

THE IMPACT OF INFORMATION AND COMMUNICATIONS TECHNOLOGIES
(ICTS) ON FIRM LOCATION

Elizabeth A. Mack

Submitted to the faculty of the University Graduate School
in partial fulfillment of the requirements
for the degree
Doctor of Philosophy
in the Department of Geography,
Indiana University
April 2010

Accepted by the Graduate Faculty, Indiana University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Doctoral Committee

Tony H. Grubestic

Tom Evans

Scott Robeson

Barry M. Rubin

April 7, 2010

Dedication

This dissertation is dedicated to three individuals who provided inspiration and encouragement throughout the pursuit of this degree.

To my dad: You always encouraged me to do my very best, irrespective of how other people might judge the outcome. You also provided solid advice that was essential to the completion of this degree. I am forever grateful for your common sense and support.

To Dr. Odland: Your keen insights into my research will always be remembered. Although you could not be physically present to see the completion of this dissertation, I know you are spiritually present. I hope this dissertation meets your reasonable but very high standards.

To Dr. Grubestic: Throughout the last four years you patiently nudged me down the research path and were always there to provide solid advice and encouragement. You were supportive of my research ideas when no one else saw their value. You also taught me how to write papers for publication in academic journals. I hope my research career in future years will be half as productive as yours.

Acknowledgements

There are a number of people who have helped me a great deal and from whom I have learned a lot in the process of earning this degree. First and foremost, I would like to thank my advisor and committee for their guidance and support. Their keen insights over the last four years have helped me grow as a researcher and have improved the quality of this dissertation. I would also like to thank Alan T. Murray, who served as an informal advisor for this dissertation, and who offered a lot of professional guidance throughout the last four years. Dr. Murray not only helped me improve my research, but helped me obtain a dissertation year fellowship from the Regional Science Association International, and a post-doctoral research position at Arizona State University.

I would like to thank the College of Arts and Science at Indiana University for funds provided by a Dissertation Year Research Fellowship and the Regional Science Association International for dissertation year funds provided by the Benjamin H. Stevens Fellowship. These funds were absolutely essential to providing the financial support I required to complete this degree in four years.

To my family and friends, thank you for listening and supporting me in my graduate work. Your understanding, patience and willingness to listen, even though you may not always have understood, are sincerely appreciated. I owe all of you some phone time.

Special thanks are in order to Elaine Yard and Susan White. I do not think anyone can fathom the number of deadlines and paperwork that are required to complete this degree. Both of you were always so patient in answering my questions no matter how many times you might have heard them before. If I missed any deadlines, neither of you

were to blame. I especially want to say thank you for helping me remotely in my last year of study. I would not have submitted things on time had it not been for your assistance.

Finally, I would like to thank the graduate students at Indiana University and Arizona State University for your collegiality these past four years. I will never forget the OMBC, now the OPBC, for Thursday morning breakfasts. I am confident that cheese in the eggs improves brainpower. To the students at Arizona State, thank you for your research assistance this past academic year. You all were always willing to take time for me when I had questions about new programs or methods.

To all of these people and so many more, I am eternally grateful. Thank you.

Abstract

Recent innovations in information and communications technologies (ICTs), particularly those related to the Internet, have fundamentally changed the environment in which businesses and regions compete around the globe. Despite widespread recognition of this change, several aspects of the manner in which ICTs have impacted business location and regional development remain unexplored. The papers that comprise this dissertation seek to provide some initial quantitative insights about ICTs, firm location, and regional development, to a literature that remains largely theoretical and speculative. The first paper explores the utility of short and mid-range broadband forecasts as potential tools for local economic development officials to flag problematic areas where broadband provision via traditional market mechanisms is doubtful. The piece finds short and mid-range spatial forecasts of broadband provision offer improved results over aspatial forecasts, which is especially important for ICT studies, given the historical lack of available data for use in empirical work. Forecasts can also be used by economic development officials to craft proactive rather than reactive intervention strategies to rollout broadband in unserved areas. The second paper examines similarities in the spatial distribution of broadband provision and firms in a variety of industries. Results indicate the relationship between the location of broadband and the location of firms varies by firm size and industry. This suggests firm size and industry membership are critical considerations when evaluating the impact of ICTs on firm location decisions. The third and final paper examines the challenges associated with benchmarking regional development given the pervasive and related technological and industrial changes in the U.S over the past thirty years. Findings suggest multivariate approaches for

benchmarking regional development are preferred over univariate approaches given the demonstrated divergence in univariate indicators in recent years. In sum, these three studies provide important information regarding the measurement of regional competitiveness in the global information economy, as well as information about the spatial relationship between firm location and broadband provision; which is likely to be a critical locational consideration for firm in specific sectors of the U.S economy.

Table of Contents

1. Introduction	1
1.1 ICTs and Firm Location	2
1.2 ICTs and Regional Benchmarking	3
1.3 Distribution of ICT Infrastructure	5
1.4 Policy	7
1.5 Economic Development	9
1.6 Objectives and Research Structure	11
1.7 References	15
2. Forecasting Broadband Provision	19
2.1 Introduction	19
2.2 Broadband Provision Forecasts	21
2.2.a <i>Differentiating Broadband Provision from Broadband Demand and Diffusion</i>	23
2.3 Modeling Framework	24
2.3.a <i>Differences Between Forecasting Models and Explanatory Models</i>	24
2.3.b <i>Model Specification</i>	25
2.3.c <i>Forecast Performance Evaluation</i>	30
2.3.d <i>Study Area</i>	31
2.3.e <i>Data</i>	32
2.3.e.1 <i>Dependent Variable</i>	35
2.3.e.2 <i>Demand Side Independent Variables</i>	35
2.3.e.3 <i>Location Indicator Independent Variables</i>	36
2.3.e.4 <i>Supply Side Independent Variables</i>	37
2.4 Results	38
2.4.a <i>Linear Regression Forecasts</i>	39
2.4.b <i>Spatial Econometric Forecasts</i>	46
2.5 Discussion and Conclusion	51
2.6 References	56
3. Broadband Provision and Firm Location	60
3.1 Introduction	60
3.2 Firm Location and ICTs	63
3.2.a <i>Regional Clusters and Enabling Infrastructure</i>	63
3.2.b <i>Firms and ICT Usage</i>	65
3.3 Study Area, Data and Methods	66
3.3.a <i>Business Data</i>	69
3.3.b <i>Broadband Data</i>	71
3.3.c <i>Exploratory Analysis</i>	71

3.4	Results	73
3.4.a	<i>Broadband and Establishment Trends</i>	73
3.4.b	<i>Agglomerative Tendencies</i>	77
3.4.c	<i>Broadband and Establishment Relationships</i>	82
3.4.d	<i>Industry Breakouts and Partial Correlations</i>	84
3.5	Discussion and Conclusion	86
3.6	References	90
4.	All Jobs Are Not Created Equal: Divergent Indicators in the Knowledge Economy	96
4.1	Introduction	96
4.2	New Economy Forces and Regional Convergence	98
4.2.1	<i>Measures of Economic Development</i>	101
4.3	Data	102
4.3.1	<i>Data Sources</i>	102
4.3.2	<i>Study Period</i>	103
4.3.3	<i>Technical Notes</i>	104
4.4	Results	105
4.4.1	<i>National Level Aggregate Trends</i>	105
4.4.1.a	<i>National Level Industry Trends</i>	106
4.4.1.b	<i>Compositional Biases</i>	109
4.4.2	<i>State Level Aggregate Trends</i>	115
4.4.3	<i>State Level Industry Trends</i>	118
4.4.4	<i>Spatial Trends in State Level Indicators</i>	121
4.5	Discussion and Conclusion	126
4.6	References	130
5.	Conclusion	135
5.1	Forecasting Broadband Provision	135
5.2	Broadband Provision and Firm Location	138
5.3	Benchmarking Regional Growth	140
5.4	Limitations	142
5.4.1	<i>Broadband Data</i>	142
5.4.1.a	<i>1999-2004 Data</i>	143
5.4.1.b	<i>2005-December 2008 Data</i>	146
5.4.1.c	<i>2009-Present</i>	146
5.4.2	<i>Spatial Scale</i>	147
5.4.3	<i>Research Impacts of Data Limitations</i>	148
5.5	Future Research	149
5.6	Concluding Remarks	152
5.7	References	154

List of Tables

Table 2.1: Variable Descriptions...	34
Table 2.2: Best Forecast Models	39
Table 2.3: Model 1 Estimation Results for 2001	41
Table 2.4: Model 2 Estimation Results for 2001	42
Table 2.5: Model 3 Estimation Results for 2001	44
Table 2.6: Model 4 Estimation Results for 2001	46
Table 2.7: Model Forecast Performance Summary	48
Table 3.1: National Business Counts by Firm Size and Industry	68
Table 3.2: Ohio Business Counts by Firm Size and Industry	69
Table 3.3: Global Moran's <i>I</i> for Broadband Provision and Establishment Counts	78
Table 3.4: Spearman Rank Correlations: Change in Broadband Providers and Establishment Counts (1999-2004)	86
Table 4.1: National Growth Trends by Indicator	106
Table 4.2: Comparison of Growth Trends by Indicator and SIC Industry	107
Table 4.3: Comparison of Growth Trends by Indicator and NAICS Industry	108
Table 4.4: National Level Earnings per Worker (2000\$)	109
Table 4.5: Snapshots of SIC Industry Shares	111
Table 4.6a: Snapshots of NAICS Industry Shares (Earnings)	112
Table 4.6b: Snapshots of NAICS Industry Shares (Employment)	113
Table 4.6c: Snapshots of NAICS Industry Shares (Establishments)	114
Table 4.7: Correlations Between Aggregate Employment and Employment by SIC Industry	120
Table 4.8: Bivariate Moran's <i>I</i> Results	125

List of Figures

Figure 2.1: Urbanized Areas, Metropolitan Statistical Areas and Incumbent Local Exchange Carrier (ILEC) Areas in Ohio	32
Figure 2.2: Geographic Spillover of Broadband Provision, 2000-2001	49
Figure 2.3: Bivariate Local Clusters: Providers (in 2001) with a Spatial Lag of Providers (in 2000)	50
Figure 3.1: Ohio ZIP Code Level Broadband Provision and Establishment Counts	74
Figure 3.2: Change in the Number of Broadband Providers (1999-2004)	75
Figure 3.3: Change in the Number of Establishments (1999-2004)	76
Figure 3.4: Ohio ZIP Code Industry Growth (1999-2004)	77
Figure 3.5: Local Moran Results for Changes in Broadband Providers, Establishments and Select NAICS Sectors (1999-2004)	79
Figure 3.6: Central and Suburban ZIP Code Local Moran Trends (1999-2004)	80
Figure 3.7: Correlation Between Broadband and Establishments (1999-2004)	82
Figure 4.1a: Gini Coefficients by Indicator (1977-2007)	116
Figure 4.1b: Difference in Gini Coefficient Values by Indicator (1977-2007)	117
Figure 4.2a: Aggregate Employment Growth (1980-1989)	123
Figure 4.2b: Manufacturing Employment Growth (1980-1989)	124

List of Appendices

Appendix 2.A: Specification of Local Spatial Statistics	54
Appendix 2.B: Descriptive Statistics for Covariates, Ohio and the United States	55

1. Introduction

One of the great ironies of globalization is the continued importance of unique regional characteristics, despite the homogenizing potential of this integrative force. In fact, it is now widely recognized that the source of enduring competitive advantage in the global economy lies in local, not global things (Porter, 1998). Competition takes place between regions, not nations, and these regions are frequently located in different countries (Fratesi and Senn, 2009).

Both the competitive pressures of globalization and the resurgence of regions as key nodes in the global economy (Scott, 1998) have renewed economic development efforts at the regional level (Gordon and McCann, 2000). A central goal of these efforts is to attract and retain globally competitive businesses that will be a source of job growth now and in future years. One key location factor for businesses may be the level of information and communications technology (ICT) infrastructure within a region.

It is widely acknowledged that information and communications technologies are key elements to the growth and development of businesses and regional economies (Abler, 1977; Richardson and Gillespie, 1996; Prekumar, 2000). The current global business environment requires that businesses be efficient, flexible, and technologically savvy to compete and survive (Martin, 2006). In accordance with this recognition, state and local governments are evaluating the technology capacity of their regions (Center for an Urban Future, 2004; OSC, 2006). Of particular concern is whether deficiencies in ICT infrastructure place regions at a relative disadvantage for retaining and attracting businesses.

Economic development efforts in the twenty-first century are perhaps complicated by Internet-related innovations in information and communications technologies (ICTs). This basket of technologies not only changed the manner in which businesses operate; it also changed the set of location factors economic development officials must consider when developing plans to retain and attract businesses. Locational preferences are no longer a simple trade-off between production and transportation costs at the intra-national level (McCann and Sheppard, 2003). Regional attractiveness now also includes access to global markets, the transactions costs of information transmission (ibid) and the frequency of face-to-face contacts with local and global contacts.

The pervasive impacts of ICTs on the global economy and their increasing importance to firms in a variety of industries (Pohjola, 2002), suggest that these technologies have altered the locational considerations of firms. It is also possible that the productivity gains associated with ICT use have impacted the accuracy of indicators used to benchmark regional performance. However, a complete understanding about the impacts of ICTs on regional economies remains elusive given the paucity of existing quantitative studies in this area. This dissertation seeks to bridge the quantitative gap in the literature by utilizing a rigorous quantitative framework to evaluate the relationship between ICTs and firm location patterns. It will also quantitatively highlight some of the complexities of benchmarking regional development in the global information economy.

1.1 ICTs and Firm Location

The relationship between ICT deployment and firm growth remains somewhat enigmatic because of the largely theoretical and speculative nature of the existing literature. Interview-oriented research and theoretical studies have injected case-specific

results and hypotheses into the existing literature. However, these studies provide little tangible and generalizable information that may be used to inform government and economic development officials about the impacts of costly ICT deployment initiatives on firm location. Of particular interest is whether regions with lower levels of ICT infrastructure are at a disadvantage for firm attention and attraction, and whether ICT deployment initiatives are capable of ameliorating this locational disadvantage. Regional deficiencies with respect to this infrastructure may also predispose economies to a certain kind of industrial composition. For example, places with lower levels of infrastructure may be incapable of attracting knowledge intensive firms, which are a rapidly growing sector of the U.S economy (Mack, 2010). In this regard, quantitative information evaluating the link between ICTs and firm location can help government and economic development officials craft better policies and design better strategic plans.

1.2 ICTs and Regional Benchmarking

Another gap in the literature is the challenge productivity gains associated with firm use of ICTs pose for regional benchmarking. As regions strive to retain and attract competitive businesses, the construction of rankings and indices to measure competitiveness has become commonplace (Martin, 2006). The increased popularity of benchmarking is perhaps a symptom of the highly competitive nature of the global economy. Benchmarking is popular because it allows regions to assess their strengths and weaknesses and compare their performance to other “competitor cities” and regions (ibid).

The uneven adoption of ICTs by firms in different industries (Forman et al., 2005), combined with the heterogeneous spatial distribution of these firms, suggests that

the productivity gains associated with ICTs will be uneven. These uneven productivity gains suggest the manner in which economic performance is measured and regional economies benchmarked needs to be reevaluated. Studies suggest the historical positive correlation between employment and productivity has shifted to a negative correlation, and that employment is now growing more rapidly in low productivity industries than in high productivity industries (Appelbaum and Schettkat, 1995). Therefore, the use of a single indicator to benchmark regional performance, like jobs, may present an inaccurate picture of economic growth. Firm and industry specific productivity gains may mean that some jobs are more productive and subsequently pay more than others. These subtle differences in job characteristics, which are likely to have become more pronounced in recent years, hold significant implications for the growth trajectories of regional economies. Regions with more productive workers are not only likely to have higher aggregate earnings than regions with less productive workers; they are also likely to produce higher value-added goods.

Given the likely divergence or difference in indicator trends in recent years stemming from ICT related productivity gains, an evaluation of the numerical biases associated with traditional univariate approaches to benchmarking regional economies needs to be conducted. A decomposition of growth trends in commonly used indicators over time, space, and industry will empirically highlight divergent growth scenarios related to the evolution of the U.S economy in the second half of the twentieth century. An illustration of issues associated with univariate measurements of economic progress can shed light on the development of more accurate multivariate measures of growth in the global information economy.

1.3 Distribution of ICT Infrastructure

An evaluation of the impact of ICTs on firm location and regional benchmarking practices is complicated by the heterogeneous distribution of these technologies. Despite the expectation of a ubiquitous distribution of this infrastructure, a variety of studies have found instead it is unevenly distributed at a variety of spatial scales (Graham, 1999; Moss and Townsend, 2000; Strover, 2001; Grubestic and O’Kelly, 2002; Grubestic and Murray, 2004). The presence of this technological divide is the result of a confluence of regulatory conditions, economic conditions, and private sector interests (Grubestic, 2008).

After the transfer of the Internet’s infrastructure from the government to the private sector in 1995 (Abbate, 1999), private firms have been charged with the deployment of this infrastructure. These profit-seeking firms are focused on servicing the most profitable areas rather than providing universal service (Greenstein, 2005). This means poor, low demand neighborhoods within otherwise ICT infrastructure-rich urban areas have persistently low levels or no access to ICTs such as broadband Internet connections (Grubestic, 2003). Rural areas also have notoriously low levels or no ICT infrastructure because of low-income populations (Strover, 2001), and the high cost of deploying the infrastructure in areas with steep terrain or few roads (Kolko, 2010). Although disparities between cities are gradually disappearing (Grubestic, 2004; Grubestic, 2006) with “second-tier” and “third-tier” locations benefiting from improved accessibility to the Internet (O’Kelly and Grubestic, 2002), the initial deployment of this infrastructure favored areas with existing ICT infrastructure (Grubestic, 2002), reinforcing historical trends and creating greater disparities between regions (Gorman, 2002).

This divide has several implications regarding the development and measurement of competitive regional economies. If this infrastructure is a key locational consideration for technology intensive firms, locales with lower levels of ICT infrastructure may be at a disadvantage for retaining and attracting these firms. This point is particularly salient for places that are looking to revitalize their industrial base and focus on higher growth sectors of a more informational nature, like Detroit, Michigan. Given the multitude of issues plaguing these metropolitan areas and competing for declining tax revenues, quantitative results can provide more concrete information about the likely success of ICT initiatives before scarce tax dollars are spent on the project.

As mentioned previously, the relationship between ICT infrastructure and the presence of ICT intensive firms is likely to produce challenges for benchmarking. These challenges are not only related to the selection of appropriate indicators to benchmark regional growth, but the selection of appropriate competitor regions against which to compare economic progress. Therefore, an evaluation of the consistency in indicator trends is certainly warranted in two respects. First, it is recognized that there is a need to modify measures of economic performance given the profound changes in the global economy in recent decades (Landefeld and Fraumeni, 2001). Second, likely industrial and spatial variations in economic indicator trends, suggest the use of multivariate indicators in place of univariate indicators is necessary to capture the multifaceted nature of regional growth in the global economy.

1.4 Policy

Quantitative analyses of the relationship between firm location and ICT infrastructure, as well as the consistency of indicator trends across time in an era of tremendous technological change, can help policymakers craft more informed policies to resolve systematic regional issues hindering growth prospects. Specifically, an analysis of potential disparities in firm location related to the uneven distribution of ICT infrastructure can help government officials develop more effective policies to remedy distributional biases across regions.

Despite the passage of federal level legislation to encourage the rollout of ICT infrastructure, the onus of bridging the private market failure to provide citizens and local area businesses with broadband¹ service, falls largely upon county and local governments (Clark et al., 2002: 4). The goal of the Telecommunications Act of 1996 was to provide consumers with higher quality and lower cost services by promoting competition through the deregulation of the telecommunications industry (TA96). The ambiguous wording of the Act however has left the implementation of this goal up to state and local governments (Grubestic and Murray, 2004). The varied interpretations of this legislation have produced a variety of approaches to deploy broadband; a comprehensive evaluation of which has not yet been compiled. Thus, local policymakers have little information regarding key ingredients to successful initiatives (Gillett et al., 2004). The regulations surrounding the rollout of telecommunications infrastructure also vary widely by state. For example, the extent that municipalities are permitted to provide telecommunications

¹ A broadband internet connection is one that permits users to send and/or receive data using the Internet at transmission rates of *greater than* 200 kilobits per second (kbps) in at least one direction (FCC, 2010). Broadband internet speeds may be delivered over a variety of platforms including cable, xDSL, broadband over power lines (BPL), wireless, and fiber-to-the-home (FTTH).

services vary from state to state. Some states prohibit municipal involvement in this sector while other states place restrictions on the activities of municipalities (Gillett, 2006: 585).

A more recent effort to bridge the broadband service gap is the Broadband Technology Opportunities Program (BTOP), which was funded with \$4.7 billion dollars from the American Recovery and Reinvestment Act (ARRA) of 2009 (H.R. 1). The goal of this initiative is to provide for-profit and other organizations with funds to roll out broadband service to underserved² and unserved³ areas (NTIA, 2009). Again, the manner in which these services will be rolled out is left to the organization that receives funding.

Although a regional approach to broadband may be the best way to deal with regional specific intricacies surrounding deployment, local governments certainly have fewer resources and information at their disposal to accomplish this task. In this regard, more quantitative information about the relationship between broadband presence and firm presence can help local governments and economic development officials formulate better plans to provide local area businesses with the resources they need to compete in the global economy. Information regarding the reliability of indicators used to measure

² The NTIA (2009) defines an underserved area for last mile projects as: “an area composed of one or more contiguous census blocks where at least one of the following is met: 1) no more than 50 percent of households in the proposed service area have access to facilities-based, terrestrial broadband service at greater than the minimum broadband speed; 2) no fixed or mobile broadband service provider advertises broadband speeds of at least 3 Mbps downstream in the proposed funded service area; or 3) the rate of broadband subscribership for the proposed service area is 40 percent of households or less.”

³ The NTIA (2009) defines an unserved area as: “an area, composed of one or more contiguous census blocks where at least 90 percent of households in the proposed funded service area lack access to facilities-based, terrestrial broadband service, either fixed or mobile, at the minimum broadband speed.”

the success of local deployment efforts can also provide these parties with critical information to properly evaluate the success of local plans and initiatives.

1.5 Economic Development

Local involvement in the provision of broadband is not only warranted to provide public services to residents, but to stimulate economic development (Bar and Park, 2006: 111; Gillett, 2006: 583). In this respect, information and communications technologies are viewed as a tool for economic development agencies to attract and retain local businesses (Bar and Park, 2006; 111). However, research findings suggest there are many subtleties associated with the adoption of ICTs by firms and the economic benefits accrued from the use of these technologies. These intricacies are likely to prove challenging to formulating strategic development plans that incorporate ICT infrastructure deployment.

Studies suggest the economic benefits associated with broadband are unlikely to accrue to all areas equally (Kolko, 2010). The findings of adoption studies also suggest the benefits of ICTs are unlikely to accrue to businesses uniformly, and that variations in benefits are related to firm size (Karshenas and Stoneman, 1993; Gibbs and Tanner, 1997; Forman 2005) and industry membership (Forman et al., 2005). For example, firm size plays a role because of differences in IT expertise and resources, which provide barriers to technology implementation for smaller firms (Gibbs, 2001). Small firms may also be unaware of the advantages of incorporating ICTs into their business processes (Center for an Urban Future, 2004). The adoption literature also finds firms in different sectors use ICTs in different ways (Forman et al., 2005) and therefore the productivity

gains associated with these technologies are likely to vary across firms in different sectors.

Quantitative insights about the impact of ICTs on firm location and the productivity of firms can provide key information to government and economic development officials about compositional impacts on their region and potential evaluation of economic development initiatives. Where composition is concerned, the determination of a strong relationship between the level of ICT infrastructure and firm presence in a particular industry means locales with little or no infrastructure may be at a relative disadvantage for attracting firms in specific industries. For example, if there is a strong relationship between ICT infrastructure and firms that produce knowledge as a primary output, locales without sufficient levels of this infrastructure may not be able to retain and attract firms in the knowledge sector.

From a measurement standpoint, the intensity of ICT use by firms in a region, which is likely related to industry membership, may cause common indicators of economic development to diverge. For example, if jobs and earnings are used to measure economic progress, one indicator may suggest more growth than the other. Regions with more technology intensive firms may have slower job growth but higher earnings growth, while regions with fewer technology intensive firms may have higher jobs growth and slower earnings growth. In this case, the jobs indicator for the technology intensive region might suggest little economic growth while the earnings indicator suggests a greater amount of economic growth. This potential for technology-related divergence in economic indicators presents an issue for measuring and benchmarking the growth and competitiveness of regions. Given the uncertain relationship between ICT-related

productivity gains and employment trends (Kolko, 2010), the potential divergence in economic indicator trends is certainly an important issue to examine.

1.6 Objectives and Research Structure

Concurrent advancements in ICTs and global integration pose several challenges to individuals charged with the task of creating and maintaining competitive regional economies. Given these challenges, this research seeks to inject some quantitative insights about ICTs, firm location, and regional development into a literature that remains largely theoretical and speculative.

The second chapter of this dissertation is a variation of a paper published in *Information Economics and Policy*. It explores the utility of short and mid-range broadband forecasts as potential tools for local economic development officials. This section of the dissertation seeks to answer the following three research questions:

1. Is it possible to development accurate yet parsimonious forecasts of broadband provision?
2. How does the treatment of space in forecasting models impact forecasting accuracy?
3. What are practical uses of broadband forecasts in policy and economic development?

Answers to these questions are expected to contribute to existing knowledge about models of broadband and are relevant to policymakers and academicians in economics, telecommunications, regional science and geography. As mentioned in section 1.3, the heterogeneous distribution of broadband reflects the confluence of multiple factors including geography, socio-economics, competition, and existing regulations at the national, state, and local levels. This complex set of factors casts doubt

on the ability to forecast the distribution of this technology. Therefore, an evaluation of broadband forecasts is certainly warranted.

The treatment of space in forecasting models also merits attention provided the complex role geography plays in the rollout of this technology. Although previous studies suggest geography plays a role in the distribution of broadband (Graham, 1999; Strover, 2001; Grubestic, 2002) they also demonstrate location is not the only determinant of provision. For example, a Grubestic (2006) demonstrates how the economics of broadband may render geography meaningless when determining places that are served, underserved, or unserved by providers. This study found some ZIP codes in urban areas or “islands of inequity” have lower levels of broadband access compared to surrounding ZIP codes because of high poverty levels in these urban ZIP codes. The second chapter will also discuss the practical uses of broadband forecasts to improve policy and economic development efforts. One of the arguments made is that broadband forecasts may be used to identify underserved areas and develop more informed, proactive policies and strategic development plans to ameliorate future disparities in broadband provision.

After the discussion of key factors relevant to forecasts of broadband provision, the third chapter of this dissertation evaluates the relationship between the spatial distribution of this infrastructure and the spatial distribution of firms in aggregate and in select industries. This chapter is a variation of a paper published in *Tijdschrift voor economische en sociale geografie*. It evaluates industry level variations in firm location related to the level of broadband provision in an area. In addition to addressing the general spatial relationship between firms and broadband, this chapter answers the following research questions:

1. Is there an intersection between areas that have experienced positive changes in broadband provision and areas that have experienced positive changes in the number of firms?
2. If a spatial relationship exists between broadband and firms, does it vary by firm size and industry?
3. Are places experiencing positive changes in broadband and number of firms located in central or suburban locations?
4. Are places with positive changes in broadband and firms clustered or more dispersed?

This exploratory analysis is important because it represents an inaugural attempt to address the potential impact of broadband access on firm location. A determination of statistically significant spatial relationships between broadband and firms also provides the foundation for additional spatial econometric analyses that address both causality and the importance of broadband to firms relative to other location factors.

The fourth and final substantive chapter of this dissertation is a variation of a paper submitted for publication consideration to *Applied Geography*. It explores the challenges associated with benchmarking regional economies given the pervasive and related technological and industrial changes in the U.S over the past thirty years. The primary research questions of this chapter are as follows:

1. Do different economic indicators present varied pictures of economic growth over the last three decades?
2. Do indicator growth trends vary over space, time, and the industrial classification industry of interest?

The analysis in this chapter is important because technological change continues to impact the industrial structure of regional economies and the productivity of jobs, yet, the manner in which their economic performance is measured is outdated. For example, many attempts to measure performance are univariate in nature and focus on employment or jobs as the primary measure of growth. However, firm and industry specific

productivity gains related to the increased use of ICTs may mean that some jobs are more productive than others and subsequently pay more than others. Thus, all jobs are not created equal. This divergence between earnings and job creation means many subtle but important differences in job quality are not captured by univariate measures of economic performance. A demonstration of the inaccuracies associated with univariate performance measurement can motivate the construction of more sophisticated composite measures of economic performance that are able to capture the multifaceted nature of economic growth and competitiveness in the global information economy. At the very least, it suggests improved performance measurement can be achieved by considering the growth trends of these indicators simultaneously rather than in isolation.

Combined, the results of this multi-scalar analysis provide important information regarding the measurement of regional competitiveness in the global information economy, as well as information about the spatial relationship between firm location and broadband provision. These insights will prove useful to current policy and economic development initiatives involving the deployment of ICT infrastructure. They will also provide potential insights about the impacts of future space-time shrinking technologies on regional economies. In sum, this dissertation presents new approaches for unraveling the impacts of advancements in information and communications technologies (ICTs) on regional economies, and their relative growth prospects in an increasingly integrated and competitive global business environment.

1.7 References

- Abbate, J. (1999). *Inventing the Internet*. Cambridge: The MIT Press.
- Abler, R. (1977). The telephone and the evolution of the American metropolitan system. In I. de S. Pool (Ed.), *The social impact of the telephone* (pp. 318-341). Cambridge: MIT Press.
- Applebaum, E., & Schetkatt, R. (1995). Are prices unimportant? The changing structure of the industrialized economies. *Journal of Post Keynesian Economics*, 21(3), 387-398.
- Bar, F., & Namkee, P. (2006). Municipal Wi-Fi networks: The goals, practices, and policy implications of the U.S. case. *Communications and Strategies*, 61, 107-125.
- Center for an Urban Future. (2004). *New York's Broadband Gap*. from www.nycfuture.org.
- Clark, D., Gillett, S., Lehr, W., Sirbu, M., & Fountain, J. (2002). Local government stimulation of broadband: effectiveness, e-government, and economic development. White Paper for Program on Digital Government. from http://itc.mit.edu/itel/docs/2002/White_Paper_NSF_DigGov.pdf.
- FCC. (2010). *FCC Broadband Deployment Data from Form 477*. from <http://www.fcc.gov/form477>.
- Forman, C. (2005). The corporate digital divide: determinants of Internet adoption. *Management Science*, 51(4), 641-654.
- Forman, C., Goldfarb, A., & Greenstein, S. (2005). How do industry features influence the role of location on Internet adoption? *Journal of the Association for Information Systems*, 6(12), 383-408.
- Fratesi, U., & Senn, L. (2009). Regional growth, connections and economic modeling: An introduction. In U. Fratesi & L. Senn (Eds.), *Growth and Innovation of Competitive Regions* (pp. 3-27). Berlin: Springer.
- Gibbs, D. (2001). Harnessing the information society? European Union policy and information and communication technologies. *European Urban and Regional Studies*, 8(1), 73-84.
- Gibbs, D., & Tanner, K. (1997). Information and communication technologies and local economic development policies: The British case. *Regional Studies*, 31, 765-774.

- Gillett, S. E. (2006). Municipal wireless broadband: hype or harbinger? *Southern California Law Review*, 79, 561-594.
- Gillett, S.E., Lehr, W.H., & Osorio, C. (2004). Local government broadband initiatives. *Telecommunications Policy*, 28, 537-558.
- Graham, S. (1999). Global grids of glass: On global cities, telecommunications and planetary urban networks. *Urban Studies*, 36, 929-949.
- Gordan, I.R., & McCann, P. (2000). Industrial clusters: Complexes, agglomeration and/or social networks? *Urban Studies*, 37(3), 513-532.
- Gorman, S.P. (2002). Where are the web factories: The urban bias of e-business location. *Tijdschrift voor Economische en Sociale Geografie*, 93(5), 522-36.
- Greenstein, S. (2005). The economic geography of Internet infrastructure in the United States. In M. Cave, S. Majumdar, & I. Vogelsang (Eds.), *Handbook of Telecommunication Economics, Volume II* (pp. 12-15). Amsterdam: Elsevier.
- Grubestic, T.H. (2002). Spatial Dimensions of Internet Activity. *Telecommunications Policy*, 26(7-8), 363-387.
- Grubestic, T.H. (2003). Inequities in the broadband revolution. *Annals of Regional Science*, 37, 263-289.
- Grubestic, T.H. (2004). The geodemographic correlates of broadband access and availability in the United States. *Telematics and Informatics*, 21(4), 335-58.
- Grubestic, T.H. (2006). A spatial taxonomy of broadband regions in the United States. *Information Economics and Policy*, 18, 423-448.
- Grubestic, T.H. (2008). The Spatial Distribution of Broadband Providers in the United States: 1999-2004. *Telecommunications Policy*, 32, (3-4), 212-233.
- Grubestic, T.H., & O'Kelly, M.E. (2002). Using points of presence to measure city accessibility to the commercial Internet. *Professional Geographer*, 54(2), 259-278.
- Grubestic, T.H., & Murray, A.T. (2004). Waiting for broadband: local competition and the spatial distribution of advanced telecommunication services in the United States. *Growth and Change*, 35(2), 139-165.
- H.R. 1. (2009). *American Recovery and Reinvestment Act of 2009*. from <http://www.govtrack.us/congress/bill.xpd?bill=h111-1>.

- Karshenas, M., & Stoneman, P.L. (1993). Rank, stock, order, and epidemic effects in the diffusion of new process technologies: an empirical model. *The RAND Journal of Economics*, 24(4), 503-528.
- Kolko, J. (2010). Does broadband boost local economic development. *Public Policy Institute of California*. from <http://www.pplic.org/main/publication.asp?i=866>
- Landefeld, J.S., & Fraumeni, B.M. (2001). Measuring the new economy. *Survey of Current Business*, March, 23-40.
- McCann, P. and Sheppard, S. (2003). The rise, fall and rise again of industrial location theory. *Regional Studies*, 37 (6-7), 649-663.
- Mack, E.A. (2010). Inter-metropolitan and intra-metropolitan location patterns of knowledge intensive firms (1999-2004). GeoDa Center and School of Geographical Sciences and Urban Planning, Arizona State University.
- Martin, R. (2006). Economic geography and the new discourse of regional competitiveness. In S. Bagchi-Sen & H.L. Smith (Eds.), *Economic geography: Past, present and future* (pp. 56-79). London: Routledge.
- Moss, M.L., & Townsend, A.M. (2000). The Internet backbone and the American metropolis. *The Information Society*, 16(1), 35-47.
- NTIA, (2009). *Broadband Technology Opportunities Program*. from <http://www.ntia.doc.gov/broadbandgrants/>.
- OSC [Ohio Supercomputer Center]. (2006). 2006 broadband Ohio study: Availability and cost of broadband Internet service options in Ohio. from <http://www.osc.edu/networking/broadband/index.shtml>
- O'Kelly, M.E., & Grubestic, T.H. (2002). Backbone topology, access, and the commercial Internet. *Environment and Planning B*, 29(4), 533-552.
- Pohjola, M. (2002). The new economy: facts, impacts and policies. *Information Economics and Policy*, 14, 133-144.
- Porter, M.E. (1998). Clusters and the new economics of competition. *Harvard Business Review*, 76, 77-90.
- Premkumar, G. (2000). Rural business and telecommunications technologies. In P.F. Korsching, P.C., Hipple, & E.A. Abbott (Eds.), *Having all the right connections: telecommunications and rural viability* (pp. 83-100). London: Praeger.

Richardson, R. & Gillespie, A. (1996). Advanced communications and employment creation in rural and peripheral regions: A case study of the highlands and islands of Scotland. *The Annals of Regional Science*, 30(1), 91-110.

Scott, A.J. (1998). *Regions and the World Economy*. Oxford: Oxford University Press.

Strover, S. (2001). Rural internet connectivity. *Telecommunications Policy*, 25, 331-347.

TA96 [Telecommunications Act of 1996]. (1996). Pub. LA. No. 104-104, 110 Stat. 56.

2. Forecasting Broadband Provision

2.1 Introduction

Despite the widespread provision of broadband telecommunications services, diverse levels of accessibility and competition exist, yielding a core-periphery landscape in the United States (Grubestic, 2008a). These persistent differences in deployment and competition have prompted local and regional evaluations of broadband availability and pricing. For example, both Orange County, California (CNOOC, 2006) and the State of Ohio (OSC, 2006) have undertaken comprehensive analyses of commercial and residential broadband deployment. These evaluations of development efforts strongly suggest that an expectation of broadband ubiquity is not yet realistic and the universal service goal set forth by the Telecommunications Act of 1996 (TA96) has not been achieved.

The recent creation of the Broadband Technology Opportunities Program (BTOP) with funds appropriated by the American Recovery and Reinvestment Act of 2009 (H.R. 1) provides additional evidence that disparities in access to broadband Internet connections persist, despite remedial efforts at the national, state, and local levels. The goal of the BTOP program is to allocate appropriated funds to “develop and expand broadband services to unserved¹ and underserved² areas and to improve access to

¹ The NTIA (2009) defines an underserved area for last mile projects as: “an area composed of one or more contiguous census blocks where at least one of the following is met: 1) no more than 50 percent of households in the proposed service area have access to facilities-based, terrestrial broadband service at greater than the minimum broadband speed broadband speed; 2) no fixed or mobile broadband service provider advertises broadband speeds of at least 3 Mbps downstream in the proposed funded service area; or 3) the rate of broadband subscribership for the proposed service area is 40 percent of households or less.”

² The NTIA (2009) defines an unserved area as: “an area, composed of one or more contiguous census blocks where at least 90 percent of households in the proposed funded service area lack access to facilities-based, terrestrial broadband service, either fixed or mobile, at the minimum broadband

broadband by public safety agencies” (NTIA, 2009). While research examining access to and use of the Internet spans more than a decade, the current need for the BTOP program suggests that gaps remain in existing knowledge about the distribution of these technologies. The current heterogeneous landscape of broadband distribution consequently reflects these gaps in knowledge, and explains why existing policies are unable to level an uneven landscape created by the deployment of Internet technologies by private interests in a competitive business environment.

Initial evaluations of broadband availability and access following the passage of the 1996 Act focused on the notion of the “digital divide” and its varied manifestations across demographic, socio-economic, and geographic lines (NTIA and RUS, 2000; Gabe and Abel, 2002). Initially, disparities were present at a variety of spatial scales including between urban and rural areas, (Strover, 2001; Grubestic and Murray, 2004), between metropolitan areas (Moss and Townsend, 2000), and within cities (Graham, 1999; Graham, 2002; Grubestic and Murray, 2002). Although the disparities between cities are gradually disappearing (Grubestic, 2006), the initial deployment of this infrastructure favored areas with existing ICT infrastructure (Grubestic, 2003).

Currently, the provision of broadband telecommunications services across the United States is no longer a simple bifurcation between urban and rural or rich and poor. Instead, the distribution is more complex, displaying high levels of spatial heterogeneity. This distribution reflects the confluence of the rollout of multiple broadband platforms by private, profit-oriented interests across regions with diverse social, demographic, and geographic profiles. As broadband becomes a necessity rather than a novelty for

speed.”

individuals and businesses around the globe it is more important than ever to understand the factors most pertinent to the evolution of broadband provision. The diversity in broadband initiatives and regulatory regimes across the United States suggest that this kind of analysis is regional in nature and will perhaps be left to economic development officials and local governments to unravel. Although an array of prior research evaluating broadband access, adoption and diffusion (Prieger and Hu, 2008; Wood, 2008; Hollifield and Donnermeyer, 2003; Downes and Greenstein, 2007; LaRose et al., 2007; Flamm and Chaudhuri, 2007) provide a list of factors impacting broadband provision, scholars have yet to evaluate the forecasting potential of these findings.

This chapter will leverage the findings of previous studies to forecast the spatial distribution of broadband provision. A combination of demographic, socio-economic, geographic, and supply side variables will be utilized in the development of cross-sectional linear and spatial econometric forecasting of broadband provision. ZIP code level forecasting models based on 2001 in-sample data will be developed for the state of Ohio. The forecasting ability of these models in future years (2002-2004) will be evaluated with broadband data kept out of sample from the model development process. Results of a comparative analysis of the cross-sectional linear and spatial econometric forecasting results find spatial econometric models provide more accurate forecasts than cross sectional linear models.

2.2 Broadband Provision Forecasts

Broadband forecasts are perhaps most commonly pursued in a telecommunications market planning context. However, forecasts of broadband provision may also be of importance to economic development agencies and local governments.

Both individuals and communities have a vested interest in the current and future distribution of broadband. This is especially true for the local business community. Broadband and other advanced telecommunications systems are considered enabling infrastructure because they enable or enhance productivity in several sectors including real estate, finance, computer services, and commerce (Zook, 2002; Grimes et al., 2007). The presence of high-speed Internet connections in communities is particularly salient for small to medium sized enterprises (SMEs) because they are more likely to rely on the speed and quality of existing broadband infrastructure than are their large business counterparts who have the financial resources to lease private high speed connections. Therefore, as regions seek to remain competitive players in the global information economy, access to quality telecommunications infrastructure with a choice of providers are increasingly important pieces to the puzzle.

As mentioned previously, the diversity in broadband initiatives and regulatory regimes throughout the United States, suggest a regional approach is necessary to understand and resolve current and future disparities in broadband provision. In particular, economic development agencies and local governments could use broadband forecasts to proactively pursue the goal of universal service set forth in the Telecommunications Act of 1996 (TA96), because of strong regional interests and the benefits associated with broadband. Further, broadband forecasts may be used to flag problematic areas, where broadband provision via traditional market mechanisms is doubtful, in an effort to tailor proactive policy-based intervention. The ability to identify these less competitive areas will permit interested parties to observe the interplay of social, economic, demographic, and geographic forces in these regions and develop

targeted, stimulus-like policies for broadband, instead of ad hoc solutions once disparities in provision become evident.

2.2.a Differentiating Broadband Provision from Broadband Demand and Diffusion

Before outlining the forecasting models utilized in this chapter it is necessary to outline the subtle yet distinct difference between forecasting the spatial distribution of broadband provision and forecasting the diffusion of broadband services or broadband demand. The most significant difference is that broadband provision *does not* equate to broadband adoption or diffusion. Although it is relatively safe to assume that broadband is “adopted” in places where it is made available, when forecasting provision there is no attempt to distinguish between *who* (e.g. residential or business users), *why* (e.g. motivations for using advanced services) or *how* (e.g. e-commerce, hosting, music downloads) broadband services are used. This effectively eliminates the considerations of issues associated with adoption and allows one to focus solely upon forecasting the presence and quantity of service providers in a given area.

Second, forecasting broadband provision requires a more comprehensive consideration of factors than does forecasting broadband demand because of the intricacies associated with provider market-entry. For example, the mere presence of the requisite demographic and socio-economic factors indicative of potential demand and probable adoption in an area do not necessarily equate to provider market-entry. In these cases, other factors such as location, market size, and the limitations associated with a particular technological platform (e.g. distance constraints for the provision of DSL) must be considered. In this context, forecasting the spatial distribution of broadband demand

sits on a unique axis. It is clearly related to both supply and demand-side determinants, but is also highly contingent upon the geographic composition of markets.

2.3 Modeling Framework

2.3.a Differences Between Forecasting Models and Explanatory Models

The forecasting models developed in this analysis are predictive rather than explanatory. This distinction is important because the development of predictive models diverges somewhat from the development of explanatory models. Shmueli (2009, 29) outlines the key differences between these two modeling approaches including evaluation criteria, performance metrics, and problems with model development. For example, the evaluation criteria used for explanatory models include goodness of fit and statistical significance while the evaluation criteria for predictive models include parsimony, predictive accuracy, and practical deployment (ibid). Other key differences between the two modeling approaches are the items Shmueli (2009) lists as “dangers” or key problems associated with each type of model. Over-fitting is listed as the principal danger when developing predictive models, while model misspecification and type I and II errors are listed as the principal dangers associated with explanatory modeling. Thus, while issues such as multicollinearity, endogeneity, and heteroskedasticity are critical to correct when developing explanatory models, correction of these issues is not necessarily critical for the development of good forecasting models.

The statistical models developed in this dissertation adhere to the notion that predictive models differ from explanatory models and thus an obedience to strict statistical principles in the modeling process is *not* as essential to forecasting as is the

ability of a specified model to accurately predict broadband provision. The modeling approach in this chapter recognizes these differences between explanatory and predictive models and focuses on developing practical, parsimonious models that produce the best forecasts of broadband provision. Therefore, the traditional concerns associated with explanatory models, such as model fit criteria, multicollinearity, and accurate measures of statistical significance are not the principal means by which model performance is evaluated. It is important to note however that the evaluation of models via predictive modeling criteria in lieu of explanatory criteria does not mean econometric theory is ignored in the model development process. In fact, the variables selected for inclusion in the model adhere to existing theory in both telecommunications and economics. The specification of the cross-sectional models and the spatial econometric models are also in line with existing econometric theory.

2.3.b Model Specification

This chapter will develop both cross-sectional linear and spatial econometric forecasting models of broadband provision and provide a comparative analysis of the results. Of principal interest is the ability of each of these types of models to capture the geographic intricacies associated with the distribution of broadband provision. Differences in forecast results are expected because of variations in their treatment of geographic space. Standard cross-sectional econometric models with spatial regimes differentiate geographic space with “dummy” variables. For example, if one is interested in discriminating between urban and rural locations, one can generate a relevant binary assignment variable (0, 1) as a control mechanism to differentiate discrete variation over space (Anselin, 1992; Grubestic, 2003). Although spatial regimes can be an effective

mechanism for parsing geographic space in standard regression models, they do not effectively account for spatial dependence between variable values amongst geographic neighbors (i.e. spatial autocorrelation) (Horrigan et al., 2006).³

Statistical models that account for spatial autocorrelation in the estimation process are commonly referred to as spatial econometric models and use maximum likelihood estimation to obtain coefficient estimates rather than ordinary least squares. One of the most significant benefits associated with explicitly spatial approaches to explanatory modeling is their ability to obtain more accurate estimates of the statistical significance of independent variables (Grubestic and Murray, 2004; Horrigan et al., 2006). Simply put, the failure to account for spatial autocorrelation produces biased standard errors that may overstate the significance of variables. Although type I and type II errors are not necessarily a concern for the development of forecasting models, the inclusion of additional spatial information via spatial econometric modeling, may improve forecasting accuracy. In this context, this chapter evaluates the viability of spatial econometric models for forecasting purposes. Specifically, the ability of spatial econometric models to incorporate additional information regarding the spatial aspect of the data generating process is explored as compared to models that fail to include spatial information or use the more simplistic strategy of incorporating spatial regimes or spatial dummy variables in forecasting models.

³ The presence of spatial autocorrelation may be identified using several exploratory statistical approaches. In this chapter, the global Moran's I (Moran, 1948) and the local Moran's I (Anselin, 1995) were utilized to examine spatial autocorrelation in each of the developed models. The specification of these two statistics may be found in Appendix A of this document.

In an effort to highlight the major differences between aspatial statistical modeling approaches, simplistic spatial modeling approaches using spatial regimes, and spatial econometric models, consider the following notation:

β is a $k \times 1$ vector of parameters

X is a $n \times k$ matrix of exogenous variables

ρ coefficient of spatially lagged dependent variable y

λ coefficient in an error term with a spatial autoregressive structure

μ is a normally distributed error term with a diagonal covariance matrix, Ω

z are the diagonal elements of the covariance matrix which are a function of $p + 1$ exogenous variables, including the constant term

W_1 and W_2 are $n \times n$ row standardized weights matrices

The general linear model, the spatial lag, and the spatial error model may all be derived from the following general expression (Anselin, 1988):

$$y = \rho W_1 y + X\beta + \varepsilon \quad (1)$$

where

$$\varepsilon = \lambda W_2 \varepsilon + \mu$$

and

$$\mu \sim N(0, \Omega),$$

$$\Omega_{ii} = h_i(z\alpha) \quad h_i > 0$$

In the event of homoskedasticity ($\alpha = 0$) and no spatial dependence in values of the dependent variable ($\rho = 0$) or in the error term ($\lambda = 0$) equation (1) simplifies to a standard linear regression model which may be estimated with ordinary least squares (Anselin, 1988):

$$y = X\beta + \varepsilon \quad (2)$$

If spatial autocorrelation is present in values of the dependent variable but the errors in the variance-covariance matrix are homoskedastic ($\alpha = 0$) and there is no

additional spatial autocorrelation in the error term ($\lambda = 0$), equation (1) becomes a spatial lag model:

$$y = \rho W_1 y + X\beta + \mu, \quad (3)$$

where

$$\mu \sim N(0, \Omega)$$

The value of ρ in this model provides an estimate of the amount of spatial dependence in the dependent variable values. Equation (1) may also be specified as a spatial error model if no spatial autocorrelation is present in the dependent variable ($\rho = 0$) and the errors are homoskedastic ($\alpha = 0$). In this case, (1) may be rewritten as follows (Anselin, 1988):

$$y = X\beta + \lambda W_2 \varepsilon + \mu \quad (4)$$

Equation (4) divides the error term into two components, an autoregressive portion that represents the autocorrelated part of the error term (λ) and a residual that contains no autocorrelation (μ) and is independently and identically distributed (i.i.d) (Odland, 1988). In general, the spatial lag model deals specifically with spatial autocorrelation in the dependent variable while the spatial error model addresses unknown causes of spatial autocorrelation. Odland (1988) notes spatial autocorrelation may be a reflection of spatial processes or may be the result of the omission of an important dependent variable or functional form misspecification.

Cross sectional linear models with spatial regimes, spatial lag and spatial error models will be developed using in sample data for 2001. Coefficient estimates from the in-sample model for 2001 will be used to produce forecasts of broadband provision in 2002, 2003, and 2004. This includes the coefficient estimates on ρ and λ from the spatial lag and spatial error models respectively, as well as the lagged values of the

dependent variable and the lagged value of the error term calculated in the estimation of the in-sample models. In this context, equations 2, 3 and 4 may be rewritten as forecasting models in the following manner:

$$y_{t+n} = X_t \beta_t + \varepsilon_{t+n} \quad (5)$$

$$y_{t+n} = \rho_t W_t y_t + X_t \beta_t + \mu_{t+n} \quad (6)$$

$$y_{t+n} = X_t \beta_t + \lambda_t W_t \varepsilon_t + \mu_{t+n} \quad (7)$$

where:

t corresponds to the year 2001

$n \geq 1$ and ≤ 3 and corresponds to each of the forecast years (2002-2004)

β is a $k \times 1$ vector of parameters that includes spatial regimes

X is a $n \times k$ matrix of exogenous variables

ρ coefficient of spatially lagged dependent variable y

λ coefficient in an error term with a spatial autoregressive structure

μ is a normally distributed error term with a diagonal covariance matrix, Ω

z are the diagonal elements of the covariance matrix which are a function of $p + 1$ exogenous variables, including the constant term

W_t is an $n \times n$ row standardized queen weights matrices

Equation 5 corresponds to a standard linear forecasting model that uses spatial regimes to capture geographic aspects of broadband provision. Equation 6 is a spatial lag forecasting model that utilizes spatial regimes *and* a spatial lag constructed with a queen contiguity weight matrix⁴ that provides information about broadband provision in neighboring ZIP codes for each ZIP code in the dataset. A first-order queen weights matrix was selected over other possibilities such as a first-order rook weights matrix or a distance based weights matrix to account for *all* ZIP codes in the *immediate* neighborhood of each ZIP code. A rook weights matrix was not selected because of the irregular nature of ZIP codes

⁴ A queen contiguity matrix is a matrix that contains information about broadband provision in neighboring ZIP codes where a ZIP code's neighbors are defined according to the movements a queen can make in the game of chess. For additional information about the queen contiguity weight matrix and other kinds of weight matrices see Grubesic (2006).

and its potential to exclude neighboring ZIP codes that are contiguous at a point but are not necessarily to the north, south, east, or west of the ZIP code of interest. Distance based weights matrices were not considered because they potentially include more ZIP codes than those to contiguous the ZIP code of interest; as long as a ZIP code is within the distance specified, it is counted as a neighbor in the weights matrix. Because the study is interested in the impact of a ZIP code's level of provision on *all* ZIP codes contiguous to the ZIP code of interest, the queen weights matrix is deemed optimal over the other possibilities.

Equation 7 is the specification of a spatial error forecasting model that includes spatial regimes in the vector of covariates and a lag of the error term constructed with a queen contiguity weight matrix. As stated previously, this model incorporates information about the error terms in neighboring ZIP codes and thus does not provide as explicit information about the spatial nature of the data generating process as does the spatial lag model. Instead, it addresses spatial autocorrelation more generally. The implications for forecasting of explicit spatial information via a spatial lag model as compared to more implicit spatial information via a spatial error model will be discussed more extensively in sections 2.4 and 2.5.

2.3.c Forecast Performance Evaluation

The three models specified in equations 5-7 will be used to generate forecasts of broadband provision for 2002, 2003, and 2004 using data kept out of sample in the initial estimation process. The predictive performance of the models will be evaluated with the

mean absolute percentage error metric (MAPE) which is specified as follows (Madden and Tan, 2007):

$$APE_i = \left| \frac{F_i - A_i}{A_i} \right| \quad (8)$$

where:

F_i is the forecasted number of providers in ZIP code area i

A_i is the actual number of providers in ZIP code area i .

The MAPE is calculated by finding the mean of the APE_i (Madden and Tan, 2007)⁵:

$$MAPE_i = (\overline{APE_i}). \quad (9)$$

Forecasting models should try and minimize the value of their MAPE; higher MAPE values indicate more forecast error. A major advantage of this metric over alternative mean squared error performance metrics is that it is invariant with scale and robust to outliers (Madden and Tan, 2007).

2.3.d Study Area

The state of Ohio is the study area of interest for this analysis. Ohio provides an interesting case study because it contains a significant level of socio-economic, demographic and geographic diversity (Figure 2.1). While it is well-known for its large urban centers (e.g. Cleveland, Columbus, Cincinnati), Ohio also has a range of medium (Akron, Toledo, Dayton) and small (Findlay, Lima, Newark) urban centers. These demographically and economically diverse metropolitan components present a strong

⁵ For some observations, the APE was undefined because the actual number of providers in that year was zero. Where this occurred, only those observations for which the APE was defined were used in the calculation of the MAPE.

contrast to the 29 counties comprising Appalachian Ohio. These counties are largely rural in character, are economically depressed and demographically homogenous (Grubestic, 2003). In sum, Ohio provides an excellent landscape from which to study broadband provision and develop forecasting tools.

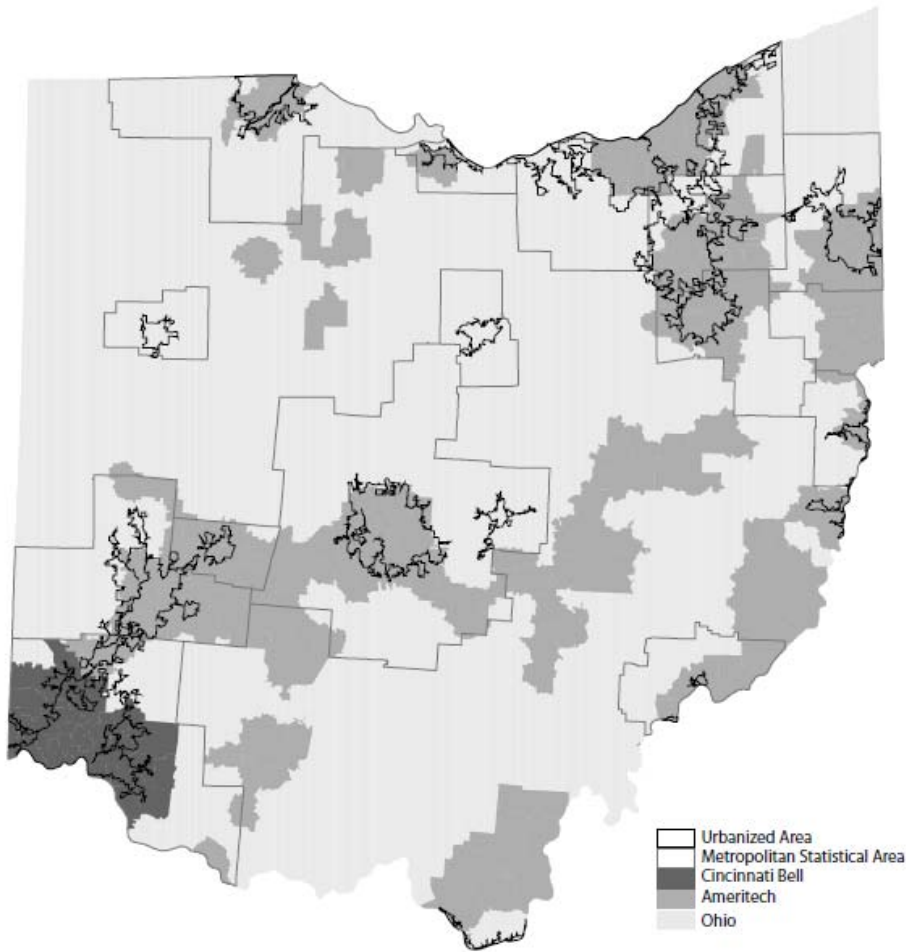


Figure 2.1: Urbanized Areas, Metropolitan Statistical Areas and Incumbent Local Exchange Carrier (ILEC) Areas in Ohio

2.3.e Data

The variables selected for use in this chapter leverage the covariates used in numerous studies that have investigated several aspects of Internet access and usage (NTIA 1998, 1999, 2000), broadband demand (Duffy-Deno, 2003; Prieger and Hu,

2008), broadband access (Prieger, 2003; Flamm and Chaudhuri, 2007), broadband availability (Flamm, 2005), and the spatial distribution of broadband (Grubestic, 2003; Grubestic and Murray, 2004; Grubestic, 2006; Grubestic, 2008a). Variables included in the specified forecasting models seek to address a variety of potential factors responsible for a heterogeneous distribution of broadband provision including demand side factors, supply side factors, and geographic factors. Table 2.1 provides a summary list of these variables with their definitions, descriptions, and hypothesized signs. Appendix 2.B provides descriptive statistics for these variables in Ohio and the rest of the continental United States. A comparison of the descriptive statistics illustrates Ohio is similar to the rest of the continental United States with respect to household density, number of establishments, median income, and population growth between 2000 and 2001. Interestingly, Ohio has higher average levels of broadband provision from 2001-2004. It also has a higher proportion of ZIP code areas located within metropolitan statistical areas. In 1999 Ohio had 60% of all ZIP code areas in MSAs compared to 46% for the continental U.S. This difference in MSA ZIP code area membership highlights an important regional characteristic of Ohio, and reemphasizes the need for a comprehensive regional approach (e.g. spatial econometric models) to evaluating and forecasting broadband provision.

Variable	Status	Definition	Description	Sign
<i>2001 Providers</i>	Dependent	Broadband provision status by ZIP code area.	Measure of broadband provision	N/A
<i>2001 Household Density</i>	Independent	Household density per square mile in ZIP code areas	Tests the effect of market density on broadband provision	+
<i>2001 Establishments</i>	Independent	Number of business establishments in each ZIP code area	Tests the effect of business presence on broadband service provision	+
<i>2001 Median Income</i>	Independent	Median Income	Tests broadband provision relative to different income levels	+
<i>2000 Providers</i>	Independent	Number of broadband providers in each ZIP code area (Dec. 2000)	Lagged broadband provider data	+
<i>Growth (2000-2001)</i>	Independent	Percent population growth in each ZIP code area (2000 - 2001)	Test the effect of market growth on broadband service provision	+
<i>Urban Area Membership*</i>	Independent	ZIP code area inside Census defined urbanized area (=1); ZIP code area not inside an urbanized area (=0).	Proxy variable for location (urban v. rural)	+
<i>MSA Membership**</i>	Independent	ZIP code area inside or intersecting Census defined metropolitan statistical area	Proxy variable for location (urban v. rural)	+
<i>ZIP Code Area (in miles)</i>	Independent	Size of ZIP code area in square miles	Proxy variable for estimating the spatial extent of observation areas	-
<i>Ameritech***</i>	Independent	ZIP code area inside Ameritech/SBC service areas	Accounts for NE and Central Ohio's largest incumbent local exchange carrier (ILEC)	-
<i>Cincinnati Bell***</i>	Independent	ZIP code area inside Cincinnati Bell service areas	Accounts for SW Ohio's largest incumbent local exchange carrier (ILEC)	-

* An urbanized area consists of core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile (Census Bureau, 2002). For more information, see http://www.census.gov/geo/www/ua/ua_2k.html

** The general concept of a metropolitan statistical area is that of a large population nucleus, together with adjacent communities, having a high level of social and economic integration with that core. Metropolitan areas comprise one or more complete counties. For more information, see <http://www.census.gov/population/www/estimates/metroarea.html>.

*** ILEC service areas were geographically defined by using wire-center service boundaries and switch data from Telcordia.

Table 2.1: Variable Descriptions

2.3.e.1 Dependent Variable

The dependent variable for all of the forecasting models is the number of broadband providers in a ZIP code area, culled from the Form 477 data from the Federal Communications Commission (FCC). This information is collected semi-annually and aggregated to the ZIP code level.⁶ Form 477 data require that any facilities-based provider with 250 or more terrestrial or wireless broadband lines (in a given state) report basic information about its services and customer base. For the purposes of this chapter, the analysis is limited to the yearly level, utilizing data collected in December 2000 – 2004. Data for 2000 and 2001 were retained in-sample for model development. Broadband data from 2002-2004 were kept out of sample for forecasting purposes. Data are masked in ZIP code areas that have fewer than four providers - with the FCC simply denoting these areas as “active”.⁷ As with previous studies (e.g. Grubestic, 2006), a conservative value of 1 is used for active but masked ZIP codes. A temporal lag of broadband provision was also included as a dependent variable to evaluate the impact of past provision on current levels.

2.3.e.2 Demand Side Independent Variables

Several demographic and socio-economic variables are cited as relevant to broadband demand, and thus the potential profitability of deploying broadband infrastructure. Variables that describe aspects of broadband demand were obtained from a

⁶ There are inherent limitations associated with the use of ZIP code areas for analysis. For more details, see Grubestic (2008b).

⁷A sensitivity analysis for the assumption of one provider for ZIP codes with fewer than four providers was conducted on the linear and spatial econometric models. Two alternative assumptions were evaluated for ZIP codes with suppressed information. The first is a change in the assumption of one provider, to two. The second is the generation of random numbers, between one and three, for each of the suppressed ZIP code areas. These changes in the original assumption produced no change in model results.

dataset provided by the Environmental Systems Research Institute (ESRI) which includes 2001 demographic and socio-economic estimates for all ZIP code areas in the United States. The use of updated estimates, rather than Census 2000 data, provides a more accurate and realistic representation of demographic, economic and social change for the state of Ohio during our study period.⁸

The variables utilized as proxies for broadband demand include household counts, median income and population. Specifically, household and population data were modified to create metrics for household density and the population growth rate for each ZIP code area between 2000 and 2001. The number of establishments in a ZIP code is also included as a business measure of demand in the model. These data were collected for 2001 from ZIP Code Business Patterns from the U.S. Census Bureau (2009a). It is also important to note that although multicollinearity is not a concern for predictive models (Shmueli, 2009); the inclusion of several related determinants does impact parsimony, which is a concern for predictive models (ibid), and is therefore avoided. For example, the establishments variable (used) was correlated with several other potentially useful independent variables including white population, Asian population, population Age 0-17, population Age 65 +, and population by gender (not used).

2.3.e.3 Location Indicator Independent Variables

Previous studies examining the distribution of broadband and its demand side determinants have demonstrated that geography impacts provision levels. To this end, several spatial regime variables are included to capture the impact of geographic

⁸ For a more detailed explanation of the ESRI updates and their associated methods, see <http://www.esri.com/library/whitepapers/pdfs/demographic-update-methodology.pdf>

heterogeneities on broadband forecasts. For example, one must be able to account for elements of urban morphology, therefore, ZIP code areas whose centroids were contained within Census defined urbanized areas⁹ (U.S Census Bureau, 2009b) were flagged as “urban”. Other geographical factors impacting broadband provision include metropolitan statistical area (MSA) membership and the area of a ZIP code in square miles. These variables were considered because they capture important subtleties of location not captured by the urban area variable. For example, MSA membership¹⁰ includes many ZIP code areas that exhibit more suburban or exurban locational profiles, but are still economically linked to a core urban area¹¹. The inclusion of ZIP code area (size in square miles) helps to control for non-standardized geographic units. Specifically, larger ZIP code areas have less concentrated consumer demand for broadband which often increases the cost of providing broadband to these areas and likely decreases coverage ubiquity. Larger ZIP code areas also correspond to more rural locations, which often experience lower levels of provision and platform choice than urban ZIP code areas (Grubestic, 2008a).

2.3.e.4 Supply Side Independent Variables

Finally, basic supply-side determinants are needed to better frame both broadband competition and provision. While the cost of broadband service and connection speeds

⁹ The U.S Census Bureau defines an urbanized area as “a large central place and adjacent densely settled census blocks that together have a total population of at least 50,000” (U.S Census Bureau, 2009b).

¹⁰ ZIP codes whose centroid was contained within a metropolitan statistical area (MSA) polygon (U.S Census Bureau, 2009c) were flagged as MSA member ZIP codes.

¹¹ This linkage may change depending on the definition of a metropolitan statistical area over time as defined by the Office of Management and Budget (OMB). The forecasting models developed in this study are constrained to the 1999 MSA definitions (U.S. Census Bureau, 2009c). However, this study recognizes the dynamic nature of these definitions, such as the 2003 change in MSA definitions, is a likely source of forecast error and recommends that if possible, definitional changes be accounted for in forecasting models.

are generally not available in publicly available databases, including the existing FCC Form 477 data, one can account for the presence of specific providers, particularly incumbent local exchange carriers (ILECs) or major cable providers. The impact of the presence of two ILECs which have been particularly aggressive in deploying xDSL in Ohio on broadband provision, Ameritech and Cincinnati Bell, are considered in this study. Ameritech is the largest xDSL provider in Ohio while Cincinnati Bell has been the most aggressive in deploying this platform in the southwestern Ohio metropolitan complex. In fact, “Cincinnati Bell’s xDSL service completely dominates the outlying communities of Cincinnati and southwest Ohio, particularly Clermont County and the western portions of Hamilton County” (Grubestic, 2003). Prior studies have used ILEC dummy variables as indicators of competition for broadband in a given area (Grubestic, 2003; Prieger, 2003) and this study will do the same. Dummy variables for Ameritech and Cincinnati Bell were derived from wire center data provided by GDT, now Tele Atlas. ZIP code areas whose centroids were within a wire center area for one of these providers were assigned a one. It is expected the presence of these aggressive xDSL providers will have a negative impact on broadband provision, effectively eliminating competition from competitive local exchange carriers (CLECs) and suppressing competition from cable providers in some areas.

2.4 Results

Twenty-eight linear regression models were developed using various combinations of variables from Table 2.1 and their forecasting ability evaluated according to the value of their mean absolute percent errors (MAPEs). These models were sorted from lowest

MAPE to highest MAPE for each of the study years (2001-2004) and a rank was assigned to each model in each year. After the ranks were assigned, the percent increase in forecast error for each rank was calculated. For example, the forecast error increased by 7.74% if one elected to use model 15 for a forecast in 2004 instead of the highest ranked model (1). Based on their performance, as specified by their MAPE derived ranks, four linear regression models were selected for further analysis and spatial econometric estimation. Table 2.2 displays the forecast error and ranks for each of these models for each of the years in the study period. Model 1 produced the best results for a model fitted to in-sample data in 2001. Models 2, 3 and 4 produced the best forecasts for 2002, 2003 and 2004 respectively.

	MAPE 2001	MAPE 2002	MAPE 2003	MAPE 2004	Rank 2001	Rank 2002	Rank 2003	Rank 2004
Model 1	0.4870	0.6247	0.6635	0.6880	1	2	10	16
Model 2	0.4872	0.6241	0.6526	0.6548	2	1	3	8
Model 3	0.5096	0.6334	0.6488	0.6333	12	5	1	6
Model 4	0.5281	0.6409	0.6649	0.6299	21	15	11	1

Table 2.2: Best Forecast Models

2.4.a Linear Regression Forecasts

The specifications for Models 1-4 along with their spatial econometric counterparts are displayed in Tables 2.3-2.6. Overall, variables display the expected sign listed in Table 2.1 with a few minor exceptions, including household density, Ameritech, and ZIP code area. The unstable sign on household density is most likely related to the small size of this coefficient. The sign on Ameritech is somewhat surprising but may

indicate disparities in ILEC impacts on broadband provision. Specifically, because Ameritech is such a large Regional Bell Operating Carrier, it is less aggressive (or unable) to effectively suppress competition in certain parts of its operating area, particularly dense urban environments where competition is stiff. This stands in stark contrast to Cincinnati Bell, which retains the hypothesized negative coefficient. The positive sign for ZIP code area suggests that larger ZIP codes are linked to higher provision levels, but this does not indicate that provision is distributed homogeneously within a ZIP code area (Prieger and Hu, 2006; Grubestic, 2008c). Overall, broadband provision in 2000 has a large impact on broadband forecasts and is perhaps the most important indicator of provision in future years. This is an important result because it confirms the findings of past studies which discovered a degree of spatial inertia to broadband provision, particularly in underserved urban areas which are leapfrogged in favor of more profitable suburban markets (Grubestic, 2006). Finally, population growth between 2000 and 2001 was also an important variable for 2002 and 2003 forecasts.

	Model 1	Model 1 Spatial Lag	Model 1 Spatial Error
Constant	-0.0821	-0.0714	-0.0195
<i>t-value/z-value²</i>	-0.5724	-0.5054	-0.1288
2000 Providers	0.6609	0.6252	0.6682
<i>t-value/z-value²</i>	18.3226**	17.04796**	18.3619**
2001 Household Density	-4.4006E-05	-2.1425E-04	-8.6726E-05
<i>t-value/z-value²</i>	-0.6172	-1.7481	-0.7930
2001 Establishments	0.0034	0.0033	0.0033
<i>t-value/z-value²</i>	20.0824**	20.31691**	20.2099**
2001 Median Income	1.2691E-05	7.3612E-06	1.0590E-05
<i>t-value/z-value²</i>	3.4068**	1.9519*	2.7506**
Growth (2000-2001)	11.3510	9.0849	10.6164
<i>t-value/z-value²</i>	3.9889**	3.2110**	3.5083**
Urban Area Membership	0.1861	0.0515	0.1426
<i>t-value/z-value²</i>	1.3631	0.3761	1.0183
MSA Membership	0.4494	0.3466	0.4457
<i>t-value/z-value²</i>	4.8597**	3.7240**	4.4542**
Cincinnati Bell	-1.0786	-0.9004	-0.9999
<i>t-value/z-value²</i>	-6.3572**	-5.3025**	-5.2926**
Rho		0.1276	
<i>t-value/z-value²</i>		4.7627**	
Lambda			0.1265
<i>t-value/z-value²</i>			3.1108**
Adjusted R-Squared/Pseudo R-Squared	0.7263	0.7342	0.7312
AIC	4184.93	4162.75	4174.6
BIC	4230.84	4213.77	4220.51
Log likelihood	-2083.46	-2071.37	-2078.30
Moran's I¹	0.0668 (-0.0008) [0.0010]	-0.0124 (-0.0008) [0.2700]	-0.0047 (-0.0008) [0.4430]

** Significant at the 1% level.

1. Expected values shown in parentheses; p-values shown in brackets.

2. t-values are for the cross-sectional linear models, z-values are for the spatial econometric models.

Table 2.3: Model 1 Estimation Results for 2001

	Model 2	Model 2 Spatial Lag	Model 2 Spatial Error
Constant	-0.1364	-0.1175	-0.0746
<i>t-value/z-value²</i>	-0.9454	-0.8263	-0.4902
2000 Providers	0.6436	0.6124	0.6504
<i>t-value/z-value²</i>	17.6435**	16.5885**	17.6864**
2001 Household Density	-6.1274E-05	-1.3657E-04	-7.6919E-05
<i>t-value/z-value²</i>	-0.8588	-1.8973	-1.0564
2001 Establishments	0.0033	0.0033	0.0033
<i>t-value/z-value²</i>	19.9960**	20.2420**	20.1063**
2001 Median Income	1.3390E-05	8.1990E-06	1.1175E-05
<i>t-value/z-value²</i>	3.5972**	2.1709*	2.9056**
Growth (2000-2001)	12.0609	9.7875	11.3727
<i>t-value/z-value²</i>	4.2345**	3.4479**	3.7512**
Urban Area Membership	0.1213	0.0034	0.0743
<i>t-value/z-value²</i>	0.8790	0.0245	0.5249
MSA Membership	0.3991	0.3092	0.3914
<i>t-value/z-value²</i>	4.2509**	3.2860**	3.8529**
Ameritech	0.2887	0.2424	0.3156
<i>t-value/z-value²</i>	2.8465**	2.4044*	2.9537**
Cincinnati Bell	-0.8942	-0.7540	-0.80149
<i>t-value/z-value²</i>	-4.9364**	-4.1902**	-4.0045**
Rho		0.1216	
<i>t-value/z-value²</i>		4.5100**	
Lambda			0.1296
<i>t-value/z-value²</i>			3.1902**
Adjusted R-Squared/Pseudo R-Squared	0.7279	0.7354	0.7331
AIC	4178.78	4158.94	4167.91
BIC	4229.8	4215.05	4218.93
Log likelihood	-2079.39	-2068.47	-2073.96
Moran's I¹	0.0685 (-0.0008) [0.0010]	-0.0077 (-0.0008) [0.3690]	-0.0050 (-0.0008) [0.4230]

** Significant at the 1% level.

* Significant at the 5% level.

1. Expected values shown in parentheses; p-values shown in brackets

2. t-values are for the cross-sectional linear models, z-values are for the spatial econometric models

Table 2.4: Model 2 Estimation Results for 2001

In addition to provision in 2000 and population growth between 2000 and 2001, spatial regime variables and supply side variables related to ILECs were also very important to forecast accuracy. All of the best performing model specifications contained

at least one of these metrics. That said, there are two important interpretive aspects of these metrics worth identifying when comparing model performance ranks in Table 2.2 with the detailed results from Tables 2.3-2.6. First, all four models contain some sort of spatial regime variable. This is an important finding because it suggests that the incorporation of these variables lowers forecast error.¹² Results also suggest that spatial regime variables become more important for longer forecast horizons. For example, in 2001 the third ranked model contained the following demand side variables: number of establishments, median income, number of providers in 2000, and population growth between 2000 and 2001. By 2004, this same model was ranked 17th overall. Interestingly, all of the models displaying superior performance (reflected by the rankings), contained at least one spatial regime variable.

¹² A sensitivity analysis of all twenty-eight model specifications with their respective forecast errors confirms the importance of spatial regime variables; models with these variables have lower forecast errors.

	Model 3	Model 3 Spatial Lag	Model 3 Spatial Error
Constant	-0.6075	-0.6930	-0.4510
<i>t-value/z-value²</i>	-3.8434**	-4.464**	-2.7576**
2000 Providers	0.6450	0.5942	0.6455
<i>t-value/z-value²</i>	17.9847**	16.5847**	17.8368**
2001 Household Density	1.2236E-04	3.5525E-05	1.2313E-04
<i>t-value/z-value²</i>	1.6599	0.4882	1.6269
2001 Establishments	0.0029	0.0028	0.0028
<i>t-value/z-value²</i>	16.3772**	16.2958**	16.1476**
2001 Median Income	2.1031E-05	1.3413E-05	1.6628E-05
<i>t-value/z-value²</i>	5.7043**	3.6640**	4.3178**
Growth (2000-2001)	11.3164	7.6974	10.3718
<i>t-value/z-value²</i>	4.0322**	2.7818**	3.3634**
Urban Area Membership	0.4797	0.3035	0.3730
<i>t-value/z-value²</i>	3.5175**	2.2709*	2.6567**
ZIP Code Area (in miles)	0.0087	0.0103	0.0095
<i>t-value/z-value²</i>	7.5431**	8.9821**	8.4415**
Ameritech	0.4144	0.3263	0.4325
<i>t-value/z-value²</i>	4.2187**	3.3861**	4.0679**
Cincinnati Bell	-0.7657	-0.5901	-0.6243
<i>t-value/z-value²</i>	-4.3361**	-3.4153**	-3.0164**
Rho		0.1806	
<i>t-value/z-value²</i>		7.0603**	
Lambda			0.2014
<i>t-value/z-value²</i>			5.0966**
Adjusted R-Squared/Pseudo R-Squared	0.7362	0.7504	0.7456
AIC	4140.81	4092.33	4115.05
BIC	4191.83	4148.45	4166.07
Log likelihood	-2060.41	-2035.16	-2047.53
Moran's I¹	0.1041 (-0.0008) [0.0010]	-0.0055 (-0.0008) [0.4060]	-0.0116 (-0.0008) [0.2510]

** Significant at the 1% level.

* Significant at the 5% level.

1. Expected values shown in parentheses; p-values shown in brackets

2. t-values are for the cross-sectional linear models, z-values are for the spatial econometric models

Table 2.5: Model 3 Estimation Results for 2001

A second important facet regarding the specifications of Models 1-4 is that minor amendments in variable combinations can produce improvements in forecast error.

Consider, for example, the performance of Model 4. This model provides the best

forecast for 2004, but is not the best fit to the in-sample data in 2001, nor does it perform particularly well for 2002 or 2003. Alternatively, Model 1 is the best fit to the in-sample data in 2001 but forecasts rather poorly in 2003 and 2004. The differences in the performances of these models highlight an important distinction in model specification when using spatial regime and supply-side dummy variables. Specifically, all of the best performing models highlighted for each year (2001-2004) include identical demand side variables. However, model composition varies with respect to their spatial regimes and their supply side dummies. While Model 1 contains all variables listed in Table 2.1 (excluding ZIP code area and Ameritech), Model 4 contains all variables but urban area and Cincinnati Bell. These minor differences strongly suggest that different spatial regimes and supply side determinants capture markedly different aspects of broadband provision. As a result, their inclusion and associated combination should be carefully considered when developing forecast models. At the very least, it is safe to say that models built with demand side variables alone are bound to miss important nuances relevant to current and future distributions of broadband.

	Model 4	Model 4 Spatial Lag	Model 4 Spatial Error
Constant <i>t-value/z-value</i> ²	-0.7247 -4.5462**	-0.7789 -4.9860**	-0.5583 -3.3732**
2000 Providers <i>t-value/z-value</i> ²	0.6564 18.7287**	0.5997 17.0670**	0.6496 18.3926**
2001 Household Density <i>t-value/z-value</i> ²	1.2281E-04 1.8129	2.2930E-05 0.3404	1.1528E-04 1.6371
2001 Establishments <i>t-value/z-value</i> ²	0.0028 16.5231**	0.0027 16.3722**	0.0027 16.2095**
2001 Median Income <i>t-value/z-value</i> ²	1.6808E-05 4.5656**	1.0081E-05 2.7648**	1.2896E-05 3.3511**
Growth (2000-2001) <i>t-value/z-value</i> ²	11.9017 4.2740**	8.2650 3.0067**	10.8556 3.5317**
MSA Membership <i>t-value/z-value</i> ²	0.4868 5.3776**	0.3693 4.1567**	0.4732 4.6171**
ZIP Code Area (in miles) <i>t-value/z-value</i> ²	0.0094 8.1857**	0.0109 9.5880**	0.0100 8.9414**
Ameritech <i>t-value/z-value</i> ²	0.5070 5.4678**	0.3937 4.3094**	0.4763 4.6589**
Rho <i>t-value/z-value</i> ²		0.1794 7.0091**	
Lambda <i>t-value/z-value</i> ²			0.2135 5.4303**
Adjusted R-Squared/Pseudo R-Squared	0.7372	0.7510	0.7476
AIC	4135.43	4087.01	4104.57
BIC	4181.3500	4138.03	4150.49
Log likelihood	-2058.72	-2033.5	-2043.29
Moran's I¹	0.1153 (-0.0008) [0.0010]	0.0015 (-0.0008) [0.4190]	-0.0133 (-0.0008) [0.2760]

** Significant at the 1% level.

* Significant at the 5% level.

1. Expected values shown in parentheses; p-values shown in brackets

2. t-values are for the cross-sectional linear models, z-values are for the spatial econometric models

Table 2.6: Model 4 Estimation Results for 2001

2.4.b Spatial Econometric Forecasts

Table 2.7 provides a forecast performance summary for each of the four models of interest as well as their spatial lag and spatial error counterparts. A perfunctory evaluation of this table suggests the spatial lag models produce the lowest forecast error,

the spatial error model produces the second lowest forecast error, and the linear regression models with spatial regimes produce the highest forecast error. This suggests that despite including spatial regimes in standard linear regressions, forecast error can be further reduced by including additional spatial information in the form of a spatial lag or spatial error model. That said, more explicit information about spatial processes, such as those modeled using spatial lags, is more effective in reducing forecast error than non-specific spatial error models. The reason for this is rather intuitive. Spatial error models do not contain specific information about spatial processes because they lag the error term, which can be a combination of several types of modeling error (e.g. lack of an important independent variable, functional form misspecification, etc). Conversely, the spatial lags incorporated in Models 1-4 reveal a key factor in predicting the distribution of broadband provision: the distribution of broadband in adjacent ZIP code areas. Specifically, if one's adjacent ZIP code areas, j , lack broadband, it is more likely that the ZIP code of interest, i , will also lack provision. The reverse is also true. If neighboring ZIP code areas display high levels of broadband provision, the ZIP code area of interest is also more likely to have higher levels of provision.

	2001	2002	2003	2004
Model 1	0.4870	0.6247	0.6635	0.6880
Model 1 Spatial Lag	0.4760	0.4636	0.4807	0.5504
Model 1 Spatial Error	0.4841	0.4691	0.4846	0.5504
Model 2	0.4872	0.6241	0.6526	0.6548
Model 2 Spatial Lag	0.4753	0.4631	0.4787	0.5462
Model 2 Spatial Error	0.4837	0.4686	0.4825	0.5462
Model 3	0.5096	0.6334	0.6488	0.6333
Model 3 Spatial Lag	0.4982	0.4709	0.4783	0.5435
Model 3 Spatial Error	0.5099	0.4834	0.4878	0.5431
Model 4	0.5281	0.6409	0.6649	0.6299
Model 4 Spatial Lag	0.5143	0.4782	0.4888	0.5486
Model 4 Spatial Error	0.5234	0.4902	0.4995	0.5476

Table 2.7: Model Forecast Performance Summary

This general process and the overall utility associated with incorporating a spatial lag into the linear forecasts is confirmed with a simple distributional analysis and an associated spatial statistical test. Utilizing a queen’s contiguity matrix to test for spatial adjacency between ZIP code areas, Figure 2.2 displays three distributions. The first is the control distribution for Ohio ZIP code areas. Each bar represents a total count of ZIP code areas and their corresponding level of spatial connectivity/adjacency to neighboring areas. For example, there are 115 ZIP code areas in Ohio that border only one other area, 98 that border two areas, etc. The second distribution utilizes an identical methodology to track the spatial connectivity of ZIP code areas that have at least one broadband provider and their corresponding number of spatial neighbors for 2000. The third calculates the distribution for ZIP code areas that either gained provision for the first time

or increased their existing level of provision between 2000 and 2001. This figure demonstrates the vast majority of gains were made in ZIP code areas that bordered neighbors with existing broadband provision. Only 11 ZIP codes without broadband-enabled neighbors improved their status in 2001.

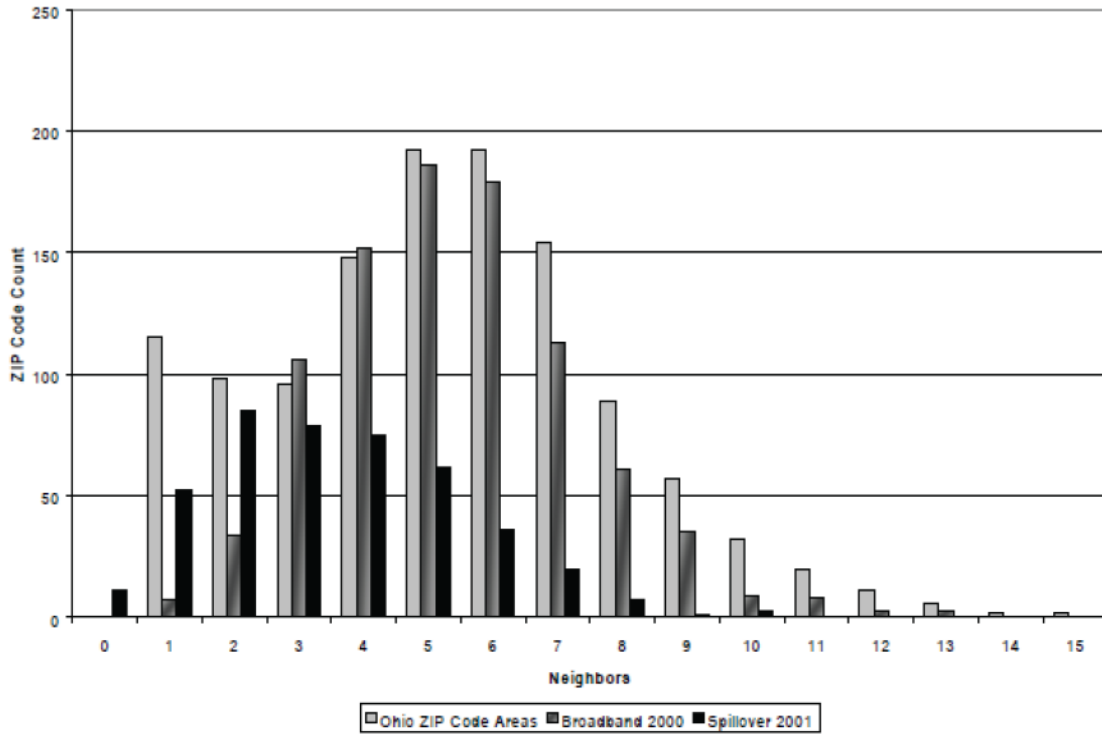


Figure 2.2: Geographic Spillover of Broadband Provision, 2000-2001

A bivariate coefficient of spatial autocorrelation (Anselin et al. 2002) was used to confirm the spatial correlation between levels of provision in 2000 and 2001 and is specified in Appendix 2.A. This measure captures the level of spatial association between observed levels of broadband providers in each ZIP code area for 2000 with the lagged value of broadband providers in each area for 2001. In essence, this is a more formal approach for capturing the statistical significance of the distributions highlighted

in Figure 2.2. With a global Moran's I value of 0.46, Figure (2.3) highlights the associated local spatial pattern. Not surprisingly, high levels of broadband provision during 2000 are strongly linked to high levels of provision in 2001, particularly in major metropolitan areas. Given this information, it is clear that a spatial forecasting approach which accounts for this spillover process is likely to be more successful than a cross-sectional linear approach that ignores the likelihood that gains in provision are partly related to the broadband status of neighboring ZIP code areas.

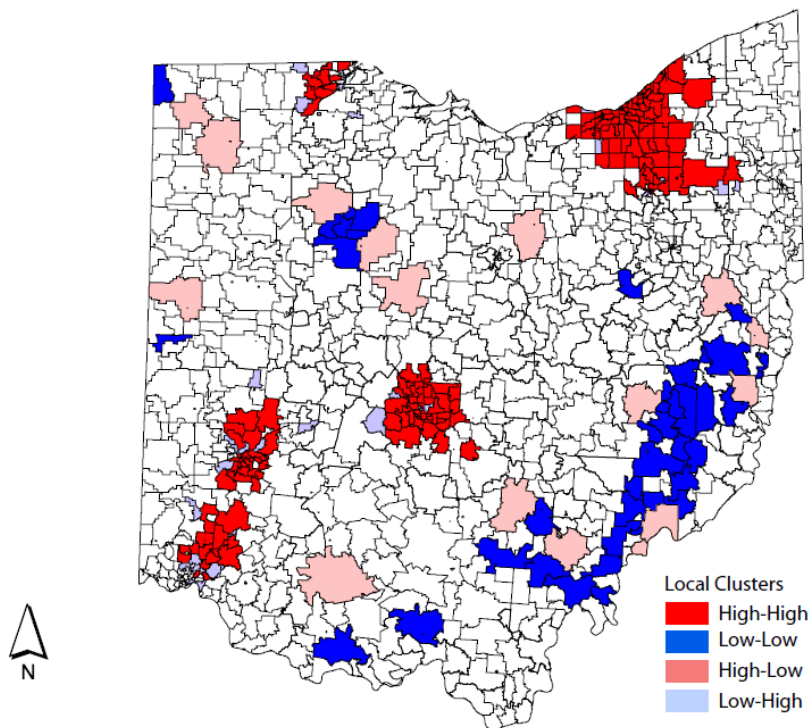


Figure 2.3: Bivariate Local Clusters: Providers (2001) with a Spatial Lag of Providers (in 2000)

Interestingly, the longer the forecast horizon, the more similar is the performance of the spatial lag and spatial error models. Although the spatial lag model provides more accurate short- term forecasts because of the explicit nature of the spatial information

included in the model, this spatial relationship is dynamic and thus the performance of the spatial lag model degrades over time. In mid-range and perhaps longer term forecast horizons, the spatial error model performance approaches that of the spatial lag model. This convergence is most likely due to the lack of specificity of the spatial information included in this model. Thus, although the implicit nature of the information in spatial error models increases error in the short-term it may also prove more flexible and therefore more adept at making more accurate mid-range forecasts.

2.5 Discussion and Conclusion

The uneven spatial distribution of broadband in the United States continues to be a salient social, economic and political issue. Given the well documented importance of advanced telecommunication services like broadband to businesses and individuals, the development of statistical approaches to forecast the future distribution of this increasingly essential technology is important. In the appropriate context, these tools can also be used proactively by economic development officials and policymakers. This chapter argues that by accurately forecasting underserved areas, proactive measures may be taken to ameliorate future disparities in broadband provision.

Although the forecast errors of the models in this chapter are relatively high, a comparison of the model results provides important spatial insights for consideration in the development of future, more accurate forecasts of broadband provision. The results of this chapter demonstrate spatial econometric models are a more accurate forecasting alternative to both cross sectional linear models with demand side factors alone and cross sectional linear models of demand with spatial regimes. Spatial models provide more

accurate forecasts because they incorporate more information about the spatial processes operating in regions than do models with spatial regimes. Models with spatial regimes merely subdivide geographic space and do not model the underlying process responsible for the production of the spatial distribution of a variable. This result is particularly important for technologies whose distribution is highly regional in nature, like broadband. However, if the estimation of spatial econometric models is not possible, cross sectional models with spatial regimes should be used in place of cross sectional models with demand side variables alone.

The estimation of spatial lag and spatial error models also suggests the forecasting ability of these models is related to their specificity of spatial processes at work within regions. Spatial lag models yield more information about a spatial process if the distribution of the dependent variable depends upon neighboring values of that variable. This result was illustrated for broadband in Ohio via the estimation of a bivariate, local Moran's I measure of spatial association. It statistically demonstrated that future broadband provision is geographically linked to prior levels of broadband provision.

Conversely, spatial error models are less specific about spatial processes because they correct for a variety of potential modeling errors that produce spatial autocorrelation in model residuals. Despite their lack of specificity however, these models may be more effective forecasting tools for regions where a complex array of supply-side or policy-based factors exert an influence on broadband provision. Spatial error models may also provide better long-term forecasts than their spatial lag counterparts. Further evaluation of the differences in performance of lag and error models in other states and across a variety of time horizons present interesting extensions to this study meriting additional

research. Future research in this area should also evaluate how the incorporation of additional variables in the models may or may not improve the forecast accuracy (as indicated by the MAPE) of spatial econometric models.

Appendix 2.A: Specification of Local Spatial Statistics

The following notation is used to specify the local spatial statistics utilized in this paper (Anselin et al., 2002):

$z_k = \frac{[x_k - \bar{x}_k]}{\sigma_k}$ or a standardized random variable with a mean equal to zero and a standard deviation equal to 1.

$z_l = \frac{[x_l - \bar{x}_l]}{\sigma_l}$ or a standardized random variable with a mean equal to zero and a standard deviation equal to 1.

W is typically a Euclidean (straight-line) row standardized spatial weights matrix with binary values of 0 or 1. However, W can also be specified using a simple spatial adjacency metric, such as queen's contiguity. n is the number of observations.

The global Moran's I statistic is specified as follows:

$$I = \frac{n \sum_k \sum_l W_{kl} z_k z_l}{W \sum_k z_k^2}$$

The local Moran's I is specified as:

$$I_k = z_k \sum_l W_{kl} z_l$$

The bivariate global Moran's I specified as follows:

$$I_{kl} = \frac{z'_k W z_l}{z'_k z_k}$$

Finally, the local version of the bivariate Moran's I is:

$$I_{kl}^i = z_k^i \sum_j w_{ij} z_l^j$$

Given specifications above, it is also important to note that since the spatial weights are row-standardized it is not necessary to account for the usual scaling factors, since $S_0 = \sum_i \sum_j w_{ij} = n$ and thus $(n/S_0)(z'_k W z_l / z'_k z_k) = z'_k W z_l / z'_k z_k$.

Appendix 2.B: Descriptive Statistics for Covariates, Ohio and the United States

Ohio Descriptive Statistics							
	Count (0)	Count (1)	Min.	Max.	Sum	Mean	Std. Dev.
2001 Household Density			5.46	6,848.63	617,827.87	508.08	811.84
2001 Establishments			0.00	2,752.00	265,807.00	218.59	334.91
2001 Median Income			0.00	94,345.95	46,198,372.75	37,992.08	11,777.33
Growth (2000-2001)			-0.05	12%	3.17	0.00	0.01
Urban Area Membership	904	312					
MSA Membership	487	729					
ZIP Code Area (in miles)			0.002	299.471	36401.136	29.935	35.321
Ameritech	804	410					
Cincinnati Bell	1136	78					
2000 Providers			0.00	8.00	1697.00	1.40	1.66
2001 Providers			0.00	11.00	2811.00	2.32	2.58
2002 Providers			0.00	14.00	3786.00	3.12	3.23
2003 Providers			0.00	16.00	4,472.00	3.68	3.64
2004 Providers			0.00	17.00	5,618.00	4.63	3.89

2.6 References

- Anselin, L. 1988. *Spatial econometrics: methods and models*. Boston: Klumer Academic Publishers.
- Anselin, L. 1992. Spatial data analysis with GIS: An introduction to application in the social sciences. Technical Report 92-10. National Center for Geographic Information and Analysis, University of California – Santa Barbara.
- Anselin, L. (1995). Local indicators of spatial association-LISA. *Geographical Analysis*, 272, 94-115.
- Anselin, L., Syabri, I., & Smirnov, O. (2002). Visualizing multivariate spatial correlation with dynamically linked windows. from <http://www.real.uiuc.edu/d-paper/02/02t-8.pdf>.
- CNOC. (Center for a New Orange County). (2006). The information and communication technology comprehensive economic development strategy ICT CEDS for Orange County, California. from http://www.wrjgroup.com/projects/ICTCEDSReport/ICTCEDS_2006.pdf.
- Downes, T., & Greenstein, S. (2007). Understanding why universal service obligations may be unnecessary: The private development of local Internet access markets. *Journal of Urban Economics*, 62, 2-26.
- Duffy-Deno, K.T. (2003). Business demand for broadband access capacity. *Journal of Regulatory Economics*, 24, 359-372.
- Flamm, K. (2005). The role of economics, demographics and state policy in broadband availability. from <http://bear.cba.ufl.edu/centers/purc/documents/Flammflammbb0205.pdf>.
- Flamm, K., & Chaudhuri, A. (2007). An analysis of the determinants of broadband access. *Telecommunications Policy*, 31, 312-326.
- Gabe, T.M., & Abel, J.R. (2002). Deployment of advanced telecommunications infrastructure in rural america: measuring the digital divide. *American Journal of Agricultural Economics*, 84, 1246-1252.
- Graham, S. (1999). Global grids of glass: On global cities, telecommunications and planetary urban networks. *Urban Studies*, 36, 929-949.
- Graham, S. (2002). Bridging urban digital divides? Urban polarisation and information and communications technologies (ICTS). *Urban Studies*, 39, 33-56.

- Grimes, D., Prime, P.B., & Walker, M. (2007). Change in the concentration of employment in computer services: spatial estimation at the U.S. metro county level. *Growth and Change*, 38, 39-55.
- Grubestic, T. H. (2003). Inequities in the broadband revolution. *Annals of Regional Science*, 37, 263-289.
- Grubestic, T. H. (2006). A spatial taxonomy of broadband regions in the United States. *Information Economics and Policy*, 18, 423-448.
- Grubestic, T.H. (2008a). The spatial distribution of broadband providers in the United States: 1999 - 2004. *Telecommunications Policy*, 32, 212-233.
- Grubestic, T. H. (2008b). Zip codes and spatial analysis: problems and prospects. *Socio-Economic Planning Sciences*, 42, 129-149.
- Grubestic, T. H. (2008c). Spatial data constraints: implications for measuring broadband. *Telecommunications Policy*, 32, 490-502.
- Grubestic, T.H., & Murray, A.T. (2002). Constructing the divide: spatial disparities in broadband access. *Papers in Regional Science*, 81, 197-221.
- Grubestic, T.H., & Murray, A.T. (2004). Waiting for broadband: local competition and the spatial distribution of advanced telecommunication services in the United States. *Growth and Change*, 35, 139-165.
- Horrigan, J. B., Stolp, C., & Wilson, R. H. (2006). Broadband utilization in space: Effects of population and economic structure. *The Information Society*, 22, 341-354.
- Hollifield, C.A. and Donnermeyer, J.F. (2003). Creating demand: influencing information technology diffusion in rural communities. *Government Information Quarterly*, 202, 135-150.
- H.R. 1. (2009). *American Recovery and Reinvestment Act of 2009*. from <http://www.govtrack.us/congress/bill.xpd?bill=h111-1>.
- LaRose, R., Gregg, J.L., Strover, S., Straubhaar, J., & Carpenter, S. (2007). Closing the rural broadband gap: Promoting adoption of the Internet in rural America. *Telecommunications Policy*, 31, 359-373.
- Madden, G., & Tan, J. (2007). Forecasting telecommunications data with linear models. *Telecommunications Policy*, 31, 31-44.
- Moran, P.A.P. (1948). The interpretation of statistical maps. *Journal of the Royal Statistical Society Series B*, 10, 243-251.

- Moss, M.L., & Townsend, A.M. (2000). The internet backbone and the American metropolis. *The Information Society*, 16, 35-47.
- NTIA. (National Telecommunications and Information Administration). (1998). Falling through the net II: New data on the digital divide. from <http://www.ntia.doc.gov/ntiahome/net2/>>.
- NTIA. (National Telecommunications and Information Administration). (1999). Falling through the net: defining the digital divide. from <http://www.ntia.doc.gov/ntiahome/fttn99/>.
- NTIA. (National Telecommunications and Information Administration). (2000). Falling through the net: toward digital inclusion. From <http://www.ntia.doc.gov/ntiahome/digitaldivide/>.
- NTIA. (2009). *Broadband Technology Opportunities Program*. from <http://www.ntia.doc.gov/broadbandgrants/>.
- NTIA and RUS. (2000). Advanced telecommunications in rural America: The challenge of bringing broadband service to all Americans. from <http://www.ntia.doc.gov/reports/ruralbb42600.pdf>
- Odland, J. (1988). *Spatial autocorrelation*. Beverly Hills: Sage.
- OSC [Ohio Supercomputer Center]. (2006). 2006 Broadband ohio study: availability and cost of broadband Internet service options in Ohio. from <http://www.osc.edu/networking/broadband/index.shtml>
- Prieger, J.E. (2003). The supply side of the digital divide: Is there equal availability in the broadband Internet access market? *Economic Inquiry*, 41, 346–363.
- Prieger, J.E. & Hu, W.M. (2006). New estimates of broadband entry and demand. from <http://www.econ.ucdavis.edu/graduate/whu/Job%20market/Paper4.pdf>.
- Prieger, J.E., & Hu, W.M. (2008). The broadband digital divide and the nexus of race, competition and quality. *Information Economics and Policy*, 20, 150-167.
- Shmueli, G. (2009). To explain or to predict? from <http://ssrn.com/abstract=1351252>.
- Strover, S. (2001). Rural internet connectivity. *Telecommunications Policy*, 25, 331-347.
- TA96 [Telecommunications Act of 1996]. (1996). Pub. LA. No. 104-104, 110 Stat. 56.
- U.S. Census Bureau. (2009a). ZIP code business patterns. from <http://censtats.census.gov/cbpnaic/cbpnaic.shtml>.

- U.S. Census Bureau. (2009b). Frequently asked questions: definition urban and rural.
from http://search.census.gov/search?q=urbanized+area&Submit.x=0&Submit.y=0&enq=0&ud=1&output=xml_no_dtd&oe=UTF-8&ie=UTF-8&client=default_frontend&proxystylesheet=default_frontend&site=census.
- U.S. Census Bureau. (2009c). Metropolitan and micropolitan statistical areas.
from <http://www.census.gov/population/www/metroareas/metroarea.html>.
- Wood, L. (2008). Rural broadband: The provider matters. *Telecommunications Policy*, 32, 326-339.
- Zook, M.A. (2002). Hubs, nodes and bypassed places: a typology of e-commerce regions in the United States. *Tijdschrift voor Economische en Sociale Geografie*, 93, 509-521.

3. Broadband Provision and Firm Location

3.1 Introduction

The relationship between information and communication technologies (ICTs) and firm location is a research area of emerging importance in geography, regional science, urban studies and telecommunications policy. ICTs are often cited as an important component for local and regional economic development (Premkumar, 2000), and therefore many government agencies are focusing on broadband infrastructure to stimulate the growth of local industry; particularly in industrial sectors that are reliant on advanced telecommunication technologies (e.g. professional, science and technical services) (NTIA, 2004). Although ICTs are not the sole determinant of economic development and “tech fundamentalism” should certainly be avoided (Clarke, 2003), the challenge for economic development officials in the current global business environment is to supply the appropriate mix of resources (including ICTs) to attract and develop competitive businesses (Sommers and Carlson, 2003). A number of states including New York, California, and Ohio have recognized the importance of this increasingly necessary infrastructure, and have conducted evaluations of current ICT infrastructure levels (Center for an Urban Future, 2004; Center for a New Orange County, 2006; OSC, 2006).

These studies, as well as many others (e.g. Gulati et al., 2000), recognize the role ICTs play in developing and attracting competitive businesses. ICTs, like broadband¹ are not only important to individual firms (OTP, 2002), but are also essential to the successful development of regional economies (Gibbs and Tanner, 1997). Unfortunately, evaluations of past ICT development initiatives suggest these programs are often founded

on inaccurate assumptions about the relationship between firms and ICTs (Gibbs and Tanner, 1997). One of these assumptions is a uniform impact of these technologies across urban areas (Graham and Marvin, 1996). Where firm location is concerned, there are three basic schools of thought regarding the impact of ICTs: the deconcentration school, the concentration school, and the heterogeneous effects school. Deconcentrationists largely subscribe to the “death of distance” hypothesis (Cairncross, 1997), and argue that technologies, like broadband, will result in the mass decentralization of firms from central locations. It is believed that this decentralization will occur for three reasons: 1) ICTs will permit firms to avoid diseconomies associated with central locations (Kutay, 1988); 2) the efficiency of these communications technologies will serve as a substitute for face-to-face interactions and transportation (Moss, 1998; Salomon, 1996); and, 3) the ubiquitous distribution of telecommunications allows for relatively instantaneous access to information, regardless of location (ibid).

Conversely, concentrationists believe that ICTs will reinforce the advantages of central city locations because of the uneven distribution of advanced infrastructure - which has a notable urban bias (Sassen, 1994; Graham, 1999; Zook, 2005), and the facilitation of face-to-face interactions offered by industrial clusters in urban areas (Leamer and Storper, 2001); the importance of which in business dealings will remain undiminished despite advances in ICTs (Gaspar and Glaesar, 1998). Moreover, reductions in processing and response times, brought about by telecommunications advances, will place an even greater premium on time, thus emphasizing the importance of firm proximity in central locations (Leamer and Storper, 2001). In short, the

¹ The Federal Communications Commission (FCC, 2007) defines broadband as the capability of supporting at least 200 kilobits per second (Kbps) in the consumer’s connection to the network, both from the provider

concentrationists believe advanced telecommunications will be unable to overcome the forces of agglomeration in central city locations (Atkinson, 1998).

A third school of thought, the heterogeneous effects or “restructuring” school (Audirac, 2005), combines the arguments of the concentrationists and deconcentrationists. Their primary theoretical argument is summarized by Kutay (1986, 247), who states, “telecommunications do not directly cause decentralization, but create the opportunity to make a decentralization decision.” Proponents of this school suggest the impact of ICTs will be dependent upon firm specific factors such as the skill level of employed workers (Warf, 1989) and industry specific location preferences (Atkinson, 1998; Audirac, 2005). Moss (1998) suggests firm use of both ICTs and face-to-face contacts will ultimately determine whether or not firms decide to make a decentralization decision.

The purpose of this chapter is to evaluate the theoretical constructs forwarded by these schools of thought by exploring the relationship between broadband provision and firm location in Ohio between 1999-2004. This exploratory component of the dissertation is important because it represents an inaugural attempt to address the potential impact of broadband access on firm location. Specifically, this chapter seeks to answer the following questions. First, is there a relationship between areas that have experienced positive changes in broadband provision and areas that have experienced positive changes in the number of firms? Second, if a relationship exists, does it vary by industry and firm size? Third, are positive changes in broadband provision and number of firms taking place in central city locations or suburban locations? Finally, do areas with positive changes have a tendency to cluster or be more dispersed? Given the numerous

to the consumer (downstream) and from the consumer to the provider (upstream).

constraints associated with broadband and related telecommunications data (Greenstein, 2007), it is unlikely that a *clear* causal or temporal ordering can be determined. However, the ability to analyze spatial and temporal similarities between broadband provision and firm location will not only uncover interesting relationships between industries and urban growth patterns, but suggest policy opportunities for targeting lagging areas with ICT expansion efforts.

These questions will be investigated through an exploratory spatial analysis of the State of Ohio between 1999 and 2004. Results suggest that while broadband provision, in general, has no relationship to firm location in Ohio, the relationship is statistically significant for a subset of industrial sectors. The remainder of this chapter is organized as follows. Section 2 reviews the literature discussing the relationship between firm locations and ICTs. This review is followed with additional detail regarding the datasets used in the analysis, as well as a rationale for the exploratory approach used to analyze trends in Ohio. Section 4 presents the results of the exploratory analysis while Section 5 provides further discussion of these results and a brief conclusion.

3.2 Firm Location and ICTs

3.2.a Regional Clusters and Enabling Infrastructure

From a spatial perspective, the benefits accrued by firms located in regional clusters of economic growth are well known. For example, firms often gain advantages from the creation of dense social and professional networks (Saxenian, 1998), backward and forward linkages between firms (Le Blanc, 2003), labor pools (Grimes et al., 2007), and knowledge spillovers (Anselin et al., 1997). The locational benefits offered by regions rich in these assets translate into other areas too, including the development

and/or availability of enabling infrastructure such as ICTs. In this context, advanced telecommunication systems such as broadband are considered enabling infrastructure because they enhance productivity in a wide variety of sectors, including real estate, finance, computer services, commerce and many others (Zook, 2002; Grimes et al., 2007). This is particularly true for small and medium sized enterprises (SMEs) which are widely recognized as important drivers of economic growth in the United States (SBA, 1997)

The spatial manifestations of enabling infrastructure and ICTs are probably most obvious in global cities (Sassen, 1994). For example, Graham (1999 p.930) notes:

“All aspects of the development and functioning of global cities are increasingly reliant on networks and services; such cities concentrate the most communication-intensive elements of all economic sectors and transnational activities within small portions of geographic space.”

Consequently, the resulting geography of this infrastructure often reflects a hierarchical arrangement, where a select subset of major city-regions dominates the supply and use of ICTs (Graham, 1999; Zook, 2005). Not surprisingly, the landscape of provision for telecommunication infrastructure(s) in many of these locations is multifaceted, sensitive to spatial scale and often reveals the distributional biases of specific technologies or platforms (Grubestic and Murray, 2002; Grubestic, 2006). Despite the widespread attention devoted to the issues surrounding ICTs, the link between these technologies and firm location remains largely unexplored for a variety of reasons; these include 1) the long-run nature of the process (Forman et al., 2005); 2) the absence of established methodologies (Sohn et al., 2003), and 3) and the lack of appropriate data (Greenstein, 2007).

3.2.b Firms and ICT Usage

A more subtle aspect of the relationship between firm location and ICTs is the manner in which the infrastructure is used by businesses. ICTs have been hypothesized to increase the opportunities for employees to telework (OTP, 2002), which ultimately improves firm productivity and increases a firm's ability to attract workers requiring more flexible work schedules (Steinfeld and Scupola-Hugger, 2007; Kraut, 1989). Forman et al., (2005) consider this a *participation* technology, with minimal requirements for coordinating between geographically isolated locations. In other instances, ICTs are directly related to a firm's business model, particularly when advanced telecommunications technologies are linked to electronic commerce (Zook, 2005; Aoyama et al., 2005). In these cases, quality infrastructure and access to bandwidth directly impact a firm's ability to receive and fulfill customer orders. Forman et al., (2005) consider this an *enhancement* technology, often requiring significant third-party support and servicing.

Forman et al., (2005) also differentiate between within-establishment Internet (WEI) technologies that coordinate intra-firm activities and cross-establishment Internet (CEI) technologies that coordinate geographically isolated inter-firm activities. Using the Harte Hanks Market Intelligence CI Technology database, Forman et al., (2005) suggest that when controlling for industry, the use of participation-based technologies decreases as the size and density of a city increase, particularly when CEI technologies are utilized. In other words, there are significant benefits for using participation-based enhancements in rural settings for firms. The opposite is true for enhancement-based technologies. As population increases, so does the probability that firms will adopt enhancement

applications for coordinating intra-firm activities (Forman et al., 2005).

Given this relatively brief glimpse at the literature, it is evident that there is significant interest in evaluating both the role that ICTs play in firm location decisions and how location influences the manner in which firms use ICTs to make their operations more efficient. The analysis provided in this chapter will focus its efforts in deepening our understanding of the former, although it certainly has implications for the latter.

3.3 Study Area, Data and Methods

This investigation of the relationship between broadband provision and firm location will be undertaken at the ZIP code level for the state of Ohio. Geographic boundary files for Ohio ZIP codes are from TeleAtlas, formerly Geographic Data Technology (GDT).² Although the use of ZIP codes for spatial statistical analysis can be problematic (Grubestic, 2008), basic standardization routines and an identical geographic base file for all years analyzed mitigates many of the confounding issues associated with this temporally and spatially dynamic geography.³ Despite these potential issues, ZIP codes remain an appealing option for this study because they represent the smallest unit of analysis for which both broadband provider data and firm count data are available.⁴ It is also important to note that the use of alternative units for analysis, such as counties, would still rely on ZIP code-based aggregations of broadband data.

The state of Ohio represents an interesting area for conducting a case study on broadband provision and firm location. Ohio is not only one of a growing number of states initiating ICT infrastructure evaluations, such as The 2006 Broadband-Ohio study

² Year 2000 ZIP code data.

³ See Grubestic (2008) for more details.

released by the Ohio Supercomputer Center (OSC), but it also boasts a diverse industrial and socio-demographic mix. Nearly 11.5 million people live in Ohio, and the state is home to over 250,000 businesses in a variety of industries (ODOD, 2007). While many Ohioans continue to work in manufacturing related jobs⁵, sectors related to healthcare, state and local government and retail trade are also large employers in the state. Interestingly, many of the growth sectors in the Ohio economy serve as focal points in the firm location and/or ICT literature. To provide some perspective on where Ohio ranks nationally in these sectors, consider the following statistics: Ohio ranked 6th among the fifty states in total employment in the Insurance Carriers industry in 2002, with five Fortune 1000 firms located within the state (ODOD, 2007). Where the information industry is concerned, Ohio ranks 9th in publishing (NAICS 511) and 9th in broadcasting and telecommunications (NAICS 513). Internet service provision and web portals (NAICS, 5181) had the largest projected job growth of all information industries in Ohio; its projected job growth is 40% by 2012. In addition to a diverse industrial structure that is representative of national industry trends, as demonstrated in Tables 3.1 and 3.2, Ohio also boasts a unique socio-economic and demographic mix, as well as an interesting blend of urban and rural areas (Grubestic and Murray, 2002; Grubestic, 2003). These features suggest the use of Ohio as a case study will provide a fairly representative evaluation of the relationship between ICTs and firm location because it does not represent an extreme case with respect to the previously mentioned items and can therefore be expected to produce fairly generalizable results.

⁴ The study recognizes that a different unit of analysis may yield different results because of the Modifiable Areal Unit Problem (MAUP) (Gehlke and Biehl, 1934; Openshaw, 1984; Unwin, 1996).

National Absolute Establishment Data: 2004				
	Total	Small	Medium	Large
All Industry Absolute Total	7,008,444	6,632,900	326,079	49,465
Selected Industries (2-Digit NAICS)				
Manufacturing (31-33)	360,244	297,292	50,349	12,603
Retail Trade (44-45)	1,111,260	1,055,392	51,802	4,066
Information (51)	126,510	114,124	10,336	2,050
Finance and Insurance (52)	418,337	401,669	13,807	2,861
Professional, Scientific, and Technical (54)	704,779	685,876	16,503	2,400
Management of Companies and Enterprises (55)	46,528	37,600	6,635	2,293
Ohio Absolute Establishment Data: 2004				
	Total	Small	Medium	Large
All Industry Absolute Total	268,368	251,965	14,723	1,680
Selected Industries (2-Digit NAICS)				
Manufacturing (31-33)	16,673	13,475	2,616	582
Retail Trade (44-45)	41,212	38,800	2,230	182
Information (51)	4,121	3,725	342	54
Finance and Insurance (52)	17,967	17,398	447	122
Professional, Scientific, and Technical (54)	25,251	24,544	627	80
Management of Companies and Enterprises (55)	1,836	1,435	290	111

Table 3.1: National Business Counts by Firm Size and Industry

⁵ In 2005, 12.3% of Ohio employees were employed in manufacturing related occupations (ODOD, 2007).

National Firm Data: 2004				
	Total	Small	Medium	Large
All Industry Total	100.0%	94.6%	4.7%	0.7%
Selected Industries (2-Digit NAICS)				
Manufacturing (31-33)	5.1%	4.9%	15.4%	25.9%
Retail Trade (44-45)	15.9%	15.9%	15.9%	8.2%
Information (51)	1.8%	1.7%	3.2%	4.1%
Finance and Insurance (52)	6.0%	6.1%	4.2%	5.8%
Professional, Scientific, and Technical (54)	10.1%	10.3%	5.1%	4.9%
Management of Companies and Enterprises (55)	0.7%	0.6%	2.0%	4.6%
Ohio Firm Data: 2004				
	Total	Small	Medium	Large
All Industry Total	100.0%	93.9%	5.5%	0.6%
Selected Industries (2-Digit NAICS)				
Manufacturing (31-33)	6.2%	5.4%	17.8%	34.6%
Retail Trade (44-45)	15.4%	15.4%	15.2%	10.8%
Information (51)	1.5%	1.5%	2.3%	3.2%
Finance and Insurance (52)	6.7%	6.9%	3.0%	7.3%
Professional, Scientific, and Technical (54)	9.4%	9.7%	4.3%	4.8%
Management of Companies and Enterprises (55)	0.7%	0.6%	2.0%	6.6%

Table 3.2: Ohio Business Counts by Firm Size and Industry

3.3.a Business Data

Annual business data were obtained from the U.S Census Bureau’s ZIP Code Business Patterns. The Census refers to businesses as establishments which are defined as “a single physical location at which business is conducted or services or industrial operations are performed. It is not necessarily identical with a company or enterprise, which may consist of one or more establishments” (U.S. Census Bureau, 2007). This source excludes government entities from its establishment counts. Industries utilized in this analysis are two-digit major industry divisions as defined by the North American Industrial Classification System (NAICS, 2002), and were selected both for their hypothesized variability in location preference and ICT use, as well as their prevalence in

the literature. The industries selected include: Manufacturing, Retail, Information, Finance and Insurance, Professional, Scientific, and Technical Services, and Management.⁶ Prior quantitative analyses have utilized Manufacturing and Retail (Sohn et. al, 2002) as well as Finance, Insurance and Real Estate (Hackler, 2003) in their studies. The suburbanization and locational preferences of Business and Professional Services (Gong and Wheeler, 2002) has also been evaluated previously. Establishments were broken down by size into small, medium, and large categories, according to the number of employees. Small establishments are defined as employing fewer than 50 people. Medium sized establishments are defined as employing 50 or more people and fewer than 250, while large establishments employ 250 or more. This definition is a departure from the current definition of small businesses provided by the U.S Small Business Administration (SBA), which defines small businesses as employing fewer than 500 employees (SBA, 2007). However, the breakdown of establishments provided in this study is justifiable. First, the outlined definition corresponds to the very broad characterization of a small business provided by the SBA, as "one which is independently owned and operated, and which is not dominant in its field of operation" (d'Amboise and Muldowney, 1988 p. 226). Second, the difficult and controversial nature of defining a small business is well noted in the business management literature (ibid). Further, a variety of small business definitions are utilized for legal and regulatory purposes in the United States (Holmes, 2001 p. 28). For example, the Family and Medical Leave Act

⁶ Although the number of studies examining these industries is certainly vaster than the list provided herein, the subsequent authors listed provide examples of the prevalence of these industries in the firm location literature. Sohn, Kim, and Hewings (2002; 2003) examined spatial patterns in retail, manufacturing and services firms. Klier and Testa (2002) and Holloway and Wheeler (1991) studied locational trends in managerial enterprises. Gong and Wheeler (2002) and O'hUallachain and Reid (1991) examined trends in Business and Professional Services. Hackler (2003) has examined firm location trends at a more disaggregate level for firms within the Finance and Insurance and Information sectors.

defines a small business as one containing 50 employees or less while the SIMPLE Pension Plan defines such establishments as those with less than 100 employees (ibid).

3.3.b Broadband Data

Broadband data were acquired from the FCC Form 477 database, which contains counts of the number of broadband service providers in each ZIP code. Due to confidentiality constraints however, the FCC does not report data for a ZIP code if it contains less than four providers. Per the precedent set by prior broadband studies (Grubestic and Murray, 2002; Grubestic and Murray 2004; Grubestic, 2006), the most conservative estimate regarding the number of broadband providers for each active, but suppressed ZIP code is used – a value of one. Also, these data do not distinguish between broadband platforms (cable, xDSL), but lump a variety of platforms together beneath the broadband umbrella (Grubestic and Murray, 2002)⁷. The implications of this platform intricacy will be discussed in a later section as it pertains to the results of the ensuing analysis.

3.3.c Exploratory Analysis

A variety of both exploratory data analysis (EDA) (Tukey, 1977) and exploratory spatial data analysis (ESDA) (Messner et al., 1999) techniques are utilized to identify potential relationships in establishment trends and broadband provision. Given the dearth of existing analyses focused on broadband and firm location, this type of exploratory analysis is appropriate. Further, provided that no verifiable statistical relationship

⁷ This data set also does not disclose information about broadband speeds, type of service, or number of customers because of confidentiality constraints. The presence of a broadband provider also does not guarantee universal access within a given zip code (Grubestic, 2004; Flamm, 2006).

between broadband and firm location has been determined in the literature, this exploratory analysis will be used to both; 1) generate hypotheses about the nature of the relationship between these two variables, and 2) determine at a very basic level if any relationship exists that warrants further exploration with more sophisticated techniques (e.g., regression). Given the multitude of issues that may yield misleading statistical or econometric results, of which spatial autocorrelation is one example, a relatively simple yet revealing exploratory approach is constructed in an effort to form a more solid foundation on which additional, more sophisticated analyses may be built.

In order to determine the degree to which firms and broadband provision cluster, both global and local indicators of spatial autocorrelation (LISA) (Moran, 1948; Anselin, 1995) were calculated in GeoDa (Anselin, 2004). The global and local Moran's I are specified as follows:

$$I = \frac{n}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum_i z_i^2} \quad (\text{global}) \qquad I_i = z_i \sum_j w_{ij} \cdot z_j \quad (\text{local})$$

where:

n is the number of observations

x_i and x_j are observations for locations i and j (with mean μ);

$$z_i = (x_i - \mu)$$

$$z_j = (x_j - \mu)$$

w_{ij} = is a binary spatial weights matrix corresponding to the Euclidean distance between ZIP code centroids.

The global Moran's I was used to examine the overall tendency for broadband and establishments to cluster for each year in the study period. The local Moran's I was used

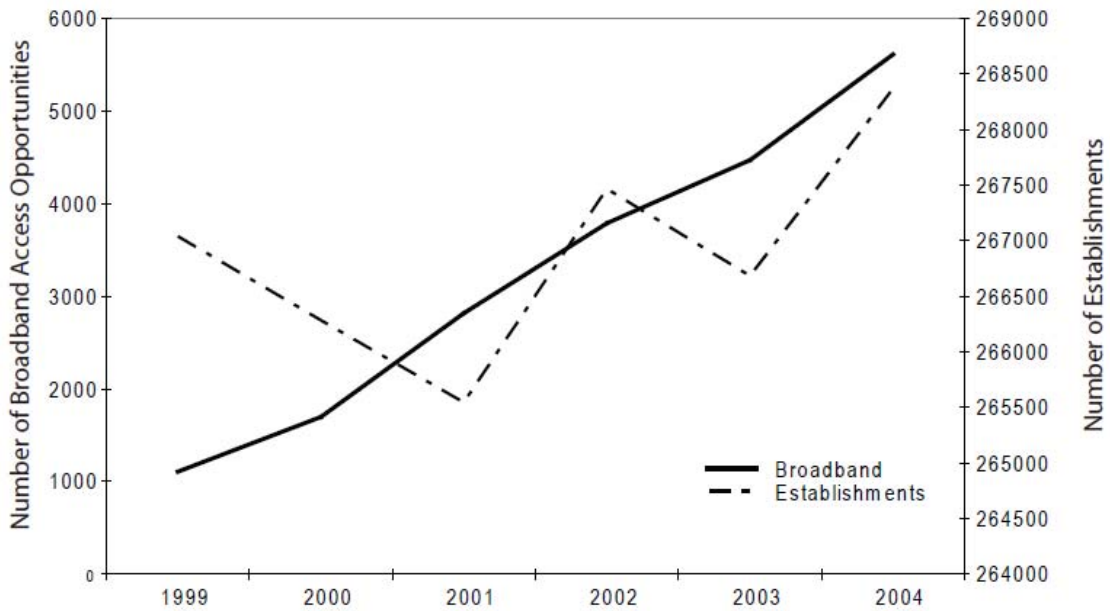
to spatially decompose the change trends for each of these variables. Due to the highly irregular shape of ZIP codes (Grubestic, 2008), a Euclidean distance weight matrix, rather than a contiguity weight matrix, was used to calculate each of the measures of spatial autocorrelation.

3.4 Results

3.4.a Broadband and Establishment Trends

Figure 3.1 illustrates the trends in broadband provision and establishment counts for the 1999 – 2004 period in Ohio. The overall level of broadband provision has grown steadily since 1999, but so has the disparity in provision amongst ZIP codes. In 1999, the average number of broadband providers was 1, but the range for the number of broadband providers amongst ZIP codes was 7. By 2004, the average had increased to almost 5, but the range had risen dramatically to 17. Figure 3.2 highlights areas with the greatest *positive* change in broadband provision such as Dayton, Columbus, and Cleveland as well as many of their adjacent suburban areas.⁸

⁸ This chapter uses changes in broadband and establishment counts, rather than percentage changes because of the massive differences in range between broadband providers and establishment counts for some ZIP codes. These ranges include values of 0 in 1999, and therefore the use of percentage changes would have excluded them from the analysis.



*The totals are a metric for broadband access opportunities and do not necessarily suggest unique providers.

Figure 3.1: Ohio ZIP Code Level Broadband Provision and Establishment Counts

Figure 3.2 also indicates that many of the ZIP codes located in less central portions of Ohio, display scant increases in the number of broadband providers. Despite overall growth in provision for Ohio, it appears that an “urban-rural hierarchy” (Grubestic and Murray, 2004 p. 162) persists in the levels of provider choice in these areas, with urban areas clearly dominating their rural neighbors in terms of broadband provision.

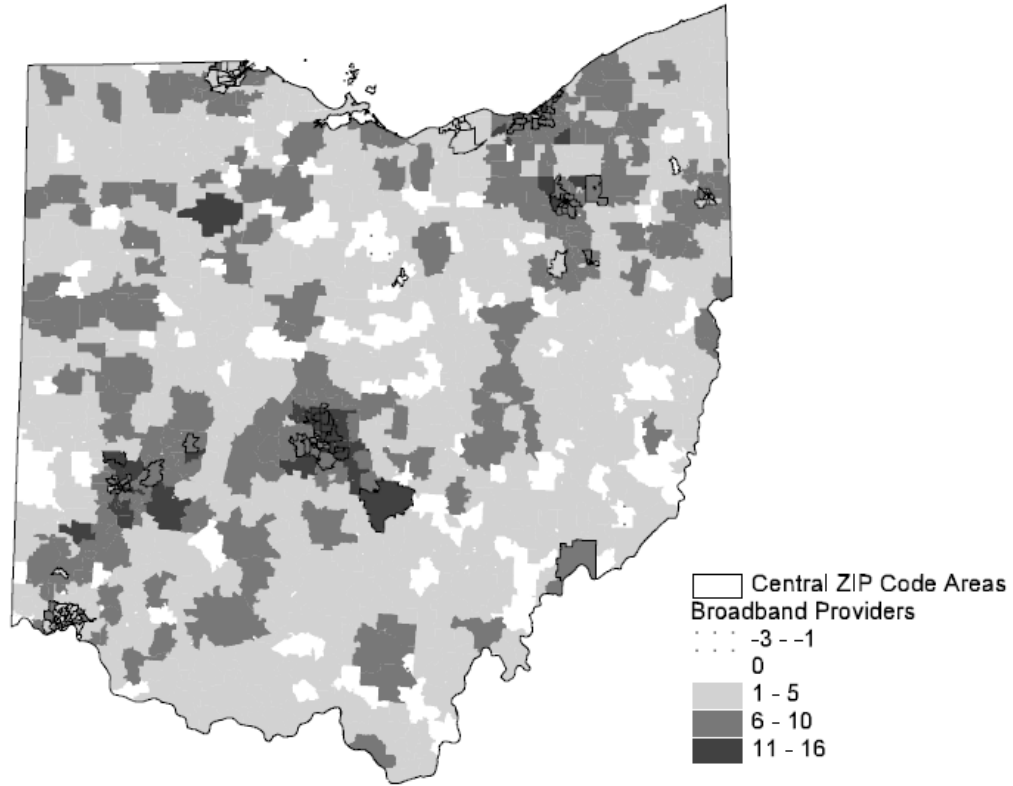


Figure 3.2: Change in the Number of Broadband Providers (1999-2004)

Similar to broadband, the number of establishments also grew between 1999-2004, however, this growth represents a relatively dramatic resurgence in establishment presence after precipitous declines in 2001 and 2003. The areas experiencing the largest positive change in establishments are suburban locales, as illustrated in Figure 3.3.

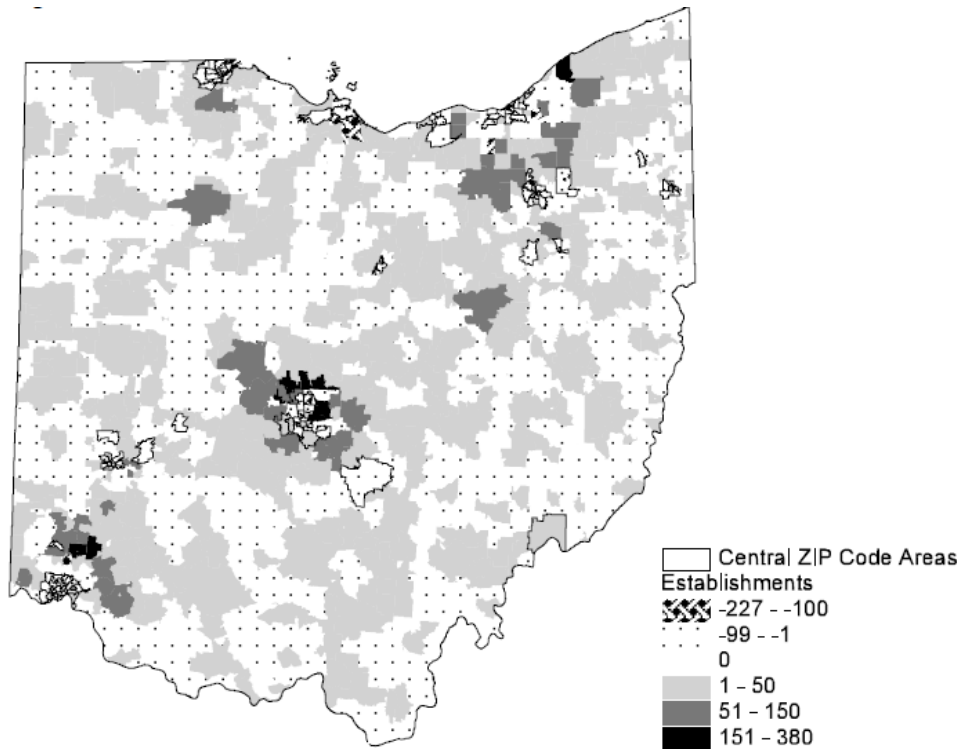


Figure 3.3: Change in the Number of Establishments (1999-2004)

For example, ZIP code areas northwest of Cincinnati and south of Dayton (both areas of tremendous population growth), as well as ZIP code areas surrounding Columbus and Cleveland are illustrative of this pattern. Not surprisingly, Figure 3.4 shows that establishment trends at the industry level are not uniform. Manufacturing and Retail establishments posted declines while Professional, Scientific, and Technical Services, Finance and Insurance, and Information experienced positive growth for this time period. Management of companies and enterprises experienced almost no growth. Clearly, patterns of positive broadband change and positive establishment change display marked differences. While high levels of broadband provision persist in urban and suburban areas, changes in establishment patterns appear to manifest in suburban areas only.

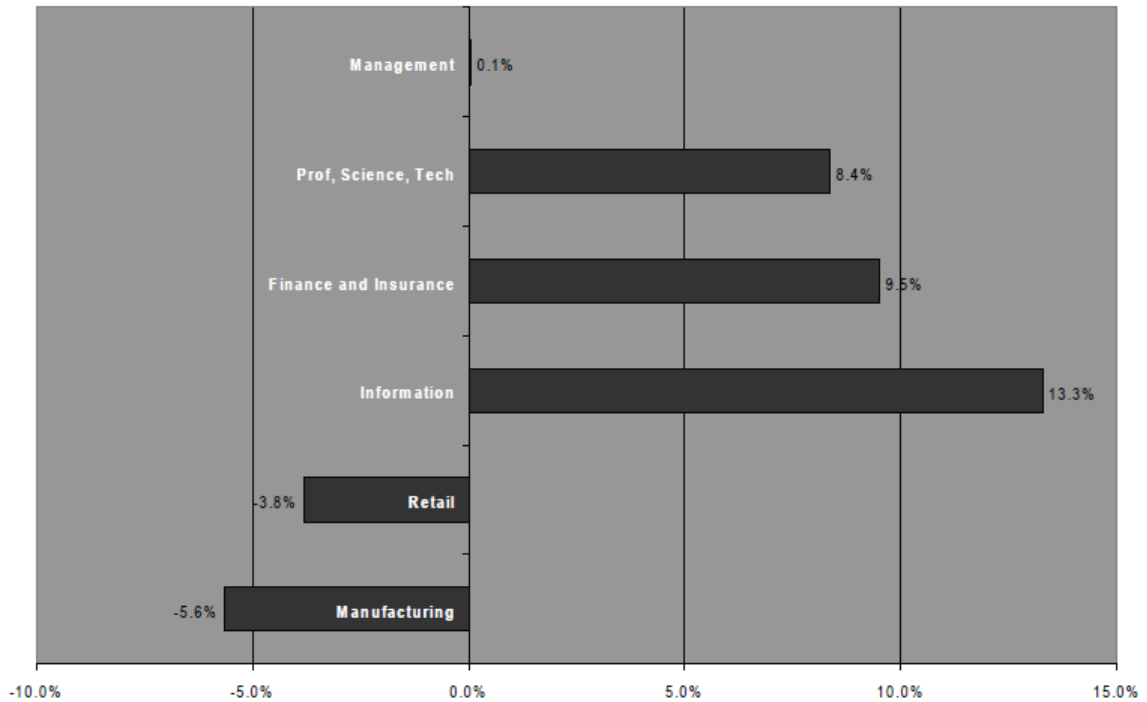


Figure 3.4: Ohio ZIP Code Industry Growth (1999-2004)

3.4.b Agglomerative Tendencies

Of particular interest in this study is the exploration of establishment and broadband provision patterns as they pertain to the hypotheses generated by the three schools of thought (deconcentration, concentration, and heterogeneous effects) discussed previously. Although Figures 3.1-3.4 were illustrative of general change patterns in these variables, they are unable to statistically determine if places with high levels of broadband provision and large numbers of establishments exhibit patterns of clustering or dispersion. Also, if clustering patterns are present are they taking place in central or suburban ZIP code areas? Clustering of broadband provision and/or firms in central areas would indicate agglomerative tendencies, consistent with the concentration school of thought. Dispersed location patterns in these variables would support the hypotheses of the deconcentration school, while location patterns exhibiting both clustering and

dispersion would support the heterogeneous effects school. Operationally, central ZIP code areas were defined as spatial units whose center was contained in the central city polygon for each MSA in Ohio. Suburban ZIP code areas were defined as those spatial units with their center outside of an Ohio central city polygon.⁹

Table 3.3 displays trends in the global Moran's *I* for both variables. In each year of the study period the value of the global Moran's *I* is higher for broadband than for establishments, indicating broadband exhibits higher levels of spatial autocorrelation than do establishments.¹⁰ The difference in spatial autocorrelation trends between these two variables was most noticeably different when the statistic was calculated for the change in broadband provision and the change in establishments. ZIP code areas experiencing similar changes in broadband provision have more of a tendency to cluster than do areas experiencing similar trends in establishment changes.¹¹ This statistic provides a generalized measure of clustering tendencies within these data and thus, the local Moran's *I* was used to evaluate more localized patterns in these data.

	Broadband	Establishments
1999	0.3456	0.3067
2000	0.5194	0.3063
2001	0.4697	0.3066
2002	0.5154	0.3059
2003	0.5287	0.3074
2004	0.4614	0.3092
1999-2004	0.4054	0.1173

Table 3.3: Global Moran's *I* for Broadband Provision and Establishment Counts

⁹ For more details regarding the definition of central city, see URL: <http://www.census.gov/population/www/estimates/00-32997.pdf>

¹⁰ The global Moran's *I* was also calculated for each of the six two-digit NAICS industries. Statistically significant spatial autocorrelation was present in each of these industries with the value of the global Moran's *I* ranging between 0.20 and 0.30 in each of the study years.

¹¹ The global Moran's *I* in each of these instances was significant at the 5% level.

Figure 3.5 displays maps visualizing the local indicators of spatial association (LISA) groups for broadband provision, all establishments, and industries of interest. The areas of greatest interest in these maps are those pertaining to the High-High and High-Low LISA categories.¹²

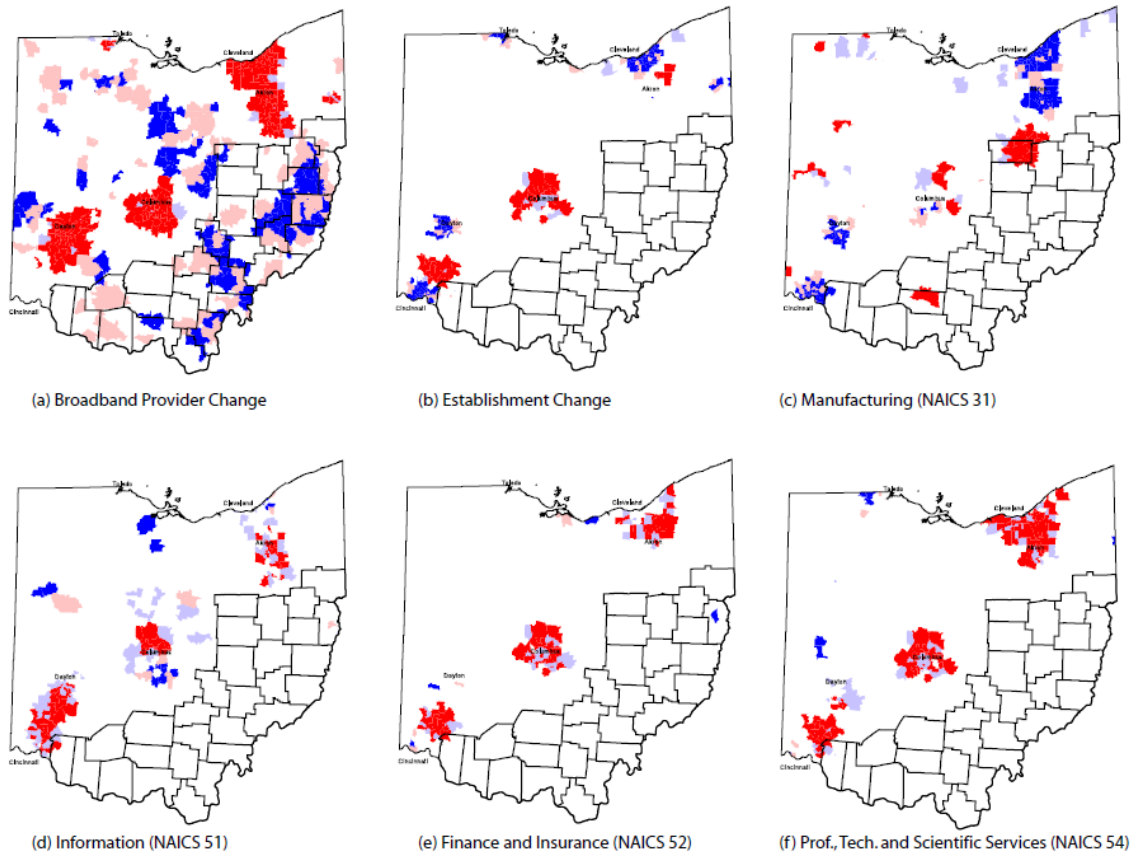


Figure 3.5: Local Moran Results for Changes in Broadband Providers, Establishments and Select NAICS Sectors (1999-2004)

From an interpretive standpoint, the patterns revealed in this type of analysis might indicate whether places experiencing the largest positive changes in broadband provision

¹² The high-high classification corresponds to ZIP codes displaying high levels of the variable of interest (e.g. firms or broadband providers) that are surrounded by other ZIP codes with similar values. The high-

are also experiencing similar changes in establishment counts. If this was the case, such results would suggest that large positive changes in establishments are correlated with large positive changes in broadband provision. This visualization of statistical patterns in the data was accompanied by a count of the number of central and suburban ZIP code areas in each of the two local Moran's *I* categories of interest; this count analysis is displayed in Figure 3.6.

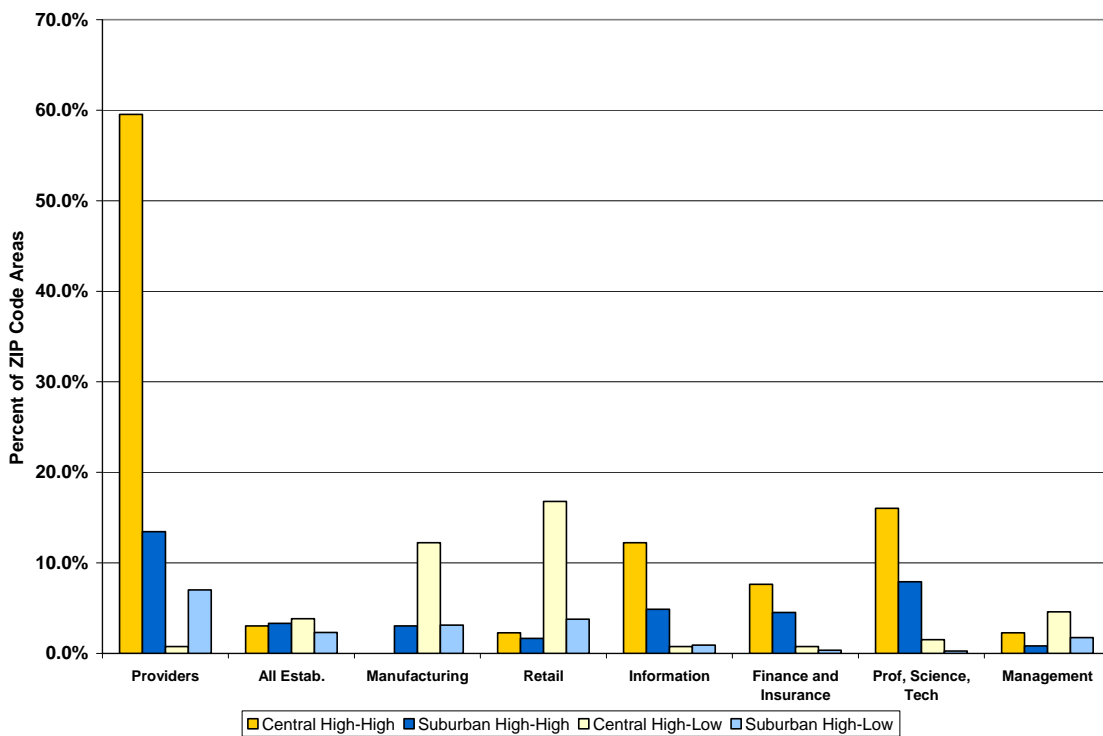


Figure 3.6: Central and Suburban ZIP Code Local Moran Trends (1999-2004)

When considered simultaneously, the results suggest that ZIP codes experiencing large positive changes in broadband provision are overwhelmingly clustered in central areas, as demonstrated by the patterns evident in cities such as Dayton, Columbus,

low classification corresponds to ZIP codes displaying high levels of the variable of interest that are

Akron, and Youngstown. Tabulations indicate that 60% of all central ZIP code areas are in the High-High LISA category while only 13.5% of suburban ZIP code areas are present in this same category. Establishments, however, exhibit a less obvious locational preference until these patterns are broken down by industry. The LISA maps and the count analysis both reveal a suburban preference for Retail and Manufacturing establishments while the remaining industries demonstrate a strong central preference. These more centrally located industries have a tendency to situate in areas with the highest levels of broadband provision. This suggests that in addition to benefits associated with central areas (e.g., agglomeration economies), that perhaps these firms have a preference for high levels of broadband provision. The strong central bias of broadband provision and establishment location is consistent with the concentration school of thought, which suggests that agglomeration effects and the uneven distribution of ICT infrastructure will reinforce the importance of central locations.

Despite this evidence in favor of the concentration school, the trends for Retail and Manufacturing provide support for proponents of the heterogeneous effects school. Although these two industries exhibit a predominantly suburban location preference, “pockets” of positive changes in central ZIP code areas are a departure from this trend. Where Retail is concerned, it is likely that this pattern is a manifestation of shopping centers with large amounts of leasable space (e.g. urban power-centers) (Lloyd, 1991; Nunn, 2001). Rookwood Pavilion/Commons in Cincinnati is one good example of such a center, ranking as the tenth largest shopping/office development in the Cincinnati Metropolitan Statistical Area with 570,000 square feet of leasable space (CBC, 2006). High-low patterns in these industries speak to the underlying theme of this school of

surrounded by other ZIP codes displaying relatively lower levels.

thought; ICT merely provides firms with the option of making a decentralization decision if it is deemed economically feasible.

3.4.c Broadband and Establishment Relationships

The previous exploratory analysis suggests the presence of some similarities between changes in broadband provision and establishment patterns, particularly at the industry level. Pattern similarity, however, is not sufficient to definitively conclude a relationship exists between broadband presence and firm location. To better examine such a relationship, a correlation analysis was performed for establishments in aggregate, establishments by industry, and establishments by firm size. Given the deviations of establishment data from a normal distribution, a Spearman rank correlation coefficient was used to analyze these relationships, similar to the approach implemented by Hackler (2003).

Figure 3.7 displays the correlations between broadband provision and establishments by firm size. The correlation coefficient between these two variables increased most rapidly between 1999 and 2002, leveled off in 2003, and declined slightly thereafter. The trajectory of this relationship suggests a potential broadband saturation point, which in this context, is analogous to market saturation for a product. Market saturation occurs when new demand is no longer being generated for a product or service (Poole et al., 2006). Such shifts in demand are often attributed to competition, decreased need or obsolescence (ibid). As a result, the stabilization in the correlation coefficients at around 0.86 could signify that provision numbers had reached a saturation point for markets in Ohio by 2003, and that increased competition beyond this level was counterproductive. It may also reflect the frenetic mergers and acquisitions activity in the

telecommunications industry in the late 1990s and initial years of the new millennium (Warf, 2003) as the industry trended toward oligopoly (Faulhaber and Hogendorn, 2000).

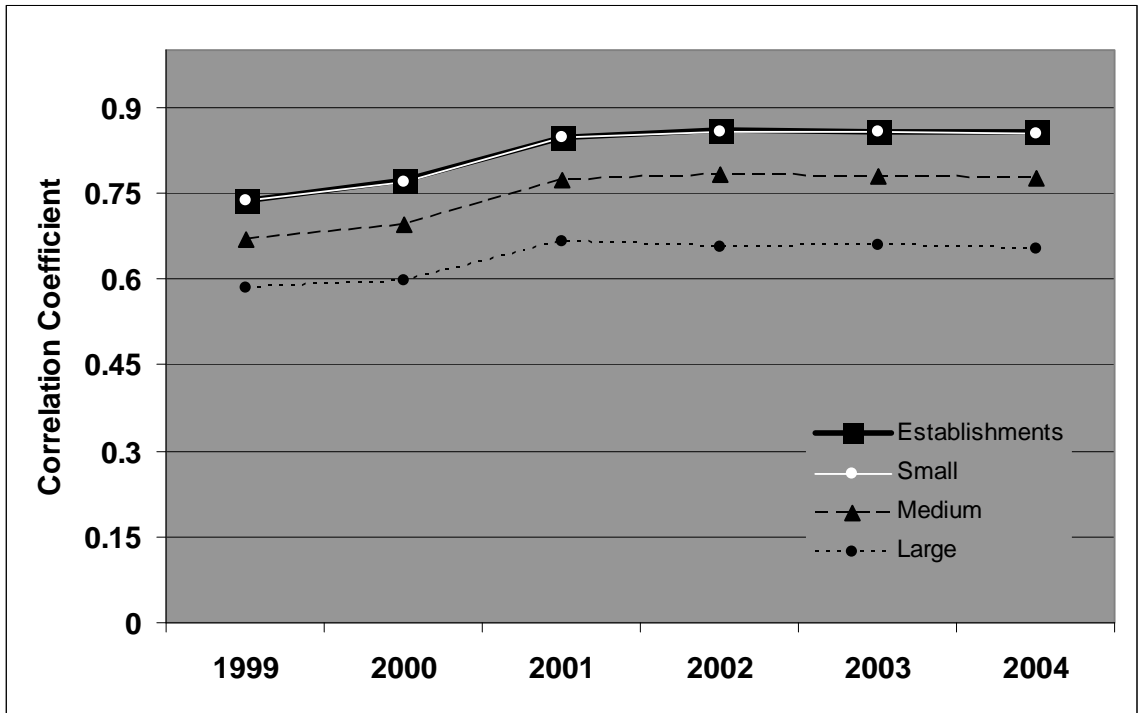


Figure 3.7: Spearman Correlation Between Broadband and Establishments (1999-2004)

This figure also illustrates the variation in the relationship between broadband and establishments by firm size. Large businesses have the lowest correlation coefficient over time while small businesses have the highest coefficients; which are nearly identical with those for all establishments.¹³ One of the reasons for such dissimilarities might stem from differences in ICT platform choice, particularly between small, medium and large businesses. For example, it is not uncommon for larger firms to opt for fiber-based telecommunication connections. Large businesses, like financial institutions, are the most likely types of establishments to use fiber for Internet connections because of the

¹³ This is not surprising given small business make up almost 94% of all business in Ohio for each of the years in the study period.

huge costs associated with such high volume connections (Hansen, 2005). Given the expense of fiber, smaller firms might be forced to use copper-based broadband technologies such as cable and xDSL. This simple dichotomy would explain the observed relationship between firm size and broadband; as firm size increases the correlation with broadband decreases.

3.4.d Industry Breakouts and Partial Correlations

Figure 3.7 also suggests that in a simultaneous framework, broadband and establishments are correlated in every year of the study period, but that the strength of this relationship varies by firm size. This result is indicative of the predictions made by the heterogeneous effects school, which also predicts that this relationship will vary by industry. In this context, one would expect the level of broadband use to coincide with a firm's business model. Thus, information intensive industries such as Finance and Insurance would have higher correlation coefficients than those which are less information intensive, such as Manufacturing. In order to examine this assertion of the heterogeneous effects school, aggregate and partial correlation coefficients were tabulated for the change in the number of broadband providers and the change in establishment counts in aggregate and by industry between 1999 and 2004 (Table 3.4). Partial correlation coefficients were calculated to eliminate the effects of population on this relationship given the evidence from prior studies that broadband and population are highly correlated (Grubestic and Murray, 2004; Flamm, 2006).¹⁴ This analysis reveals

¹⁴A comparison of the year-by-year "aggregate" and partial correlation coefficients for all establishments and establishments by industry reveals that the partial correlation coefficient is dramatically lower than the "aggregate" correlation coefficient. When the partial correlations are calculated, the average "aggregate" correlation coefficient between broadband provision and all establishments for the study period drops from 0.82 to 0.28, a decline of 65%.

that changes in broadband are not correlated with changes in establishments, but that this relationship varies by industry. Although the size of these coefficients is small at the industry level, the presence of some correlation between establishments and broadband at the firm level is important in the context of this exploratory study. The goal of this chapter was to uncover whether there was any significant relationship at all between these two variables. Therefore, although the size of the aggregate and partial correlation coefficients is small, the fact that some significant relationship suggests that more sophisticated statistical analyses may be worthwhile.

Additional analysis of the correlation results highlights changes in Manufacturing and Retail have a negative and significant relationship with changes in broadband. Information, Finance and Insurance, and Professional, Scientific, and Technical Services have a small positive and significant relationship with broadband. These relationships hint to the similarities/dissimilarities in locational preferences between broadband and each of these industries discussed previously. Broadband, Information, Finance and Insurance, and Professional, Scientific, and Technical Services all have distinct central biases while Manufacturing and Retail have a suburban bias. The negative relationship between those industries with a suburban bias and broadband is of particular interest because of its implications for the growth prospects of suburban areas. Grubestic and Murray (2002) found that growing suburban location were likely to experience low levels of broadband provision due to infrastructure challenges related to xDSL services. Further, the locational preferences of each industry and their relationship with broadband provision preferences suggest that there will be limits to the types of industries an area can attract and develop because of insufficient levels of broadband provision.

	Aggregate	Partial¹⁵
All Establishments	-0.04	-0.03
Manufacturing	-0.18*	-0.18*
Retail	-0.16*	-0.16*
Information	0.12*	0.12*
Finance and Insurance	0.19*	0.19*
Prof., Scientific, and Technical	0.22*	0.23*
Management	0.05**	0.06*

Table 3.4: Spearman Rank Correlations: Change in Broadband Providers and Establishment Counts (1999-2004)

3.5 Discussion and Conclusion

An examination of the relationship between broadband and firm location in an ESDA framework yielded several important results. First, the data visualization and spatial autocorrelation analysis revealed important spatial patterns in establishment and broadband provision trends that might not have been apparent in a standard tabular database. These analyses demonstrated industry level variations in the spatial distribution of firms between urban and suburban areas which may be related to the persistent urban bias of broadband provision. Locational variations by industry support the results of previous studies (Sohn et. al, 2002) and affirm the importance of considering industry specific characteristics when designing economic development strategies and telecommunications policy. Second, the correlation analysis presented above suggests that in a simultaneous framework, a statistically significant relationship exists between broadband and establishments, but that the intensity of this relationship varies by firm size and industry. Small businesses have a higher correlation with broadband provision than do medium and large businesses. Industries that are more likely to require broadband

¹⁵ This adjusts the correlation between firms and broadband for population.

access for business functions, such as Information and Finance and Insurance, display a central zip code location bias which perhaps reflects the central location tendency of broadband provision. Third, changes in broadband provision do not necessarily correspond to changes in aggregate establishment patterns, although significant relationships are present at the two-digit NAICS industry level, however small. Finally, the subtle, yet significant relationships between broadband provision and firm location might never have been uncovered in a standard spatial-econometric analysis, particularly given the complexities associated with standard regression analyses. The determination of the presence of spatial autocorrelation in these data is particularly important given the potential for spurious regression results if this violation of statistical independence is ignored (Messner et al., 1999).

The conclusions generated by this study also present avenues for additional research. Although Ohio is an interesting case study, the relative intensity of Internet use across Ohio's industries may not be as high as states with higher levels of Information industry employment such as California, New York, and Texas (ODOD, 2007). Therefore, a comparison of results across multiple states is important for the verification of the findings of this study. Second, the use of two-digit NAICS industries to decompose industry-level establishment relationships with broadband may be insufficient industrial resolution given the variety of firms included at the two-digit level of aggregation. A more disaggregate analysis of the relationship between broadband and more Internet intensive firms (Hackler, 2003), such as those producing Internet content (Zook, 2000), may yield higher correlation coefficients than those produced in this study. Third, the results of this analysis assume a simultaneous relationship exists between broadband and

establishments. This assumption may be unrealistic, particularly if a lagged effect exists between these two variables. Finally, the Spearman rank correlation measures the strength of the *linear* relationship between two variables, when the nature of the relationship between the variables of interest may in fact be nonlinear.

This exploratory analysis of the spatial patterns of broadband provision and establishment counts partially debunks the deconcentration school's prediction about the impact of ICTs on firm location. Instead, the relationships uncovered between broadband and establishments agree with the predictions of the concentration and heterogeneous effects schools of thought. Firms have not decentralized en masse, but exhibit locational preferences that vary by firm size and industry. While the location patterns of industries like Professional, Scientific, and Technical Services certainly suggest the presence of agglomeration economies in central locations, these patterns also provide arguments for potentially constrained development patterns for the more Internet-intensive industries examined in this study. These findings imply that if firms in Internet-intensive industries wish to relocate to suburban locations, the urban bias of broadband, and lower levels of broadband provision in the suburban and exurban reaches of Ohio may prevent this from occurring. This is particularly true when the inverse relationship between broadband costs and population density (OSC, 2006) are added to the picture.

These considerations suggest an understanding of the complex relationship between ICTs, like broadband, and firm location is critical to the design of successful development strategies and policies to encourage regional economic growth. Quantitative analyses, like the present study, in combination with state level initiatives to evaluate existing levels of ICT infrastructure, represent important steps in the development of

informed, comprehensive strategies to develop and attract businesses in an increasingly competitive global business environment.

3.6 References

- Anselin, L. (1995). Local indicators of spatial association-LISA. *Geographical Analysis*, 27, 93-115.
- Anselin, L. (2004). Geoda 0.9.5-i5. Spatial Analysis Laboratory, Department of Agricultural and Consumer Economics. University of Illinois, Urbana-Champaign, Urbana.
- Anselin, L., Varga A., & Acs, Z. (1997). Local geographic spillovers between university research and high technology innovations. *Journal of Urban Economics*, 42, pp. 422-448.
- Aoyama, Y., Ratick, S.J., & Schwarz, G. (2005). Modeling the impact of business-to-business electronic commerce on the organization of the logistics industry. *Geographical Analysis*, 37, 46-68.
- Atkinson, R.D. (1998). Technological change and cities. *Cityscape*, 3, 129-70.
- Audirac, I. (2005). Information technology and urban form: challenges to smart growth. *International Regional Science Review*, 28, 119-45.
- Cairncross, F. (1997). *The death of distance*. Boston: Harvard Business School Press.
- CBC [Cincinnati Business Courier]. (2006). *Top 10 largest shopping centers*. from: http://www.cincinnatiusa.org/pdf/bus_lists/lgst_shopping.pdf.
- Center for a New Orange County. (2006). *The information and communication technology comprehensive economic development strategy ICT CEDS for Orange County, California*. from http://www.wrjgroup.com/projects/ICTCEDSReport/ICTCEDS_2006.pdf.
- Center for an Urban Future. (2004). *New York's broadband gap*. from www.nycfuture.org.
- Clarke, M. (2003). *e-development? Development and the new economy*. United Nations University. World Institute for Development Economics Research. from http://www.wider.unu.edu/publications/policy-briefs/wider-policy-briefs/en_GB/pb7/
- D'Amboise, G., & Muldowney, M. (1988). Management theory for small business: Attempts and requirements. *The Academy of Management Review*, 13, 226-240.
- Faulhaber, G., & Hogendorn, C. (2000). The market structure of broadband telecommunications. *The Journal of Industrial Economics*, 48, 305-329.

- FCC [Federal Communications Commission]. (2007). *High-speed Internet access "broadband."* from <http://www.fcc.gov/cgb/consumerfacts/highspeedinternet.html>
- Flamm, K. (2006). *Diagnosing the disconnected: Where and why is broadband access unavailable in the U.S?* Telecommunications Policy Research Conference, Fairfax, VA, from <http://web.si.umich.edu/tprc/papers/2006/588/flammmbb0806.pdf>
- Forman, C., Goldfarb, A., & Greenstein, S. (2005). How did location affect adoption of the commercial Internet? Global village vs. urban leadership. *Journal of Urban Economics*, 58, 389-420.
- Gaspar, J., & Glaeser, E.L. (1998). Information technology and the future of cities. *Journal of Urban Economics*, 43, 136-56.
- Gehlke, C., & Biehl, K. (1934). Certain effects of grouping upon the size of the correlation coefficient in census tract material. *Journal of American Statistical Association*, 29, 169-170.
- Gibbs, D., & Tanner, K. (1997). Information and communication technologies and local economic development policies: The British case. *Regional Studies*, 31, 765-774.
- Gong, H., & Wheeler, J.O. (2002). The location and suburbanization of business and professional services in the Atlanta metropolitan area. *Growth and Change*, 33, 341-369.
- Graham, S. (1999). Global grids of glass: On global cities, telecommunications and planetary urban networks. *Urban Studies*, 36, 929-949.
- Graham, S., & Marvin, S. (1996), *Telecommunications and the City*. New York: Routledge.
- Greenstein, S. (2007). *Data constraints & the Internet economy: Impressions & imprecision*. NSF/OECD meeting on Factors Shaping the Future of the Internet. from: <http://www.oecd.org/dataoecd/5/54/38151520.pdf>
- Grimes, D., Prime, P.B., & Walker, M.B. (2007). Change in the concentration of employment in computer services: spatial estimation at the U.S. metro county level. *Growth and Change*, 38, 39-55.
- Grubestic, T.H. (2003). Inequities in the broadband revolution. *The Annals of Regional Science*, 37, 263-89.
- Grubestic, T.H. (2004). The geodemographic correlates of broadband access and availability in the United States. *Telematics and Informatics*, 21, 335-58.

- Grubestic, T.H. (2006). A spatial taxonomy of broadband regions in the United States. *Information Economics and Policy*, 18, 423-448.
- Grubestic, T.H. (2008). Zip codes and spatial analysis: Problems and prospects. *Socio-Economic Planning Sciences*, 42(2), 129-149.
- Grubestic, T.H., & Murray, A.T. (2002). Constructing the divide: Spatial disparities in broadband access. *Papers in Regional Science*, 81, 197-221.
- Grubestic, T.H., & Murray, A.T. (2004). Waiting for broadband: Local competition and the spatial distribution of advanced telecommunication services in the United States. *Growth and Change*, 35, 139-165.
- Gulati, R., Nohria, N., & Zaheer, A. (2000). Strategic networks. *Strategic Management Journal*, 21, 203-215.
- Hackler, D. (2003). Invisible infrastructure and the city. *American Behavioral Scientist* 46, 1034-55.
- Hansen, E. (2005, January 17). *Google want 'dark fiber'*. CNET News.com
http://www.news.com/Google-wants-dark-fiber/2100-1034_3-5537392.html
- Holloway, S.R., & Wheeler, J.O. (1991). Corporate headquarters relocation and changes in metropolitan corporate dominance, 1980-1987. *Economic Geography*, 67, 54-74.
- Holmes, S., & Gibson, B. (2001). *The definition of small business*. The Small Business Coalition (SBC), Australia. from:
<http://www.smallbusiness.org.au/sbc/publications/sbc004.pdf>
- Klier, T., & Testa, W. (2002). Location trends of large company headquarters during the 1990s. *Federal Reserve Bank of Chicago Economic Perspectives*, 26, 12-26.
- Kraut, R.E. (1989). Telecommuting: The trade-offs of home work. *Journal of Communication*, 39, 19-47.
- Kutay, A. (1986). Optimum Office Location and the Comparative Statics of Information Economies. *Regional Studies*, 20(6), 551-64.
- Kutay, A. (1988). Technological change and spatial transformation in an information economy: 1. A structural model of transition in the urban system. *Environment and Planning A*, 20, 569-593.

- Le Blanc, G. (2003). Regional specialization, local externalities and clustering in information technology industries. In L. Pagnetto (Ed.), *Knowledge economy, information technologies and growth* (pp. 453-487). Burlington: Ashgate.
- Leamer, E. E., & Storper, M. (2001). The economic geography of the Internet age. In: *NBER Working Paper Series: National Bureau of Economic Research*.
- Lloyd, W.J. (1991). Changing suburban retail patterns in metropolitan Los Angeles. *Professional Geographer*, 43, 335-344.
- Messner, S.F., Anselin, L., Baller, R.D., Hawkins, D.F., Deane, G., & Tolnay, S.E. (1999). The spatial patterning of county homicide rates: An application of exploratory spatial data analysis. *Journal of Quantitative Criminology*, 15, 423-450.
- Moran, P.A.P. (1948). The Interpretation of Statistical Maps. *Journal of the Royal Statistical Society: Series B*, 10(2), 243-251.
- Moss, M.L. (1998). Technology and cities. *Cityscape*, 3, 107-27.
- NAICS. (2002). *North American Industry Classification System* U.S. Census Bureau. <http://www.census.gov/epcd/naics02/def/NDEF51.HTM#N51>.
- NTIA [National Telecommunications and Information Administration]. (2004). *A nation online: Entering the broadband age*. Washington, D.C.
- Nunn, S. (2001). Planning for inner-city retail development: The case of Indianapolis. *Journal of the American Planning Association*, 67, 159-172.
- ODOD [Ohio Department of Development]. (2007). from: <http://www.odod.state.oh.us/research/>.
- O'hUallachain, B., & Reid, N. (1991). The location and growth of business and professional services in American metropolitan areas, 1976-1986. *Annals of the Association of American Geographers*, 81, 254-270.
- Openshaw, S. (1984). *The modifiable areal unit problem*. Norwich: Geobooks.
- OSC [Ohio SuperComputer Center]. (2006). *2006 Broadband Ohio study: Availability and cost of broadband Internet service options in Ohio*. from: <http://www.osc.edu/networking/broadband/index.shtml>
- OTP [Office of Technology Policy]. (2002). *Understanding Broadband Demand*. U.S. Department of Commerce. Washington, D.C.

- Poole, R., Clarke, G.P., & Clarke, D.B. (2006). Competition and saturation in West European grocery retailing. *Environment and Planning A*, 38, 2129-2156.
- Prekumar, G. (2000). Rural business and telecommunications technologies. In: P.F. Korsching, P.C., Hipple, & E.A. Abbott (Eds.), *Having All the Right Connections: Telecommunications and Rural Viability* (83-100). London: Praeger.
- Salomon, I. (1996). Telecommunications, cities and technological opportunism. *Annals of Regional Science*, 30, 75-90.
- Sassen, S. (1994). *Cities in a world economy*. Thousand Oaks: Pine Forge Press.
- Saxenian, A.L. (1998). Immigrant entrepreneurs in Silicon Valley. *Berkeley Planning Journal*, 12, 32-49.
- SBA [Small Business Administration]. (1997). *The economic impact of small businesses*. Washington, D.C.
- SBA [Small Business Administration]. (2007). from: <http://app1.sba.gov/faqs/faqindex.cfm?areaID=24>
- Sohn, J., Tschangho, J.K., & Hewings, G.J.D. (2002). Information technology impacts on urban spatial structure in the Chicago region. *Geographical Analysis*, 34(4), 313-329.
- Sohn, J., Tschangho, J.K., & Hewings, G.J.D. (2003). Information technology and urban spatial structure: A comparative analysis of the Chicago and Seoul regions. *Annals of Regional Science*, 37, 447-462.
- Sommers, P., & Carlson, D. (2003). What the IT revolution means for regional economic development. *The Brookings Institution Center on Urban and Metropolitan Policy*. from http://www.brookings.edu/reports/2003/02labormarkets_sommers.aspx.
- Steinfeld, C., & Scupola-Hugger, A. (2007). When do SME's benefit from e-commerce in an industrial cluster? Evidence from a biotech cluster. *APEC Symposium on Industrial Clustering for SMEs, Taipei*. from: https://ebusiness.tc.msu.edu/papers/paper_CharlesSteinfeld.pdf
- Tukey, J.W. (1977). *Exploratory Data Analysis*. Reading: Addison-Wesley.
- Unwin, D. J. (1996). Gis, spatial analysis and spatial statistics. *Progress in Human Geography*, 20, 540-541.

U.S. Census Bureau. (2000). *Office of Management and Budget: Standards for Defining Metropolitan and Micropolitan Statistical Areas*. from:
<http://www.census.gov/population/www/estimates/00-32997.pdf>.

U.S. Census Bureau. (2007). *County Business Patterns*. from:
<http://www.census.gov/epcd/cbp/view/cbpview.html>.

Warf, B. (1989). Telecommunications and the globalization of financial services. *Professional Geographer*, 41, 257-271.

Warf, B. (2003). Mergers and acquisitions in the telecommunications industry. *Growth and Change*, 34, 321-344.

Zook, M.A. (2000). The web of production: The economic geography of commercial Internet content production in the United States. *Environment and Planning A*, 32, 411-426.

Zook, M.A. (2002). Hubs, nodes and by-passed places: A typology of e-commerce regions in the United States. *Tijdschrift voor Economische en Sociale Geografie*, 93, 509-521.

Zook, M.A. (2005). *The geography of the internet industry: Venture capital, dot-coms and local knowledge*. New York: Blackwell.

4. All Jobs Are Not Created Equal: Divergent Indicators in the Knowledge Economy

4.1. Introduction

As the global economy continues to integrate, the economic fate of nation-states is no longer conceptualized as a singular outcome. Instead, the economic viability of countries is determined by the dynamic growth prospects of sub-national economic regions within their traditional geo-political boundaries.¹ As a result, regions, not nation-states, are considered the nexus of competitive advantage in the global economy, and the economic fate of countries depends upon the unique competencies of their component regions (Scott, 1998; 2006; Porter, 1998). In turn, the strength of these sub-national regions depends upon the strong presence of technologically advanced firms, which are more likely to compete successfully in the global marketplace (Martin, 2006).

Although advancements in computing technology are unlikely to be a sustained source of competitive advantage, (Schumpeter, 1961; Porter 1990) regional competitiveness is linked to the ability of individual firms to innovatively leverage the efficiency gains and flexibility provided by computing technologies. It is also widely recognized that the use of information and communication technologies (ICT) increases the productivity of firms (Pohjola, 2002). However, quantifying these productivity gains on the growth prospects of regional economies is challenging given heterogeneities in ICT access and availability (Graham and Marvin, 2001; Grubestic, 2006), variations in firm adoption of these technologies (Forman et al., 2005), and differences in firm specific efficiency gains associated with ICT use (Yilmaz and Dinc, 2002).

¹ *Region* is a relatively generic term that refers to a geographic area of subnational extent.

The uneven adoption of ICTs by firms in different industries, combined with the heterogeneous spatial distribution of these firms, suggests that the productivity gains associated with ICTs will be somewhat irregular. As a result, the manner in which economic performance is measured and regional economies are benchmarked needs to be reevaluated. One frequently used indicator of economic performance is employment growth (Bartolome and Spiegel, 1997; Gabe and Kraybill, 2002; Faulk, 2002). However, firm and industry specific productivity gains may mean that some jobs are more productive and subsequently pay more than others. Thus, all jobs are not created equal. These subtle differences in job characteristics, which are likely to have become more pronounced in recent years, hold significant implications for the growth trajectories of regional economies. Regions with more productive workers are not only likely to have higher aggregate earnings than regions with less productive workers; they are also likely to produce higher value-added goods. These subtle but important differences in jobs and job quality are not easily captured by univariate indicators of economic performance. As a result, there is a strong need to create and apply more sophisticated, multivariate indicators for evaluating regional development.

While the development of multivariate indicators is crucial, the purpose of this chapter is more modest. The goal of this chapter is to highlight and discuss the numerical biases associated with using univariate indicators to benchmark regional economic performance. If the hypothesis that all jobs are not created equal is true, growth trends in univariate indicators (e.g employment and earnings) will differ (i.e. diverge) over time. This divergence in trends may be particularly acute between regions where the productivity gains associated with ICT use are uneven. In the analysis that follows,

indicator trends and their consistencies over time will be explored at the national and state levels for the United States between 1977 and 2007. Specifically, growth trends in commonly used indicators (e.g. employment, earnings and establishments) will be decomposed over time, space, and industries to empirically highlight divergent growth scenarios related to the evolution of the U.S economy in the second half of the twentieth century.

4.2. New Economy Forces and Regional Convergence

While the structural and technological changes in the U.S. economy during the latter half of the twentieth century were spawned by a complex web of macroeconomic and geopolitical factors, there are three periods of change worth noting. Singh (1995) characterizes 1950-1973 as the “golden age” of the world economy - an era demarcated by unprecedented levels of production and consumption. During the latter years of this golden age and the twenty year period that followed, declining trade volumes in manufactured goods and a growing emphasis on knowledge work in the U.S. economy began to emerge (Singh, 1995), ushering in the beginnings of a post-industrial society (Machlup, 1962; Drucker, 1969; Bell, 1973; Porat, 1976). The 1980s witnessed significant shrinkage in manufacturing industries throughout the U.S. (DiGaetano and Lawless, 1999) due to increased international competition and a drive to reduce inefficiencies and costs. This was closely followed by several significant technological advancements in computing and telecommunications infrastructure in the 1990s, spawning both productivity improvements and the creation of new sectors of the economy (Bresnahan and Tratjenberg, 1995; Graham and Marvin, 1996). By the end of

the 1990s, experts suggested the economic metamorphosis was so dramatic and so complete, that the world economy had been permanently altered by globalization and the ICT revolution, ushering in the New Economy (Pohjola, 2002).

Not surprisingly, this transformation of the world economy changed some fundamental relationships, once taken for granted, in benchmarking regional economic growth. One of these relationships is the historical correlation between employment and productivity. Studies suggest the historical positive correlation between employment and productivity has shifted to a negative correlation, and that employment is now growing more rapidly in low productivity industries than in high productivity industries (Appelbaum and Schettkat, 1995). This reversal in correlation suggests that the use of employment as the sole indicator of economic development can be misleading. This is most likely true in a post-industrial economy driven by the innovative use of ICTs. Therefore, a reliance on employment as the sole (i.e. univariate) measure of development success can obscure important differences in other indicators such as earnings and business growth.

Other trends that should be considered when benchmarking regional economic growth are highlighted in recent studies of income convergence which find significant variations in income over space, time and industry. For example, Rey and Montouri (1999) find spatial autocorrelation in the convergence of relative income growth for states. In other words, there is a tendency for states to exhibit convergence behavior similar to their neighbors. In addition, Yamamoto (2008) finds that finer spatial scales exhibited greater income disparities between 1955 and 2003 in the United States, particularly in the last few decades of the study. Not surprisingly, these decades

correspond to a period with a marked rise in the use of information and communication technologies. Time series analyses also provide evidence of regional fluctuations in income convergence trends within the United States. For example, Carlino and Mills (1996a) uncovered divergence in state and regional earnings per capita between 1978 and 1988 despite general convergence trends in prior decades.

Of particular relevance to this chapter, are the findings of time series analyses which suggest significant variations in income convergence trends related to indicator selection and industrial composition. For instance, Carlino and Mills (1996b) find less conclusive evidence for convergence in per capita earnings than per capita income because of more persistent shocks to earnings. Checherita (2009) suggests that the compositional effects of industry on regional convergence is significant, and plays an important role in explaining economic growth for states in the U.S. Similarly, Bernard and Jones' (1996a) examination of total factor productivity (TFP) in OECD countries from 1970-1987 found that convergence in aggregate TFP is related to industrial composition – manifesting in services instead of manufacturing. Similar results were found for wage divergence in the United States, where producer services had negative effects on wages between 1969 and 1979, but a positive impact between 1979 and 1999 (Drennan, 2005).

What factors are generating these mixed results? The results of the previously mentioned studies certainly suggest that a consideration of variations in the technological sophistication of industries is necessary when evaluating regional growth trends, irrespective of the macro-economic factors fueling convergence or divergence (Nissan and Carter, 1990; Bernard and Jones, 1996b). The literature also suggests that an

examination of variations in growth trends across space, time, and industry dimensions is necessary to avoid biased perspectives on regional development. One major analytical hurdle that contributes to these biases, are the current numerical and statistical limitations of standard measures of economic progress.

4.2.1 Measures of Economic Development

The evolution of the global economy has led to the recognition that revisions are necessary in the ways that industries are classified (Walker and Murphy, 2001) and the ways in which economic progress is measured. Specifically, Landefeld and Fraumeni (2001, 23) note:

“Many have hypothesized that we are in a new economy that is the product of various structural changes occurring in the last two decades and that has contributed to the recent improvement in economic performance.”

Ironically, univariate evaluations of economic development persist despite widespread recognition that measures of economic performance need to be modified to account for recent changes in the global economy. Commonly used univariate measures of growth include *employment* (Wasylenko and McGuire, 1985; Bartolome and Spiegel, 1997; Gabe and Kraybill, 2002; Faulk, 2002), *firms* (Hart, 1956; Simon and Bonini, 1958; Hymer and Pashigian, 1962; Singh and Whittington, 1975; Carlton, 1983; Dunne et al., 1989) and *income* (Braun, 1991; Ram, 1997; Wink and Eller, 1998; Morrill, 2000).

The preference for univariate measures is also compounded by the use of popular diagnostic tools for comparative economic analysis, such as location quotients, shift-share analysis, input-output models and indices of industrial composition (Siegel et al., 1995; Wagner, 2000; Dissart, 2003). All of these tools, in their traditional form, are

univariate in nature – typically focusing on employment. Unfortunately, multivariate extensions of these tools often lead to fairly significant degradation in their utility. For example, in an evaluation of several classic indices of industrial diversity, Mack et al. (2007) found that multivariate applications often yield nonsensical and non-intuitive results, particularly in a spatial context.

Another explanation for the persistent use of univariate indicators is the difficulty associated with constructing multivariate time-series. This is particularly true for higher resolution spatial units such as census tracts and ZIP codes, the latter of which is highly dynamic and largely unreliable for many spatial applications (Grubestic and Matisziw, 2006; Grubestic, 2008). Despite these limitations and the difficulties associated with constructing multivariate time-series, this analysis will empirically evaluate the need for analysts to make a final and lasting effort to depart from univariate analyses of regional economic development. Again, if one accepts the premise that all jobs are not created equal in the global information economy, univariate snapshots of regional development trends will no longer suffice.

4.3. Data

4.3.1 Data Sources

Data were collected at the national and state levels for all indicators of interest for the 48 contiguous U.S. states from three sources: REIS, County Business Patterns, and the Geospatial & Statistical Data Center at the University of Virginia. Earnings and employment data were collected from the REIS (BEA, 2009a). Earnings are in 2000 dollars and were deflated with the Consumer Price Index from the Bureau of Labor

Statistics (BLS, 2009).² Firm data are from County Business Patterns of the U.S. Census Bureau (2009) and the Geospatial & Statistical Data Center at the University of Virginia (UVA, 2009). The latter source was used to collect historical firm data prior to 1986 which are not currently available on the Census Bureau's website.

4.3.2 Study Period

The data acquired for this analysis span a thirty-year time period (1977-2007). This is a particularly interesting era to examine trends in indicators because of a number of major economic events that include both abrupt shocks to the U.S economy as well as more gradual changes associated with the evolution to a post-industrial era and a services-oriented economy. For example, the study period includes the boom (1999) and bust (2000) years for two stock market bubbles associated with Dot-com companies and telecommunications companies (Lowenstein, 2004). It also includes the recession of 2001 (March 2001-November 2001) (NBER, 2009) and the economic impacts related to the terrorist attacks of September 11, 2001. Finally, this period also corresponds to rapid growth in the deployment and adoption of information and communications technologies (ICTs) like the Internet (NTIA, 2000).

Data were analyzed in aggregate and at the industry level. The aggregate data are analyzed for the period as a whole (1977-2007) and by decade (1980-1989, 1990-1999,

² The CPI from the BLS was for all urban consumers, US city average, all items with a base year (1982-1984). A change of base calculation was performed to convert the base year from 1982-1984 to 2000 (BLS, 2009).

2000-2007).³ The industry level analysis is split into two time periods, 1977-1997 and 2001-2007. This division was necessary for two reasons. First, the classification systems used to divide industrial activity changed from the Standard Industrial Classification System (SIC) to the North American Industrial Classification System (NAICS) in 1997. Therefore, data prior to 1998 are classified by SIC industry, while 1998 data and beyond are classified by NAICS industry. Since these classification systems are incompatible (Walker and Murphy, 2001), two separate time-series are used in this study to account for this shift in industrial classification systems. Second, the Regional Economic Information System (REIS) reports industry data corresponding with the NAICS from 2000 forward (BEA, 2009a). Therefore, the start and end years of the two time series were adjusted to correspond with the Bureau of Economic Analysis (BEA) reporting conventions. Decadal analyses for industry level data were partitioned to coincide with the NAICS and BEA reporting conventions: 1980-1989, 1990-1997, and 2001-2007.

4.3.3 Technical Notes

Before proceeding to a discussion of the analysis, there are a few technical details worth mentioning. First, earnings were selected for use over Gross State Product (GSP) because of a time-series break in the GSP data produced by the BEA. This break is not only a factor of the SIC/NAICS industry classification change but other sources, “including differences in source data and different estimation methodologies” (BEA, 2009b). Further, the use of earnings in place of GSP is not considered a major drawback

³ The 1970s are not included in the analysis of decadal trends, primarily because data prior to 1977 are not available for sub-interval study periods. However, analyses that use end points of decades can be included with the available data.

because “earnings represent 64 percent of GDP and provide a reasonable indicator of economic output for most regions” (BEA, 2009c). Second, earnings per worker (EPW) are used in this study as a proxy for productivity. This metric is utilized to quantify differences in earnings trends and employment trends.

In the next section, the results of the analysis are presented at two different scales. First, a broad-based, numerical overview of national level trends in employment, earnings, earnings per worker (EPW) and establishments (collectively referred to as “indicators”) is presented. The intent of this macro-level analysis is to provide a succinct backdrop for exploring temporal, industrial, and spatial variations in these indicators at the state level. Next, the state level analysis is undertaken to evaluate regional differences in aggregate indicators trends. For example, is there a positive correlation for aggregate indicators in some areas and a negative correlation in other areas? This analysis is also designed to examine divergence in indicator trends related to the uneven spatial distribution of firms across regions. In other words, does the growth or decline of particular sectors drive aggregate indicator trends at the state level? Findings of a consistent industry-level impact may inform regions with a large presence in particular industries about the size of the numerical bias presented by univariate indicators.

4.4. Results

4.4.1 National Level Aggregate Trends

Table 4.1 illustrates national level trends for employment, earnings, earnings per worker (EPW) and establishments for the 1977-2007, with breakouts by decade. Two additional time periods, 1990-1997 and 2001-2007, are also included to maintain consistency with the industry level analysis time-series to be discussed in the next

section. Table 4.1 shows that growth is positive across all indicators but that the level of growth varies dramatically by indicator and decade. For example, both employment and establishments experienced the largest amount of growth in the 1980s, while earnings experienced the highest growth in the 1990s. These trends in employment and earnings appear to coincide with the growth in services in the 1980s and growth in “new economy” jobs in the 1990s.

Indicator	1977-2007	1980-1989	1990-1997	1990-1999	2000-2007	2001-2007
Employment	84.2%	23.5%	13.6%	19.4%	9.3%	9.3%
Earnings	103.9%	27.7%	17.3%	31.9%	11.5%	11.6%
Earnings per Worker (EPW)	10.7%	3.4%	3.3%	10.4%	2.0%	2.1%
Establishments	76.9%	34.4%	11.7%	13.5%	9.0%	8.6%

Table 4.1: National Growth Trends by Indicator

4.4.1.a National Level Industry Trends

Although the national level trends are fairly straightforward, the industry-level analysis of growth demonstrates several idiosyncrasies in these indicators (Tables 4.2 and 4.3). Specifically, the depiction of growth provided by each indicator is dramatically different for some industries, even within the same time period. For example, while *manufacturing* employment declined (-3.6%), the number of *manufacturing* establishments increased 19.9% (Table 4.2). A similar situation exists for NAICS industry 51 (Information) between 2001 and 2007 (Table 4.3). This industry displays negative growth in employment and earnings, but positive growth in establishments.

		1977-1997		
SIC Industry	Establishments	Employment	Earnings	EPW
Agriculture	158.8%	163.0%	121.6%	-15.7%
Mining	-3.5%	-13.1%	-13.9%	-1.0%
Construction	51.8%	64.4%	32.4%	-19.5%
Manufacturing	19.9%	-3.6%	4.4%	8.3%
Transportation	80.3%	43.6%	36.0%	-5.3%
Wholesale	41.3%	38.8%	48.8%	7.2%
Retail trade	25.5%	58.2%	27.6%	-19.3%
Finance, Insurance, and Real Estate	63.9%	47.0%	145.0%	66.6%
Services	106.1%	118.5%	141.6%	10.6%
		1980-1989		
SIC Industry	Establishments	Employment	Earnings	EPW
Agriculture	72.2%	51.2%	73.8%	15.0%
Mining	0.1%	-18.4%	-33.6%	-18.6%
Construction	30.9%	29.0%	26.8%	-1.7%
Manufacturing	13.7%	-3.8%	3.5%	7.6%
Transportation	35.6%	12.0%	10.8%	-1.1%
Wholesale	19.5%	16.7%	24.6%	6.7%
Retail trade	22.2%	26.6%	22.2%	-3.5%
Finance, Insurance, and Real Estate	25.8%	22.0%	48.7%	21.9%
Services	54.6%	48.6%	70.8%	14.9%
		1990-1997		
SIC Industry	Establishments	Employment	Earnings	EPW
Agriculture	37.4%	34.2%	12.0%	-16.5%
Mining	-11.7%	-17.0%	2.3%	23.3%
Construction	15.3%	15.1%	7.0%	-7.1%
Manufacturing	4.0%	-1.6%	5.0%	6.8%
Transportation	27.8%	13.4%	18.6%	4.6%
Wholesale	11.3%	6.9%	12.1%	4.9%
Retail trade	3.8%	13.7%	10.0%	-3.3%
Finance, Insurance, and Real Estate	24.4%	9.4%	51.3%	38.2%
Services	23.5%	23.5%	24.6%	0.9%

Table 4.2: Comparison of Growth Trends by Indicator and SIC Industry

		2001-2007		
NAICS Industry (Two-digit code)	Establishments	Employment	Earnings	EPW
Forestry, fishing, related activities, other (11)	-10.6%	-1.8%	-6.9%	-5.2%
Mining (21)	7.7%	19.5%	68.5%	41.0%
Utilities (22)	-5.8%	-7.0%	10.1%	18.4%
Construction (23)	16.1%	18.1%	13.8%	-3.7%
Manufacturing (31)	-6.0%	-14.6%	-2.4%	14.4%
Wholesale trade (42)	-1.0%	6.1%	14.5%	7.9%
Retail Trade (44)	0.3%	4.0%	2.5%	-1.5%
Transportation and warehousing (48)	15.3%	7.5%	5.9%	-1.5%
Information (51)	4.7%	-12.8%	-5.1%	8.8%
Finance and insurance (52)	19.5%	7.5%	17.2%	9.0%
Real estate and rental and leasing (53)	23.8%	46.7%	5.5%	-28.1%
Professional and technical services (54)	17.8%	12.2%	16.4%	3.8%
Management of companies and enterprises (55)	6.5%	10.4%	27.4%	15.3%
Administrative and waste services (56)	6.0%	16.2%	19.0%	2.4%
Educational services (61)	22.6%	25.4%	26.0%	0.5%
Health care and social assistance (62)	16.8%	16.6%	23.0%	5.5%
Arts, entertainment, and recreation (71)	18.2%	15.3%	13.4%	-1.6%
Accommodation and food services (72)	15.3%	13.2%	18.8%	5.0%
Other services, except public administration (81)	3.5%	11.8%	11.7%	-0.1%

Table 4.3: Comparison of Growth Trends by Indicator and NAICS Industry

To provide some additional perspective on these idiosyncrasies, an examination of earnings per worker is needed. As mentioned previously, EPW is a good proxy for productivity. Thus, EPW provides a way of differentiating between high wage jobs and low wage jobs. In the context of wage inequalities in job creation across industries, growth in EPW between 1977 and 1997 for *retail trade* is negative (-19.3%) despite positive employment growth (58%) in the same period. Conversely, EPW for *manufacturing* (8.3%) is positive despite negative job growth (-3.62%) in this sector. This suggests jobs in *retail trade* pay relatively lower wage than *manufacturing* jobs.

This is confirmed when EPW by industry is examined for the terminal year of the three decades included within the study period of interest (Table 4.4). *Retail trade* wages are demonstrably lower and declining when compared to industries such as *manufacturing* and *wholesale trade*. Interestingly, EPW in *finance, insurance and real estate (FIRE)* have increased dramatically since the 1970s. According to Table 4.2, wages in this sector have increased the most (66%) of all industries over the study period. These analytical results clearly demonstrate that job creation and earnings growth are not necessarily coincident. The joint consideration of job growth and earnings together via EPW emphasizes the fact that all jobs are not created equal; jobs in some industries have distinctly higher wage growth than do jobs in other industries. Combined, these results suggest there is a marked industrial bias to indicator trends.

	1979	1989	1997
Private	\$ 35.21	\$ 34.73	\$ 35.45
Agriculture	\$ 21.30	\$ 21.45	\$ 18.22
Mining	\$ 59.30	\$ 50.07	\$ 62.23
Construction	\$ 43.95	\$ 40.78	\$ 36.71
Manufacturing	\$ 46.17	\$ 48.08	\$ 50.55
Transportation	\$ 52.62	\$ 49.53	\$ 50.94
Wholesale	\$ 45.25	\$ 46.35	\$ 48.37
Retail Trade	\$ 22.44	\$ 20.19	\$ 18.92
FIRE	\$ 26.47	\$ 30.95	\$ 43.03
Services	\$ 28.64	\$ 31.71	\$ 32.08

Table 4.4: National Level Earnings per Worker (2000\$)

4.4.1.b Compositional Biases

Thus far, the national level analysis has demonstrated that growth trends vary over time and by industry. The industry-level decomposition of national trends also revealed that some industries are more sensitive to divergent trends than others, but that

this industrial bias is not constant over time. Another drawback of using a single measure of economic performance is the compositional bias of certain indicators, which is demonstrated in Tables 4.5 and 4.6. Although earnings and employment present a fairly consistent picture of industrial composition, this is not the case for establishments.⁴ For example, the proportion of the national economy dedicated to *manufacturing* activities in 1989 is 24.6% if earnings are used as the indicator of interest, but only 17.7% if employment is the indicator of interest, and 6% if establishments is the indicator used. Conversely, the proportion of the national economy involved in *retail* and *services* activities is more consistent across indicators (Tables 4.5 and 4.6a-4.6c). Further analysis of this apparent contradiction in composition reveals it is related to the number of people employed by an establishment. For example, between 1977 and 1997 approximately 80% of manufacturing businesses in the U.S. employed fewer than 50 people. In that same time period, roughly 95% of retail and 96% of service establishments employed fewer than 50 people. Thus, the number of establishments in a particular industry may, in fact, under represent an industry's importance to the regional economy in terms of employment or earnings. This is certainly the case in industries with larger-scale operations like manufacturing, as opposed to smaller scale retail or service operations.

⁴ In this chapter, composition is measured by industry shares.

Earnings	1979	1989	1997	1977-1997
Agricultural services, forestry, fishing & other	0.6%	0.7%	0.8%	43.0%
Mining	2.1%	1.3%	1.2%	-44.4%
Construction	8.1%	7.6%	6.6%	-14.6%
Manufacturing	31.1%	24.6%	21.2%	-32.6%
Transportation and public utilities	9.2%	8.0%	8.1%	-12.3%
Wholesale trade	8.0%	7.9%	7.5%	-4.0%
Retail trade	12.4%	11.6%	10.6%	-17.6%
Finance, insurance, and real estate	7.0%	8.4%	10.9%	58.1%
Services	21.5%	29.9%	33.1%	55.9%
Employment				
Employment	1979	1989	1997	1977-1997
Agricultural services, forestry, fishing & other	0.9%	1.2%	1.5%	68.3%
Mining	1.3%	0.9%	0.7%	-44.4%
Construction	6.5%	6.4%	6.4%	5.2%
Manufacturing	23.7%	17.7%	14.9%	-38.3%
Transportation and public utilities	6.2%	5.6%	5.7%	-8.1%
Wholesale trade	6.2%	5.9%	5.5%	-11.2%
Retail trade	19.5%	20.0%	19.9%	1.2%
Finance, insurance, and real estate	9.3%	9.4%	9.0%	-5.9%
Services	26.4%	32.8%	36.5%	39.8%
Establishments				
Establishments	1979	1989	1997	1977-1997
Agricultural services, forestry, fishing & other	1.0%	1.3%	1.7%	63.5%
Mining	0.6%	0.5%	0.4%	-39.1%
Construction	9.9%	9.0%	9.7%	-4.1%
Manufacturing	7.1%	6.0%	5.7%	-24.3%
Transportation and public utilities	3.7%	3.7%	4.3%	13.9%
Wholesale trade	8.4%	7.5%	7.7%	-10.8%
Retail trade	27.3%	24.5%	23.0%	-20.7%
Finance, insurance, and real estate	9.3%	8.7%	9.8%	3.5%
Services	27.8%	32.4%	36.9%	30.2%

Table 4.5: Snapshots of SIC Industry Shares

Earnings	2001	2007	2001-2007
Forestry, fishing, related activities, other (11)	0.46%	0.39%	-16.56%
Mining (21)	1.08%	1.63%	51.03%
Utilities (22)	1.25%	1.23%	-1.35%
Construction (23)	7.26%	7.40%	1.97%
Manufacturing (31)	16.67%	14.58%	-12.49%
Wholesale trade (42)	6.26%	6.42%	2.62%
Retail Trade (44)	8.13%	7.47%	-8.10%
Transportation and warehousing (48)	4.17%	3.96%	-5.11%
Information (51)	5.07%	4.31%	-14.96%
Finance and insurance (52)	9.02%	9.47%	5.03%
Real estate and rental and leasing (53)	2.79%	2.64%	-5.47%
Professional and technical services (54)	11.42%	11.92%	4.33%
Management of companies and enterprises (55)	2.51%	2.86%	14.16%
Administrative and waste services (56)	4.27%	4.55%	6.64%
Educational services (61)	1.45%	1.64%	12.96%
Health care and social assistance (62)	10.37%	11.44%	10.26%
Arts, entertainment, and recreation (71)	1.23%	1.25%	1.62%
Accommodation and food services (72)	3.17%	3.37%	6.49%
Other services, except public administration (81)	3.45%	3.45%	0.12%

Table 4.6a: Snapshots of NAICS Industry Shares (Earnings)

Employment	2001	2007	2001-2007
Forestry, fishing, related activities, other (11)	0.73%	0.65%	-10.1%
Mining (21)	0.58%	0.63%	9.4%
Utilities (22)	0.44%	0.37%	-14.9%
Construction (23)	7.00%	7.57%	8.1%
Manufacturing (31)	12.12%	9.47%	-21.9%
Wholesale trade (42)	4.46%	4.34%	-2.9%
Retail Trade (44)	13.15%	12.53%	-4.8%
Transportation and warehousing (48)	3.88%	3.82%	-1.6%
Information (51)	2.88%	2.30%	-20.2%
Finance and insurance (52)	5.58%	5.49%	-1.6%
Real estate and rental and leasing (53)	3.94%	5.28%	34.3%
Professional and technical services (54)	7.52%	7.72%	2.7%
Management of companies and enterprises (55)	1.27%	1.28%	1.1%
Administrative and waste services (56)	6.83%	7.27%	6.4%
Educational services (61)	2.17%	2.49%	14.8%
Health care and social assistance (62)	11.09%	11.84%	6.7%
Arts, entertainment, and recreation (71)	2.30%	2.42%	5.5%
Accommodation and food services (72)	7.65%	7.93%	3.6%
Other services, except public administration (81)	6.44%	6.59%	2.3%

Table 4.6b: Snapshots of NAICS Industry Shares (Employment)

Establishments	2001	2007	2001-2007
Forestry, fishing, related activities, other (11)	0.37%	0.31%	-17.7%
Mining (21)	0.34%	0.34%	-0.8%
Utilities (22)	0.25%	0.22%	-13.3%
Construction (23)	9.85%	10.53%	6.9%
Manufacturing (31)	4.97%	4.30%	-13.5%
Wholesale trade (42)	6.19%	5.64%	-8.8%
Retail Trade (44)	15.78%	14.58%	-7.6%
Transportation and warehousing (48)	2.69%	2.85%	6.2%
Information (51)	1.93%	1.87%	-3.6%
Finance and insurance (52)	5.99%	6.59%	10.1%
Real estate and rental and leasing (53)	4.33%	4.93%	14.0%
Professional and technical services (54)	10.38%	11.26%	8.5%
Management of companies and enterprises (55)	0.67%	0.66%	-1.9%
Administrative and waste services (56)	5.11%	4.99%	-2.4%
Educational services (61)	1.00%	1.13%	12.9%
Health care and social assistance (62)	9.46%	10.18%	7.6%
Arts, entertainment, and recreation (71)	1.49%	1.63%	8.8%
Accommodation and food services (72)	7.73%	8.21%	6.2%
Other services, except public administration (81)	10.14%	9.66%	-4.7%

Table 4.6c: Snapshots of NAICS Industry Shares (Establishments)

This dramatic difference in composition is entirely related to the indicator of choice, and clearly highlights the importance of considering the impacts of indicator selection when evaluating the industrial composition of regional economies. Regardless of the underlying macroeconomic factors that contribute to these differences, these findings reiterate the point that univariate indicators of regional growth, like employment or establishments, can completely mask the subtle characteristics of industries. Further, although some of these differences can be smoothed with the aggregation of employment,

establishment or earnings to the national level, this is not the case for more disaggregate analyses, where differences in industrial composition and economic development display more local variation.

4.4.2 State Level Aggregate Trends

The state level analysis in this section demonstrates the dramatic differences in growth trajectories presented by univariate indicators, as did the national level analysis. However, a state level analysis also provides more information about regional differences in aggregate growth trends. One major regional difference that will be highlighted is the uneven distribution of industries across states.

In an effort to provide a slightly different perspective on temporal variations in indicator trends, a commonly used metric of inequality, the Gini coefficient, is used. This metric is typically used in regional convergence studies (Tam and Persky, 1982) and has a range of 0 to 1. A value of 0 corresponds to complete equality, while a value of 1 corresponds to complete inequality amongst the spatial units of interest. For the purposes of this chapter, *no* divergence in indicator trends means the Gini coefficients for each indicator should be nearly identical. The reverse will be true if indicators display divergence.

Figure 4.1a, presents the Gini coefficients derived from state level totals of earnings, employment and establishments, which present dramatically different pictures of inequality. For example, earnings display the largest amount of inequality at the state level across all time periods, while establishments display the least amount of inequality. The temporal trajectories of these Gini coefficients also present different trends in regional inequality. The Gini coefficient for earnings increased slightly over the study

period (+0.19%) suggesting a slight increase in regional disparities, while the Gini coefficients for employment (-2.40%) and establishments (-0.63%) suggested decreasing disparities across states. These varying temporal signatures suggest increased differences in earnings between states, which may be related to industry level variations in productivity.

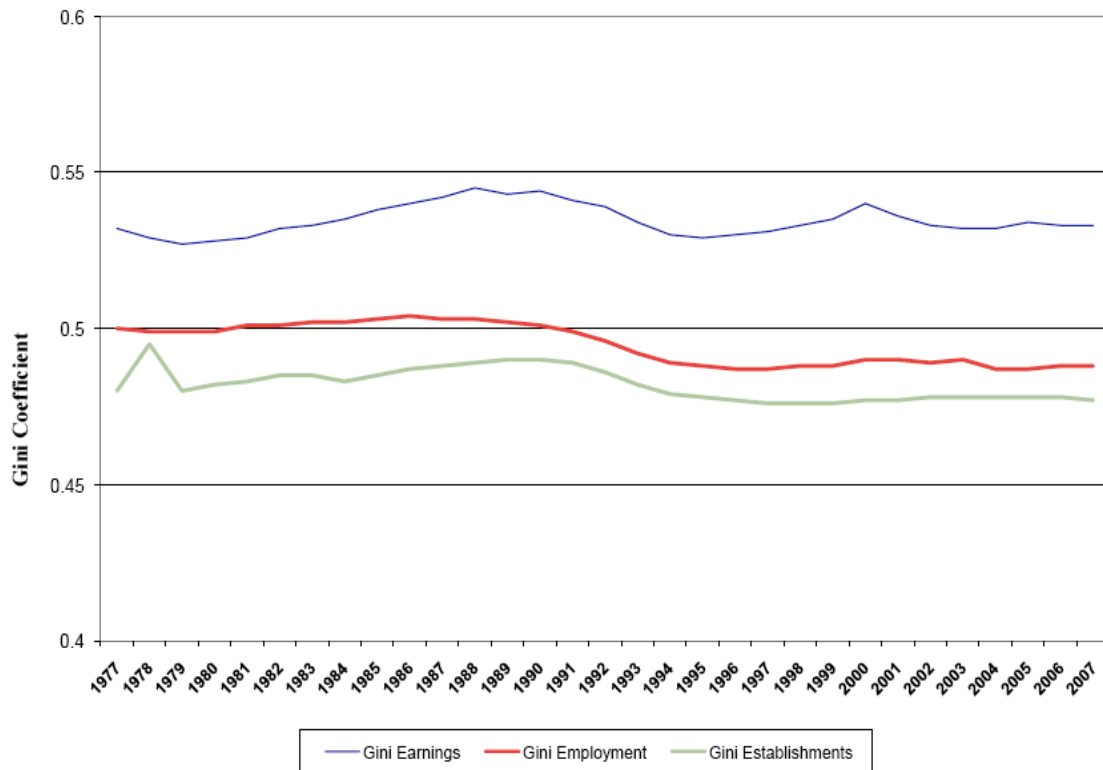


Figure 4.1a: Gini Coefficients by Indicator (1977-2007)

Another way to quantify the differences in the level of regional inequality presented by each indicator is to examine the difference in the Gini coefficient values in pairwise combinations. Figure 4.1b presents the difference in Gini coefficient values for three different combinations of indicator pairs: earnings and employment, employment

and establishments, and earnings and establishments. In effect, the trend lines represent the gap in Gini coefficient values for each of these pairs over time. Of particular interest is the difference in the Gini coefficient values for earnings and employment, which grew steadily during the 1980s and 1990s, and became most pronounced in 2000. This growing gap suggests earnings growth outpaced employment growth for some regions of the country, particularly in the final two decades of the twentieth century. One explanation for this growing disparity in earnings may be gleaned from the analysis of earnings per worker (EPW) in section 4.1.a. It depicted industrial differences in wage growth over time, and suggests industry level trends may explain the relatively higher level of inequality when the Gini coefficient is computed with earnings instead of employment. The question is; do actual shifts in industrial composition empirically confirm these findings?

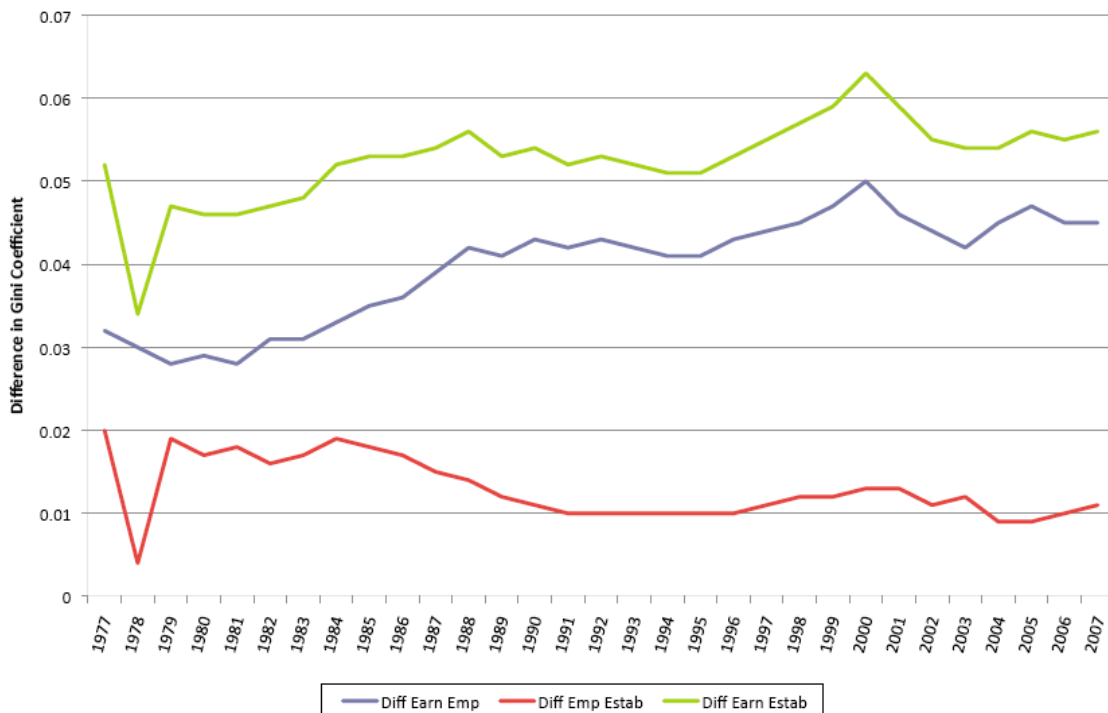


Figure 4.1b: Difference in Gini Coefficient Values by Indicator (1977-2007)

4.4.3 State Level Industry Trends

The analysis in this section focuses on evaluating whether industry trends can explain the divergent regional growth trajectories presented by aggregate indicators. As mentioned previously, adoption studies demonstrate industry level differences in firm use of information technology (Forman et al., 2005) and suggest an industrial bias in the productivity gains associated with ICTs. This bias should be reflected in industry level indicator trends. Specifically, technology intensive industries should have higher earnings growth than less technology intensive industries. Therefore, it is expected that less technology intensive industries will experience greater divergence in employment and earnings than technology intensive industries.

This portion of the analysis will focus solely on trends in SIC earnings and employment for two reasons. First, the SIC industry data covers a longer time series than the NAICS industry data. Second, earnings and employment are relatively free from the compositional bias associated with the use of some indicators, like establishments, demonstrated earlier in section 4.1. Three SIC industries were selected for this portion of the analysis based on their large shares of employment and earnings: *manufacturing*, *retail*, and *services*. A fourth sector, *FIRE*, was also selected to serve as a litmus test because of the sector's propensity to utilize ICTs more intensively than other industries (Brown and Goolsbee, 2002; Forman et al., 2002; Hipple and Kosanovich, 2003). Combined, these four sectors account for about 70% of the earnings and employment in the U.S. between 1977-1997.

In order to evaluate whether changes in aggregate employment and earnings reflect changes in industry level indicators, a series of basic correlations were calculated

for the entire study period (1977-1997) as well as by decade. The results of these calculations are reported for employment in Table 4.7.⁵ Interestingly, while the relationship between employment in *manufacturing* and *FIRE* exhibit decade specific trends, *services* and *retail trade* employment display more general trends for the study period. In the 1980s for example, an increase in state *manufacturing* employment displayed a significant and negative correlation with overall employment growth.⁶ In the 1990's, however, this trend is reversed and there is a significant, positive correlation between aggregate employment growth and the number of people employed in manufacturing.⁷ Although there is no singular explanation for such a change, this reversal in trends may be related to transformations in manufacturing during the study period from a lower-value added product base to a higher-valued added product base (Oliner et al., 2008). For instance, while the 1980s were characterized by declines in durable goods manufacturing, including automobiles (Sachs et al., 1994), the 1990s experienced growth in high value-added manufacturing (i.e. semiconductors) in places like Silicon Valley (Oliner and Sichel, 2000; Oliner et al., 2008).

⁵ Because the results for employment were quite similar to those for earnings, the general interpretation and discussion of the results apply to both indicators.

⁶ Significance in this discussion will refer to p-values of 0.05 and lower.

⁷ In this decade there was no correlation between manufacturing earnings and aggregate earnings.

	Total Emp. (1977-1997)	Total Emp. (1980-1989)	Total Emp. (1990-1997)		Total Emp. (1977-1997)	Total Emp. (1980-1989)	Total Emp. (1990-1997)
Manufacturing Emp. (1977-1997)	0.2109 (0.1502)	--	--	FIRE Emp. (1977-1997)	-0.0964 (0.5145)	--	--
Manufacturing Emp. (1980-1989)	--	-0.3214 (0.0259)	--	FIRE Emp. (1980-1989)	--	-0.0016 (0.9912)	--
Manufacturing Emp. (1990-1997)	--	--	0.3537 (0.0136)	FIRE Emp. (1990-1997)	--	--	0.4638 (0.0009)
	Total Emp. (1977-1997)	Total Emp. (1980-1989)	Total Emp. (1990-1997)		Total Emp. (1977-1997)	Total Emp. (1980-1989)	Total Emp. (1990-1997)
Services Emp. (1977-1997)	-0.6003 (0.0000)			Retail Emp. (1977-197)	-0.2636 (0.0703)		
Services Emp. (1980-1989)		-0.4311 (0.0022)		Retail Emp. (1980-1989)		-0.2584 (0.0761)	
Services Emp. (1990-1997)			-0.652 (0.0000)	Retail Employment (1990-1997)			-0.0923 (0.5327)

p-values are in parentheses

Table 4.7: Correlations Between Aggregate Employment and Employment by SIC Industry

The relationship between employment growth in the *FIRE* sector and aggregate employment growth also exhibited decade specific trends. For example, there was no discernable relationship between FIRE growth in the 1980s and aggregate employment. However, a much stronger and positive relationship exists between the two during the 1990s. This is not unexpected, particularly given the tremendous growth in the stock market in the 1990s related to the Dot-com and telecommunications bubbles (Lowenstein, 2004).

Unlike the higher productivity *FIRE* sector, employment growth in the *services* sector displayed a significant, negative correlation with aggregate employment for both

decades and the study period as a whole. *Retail trade* had a similar correlation with aggregate employment for the entire study period, but did not display any decade specific trends. These results suggest higher productivity industries have a positive impact on aggregate indicator growth while lower productivity industries have a negative impact on aggregate indicator growth. These state-level industry findings largely confirm the results of Applebaum and Schetkatt (1995) and strongly support the principle that all jobs are not created equal. Specifically, job creation in productive industries is positively correlated with aggregate employment growth while job creation in less productive industries is negatively correlated with aggregate employment growth.

The temporal and industrial decomposition of growth trends in this section highlighted the underlying numerical biases associated with the use of univariate indicators for evaluating regional economic development. A final challenge is to translate this information into a spatial context. In addition to major differences in jobs, the distribution of jobs is also likely to vary across geographic space. Thus, it is important to have the ability to identify which regions benefit most from job creation. Again, if employment, establishments, earnings and EPW diverge across time and industries, understanding *where* they diverge in geographic space is a critical piece of the regional development puzzle.

4.4.4 Spatial Trends in State Level Indicators

If the premise that all jobs are not created equal is true, then one of the implications of the analytical results thus far is that employment growth in high productivity industries also produces high earnings growth. Conversely, employment growth in low productivity industries will likely produce low earnings growth. In sum,

this suggests that divergent indicator trends occur in regions with growth in low productivity industries. Therefore, the goal of the statistical analysis in this section is to determine if the uneven spatial distribution of productive industries yields divergent indicator trends in some states and not others.

Figures 4.2a and 4.2b illustrate the spatial distribution of aggregate state employment growth and *manufacturing* employment growth between 1980 and 1989. While it is difficult to detect any correspondence in spatial patterns via a visual inspection of these maps, it is possible to statistically determine the coincidence of spatial trends via global measures of spatial association.⁸ Specifically, a bivariate version of the global Moran's *I* statistic (Anselin, et al., 2002) is implemented to detect the spatial association between states with aggregate earnings and employment growth, and states with earnings and employment growth for our target industries (*manufacturing, retail trade, services* and *FIRE*).⁹ The bivariate Moran's *I* statistic was computed separately for each indicator pair by industry in order to highlight differences in industrial trends across space. The interpretation of the bivariate Moran's *I* statistic is relatively simple for this application. Statistically significant and positive *z*-values suggest that a spatial association exists between states with aggregate growth in earnings or employment and industry specific growth in these same indicators. Conversely, a statistically significant and negative *z*-value suggests negative spatial association, or a repellent spatial trend between states.

⁸ Please see Anselin et al. (2002) for the specification of the global Moran's *I* statistic and its bivariate, local version.

⁹ These statistics were calculated with a first-order queen contiguity matrix.

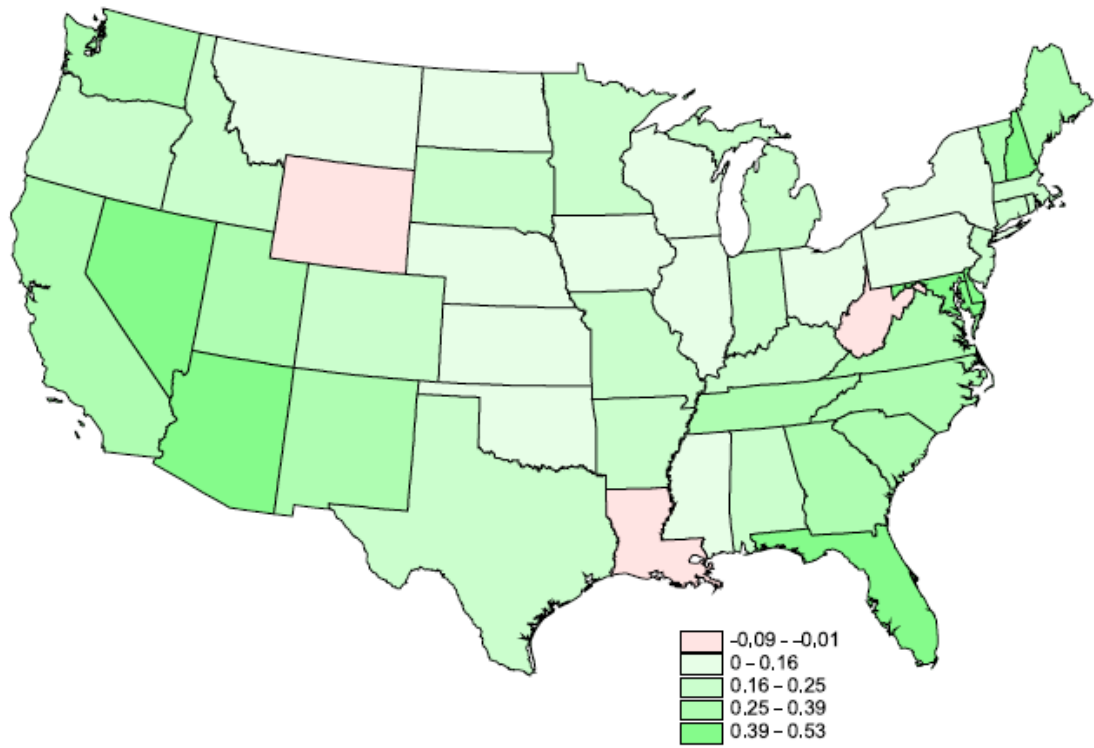


Figure 4.2a: Aggregate Employment Growth (1980-1989)

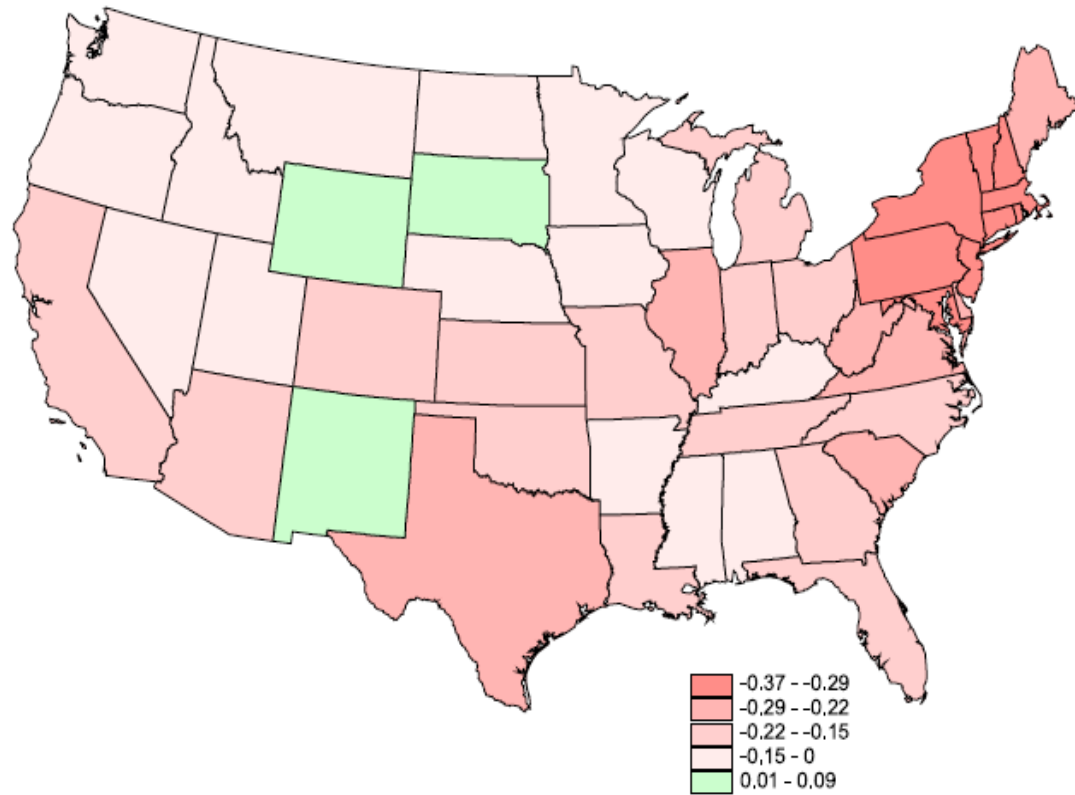


Figure 4.2b: Manufacturing Employment Growth (1980-1989)

The results of these tests are highlighted in Table 4.8 and provide strong empirical support for a spatial association exists between earnings and employment growth. Specifically, there is a positive spatial relationship between earnings and employment growth for high productivity industries (*FIRE*) and a negative spatial relationship between these two indicators for low productivity industries (*services*). This finding is consistent with the anticipated relationship based upon the premise that all jobs are not created equal. The results for *manufacturing* and *retail trade*, however, merit further discussion.

	Employment Growth (1980-1989)	
	z-value (Moran's I)	p-value
Percent Change Earnings Retail Trade (1980-1989)	2.8407	0.0122
	Employment Growth (1990-1997)	
	z-value (Moran's I)	p-value
Percent Change Earnings Manufacturing (1990-1997)	3.8138	0.0009
Percent Change Earnings Services (1990-1997)	-3.0537	0.0013
Percent Change Earnings FIRE (1990-1997)	2.5963	0.027
Percent Change Earnings Retail Trade (1990-1997)	2.7018	0.0166
	Earnings Growth (1980-1989)	
	z-value (Moran's I)	p-value
Percent Change Employment Manufacturing (1980-1989)	-5.3479	0.0001
Percent Change Employment Services (1980-1989)	-1.6624	0.0536
Percent Change Employment FIRE (1980-1989)	3.4889	0.0023
Percent Change Employment Retail Trade (1980-1989)	5.1963	0.0001
	Earnings Growth (1990-1997)	
	z-value (Moran's I)	p-value
Percent Change Employment Manufacturing (1990-1997)	2.7439	0.0171
Percent Change Employment Services (1990-1997)	-3.9535	0.0001
Percent Change Employment FIRE (1990-1997)	2.5782	0.0266
Percent Change Employment Retail Trade (1990-1997)	0.6355	0.7661

Table 4.8: Bivariate Moran's I Results

Manufacturing demonstrates decade specific spatial trends which are related to productivity trends in this industry. Again, these trends may be related to a change in manufacturing emphasis from a lower-value added focus in the 1980s to a higher-value added focus in the 1990s (Oliner et al., 2008). In the 1980s there is a significant and negative spatial association between states with growth in manufacturing employment and those with aggregate earnings growth. In the 1990s, however, there is a positive relationship between states with growth in manufacturing earnings and employment and

states with aggregate growth in employment and earnings. This represents a shift from the negative spatial association uncovered in the 1980s, and is similar to the findings from the industry level correlation analysis presented earlier.

The results for *retail trade* are somewhat different. Interestingly, while retail trade is a low productivity industry, a positive spatial relationship exists between employment and earnings. As noted previously, this signature is typically associated with high productivity industries. One explanation for this apparently contradictory trend is the fact *retail trade* is a supporting industry for high-productivity industries. Therefore, growth in higher productivity industries can promote growth in this lower productivity industry (e.g. *retail trade*) in certain situations. Not surprisingly, this result is consistent with economic base theory. However, this trend obscures potential wage issues associated with job growth *retail trade*, which displays declining earnings per worker (Table 4.4). In sum, the spatial relationship between industry specific indicator trends and aggregate indicator trends support the case of Applebaum and Schetkatt (1995), who suggested that a link exists between growth in highly productive industries and overall economic expansion. This industry specific link with productivity is a break from the historic positive correlation between employment and productivity, and hallmark of a post-industrial economy (ibid).

4.5. Discussion and Conclusion

The dynamic temporal, industrial, and spatial trends in economic indicators uncovered in this analysis are not only indicative of a post-industrial informational economy, but also demonstrate the pitfalls associated with the current univariate bias to regional benchmarking practices. The considerable inconsistencies in indicator trends

reflect the complexities associated with performance measurement and regional benchmarking in the global information economy. These inconsistencies mean that a single indicator *should not* be used and then adjusted for some systematic bias. In fact, the demonstrated inconsistencies over space, time, and industry suggest that there is no way of knowing, a priori, the size of the bias introduced into an analysis by utilizing a single indicator as a measure of economic growth.

The analytical results of this chapter largely support the premise that all jobs are not created equal. The analysis of earnings per worker (EPW), which served as a proxy for productivity, highlighted growing wage disparities across industries at the national level. This was supported by the Gini coefficient analysis, which highlighted growing wage disparities across industrial sectors, and suggested that these disparities are linked to industrial variations in productivity. An evaluation of indicators for four industries of interest (*manufacturing, services, FIRE, and retail trade*) revealed several interesting trends related to the productivity of these sectors. Low productivity industries like *services* and *retail trade* had a negative impact on aggregate indicator trends while high productivity industries like *manufacturing* and *FIRE* had a positive impact on aggregate indicator trends (e.g. employment). A spatial analysis of employment, earnings and establishments largely supported these industry level findings.

Taken together, these results demonstrate widespread variability in indicators across time, space, and industry. Where policy is concerned, these results serve as a warning against the use of univariate indicator trends, in isolation, to measure economic performance. Results also suggest that multivariate benchmarking practices should become the norm and not the exception. One possible solution to mitigating variations in

indicator performance and interpretation is to use a composite metric, similar to the CS-Index introduced by Mack et al. (2007). This metric effectively reduces the influence of (and reliance on) a single indicator for summarizing extremely complex and nuanced phenomena such as regional development. Multiple indicators may also be used in conjunction with one another to better understand the impact of industry level trends on aggregate economic growth, as demonstrated in the spatial analysis of indicator trends.

The temporal and spatial variations in indicator trends, related to the relative productivity of firms within regions, also cautions against the blind selection of peer groups (e.g. counties or metropolitan areas) based on spatial proximity or historical precedent alone. Variation in indicator trends also means that it is not possible to use established peer groups consistently over time without first verifying their viability. This determination should be based upon metrics associated with industrial composition and growth rates via composite, not univariate, measures.

In all, while many of the variations in trends highlighted in this chapter are somewhat nuanced, accuracy and the absence of bias are critical considerations for developing meaningful benchmarks of regional economic performance – an increasingly popular tool in a globalized economy where regions strongly compete (Martin, 2006). Although further econometric research is required to confirm the impact of industrial composition on divergent indicator trends across regions, this chapter certainly demonstrated some of the pitfalls associated with traditional benchmarking approaches. Now more than ever, this suggests that development policies are not a “one size fits all” formula and unique regional characteristics and circumstances should be addressed in the design of economic development strategies and performance evaluation. Shocks to

national economies, both abrupt and gradual, have heterogeneous impacts on regional economies that cannot be summarized by a single measure of economic performance. As globalization continues apace and technology continues to impact the industrial structure of regional economies and the productivity of jobs, evaluations of economic performance must adapt accordingly lest they grossly misrepresent the true growth trajectory of regional economies.

4.6 References

- Anselin, L., Syabri, I., & Smirnov, O. (2002). *Visualizing multivariate spatial correlation with dynamically linked windows*. from: <http://www.real.uiuc.edu/d-paper/02/02t-8.pdf>.
- Applebaum, E., & Schetkatt, R. (1995). Are prices unimportant? The changing structure of the industrialized economies. *Journal of Post Keynesian Economics*, 21(3), 387-398.
- Bartolome, C.A.M., & Spiegel, M.M. (1997). Does state economic development spending increase manufacturing Employment. *Journal of Urban Economics*, 41, 153-175.
- BEA [Bureau of Economic Analysis]. (2009a). *Regional economic information system (REIS)*. from <http://www.bea.gov/regional/docs/cd.cfm>.
- BEA [Bureau of Economic Analysis]. (2009b). *Gross domestic product by state*. from <http://www.bea.gov/regional/gsp/>.
- BEA [Bureau of Economic Analysis]. (2009c). *News release: GDP by metropolitan area for 2006 and Revised 2004-2005*. from: http://www.bea.gov/newsreleases/regional/gdp_metro/2008/gdp_metro0908.htm.
- Bell, D. (1973). *The coming of post-industrial society*. Basic Books Inc: New York.
- Bernard, A.B., & Jones, C.I. (1996a). Productivity across industries and countries: time series theory and evidence. *The Review of Economics and Statistics*, 78(1), 135-146.
- Bernard, A.B., & Jones, C.I. (1996b). Technology and convergence. *The Economic Journal*, 106(437), 1037-1044.
- BLS [Bureau of Labor Statistics]. (2009). Consumer Price Index. from <http://www.bls.gov/cpi/#data>.
- Braun, D. (1991). Income inequality and economic-development-geographic divergence. *Social Science Quarterly*, 72(3), 520-536.
- Bresnahan, T.F., & Tractenberg, M. (1995). General purpose technologies 'engines of growth'? *Journal of Econometrics*, 65, 83-108.
- Brown, J.R., & Goolsbee, A. (2002). Does the Internet make markets more competitive? evidence from the life insurance industry. *Journal of Political Economy*, 110(3), 481-507.

- Carlino, G.A., & Mills, L. (1996a). Convergence and the U.S. States: A Time-Series Analysis. *Journal of Regional Science*, 36(4), 597-616.
- Carlino, G.A., & Mills, L. (1996b). Testing neoclassical convergence in regional incomes and earnings. *Regional Science and Urban Economics*, 26(6), 565-590.
- Carlton, D.W. (1983). The location and employment choices of new firms-an econometric model with discrete and continuous endogenous variables. *Review of Economics and Statistics*, 65(3), 440-449.
- Checherita, C.D. (2009). Variations on economic convergence: The case of the United States. *Papers in Regional Science*, 88(2), 259-278.
- DiGaetano, A., & Lawless, P. (1999). Urban Governance and industrial decline: governing structures and policy agendas in Birmingham and Sheffield, England, and Detroit, Michigan, 1980-1997. *Urban Affairs Review*, 34(4), 546-577.
- Dissart, J.C. (2003). Regional economic diversity and regional economic stability: research results and agenda. *International Regional Science Review*, 26 (4), 423-446.
- Drennan, M.P. (2005). Possible sources of wage divergence among metropolitan areas of the United States. *Urban Studies*, 42(9), 1609-1620.
- Drucker, P. (1969). *The age of discontinuity*. Harper & Row: New York.
- Dunne, T., Roberts, M.J., & Samuelson, L. (1989). The growth and failure of U.S. manufacturing plants. *The Quarterly Journal of Economics*, 104(4), 671-698.
- Faulk, D. (2002). Do state economic development incentives create jobs? An analysis of state employment tax credits. *National Tax Journal*, 55(2), 263-280.
- Forman, C., Goldfarb, A., & Greenstein, S. (2002). Digital dispersion: An industrial and geographic census of commercial Internet use. *National Bureau of Economic Research Working Paper 9287* from <http://www.nber.org/papers/w9287>.
- Forman, C., Goldfarb, A., & Greenstein, S. (2005). How did location affect adoption of the commercial Internet? Global village vs. urban leadership. *Journal of Urban Economics*, 58, 339- 420.
- Gabe, T.M., & Kraybill, D.S. (2002). The effect of state economic development incentives on employment growth of establishments. *Journal of Regional Science*, 42(4), 703-730.

- Graham, S., & Marvin, S. (1996). *Telecommunications and the city*. Routledge: New York.
- Graham, S., & Marvin, S. (2001). *Splintering urbanism: networked infrastructures, technological mobilities, and the urban condition*. Routledge: New York.
- Grubestic, T. H. (2006). A spatial taxonomy of broadband regions in the United States. *Information Economics and Policy*, 18, 423-448.
- Grubestic, T.H. (2008). Zip codes and spatial analysis: Problems and prospects. *Socio-Economic Planning Sciences*, 42(2), 129-149.
- Grubestic, T.H., & Matisziw, T.C. (2006). On the use of ZIP codes and ZIP code tabulation areas (ZCTAs) for the spatial analysis of epidemiological data. *International Journal of Health Geographics*, 5, 58.
- Hart, P.E. (1956). The analysis of business concentration-a statistical approach. *Journal of The Royal Statistical Society Series A*, 119(2), 150-191.
- Hipple, S., & Kosanovich, K. (2003). Computer and Internet use at work in 2001. *Monthly Labor Review*, February, 26-35.
- Hymer, S., & Pashigian, P. (1962). Firm size and rate of growth. *Journal of Political Economy*, 70(6), 556-569.
- Landefeld, J.S., & Fraumeni, B.M. (2001). Measuring the new economy. *Survey of Current Business*, March, 23-40.
- Lowenstein, R. (2004). *Origins of the crash: The great bubble and its undoing*. The Penguin Press: New York.
- Machlup, F. (1962). *The production and distribution of knowledge in the United States*. Princeton University Press: Princeton.
- Mack, E.A., Grubestic, T.H., & Kessler, E. (2007). Indices of industrial diversity and regional economic composition. *Growth and Change*, 38(3), 474-509.
- Martin, R. (2006). Economic geography and the new discourse of regional competitiveness. In: S., Bagchi-Sen, & H.L. Smith (Eds.), *Economic geography: Past, present and future*. (pp. 56-79). Routledge: London.
- Morrill, R. (2000). Geographic variation in change in income inequality among US states, 1970–1990. *The Annals of Regional Science*, 34(1), 109-130.
- NBER (2009). *Business Cycle Expansions and Contractions*. from: <http://www.nber.org/cycles.html>.

- Nissan, E., & Carter, G. (1999). Spatial and temporal metropolitan and nonmetropolitan trends in income inequality. *Growth and Change*, 30, 407-429.
- NTIA [National Telecommunications Administration Information]. (2000). Falling through the Net: Toward digital inclusion. from <http://search.ntia.doc.gov/pdf/fttn00.pdf>
- Oliner, S.D., Sichel, D.E., & Stiroh, K.J. (2008). Explaining a productive decade. *Journal of Policy Modeling*, 30, 633-673.
- Oliner, S.D., & Sichel, D.E. (2000). The resurgence of growth in the late 1990s: Is information technology the story? *The Journal of Economic Perspectives*, 14(4), 3-22.
- Pohjola, M. (2002). The new economy: facts, impacts and policies. *Information Economics and Policy*, 14, 133-144.
- Porat, M. (1976). *The information economy*. Doctoral Dissertation. Department of Economics, Stanford University.
- Porter, M.E. (1990). *The competitive advantage of nations*. Macmillan Inc: New York.
- Porter, M.E. (1998). Clusters and the new economics of competition. *Harvard Business Review*, 76, 77-90.
- Ram, R. (1997). Level of economic development and income inequality: Evidence from the postwar developed world. *Southern Economic Journal*, 64(2), 576-583.
- Rey, S.J., & Montouri, B.D. (1999). US regional income convergence: A spatial econometric perspective. *Regional Studies*, 33(2), 143-156.
- Sachs, J.D., Shatz, H.J., Deardoff, A., & Hall, R.E. (1994). Trade and jobs in U.S. manufacturing. *Brookings Papers on Economic Activity*, 1, 1-84.
- Schumpeter, J. (1961). *The theory of economic development*. Cambridge: Harvard University Press.
- Scott, A.J. (1998). *Regions and the world economy*. Oxford University Press: Oxford.
- Scott, A.J. (2006). A perspective of economic geography. In: S. Bagchi-Sen & H.L. Smith (Eds.), *Economic geography: Past, present and future* (pp. 56-79). Routledge: London.
- Siegel, P. B., Johnson, T. G., & Alwang, J. (1995). Regional economic diversity and diversification. *Growth and Change*, 26(2), 261-84.

- Simon, H.A., & Bonini, C.P. (1958). The size distribution of business firms. *American Economic Review*, 48(4), 607-617.
- Singh, A. (1995). Institutional requirements for full employment in advanced economies. *International Labour Review*, 134(4-5), 471-495.
- Singh, A., & Whittington, G. (1975). The size and growth of firms. *Review of Economic Studies*, 42(1), 15-26.
- Tam, M.S., & Persky, J. (1982). Regional convergence and national inequality. *The Review of Economics and Statistics*, 64(1), 161-165.
- U.S. Census Bureau. (2009). *County Business Patterns*. from <http://www.census.gov/epcd/cbp/view/cbpview.html>.
- UVA [University of Virginia]. (2009). *Geospatial & Statistical Data Center at the University of Virginia* from <http://fisher.lib.virginia.edu/collections/stats/cbp/>.
- Wagner, J. E. (2000). Regional economic diversity: Action, concept, or state of confusion. *The Journal of Regional Analysis and Policy*, 30(2), 1-22.
- Walker, J.A., & Murphy, J.B. (2001). Implementing the North American classification system at BLS. *Monthly Labor Review*, December, 15-21.
- Wasylenko, M., & McGuire, T. (1985). Jobs and taxes: The effect of business climate on states' employment growth rates. *National Tax Journal*, 38, 497-511.
- Wink, K.A., Eller, S.F. (1998). The effects of local economic development efforts-An empirical assessment of expenditures on income growth in North Carolina counties. *American Politics Quarterly*, 26(2), 196-217.
- Yamamoto, D. (2008). Scales of regional income disparities in the USA, 1955-2003. *Journal of Economic Geography*, 8, 79-103.
- Yilmaz, S., Dinc, M. (2002). Telecommunications and regional development: Evidence from the U.S. states. *Economic Development Quarterly*, 16(3), 211-228.

5. Conclusion

This dissertation provided a quantitative foundation about the relationship between broadband provision and firm location patterns. It also discussed some of the challenges associated with benchmarking regional development in the global information economy. The development of such a foundation is particularly important given the extant literature examining the impact of Internet-related information and communications technologies (ICTs) on regional economies is largely theoretical and speculative in nature. The results of this dissertation are also important because the current regional benchmarking and regional convergence literature provides little information about ICT related productivity impacts on indicators used to measure the growth trajectories of regional economies. As a whole, the three substantive chapters comprising this dissertation provide important information about the regional challenges associated with attracting and retaining technologically advanced, competitive businesses in the global information economy.

5.1 Forecasting Broadband Provision

The analysis in this chapter sought to resolve some of the informational issues associated with developing proactive instead of reactive solutions to regional disparities in broadband access. In particular, it evaluated whether forecasts of the spatial distribution of broadband provision might be a viable tool for policymakers and economic development officials. Understanding the current and future geographic distribution of broadband represents a challenge for local government and economic development officials. Despite the passage of federal legislation to encourage universal

broadband access (TA96), the responsibility of brooking regional disparities in provision fall largely upon county and local governments (Clark et al., 2002: 4).

Local officials face several challenges in developing successful broadband deployment initiatives. Not only is there little information regarding the components of successful initiatives (Gillett et al., 2004), but also there is limited data to use in evaluating regional disparities in this increasingly important infrastructure (Greenstein, 2007). In light of the paucity of available information for use in constructing informed broadband initiatives, this chapter explored a variety of approaches for forecasting the spatial distribution of broadband. Forecasts are valuable not only from an informational perspective, but they might also be used to flag areas where provision via private companies is doubtful. In this regard, advance information about the impact of social, economic, demographic, and geographic forces on broadband provision can help local officials generate more pro-active and effective intervention strategies to fill gaps in provision within their regions.

This analysis developed both cross-sectional and spatial forecasts of broadband provision from 2001 ZIP code area data in Ohio for 2002, 2003, and 2004. The forecasting accuracy of these models was then evaluated with broadband data kept out of sample from the model development process. Model results demonstrate forecasts are a viable tool for understanding current and future geographic disparities in broadband provision at the local level. However, spatial econometric models provide better forecasts than both cross sectional models with spatial dummy variables and aspatial cross-sectional models based on demand-side factors alone.

Spatial models generate better forecasts than models that incorporate space via spatial regimes. This result reflects the fact that dummy variables generate better model results without explaining the underlying spatial process. The superior performance of spatial forecasting models is related to the specific information about spatial processes they provide, as opposed to merely subdividing geographic space like their spatial regime counterparts. However, if local resources prevent the estimation of spatial econometric models, then it is better to use models that include spatial regimes than models with no spatial component at all. The aspatial cross sectional models estimated in this analysis generated the poorest forecasts of all the models considered.

An analysis of forecast accuracy also demonstrated the specification of spatial econometric models impacts performance. Spatial lag models produce better short-term forecasts than do spatial error models. This is because lag models incorporate more specific information about underlying spatial processes than do spatial error models. Error models simply lag the error term instead of the dependent variable to account for spatial dependence in the residuals. This spatial dependence may arise from a number of problems including missing variables or functional form misspecification. Therefore an error model is essentially a fix for an underlying issue with the model specification and does not incorporate additional spatial information. That said however, spatial error models were found to produce better mid-term and long-term forecasts than spatial lag models. This performance is likely due to the lack of explicit spatial information in these models, which provides more flexibility and therefore better forecasts. Further validation of these findings across different study areas and forecast horizons is certainly warranted, and will be discussed later as a topic meriting additional research.

5.2 Broadband Provision and Firm Location

While chapter two demonstrated the utility of forecasting models to better understand the future spatial distribution of broadband provision, the goal of the third chapter was to provide additional information regarding the spatial relationship between broadband provision and firm location. Of particular interest is determining whether locales with lower levels of broadband provision might be at a relative disadvantage for retaining and attracting businesses, and if this disadvantage is related to firms of specific sizes and in specific industries.

Ohio ZIP code area broadband provision data from the Federal Communications Commission (FCC) and industry level business data from ZIP Code Business Patterns were used in an exploratory framework to evaluate some of the hypothesized relationships between firms and ICTs discussed in the theoretical literature. Answers to four specific questions were pursued. One, is there a relationship between areas that have experienced positive changes in broadband provision and areas that have experienced positive changes in the number of firms? Two, if a spatial relationship exists between these two variables, does it vary by industry and firm size? Three, are positive changes in broadband provision and firm presence taking place in central city or suburban locations? Finally, do areas with positive changes have a tendency to cluster or be more dispersed?

Results reveal several important subtleties about the spatial relationship between firm location and broadband provision. First, industry level variations in the spatial distribution of firms may be related to the persistent urban bias of broadband. Firms that are more likely to use broadband intensively in their business processes (Information; Finance and Insurance; and Professional, Scientific and Technical Services) have a

propensity to cluster in central locations. Firms that are less likely to use broadband (Manufacturing and Retail) were found to locate in more peripheral areas.

This exploratory analysis also uncovered a significant, positive correlation between broadband and establishments, but found that this relationship varied by firm size and industry. Small firms had a higher correlation with broadband than did medium and large businesses. This result confirms what we know about the use of existing broadband infrastructure by firms of various sizes. Small firms rely on existing broadband infrastructure because of their inability to pay for a privately leased line. Large firms have the financial resources to pay for fiber-based connections (Hanson, 2005) and are therefore less likely to rely on local firms for telecommunications connections.

A final important finding was the determination of the presence of spatial autocorrelation in both broadband provision and firms. This is a particularly relevant finding for future econometric studies. Failure to include a spatial lag of the dependent variable of interest when one is required produces biased and inconsistent coefficient results (Anselin, 1988). Overall, the results of this chapter provide a foundation upon which future quantitative studies may be based. These findings are also informative for policymakers and economic development officials. More specifically, analytical results suggest development inertia for areas with lower levels of broadband provision, particularly with respect to firms that use ICTs, such as broadband, more intensively. This finding is especially relevant for metropolitan areas, like Detroit, who are seeking to overhaul their economic base to perhaps including growing sectors of an informational as opposed to an industrial nature.

5.3 Benchmarking Regional Growth

The results of the previous chapter suggest a link between firm location in particular industries and the level of broadband infrastructure in a region. This link is important not only for firm retention and attraction, but for individual firm productivity. Although the presence of ICT infrastructure is unlikely to be a sustained source of competitive advantage (Schumpeter, 1961; Porter 1990), the manner in which individual firms incorporate these technologies into their business processes is linked to increased productivity (Pohjola, 2002).

Despite this recognition, the full impacts of Internet-related ICTs on the productivity gains of regional economies remain unclear. This uncertainty of impacts stems from both the uneven adoption of ICTs by firms in different industries (Forman et al., 2005) and the uneven distribution of these firms across regions. This heterogeneity in adoption and firm distribution suggests that the productivity gains associated with ICTs will vary by region and that changes in the manner in which competitiveness is measured and regional economies benchmarked, may be necessary. The final substantive chapter of this dissertation examines potential challenges for benchmarking regional development given the tremendous technological and industrial changes in the U.S. economy in the past thirty years. This analysis evaluates trends for three commonly used measures of economic performance: earnings, employment, and establishments.

The investigation of temporal, industrial and spatial variations in these indicators at the state and national levels cautions against the use of univariate indicator trends in isolation to measure economic performance and suggests multivariate benchmarking practices should become the norm and not the exception. At the national level, indicator

trends were demonstrated to vary over time and by industry. This variation in trends was perhaps best illustrated by an examination of earnings per worker (EPW), which highlighted growing wage disparities across industries since the 1970s.

The state level analysis provided more detail about many of the national level findings, particularly those related to temporal and industrial fluctuations in indicator trends. A Gini coefficient analysis of regional trends supported national level findings regarding growing wage disparities across industrial sectors. Additional analysis of earnings and employment trends for four specific industries (Manufacturing, Services, FIRE, and Retail Trade) found the impact of industry level trends on aggregate indicator trends is related to the productivity of the industry. Low productivity industries have negative impacts on aggregate indicator growth while high productivity industries have a positive impact on aggregate indicator growth. A spatial analysis of indicator trends largely supported these industry level findings; regions with industry growth in high productivity industries were also regions with overall growth in earnings and employment.

Combined, the state and national level results demonstrate variability in univariate indicators across time, space, and industry. This widespread variation presents a strong argument in favor of using composite or multiple indicators simultaneously when evaluating the growth and development of regional economies. Additional research about the statistical impact of industrial composition on regional convergence trends is certainly warranted however and will be discussed as an area for future research.

5.4 Limitations

The availability of broadband data is notoriously poor and is one reason research in this area remains largely descriptive in nature (Greenstein, 2007). The rollout of Internet infrastructure by private companies means important information about providers, pricing, and broadband revenues are publicly unavailable (ibid). Given this lack of data, a key public source of information about broadband is the Federal Communications Commission (FCC). Information about broadband providers collected by the FCC via Form 477 is currently the only public source of data about the level of broadband infrastructure within a region. Although there are limitations associated with these data, they represent a superior data source compared to proxies for ICT infrastructure used in previous studies such as bandwidth capacity (Hackler 2003a,b) and the number of information intensive businesses in a region (Sohn, 2004).

This section will discuss the limitations of these data and their impact on the analytical results presented in this dissertation. The discussion will also note recent changes to the FCC broadband data and evaluate their impact on future research on this topic. In this context, it is important to note that the data limitations of this dissertation are a reflection of the data available at the time these analyses were conducted. Therefore the conclusions in this research are meant to represent a snapshot of the spatial distribution of firms and broadband in time. Recent changes to the data are expected to add additional detail to the analytical foundation established by this dissertation.

5.4.1 Broadband Data

The FCC collects information from broadband providers via Form 477. This information is collected bi-annually and reported on the FCC website with a two-year

time lag. Recent changes to these data however mean this source may be considered an interrupted time series that consists of three incongruent sub-periods: 1999-2004, 2005-December 2008, and 2009-present. Although the definition of a broadband internet connection¹ is consistent across all years for which the FCC has collected Form 477 information, several changes have been made to these data. These modifications include changes regarding the providers required to report information to the FCC, changes in the spatial scale at which these data are reported, and the inclusion of speed tier information (FCC, 2010b).

5.4.1.a 1999-2004 Data

The analyses comprising this dissertation make use of the 1999-2004 data series since it was both available at the time of this research and represents the longest time series of all the Form 477 data. Data collected in this time period compiles information from facilities-based providers of broadband with 250 or more high-speed lines (in a given state) to obtain a count of the number of broadband service providers in each ZIP code (FCC, 2010a). One of the limitations of these data is that the information is constrained for confidentiality purposes. The FCC does not report data for a ZIP code if it contains fewer than four providers; it simply flags these ZIP codes as active (Grubestic, 2006). Per the precedent set by prior broadband studies (Grubestic and Murray, 2002; Grubestic and Murray 2004; Grubestic, 2006), the most conservative estimate for the number of broadband providers for each active, but suppressed ZIP code is used— a value

¹ This source defines a *broadband internet connection* as one “that permits users to send and/or receive data using the Internet at transmission rates of *greater than* 200 kilobits per second (kbps) in at least one direction” (FCC, 2010a).

of one. The suppression issue limits the resolution of these data and forces researchers to either omit these ZIP code areas from their analysis or treat all suppressed ZIP codes as if they contained the same number of providers. Equal treatment of suppressed ZIP codes ignores the important differences between what amounts to monopolistic provision of broadband in places with one provider and ZIP code areas with two or three providers and slightly higher levels of competition.

A second limitation of these data is they do not distinguish between the different platforms over which broadband is delivered² and instead lump all providers together beneath a general broadband umbrella (Grubestic and Murray, 2002). This inability to distinguish between different platforms masks key issues associated with platform dependent availability issues within a given region. For example, the use of copper in DSL (digital subscriber line) technology infrastructure places limits on the transmission capabilities of this platform (Grubestic and Murray, 2002; Grubestic and Horner, 2006). The maximum coverage radius for DSL is 18,000 ft. but most providers are unwilling to provide service to customers whose distance from the central switching office (CO) exceeds 12,000 ft (Grubestic and Murray, 2002). Although higher platform resolution would not impact the inherent assumption of the FCC data that broadband is homogeneously available across the spatial units for which the data are reported, it would certainly provide more information about the likely heterogeneity of availability across spatial units.

²The Form 477 FCC data reports combined information about cable, DSL, and wireless broadband providers (FCC, 2010a).

A third limitation of the 1999-2004 data is its inability to subdivide providers by the speed at which they provide service. This effectively treats all broadband providers equally when in reality there may be large differences in the speed of broadband delivered within the same area. In New York City, for example, which is widely recognized as one of the more technologically advanced areas of the United States, large disparities in broadband platforms and speeds are present within its five component boroughs (Center for an Urban Future, 2004). This lack of data detail prevents us from examining some research questions related to firm use of ICTS such as the continued importance of space and face-to-face contacts irrespective of the ability to videoconference with distant co-workers and clients.

A final limitation of this dataset is the lack of pricing information. This information is considered proprietary and is not reported by the FCC. Although some states have reported pricing information in their broadband studies they have done so at a very coarse spatial scale, such as the county level (OSC, 2006). This is not to say that no information about relative prices can be inferred from the FCC data however. In fact, the manner in which the data are reported (number of providers) does provide some idea about the level of competition in an area and subsequently, the relative price levels of broadband across ZIP code areas; ZIP code areas with more providers have more competition and lower prices than do ZIP code areas with fewer providers. Therefore, this data subtlety is perhaps not as limiting as the other three discussed in this section. However, these limitations are gradually disappearing as changes to the FCC data are made.

5.4.1.b 2005-December 2008 Data

As of June 30, 2005, the FCC changed which providers were required to report information via Form 477 (FCC, 2010b). The change removed the 250 high-speed line threshold discussed previously and required all providers with more than one high-speed line (in a given state) to report their information (ibid). This subtle change in reporting requirements impacts future analyses of broadband using the FCC data in two ways. First, it creates a structural break in the data which prevents researchers from adding data post 2005 to the 1999-2004 time series. Second, the removal of the 250 high-speed line threshold will likely increase the number of providers in ZIP code areas across the United States. Perhaps the most important implication of this increase is that areas previously reported as having no providers via the old data may now be reported as having broadband providers.

5.4.1.c 2009-Present

On December 31, 2008 two more revisions were made to the Form 477 data. The first revision changed the spatial scale to which provider data are aggregated. Previous to this date, providers were aggregated to ZIP code areas. After 2008, providers are aggregated to census tracts (FCC, 2010b). This change in spatial scale has several important implications which will be discussed in greater detail in the following section about issues related to spatial scale. A second revision made to the data in 2008 is that speed tier detail is now included in the provider data that are reported (FCC, 2010b). The ability to distinguish providers by speed-tiers will allow more inferences to be drawn about how individuals and businesses use broadband in particular areas. It will also allow distinctions to be drawn about the quality of broadband provision in a region; where

regions with more providers in high-speed tiers are defined to have higher quality broadband provision than regions with few providers or more providers in low-speed tiers.

5.4.2 Spatial Scale

The 2008 revision that reports provider information by census tracts instead of ZIP code areas has several implications for future spatial analyses. Although this change creates another time-series break in the data, it is an improvement over data reported by ZIP code areas. Previous studies have highlighted some of the issues ZIP code areas present for spatial analysis (Grubestic and Matisziw, 2006; Grubestic, 2008). The issues highlighted in these studies are as follows: ZIP codes are actually non-contiguous, non-discrete linear features interpolated to produce polygonal boundaries, ZIP codes are not nested spatial units, ZIP code areas change over time, and ZIP codes do not necessarily offer higher geographic resolution, particularly in rural areas.

These characteristics of ZIP codes provide significant challenges for spatial analyses of broadband. Although the impact of the dynamic nature of these features can be mitigated by utilizing the same set of ZIP codes over time, the non-nested characteristic of these features perhaps presents the greatest issue for future evaluations of the link between broadband and firm location. The non-nested nature of these features is problematic for assessments of the modifiable areal unit problem (MAUP) on analytical results (Grubestic, 2008). The ZIP codes included in a county as opposed to a metropolitan statistical area (MSA) may be very different if ZIP codes are aggregated to counties and MSAs separately and not sequentially. The rather arbitrary nature of ZIP codes is also likely to produce arbitrary spillover effects from measurement errors

(Anselin, 1988) in spatial lag models evaluating the link between broadband and firm presence in a region. Given the multitude of issues associated with data reported at the ZIP code level, the 2008 census tract modification of the broadband data is a welcome change.

5.4.3 Research Impacts of Data Limitations

Despite the limitations associated with the ZIP code level 1999-2004 time series data used in the component analyses of this dissertation, the analytical results obtained in chapters two and three still offer important insights about broadband and firm location. Care was taken to minimize the impact of the two most challenging limitations on the analyses, the data suppression issue and the dynamic nature of ZIP code areas. In chapter two, model results generated with a replacement value of one provider for suppressed ZIP codes were compared to results generated with replacement values of two and three. This sensitivity analysis yielded no change in the results of the analysis. In both chapters two and three, a common set of ZIP codes was used for the time series analyses to avoid issues associated with the dynamic spatial nature of these features.

Although the 1999-2004 time series data do not contain details about platforms, speed, or pricing, their absence does not invalidate the results of chapters two and three. The value of this additional information, as mentioned previously, is that it adds a quality dimension to the provision data. For example, although two ZIP codes might have similar provider counts, the characteristics of this provision might vary greatly. One ZIP code may have high-speed connections, more platform choice, and lower costs than nearby ZIP codes. In this respect, similar provision levels do not equate to similar provision quality.

5.5 Future Research

The findings of this dissertation represent important advancements in unraveling the complex impacts of Internet-related advancements in information and communications technologies on the growth and development of regional economies. The second chapter presented some practical forecasting approaches for proactively identifying local disparities in broadband provision, the results of which may be used to develop better policies and development strategies to increase the technology attractiveness of regions to firms. The third chapter highlighted variations in the statistical and spatial relationship between firm location and broadband provision related to firm size and industry membership. The fourth chapter identified problems associated with univariate benchmarking practices and offered solutions to improve current benchmarking practices to better evaluate the development of regions. Together these studies form a solid foundation for further inquiry into this subject area. Recent federal level programs and plans like the Broadband Technology Opportunities Program (BTOP) and the FCC's National Broadband Plan (FCC, 2010c) have reemphasized the importance of broadband infrastructure to the growth prospects of regional economies, and renewed national interest about this research topic. This reemphasis on broadband and subsequent resurgence in interest present several opportunities for future work beyond the current scope of this dissertation. Potential topics for future research in addition to extensions to the chapters comprising this dissertation will be discussed in this section.

The extension of the forecasting approach presented in chapter two to other states and to longer time periods will provide more information about the utility of this methodology for regions outside of Ohio. It may also shed light on the subtle differences

in performance of spatial lag and spatial error models. For example, it may provide more information about the temporal horizon in which the forecast performance of spatial lag models outperforms the forecast performance of spatial error models.

Although chapter three revealed significant statistical and spatial relationships between firm presence and broadband provision, these relationships do not account for other factors that may impact both firm location and broadband provision. In this regard, spatial econometric models evaluating the impact of the level of broadband provision on firm location can provide key insights about the relative attractiveness of these technologies and their potential impact on regional business climates. Key considerations for the development of these models include the spatial dependence in firm location and broadband provision uncovered in chapter three, as well as likely simultaneity between these two variables. An evaluation of variations in this relationship with respect to firm size and industry is also worthy of additional analysis. Finally, it is recommended that both global and regional specific models be estimated to examine heterogeneity in this relationship across space, which is likely given the highly regional nature of the current global business environment.

Potential extensions to the analysis in chapter 4 include the estimation of convergence models to more rigorously evaluate the impact of industrial composition and ICTs on regional economies within the United States. Specifically, it is recommended that convergence models be estimated for U.S counties that incorporate different measures of industrial composition as well as data for the level of broadband in these counties. Although compositional issues related to convergence has been addressed somewhat at the state level (Checherita, 2009) and for European regions (Le Gallo and

Dall'erba, 2008), it has been recommended that more disaggregate models be estimated to address the modifiable areal unit problem (MAUP) (Checherita, 2009). A more thorough treatment of composition for the U.S case should also be undertaken following the sigma convergence approach of Le Gallo and Dall'erba, (2008). This approach may shed additional light on sectoral specific ICT-related productivity impacts on regional inequality trends in the United States.

An evaluation of the impact of funds provided by the BTOP on regions that were previously underserved³ or unserved⁴ by broadband providers represents a topic for future research beyond the scope of this dissertation. These regions represent a rare opportunity to obtain a before broadband and after broadband snapshot of economic activity that may shed additional light on the enabling capacity of this technology. Evaluation of the impacts of an infusion of broadband to regions will also benefit from the improvements in the FCC data made in recent years. These data changes will provide better spatial data and higher resolution information about the quality of broadband rolled out in these areas which will be essential in explaining the impact or lack of impact of broadband on these regions.

³ The NTIA (2009) defines an underserved area for last mile projects as: “an area composed of one or more contiguous census blocks where at least one of the following is met: 1) no more than 50 percent of households in the proposed service area have access to facilities-based, terrestrial broadband service at greater than the minimum broadband speed broadband speed; 2) no fixed or mobile broadband service provider advertises broadband speeds of at least 3 Mbps downstream in the proposed funded service area; or 3) the rate of broadband subscribership for the proposed service area is 40 percent of households or less.”

⁴ The NTIA (2009) defines an unserved area as: “an area, composed of one or more contiguous census blocks where at least 90 percent of households in the proposed funded service area lack access to facilities-based, terrestrial broadband service, either fixed or mobile, at the minimum broadband speed.”

5.6 Concluding Remarks

Recent federal level broadband initiatives demonstrate that access to and use of information and communications technologies like broadband, remain a salient social and economic issue. This reemphasis on rolling out broadband to unserved and underserved areas is a reflection of the powerful space-time shrinking impacts of this technology. Unlike previous advancements in ICTs, like the telephone or fax, these technologies permit virtual face-to-face contacts with individuals around the globe, and thus, wider participation in the global information economy.

In order for previously isolated regions to fully benefit from these technologies, the rollout of ICTs must focus not only on the mere provision of broadband, but the speed and cost of access. Both the quality and affordability of access as well as the universal rollout of broadband are featured in the FCC's recently unveiled National Broadband Plan (FCC, 2010c). The plan also highlights the need for additional research regarding the link between broadband provision, firm location, and regional growth. Recent improvements to broadband data suggest future research in this area will be able to provide more complete information about these linkages that will highlight not only issues of access, but the impact of broadband quality on the growth trajectories of regions.

This dissertation provides some initial quantitative evidence about the link between ICTs and regional growth, with a focus on broadband provision and firm location patterns. Analytical results suggest the technology capacity of regional economies is an important component to retaining and attracting competitive businesses. They also provide support for the incorporation of broadband deployment initiatives into

a comprehensive economic development plan to foster sustained regional growth. This body of research also discusses the multifaceted nature of regional growth in the global knowledge economy and the subsequent challenges associated with measuring economic performance.

Although the complex impacts of innovations in information technology on firm growth and regional competitiveness have yet to be fully unraveled, this piece provides a solid foundation for further quantitative inquiry on this topic. Persistent disparities in access and cost suggest additional quantifiable knowledge in this area is essential to unraveling the dynamic geography of regional competitiveness in the global information economy.

5.7 References

- Anselin, L. 1988. *Spatial econometrics: methods and models*. Boston: Klumer Academic Publishers.
- Center for an Urban Future. (2004). *New York's Broadband Gap*. from www.nycfuture.org.
- Checherita, C.D. (2009). Variations on economic convergence: The case of the United States. *Papers in Regional Science*, 88(2), 259-278.
- Clark, D., Gillett, S., Lehr, W., Sirbu, M., & Fountain, J. (2002). Local government stimulation of broadband: effectiveness, e-government, and economic development. White Paper for Program on Digital Government. from http://itc.mit.edu/itel/docs/2002/White_Paper_NSF_DigGov.pdf.
- FCC. (2010a). *FCC Broadband Deployment Data from Form 477*. from <http://www.fcc.gov/form477>.
- FCC. (2010b). *High-Speed Services for Internet Access: Status as of December 31, 2008*. from http://www.fcc.gov/Daily_Releases/Daily_Business/2010/db0212/DOC296239A1.pdf.
- FCC. (2010c). *Connecting America: The National Broadband Plan*. from <http://download.broadband.gov/plan/national-broadband-plan.pdf>.
- Gillett, S.E., Lehr, W.H., & Osorio, C. (2004). Local government broadband initiatives. *Telecommunications Policy*, 28, 537-558.
- Greenstein, S. (2007). *Data constraints & the Internet economy: Impressions & imprecision*. NSF/OECD meeting on Factors Shaping the Future of the Internet. from: <http://www.oecd.org/dataoecd/5/54/38151520.pdf>
- Grubestic, T.H. (2006). A spatial taxonomy of broadband regions in the United States. *Information Economics and Policy*, 18, 423-448.
- Grubestic, T. H. (2008). Zip codes and spatial analysis: problems and prospects. *Socio-Economic Planning Sciences*, 42, 129-149.
- Grubestic, Tony H. & Horner, M. W. (2006). Deconstructing the Divide: Extending Broadband xDSL Services to the Periphery. *Environment and Planning B*, 33, 685-704.
- Grubestic, Tony H., Matisziw, Timothy C. (2006). On the use of ZIP codes and ZIP code tabulation areas (ZCTAs) for the spatial analysis of epidemiological data. *International Journal of Health Geographics*, 5, 58.

- Grubestic, T.H., & Murray, A.T. (2002). Constructing the divide: spatial disparities in broadband access. *Papers in Regional Science*, 81, 197-221.
- Grubestic, T.H., & Murray, A.T. (2004). Waiting for broadband: local competition and the spatial distribution of advanced telecommunication services in the United States. *Growth and Change*, 35(2), 139-165.
- Hackler, D. (2003a). High-Tech Location in Five Metropolitan Areas. *Journal of Urban Affairs*, 25(5), 625-640.
- Hackler, D. (2003b). Invisible Infrastructure and the City. *American Behavioral Scientist*, 46, 1034-55.
- Hansen, E. (2005, January 17). *Google want 'dark fiber'*. CNET News.com
http://www.news.com/Google-wants-dark-fiber/2100-1034_3-5537392.html
- LeGallo, J., & Dall'erba, S. (2008). Spatial and sectoral productivity convergence between European regions, 1975–2000. *Papers in Regional Science*, 87(4), 505-525.
- NTIA, (2009). *Broadband Technology Opportunities Program*. from
<http://www.ntia.doc.gov/broadbandgrants/>.
- OSC [Ohio Supercomputer Center]. (2006). 2006 broadband Ohio study: Availability and cost of broadband Internet service options in Ohio. from
<http://www.osc.edu/networking/broadband/index.shtml>
- Pohjola, M. (2002). The new economy: facts, impacts and policies. *Information Economics and Policy*, 14, 133-144.
- Porter, M. (1990). *The competitive advantage of nations*. New York: Free Press.
- Schumpeter, J. (1961). *The theory of economic development*. Cambridge: Harvard University Press.
- Sohn, J. (2004). Information Technology in the 1990's: More Footloose or More Location-Bound?. *Papers in Regional Science*, 83, 467-85.
- TA96 [Telecommunications Act of 1996]. (1996). Pub. LA. No. 104-104, 110 Stat. 56.

ELIZABETH A. MACK

elmack@indiana.edu

www.elizabethmack.com

Office

GeoDa Center for Geospatial Analysis and Computation
Lattie F. Coor Hall, Coor 5671
P.O Box 875302
Tempe AZ 85287-5302
Phone: (480) 965-1395
Fax: (480) 965-8313

Home

5038 S. Hardy Dr.
Apt. 2040
Tempe, AZ 85282
Cell: (812) 679-8620

Teaching and Research Interests

Topical: Urban/economic geography, regional development, technological change, public policy evaluation and crime analysis

Methodological: Spatial econometrics, spatial statistics, geographic information systems (GIS), input output modeling

Education

- Ph.D. Department of Geography, Indiana University, Bloomington, Indiana.
(Anticipated Graduation, 2010)
(Minor: Economic Development) Advisor: Tony H. Grubestic
- 2006** M.A Department of Economics, University of Cincinnati, Cincinnati, Ohio.
- 2002** B.S Department of Finance, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.
- 2002** B.A Department of Spanish, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Positions

- 2009- Present** Visiting Scholar- GeoDa Center for Geospatial Analysis and Computation
School of Geographical Sciences and Urban Planning, Arizona State University
Host: Alan T. Murray
- 2008-2009** Instructor – Department of Geography, Indiana University
Introduction to Human Geography (90 students)
- 2007-2008** Associate Instructor – Department of Geography, Indiana University
Introduction to Human Geography (90-180 students)
- 2006-2007** Graduate Fellow – Department of Geography, Indiana University
- 2007** Intern – Seer Analytics; Tampa, FL/Pittsburgh, PA
- Developed marketing clusters for a major account.
 - Generated SPSS syntax for marketing cluster implementation.
 - Applied statistical analysis to large datasets.
- 2006** Graduate Teaching Assistant – Department of Economics, University of Cincinnati
- Intermediate Microeconomic Theory (15 students)

- 2005** Graduate Research Assistant – The Applied Economics Research Institute, University of Cincinnati
- Developed an economic profile of Dearborn County, IN.
 - Wrote “Perspectives on Economic Development: Dearborn County Case Study.”
- 2005** Intern – The Assaley Group, Morgan Stanley; Cincinnati, OH
- Conducted financial research and assisted in data analysis for institutional clients.
 - Developed reports for high net worth clients.
- 2005** Intern – Dearborn County Economic Development Initiative; Lawrenceburg, IN
- Collected economic/demographic data used to complete the International Economic Development Council’s (IEDC) Site Selection Data Standards.
 - Produced content for web-based brochure promoting business development in Dearborn County

Honors

- 2009-2010** 10th Annual Benjamin H. Stevens Graduate Fellowship (\$28,000)
North American Regional Science Council
- 2009-2010** Dissertation Year Research Fellowship (\$18,000)
College of Arts and Sciences, Indiana University
- 2008** Chairman’s Graduate Student Recognition Award
Department of Geography, Indiana University
- 2008** Departmental Graduate Fellowship (\$1,000)
Department of Geography, Indiana University
- 2008** General Scholarship (\$3,000)
Indiana University Foundation
- 2007** Chairman’s Graduate Student Recognition Award
Department of Geography, Indiana University
- 2006-2007** Graduate Fellowship (\$21,000 and tuition)
Department of Geography, Indiana University
- 2004-2005** Taft Fellowship (\$3,297 and tuition)
Department of Economics, University of Cincinnati
- 2002-Present** Phi Beta Kappa Society
- 2001** Sigma Delta Pi National Scholarship for summer study at the Center for Bilingual Multicultural Studies in Cuernavaca, Mexico
- 2001** Omicron Delta Kappa National Leadership Honors Society
- 2000** Mr. and Mrs. Leonard Starr Jr. Scholarship
Pamplin College of Business, Virginia Polytechnic Institute and State University
- 1999-2002** Founding Member of the Virginia Polytechnic Institute and State University Honors Community

- 1999 Beta Gamma Sigma Business Honors Society
- 1999 Phi Eta Sigma National Honors Society
- 1997-2002 Faculty Honors Scholarship
Office of Scholarships and Financial Aid, Virginia Polytechnic and State University
- 1997 Dean's Scholarship
Department of Foreign Languages and Literatures, Virginia Polytechnic and State University

Publications

- 2010 **Mack, E. A.** and Grubestic, T.H.. "Social Disorganization, Sex Offenders And Residential Location: A Predictive Analytical Framework." (forthcoming *Environment and Planning A*).
- 2009 **Mack, E.A.** and T.H. Grubestic. Forecasting Broadband Provision. *Information Economics and Policy*. 21(4): 297-311.
- 2009 **Mack, E.A.** and T. H. Grubestic. Broadband Provision and Firm Location: An Exploratory Spatial Analysis. *Tijdschrift voor economische en sociale geografie*. 100(3): 298-315.
- 2008 Grubestic, T.H., Murray, A.T. and **E.A. Mack**. Sex Offenders, Housing and Spatial Restriction Zones. *GeoJournal*. 73(4): 255-269.
- 2008 Grubestic, T. H. and **E. A. Mack**. Spatio-Temporal Interaction of Urban Crime. *Journal of Quantitative Criminology*. 24(3): 285-306.
- 2007 **Mack, E.A.**, Grubestic, T.H. and E. Kessler. Indices of Industrial Diversity and Regional Economic Composition. *Growth and Change*. 38(3): 474-509.
- 2007 Grubestic, T. H., Murray, A. T. and **E.A. Mack**. Geographic exclusion: Spatial analysis for evaluating the implications of Megan's Law. *Social Science Computer Review*. 25(2): 143-162.

Publications Under Review

- 2010 **Mack, E.A.**, Anselin, L. and T.H. Grubestic. "The Importance of Broadband Provision to Knowledge Intensive Firm Location". (submitted to *Journal of Regional Science*).
- 2010 Buckman, S. and **Mack, E.A.** "Urban Morphology & the Coalition Politics of Downtown Redevelopment Projects". (submitted to *Journal of Urbanism*).
- 2009 **Mack, E.A.** and T.H. Grubestic. "All Jobs Are Not Created Equal: Divergent Indicators in the Information Economy". (submitted to *Applied Geography*).

Professional Presentations

- 2010 All Jobs Are Not Created Equal: Divergent Indicators in the Knowledge Economy. *Annual Meeting of the Association of American Geographers*. Washington, D.C. (April 14-18).

- 2010** Sex Offenders and Residential Location: A Predictive-Analytical Framework. *Meeting of the Western Regional Science Association*. Sedona, AZ. (February 21-24).
- 2009** The Importance of Broadband Provision to Knowledge Intensive Firm Location. *North American Meeting of the Regional Science Association International*. San Francisco, CA. (November 18-21).
- 2009** Sex Offender Residency and Spatial Risk: Approaches for Managing Community Exposure. *10th Crime Mapping Research Conference*. New Orleans, LA. (August 19-August 22).
- 2009** The Spatio-Temporal Dynamics of Nodal Regions: Airports as Central Places. *Annual Meeting of the Association of American Geographers*. Las Vegas, NV. (March 22-March 27).
- 2008** The Distribution of Information-Intensive Industries: Coincidence or A Reflection of Regional Comparative Advantage? *North American Meeting of the Regional Science Association International*. Brooklyn, NY. (November 19-November 22).
- 2008** Predicting Residential Locations of Registered Sex Offenders. *The National Institute for Justice Conference*. Arlington, VA. (July 21-July 23).
- 2008** Forecasting Broadband Provision. *Annual Meeting of the Association of American Geographers*. Boston, MA. (April 15- April 19).
- 2007** Broadband Provision and Firm Location in Ohio: An Exploratory Analysis (1999-2004). *North American Meeting of the Regional Science Association International*. Savannah, GA. (November 7-November 10).
- 2007** Indexing and Regional Competitiveness: A Comparative Analysis. *Annual Meeting of the Association of American Geographers*. San Francisco, CA. (April 17- April 21).
- 2007** Spatio-Temporal Methods for Identifying Crime Hot-Spots: Approaches, Problems and Prospects. *9th Crime Mapping Research Conference*. Pittsburgh, PA. (March 28-March 31).
- 2005** Perspectives on Economic Development: Dearborn County Case Study. Argosy Casino and Hotel. Lawrenceburg, IN. (June 8, 2005).

Grants

- 2009** Travel grant from the Mapping & Analysis for Public Safety (MAPS) Program, National Institute of Justice
- 2008** Travel grant from the National Institute of Justice
- 2008** Travel Grant (\$300)
College of Arts and Sciences, Indiana University
- 2008** Travel Grant (\$350)
Office of Women's Affairs, Indiana University
- 2007** Travel grant from the Mapping & Analysis for Public Safety (MAPS) Program, National Institute of Justice
- 2007** Travel Grant (\$300)
Office of Women's Affairs, Indiana University

Service

- 2009-Present** Journal Reviewer
International Regional Science Review
Journal of Transport Geography
Annals of Regional Science
Papers in Regional Science
- 2010** Session Organizer, Regions in the Global Knowledge Economy
Association of American Geographers Annual Meeting. Washington, D.C
- 2009** Session Chair, Location and Spatial Modeling D
North American Meeting of the Regional Science Association International.
San Francisco, CA.
- 2008-2009** Colloquia Committee
Department of Geography, Indiana University
- 2008** Session Chair, Spatial Modeling IV
North American Meeting of the Regional Science Association International. Brooklyn,
NY.
- 2007-2009** Graduate Student Representative
Department of Geography, Indiana University
- 2007-2008** Equipment and Computer Technology Committee
Department of Geography, Indiana University
- 2006** Library Committee
Department of Geography, Indiana University

Workshops

- 2008** Spatial Econometrics Advanced Institute (SEAI). Rome, Italy.
Organized by the Spatial Econometrics Association.

Affiliations

- Association of American Geographers (AAG)
- North American Regional Science Council (NARSC)
- Industry Studies Association (ISA)