmanu02)				
Variable	Coefficient	Std.Error	z-value	Probability
W_pmanu02	0.091	0.007	13.775	0.000
CONSTANT	-0.843	0.220	-3.838	0.000
dBB99	0.376	0.060	6.226	0.000
dUrban	0.247	0.049	5.069	0.000
lpop2k	0.192	0.023	8.405	0.000
grcol90s	-0.001	0.000	-4.565	0.000
pcol2k	-0.014	0.003	-5.546	0.000
pit98	0.019	0.009	1.992	0.046
pmanu98	0.737	0.005	135.725	0.000
pserv98	-0.013	0.003	-4.660	0.000
pfire98	-0.034	0.007	-5.244	0.000
grmanu9800	0.010	0.000	23.906	0.000
R^2 0.677				

Table 60. 7A2 Manufacturing Share 2004 (pmanu04)				
Variable	Coefficient	Std.Error	z-value	Probability
W_pmanu04	0.071	0.006	11.347	0.000
CONSTANT	1.213	0.205	5.921	0.000
dBB99	0.105	0.056	1.872	0.061
dUrban	0.280	0.045	6.170	0.000
lpop2k	0.027	0.021	1.249	0.212
grcol90s	-0.001	0.000	-5.470	0.000
pcol2k	-0.014	0.002	-5.715	0.000
pit98	-0.019	0.009	-2.162	0.031
pmanu98	0.752	0.005	148.898	0.000
pserv98	-0.021	0.003	-7.775	0.000
pfire98	-0.020	0.006	-3.209	0.001
grmanu9800	0.008	0.000	18.598	0.000
R^2 0.721				

Table 61. 7A3 Manufacturing Share 2006 (pmanu06)				
Variable	Coefficient	Std.Error	z-value	Probability
W_pmanu06	0.095	0.008	12.138	0.000
CONSTANT	-2.367	0.266	-8.897	0.000
dBB99	0.658	0.073	8.994	0.000
dUrban	0.498	0.059	8.435	0.000
lpop2k	0.344	0.028	12.406	0.000
grcol90s	-0.001	0.000	-4.518	0.000
pcol2k	-0.017	0.003	-5.245	0.000
pit98	0.030	0.011	2.671	0.008
pmanu98	0.628	0.006	96.645	0.000
pserv98	-0.012	0.003	-3.480	0.001
pfire98	-0.047	0.008	-5.959	0.000
grmanu9800	0.007	0.001	13.159	0.000
R^2 0.515				

Table 62. 7A4 Manufacturing Share 2008 (pamnu08)				
Variable	Coefficient	Std.Error	z-value	Probability
W_pmanu08	0.086	0.008	10.751	0.000
CONSTANT	-1.729	0.275	-6.287	0.000
dBB99	0.697	0.076	9.229	0.000
dUrban	0.514	0.061	8.426	0.000
lpop2k	0.314	0.029	10.989	0.000
grcol90s	-0.002	0.000	-6.039	0.000
pcol2k	-0.017	0.003	-5.148	0.000
pit98	0.012	0.012	1.002	0.317
pmanu98	0.602	0.007	90.050	0.000
pserv98	-0.015	0.004	-4.178	0.000
pfire98	-0.049	0.008	-5.922	0.000
grmanu9800	0.006	0.001	10.288	0.000
R^2 0.482				

Service Industry

Table 63. 8A1 Service Share 2002 (pserv02)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	-12.725	0.583	-21.821	0.000
dBB99	0.944	0.154	6.128	0.000
dUrban	0.660	0.144	4.575	0.000
lpop2k	1.609	0.060	26.782	0.000
grcol90s	0.000	0.001	0.019	0.985
pcol2k	0.069	0.007	9.277	0.000
pit98	0.072	0.024	2.991	0.003
pmanu98	-0.028	0.014	-2.054	0.040
pserv98	0.807	0.008	105.673	0.000
pfire98	0.145	0.017	8.513	0.000
grserv9800	0.047	0.001	31.579	0.000
LAMBDA	0.292	0.009	31.908	0.000
R^2 0.653				

Table 64. 8A2 Service Share 2004 (pserv04)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	-7.533	0.526	-14.323	0.000
dBB99	0.620	0.142	4.359	0.000
dUrban	0.524	0.121	4.335	0.000
lpop2k	1.310	0.054	24.034	0.000
grcol90s	0.001	0.001	1.448	0.148
pcol2k	0.065	0.006	10.264	0.000
pit98	0.015	0.022	0.663	0.507
pmanu98	-0.039	0.012	-3.179	0.001
pserv98	0.785	0.007	113.658	0.000
pfire98	0.131	0.016	8.431	0.000
grserv9800	0.028	0.001	23.244	0.000
LAMBDA	0.115	0.010	11.529	0.000
R^2 0.677				

Table 65. 8A3 Service Share 2006 (pserv06)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	-21.948	0.776	-28.298	0.000
dBB99	2.680	0.204	13.138	0.000
dUrban	1.330	0.195	6.806	0.000
lpop2k	2.609	0.080	32.684	0.000
grcol90s	0.002	0.001	2.387	0.017
pcol2k	0.106	0.010	10.630	0.000
pit98	0.110	0.032	3.423	0.001
pmanu98	-0.036	0.018	-1.927	0.054
pserv98	0.694	0.010	68.393	0.000
pfire98	0.157	0.023	6.953	0.000
grserv9800	0.035	0.002	17.317	0.000
LAMBDA	0.328	0.009	36.738	0.000
R^2 0.498				

Table 66. 8A4 Service Share 2008 (pserv08)				
Variable	Coefficient	Std.Error	z-value	Probability
CONSTANT	-23.660	0.732	-32.316	0.000
dBB99	2.692	0.198	13.566	0.000
dUrban	0.797	0.167	4.775	0.000
lpop2k	2.873	0.076	37.837	0.000
grcol90s	0.003	0.001	4.185	0.000
pcol2k	0.129	0.009	14.712	0.000
pit98	0.116	0.031	3.760	0.000
pmanu98	-0.079	0.017	-4.597	0.000
pserv98	0.722	0.010	75.026	0.000
pfire98	0.121	0.022	5.594	0.000
grserv9800	0.024	0.002	14.439	0.000
LAMBDA	0.093	0.010	9.212	0.000
R^2 0.585				

Appendix F: Spatial Model Selection

Rent (1A1)			
	OLS	Lag	Error
LL	776.685	1049.81	4088.895
AIC	-1541.37	-2085.63	-8165.79
SC	-1495.71	-2032.36	-8120.13
Error			

Rent (1A2)			
	OLS	Lag	Error
LL	5190.2	5232.25	5663.967
AIC	-10366.4	-10448.5	-11313.9
SC	-10313.1	-10387.6	-11260.7
Error			

Rent (1A3)			
	OLS	Lag	Error
LL	5191.07	5523.42	5665
AIC	-10368.1	-11030.8	-11316
SC	-10314.9	-10970	-11262.7
Error			

Salary (2A1)			
	OLS	Lag	Error
LL	-1408.05	-1344.54	-1365.86
AIC	2832.09	2707.07	2747.72
SC	2892.97	2775.56	2808.6
Lag			

Salary (2A2)			
	OLS	Lag	Error
LL	-1033.99	-983.862	-1003.74
AIC	2093.97	1995.72	2033.47
SC	2192.9	2102.26	2132.4
Lag			

Salary (2A3)			
	OLS	Lag	Error
LL	-6704.43	-6483.37	-6537.08
AIC	13434.9	12994.7	13100.2
SC	13533.8	13101.3	13199.1
Lag			

Employment (3A1)			
	OLS	Lag	Error
LL	467.322	608.949	605.7782
AIC	-926.644	-1207.9	-1203.56
SC	-896.206	-1169.85	-1173.12
Lag			

Employment (3A2)			
	OLS	Lag	Error
LL	925.733	1040.1	1028.232
AIC	-1831.47	-2058.21	-2036.46
SC	-1755.37	-1974.5	-1960.37
Lag			

Employment (3A3)			
	OLS	Lag	Error
LL	-5065.11	-4646.52	-4671.43
AIC	10150.2	9315.04	9362.85
SC	10226.3	9398.74	9438.95
Lag			

Establishments (4A1)			
	OLS	Lag	Error
LL	10526.6	10913	10770.12
AIC	-21043.3	-21814	-21530.2
SC	-21005.2	-21768.3	-21492.2
Lag			

Establishments (4A2)			
	OLS	Lag	Error
LL	10802	11177.6	11047.43
AIC	-21582.1	-22331.2	-22072.9
SC	-21498.4	-22239.9	-21989.2
Lag			

Establishments (4A3)			
	OLS	Lag	Error
LL	2608.28	3571.11	3314.198
AIC	-5194.56	-7118.22	-6606.4
SC	-5110.85	-7026.9	-6522.69
Lag			

IT-Intensive (5A1)			
	OLS	Lag	Error
LL	-27537.3	-27430.6	-27444.6
AIC	55088.6	54877.2	54903.3
SC	55141.8	54938.1	54956.5
Lag			

IT-Intensive (5A2)			
	OLS	Lag	Error
LL	-27473	-27369.7	-27383.8
AIC	54968	54763.5	54789.6
SC	55051.7	54854.8	54873.3
Lag			

IT-Intensive (5A3)			
	OLS	Lag	Error
LL	-26975.2	-26873.9	-26924.6
AIC	53972.4	53771.8	53871.1
SC	54056.1	53863.1	53954.8
Lag			

IT-Intensive (5A4)			
	OLS	Lag	Error
LL	-27700.3	-27498.3	-27508
AIC	55422.6	55020.7	55037.9
SC	55506.3	55112	55121.6
Lag			

IT-Intensive (5A5)			
	OLS	Lag	Error
LL	-24134	-24124.4	-24127.5
AIC	48290	48272.7	48276.9
SC	48373.7	48364.1	48360.6
Lag			

Fire (6A1)			
	OLS	Lag	Error
LL	-34949.8	-34839.2	-34698.5
AIC	69921.6	69702.4	69419
SC	70005.3	69793.7	69502.7
Error			

Fire (6A2)			
	OLS	Lag	Error
LL	-34557.4	-34516	-34483
AIC	69136.8	69056	68988.1
SC	69220.5	69147.3	69071.8
Error			

Fire (6A3)			
	OLS	Lag	Error
LL	-38600.4	-38409.4	-38274.5
AIC	77222.9	76842.9	76570.9
SC	77306.6	76934.2	76654.6
Error			

Fire (6A4)			
	OLS	Lag	Error
LL	-38085.9	-38071.1	-38037.7
AIC	76193.8	76166.2	76097.5
SC	76277.5	76257.5	76181.2
Error			

Manufacturing (7A1)			
	OLS	Lag	Error
LL	-34349.3	-34254.5	-34214
AIC	68720.6	68533	68450.1
SC	68804.3	68624.3	68533.8
Lag			

Manufacturing (7A2)			
	OLS	Lag	Error
LL	-33240.1	-33175.6	-33201
AIC	66502.3	66375.2	66424
SC	66586	66466.5	66507.7
Lag			

Manufacturing (7A3)			
	OLS	Lag	Error
LL	-37192.9	-37118.3	-37128.5
AIC	74407.8	74260.6	74279
SC	74491.5	74351.9	74362.7
Lag			

Manufacturing (7A4)			
	OLS	Lag	Error
LL	-37653.6	-37596	-37618
AIC	75329.2	75216	75258
SC	75412.9	75307.3	75341.7
Lag			

Service (8A1)			
	OLS	Lag	Error
LL	-48633.3	-48504.1	-48144.4
AIC	97288.7	97032.2	96310.9
SC	97372.4	97123.5	96394.6
Error			

Service (8A2)			
	OLS	Lag	Error
LL	-46936	-46926	-46875.5
AIC	93894	93875.9	93772.9
SC	93977.7	93967.2	93856.6
Error			

Service (8A3)			
	OLS	Lag	Error
LL	-53018.8	-52791.7	-52382.1
AIC	106060	105607	104786
SC	106143	105699	104870
Error			

Service (8A4)			
	OLS	Lag	Error
LL	-51903.1	-51897.8	-51863.3
AIC	103828	103820	103749
SC	103912	103911	103832
Error			