The Relationship between Economic Well-Being and Gigabit Broadband Network Penetration

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ABSTRACT

The objective of this study was to examine the relationship between gigabit broadband network penetration (GBNP) and the economic well-being in Metropolitan Statistical Areas (MSA) in the United States. The literature highlights the colloquial examples of how gigabit connectivity has impacted MSA economies, the governance structure, and the economic indicators of a local economic health. Variables in the analysis were separated into four categories: time, geographic, economic, and employment. Data was collected from the FCC Form 477, US Census Bureau ACS 5 year estimates, and the Bureau of Economic Analysis between the years 2011 and 2014. A descriptive analysis explored the statistical relationships between the selected factors. Results showed that the time variable, selected economic variables, and selected employment variables all show positive relationships with GBNP. The study offers the opportunity for future research to build off of in order to comprehensively answer the question about the relationship between economic well-being and GBNP

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Executive Summary

This research was conducted to examine the relationship between gigabit broadband network penetration (GBNP) and economic well-being. Gigabit broadband networks are representative of the future of Internet connection speeds. The FCC has already released a number of statements encouraging the creation and deployment of the networks, that offer over 3,000% faster speeds than the average.

GBNP data was collected from the FCC Form 477 at the MSA level for the years 2011 to 2014. The indicators of economic well-being are split into four group: (1) Time, (2) Geography, (3) Economy and (4) Employment. Time was an important variable and measured by year of the data point. Geographic variables looked at the population density and MSA size to find the relationship with those and was data collected by the US Census Bureau. Using GIS techniques calculated people per square mile, providing the population density variable. The economic variables broke down key economic indicators of GDP per Capita, Median Household Income, Educational Attainment, and Median Home Value. The data from these came from US Census Bureau ACS 5 year estimates and the Bureau of Labor Statistics. The final variable group was the industry employment percentage for different industries using data collected by the US Census Bureau ACS 5 year estimates.

Descriptive analysis of the correlation between GBNP and economic well-being indicators was conducted. Through correlation analysis the study found six expected relationships and eight unexpected relationships. The largest r coefficient ($r = 0.204$, $p = <0.001$) of any of the relationships to GBNP, was the time grouped variable of year. Statistically significant positive relationships existed between GBNP and year, GDP per capita, education,

information industry employment and professional scientific industry employment. Table 1 shows all statistically significant relationships, the expected signs and the actual signs.

Table 1: Summary of Findings

Category	**Variable**	**Statistically Significant**	**Expected Sign**	**Actual Sign**
Time	*Year***	Yes	(+)	(+)
Geographic	*Population Density*	No	(+)	(-)
	MSA Size	No	(+)	(-)
Economic	*GDP per Capita***	Yes	(+)	(+)
	Median Income	No	(+)	(+)
	*Educational Attainment***	Yes	(+)	(+)
	Median Home Value	No	(+)	(-)
Employment	*Agriculture, Forestry, Fishing, Hunting, Mining*	No	(-)	(+)
	*Whole Sale Trade***	Yes	(-)	(-)
	*Information***	Yes	(+)	(+)
	Finance, Insurance, Real Estate, Rental, Leasing	No	(+)	(+)
	*Professional Scientific, Management, Administrative, and Waste Management Services***	Yes	(+)	(+)
	Transportation and Warehousing	No	(+)	(+)

N= 1,428

***= statistically significant at the 95% confidence interval*

The reason for some of the unexpected signs and non-statistical significant findings could be MSA as the level of geography analyzed being too large and smaller areas of analysis could provide more statistically significant results.

The research can be used by both planners and future researchers. The positive relationships between GBNP and GDP per capita and education show that one potential way to raise the productivity of firms and attract a more educated populace would be to focus on the creation or attraction of a gigabit broadband network. The small r coefficient of the relationships suggests there is no guarantee that either GDP or education will change with greater deployment but the opportunity does exist. The relationship to the information and professional scientific industry employment show that fields requiring network access are larger in places with greater GBNP. The relationships show potential and further research would help determine the causal relationship between the variables that in turn communities could use to grow their local economies.

1. Introduction

1.1 Overview of Broadband and Gigabit Broadband Networks

The world changed in 1993 with the introduction of the World Wide Web, because for the first time in the history of the Internet, it allowed to connect to web pages through a URL making it easy to access and browse the web (Eha, 2013). The typical speed in 1993 was limited to 56 kilobytes per second which was based on connecting modems through phone lines (Eha, 2013). By 1996 the United States had about 18% of the population with home Internet connection (Newburger, 2001, pg. 2). The United States Congress passed the Telecommunications Act of 1996, which made the Federal Communication Commission the governing body over Internet connectivity (Newburger, 2001). As the network technology evolved the term “broadband” was coined and was meant to refer to networks with faster speeds than dial-up with modems that were “always on” (Lohr, 2015, para 5).

The definition continued to evolve with the FCC in 2010 defining broadband as connection speeds with at least 4 Megabits per second (down) and 1 Megabits per second (upload) (Lohr, 2015). Due to the changes in faster home connection speeds the FCC in 2015 set the new standard to label a service broadband at 25 Mbps (down) and 4 Mbps (upload) (Lohr, 2015). In the late 2000’s and early 2010’s the future of network technology, the gigabit broadband networks began to emerge and were networks that offered 4000% faster speeds that the standards set by the FCC, with download and upload speeds of 1,000 Mbps (Maniscalo, 2014). The FCC has recognized these as the future of network connectivity as through their words saying that they aim to “ensure that the United States has the world’s most dynamic and competitive broadband ecosystem” (FCC, 2014, pg. 6).

The introduction of broadband and the Internet have changed the economy. Sosa (2014) said, "Broadband has demonstrated the ability to fundamentally change how and where economic activity is organized" (pg. 2). One way to see this change is through what scholars refer to as the "new economy," which intertwines technology and the city (Katz, 2009).

Advances in Information Technology (IT) that started in the 1990's and beyond, have changed the fundamental economic rules with network connectivity becoming a business medium (Katz, 2009). The technology grew to allow for faster internet connection speeds which facilitated the development of new innovations, new processes, new businesses models, and has increased competitiveness and flexibility in the new economy (Sosa, 2014). The Bureau of Labor Statistics projects that IT jobs depending on broadband connectivity will grow over 25% by the year 2018, which is 2.5 times faster than all other occupations (BLS, 2014). Furthermore it has shaped the way consumers purchase things with 69% of Americans regularly buying products online and there has been double digit ecommerce growth in the last 4 years (Lee, 2014).

Gigabit broadband networks represent the future of network technologies as the speeds are exponentially greater than the average connection speeds. There have been a number of examples of successful economic impacts of the deployment of the gigabit broadband networks. The prime example comes from Chattanooga Tennessee's Electric Power Board's gigabit network created in 2009 that aimed to bring affordable gigabit speeds to businesses and residents (O'Toole, 2014). Two of the most notable success stories from Chattanooga's experience are the Volkswagen plant expanding due the better connectivity and Amazon opening a facility in Chattanooga (Wyatt, 2014). Between 2011 and 2014 Chattanooga created about 1,000 new jobs, and had about 55% of businesses sign up for the gigabit network services (Wyatt, 2014).

Chattanooga is considered to be the best example of success of a gigabit broadband network, but other places with gigabit connections; Fargo, ND and Kansas City, MO have also experienced economic growth (Gold, 2014). The success in changing these economies to more technology oriented has made the deployment of networks seen as a tool that can be used by local governments to strengthen local economies. The perception of success is so great that the worst economic city Detroit has put into place plans for deployment of a network to try and attract new businesses to help restart their economy (Thibodeau, 2016).

Industry has already adopted the current network technologies to their business models, but the question must be asked, what is the future of the network technologies and what does that mean for a locality's economic development? The first wave of Internet connectivity changed the economy and planners must embrace the changes in technology and reliance on quality internet connection in order to build strong and resilient economies. The next generation gigabit broadband networks are already being used as tool to help local economies (Thibodeau, 2016). It is important to determine the relationship between the economic well-being of a community and gigabit broadband network penetration (GBNP). Since the phenomena of gigabit broadband networks are new, there is a dearth of information and studies that analyze the relationship.

1.2 Research Questions:

What is the relationship between gigabit broadband network penetration and the economic well-being of a Metropolitan Statistical Area (MSA)?

What is the relationship between gigabit broadband network penetration and different industry employment?

1.3 Significance of the Study

This is an important topic to explore because if the relationship exists gigabit broadband networks could be a planning tool to help strengthen local economies. The study will give an overview of the previous broadband research. The research design and identification of key variables sets up for the statistical analysis. The results show the relationships between the economic well-being indicators and GBNP. The discussion will explore what relationships mean for planners and communities.

2. Review of the Literature

2.1 Introduction

This literature review centers around the question "what is the relationship between broadband network penetration and a locality's economic well-being?" The review focuses on (1) an overview to gigabit broadband networks; (2) identification of economic well-being indicators; (3) the relationship between the economic indicators and broadband research; and (4) identification of what research still needs to be done.

2.2 History of Broadband

Rouse (2007) defined broadband as "a telecommunication network, which has a wide band of frequencies available to transmit information" (para.1). The United States defines broadband in terms of standard upload and download speeds (FCC, 2014). Gigabit broadband networks provide connection speeds through a number of different network infrastructures. The next generation of broadband networks will provide a minimum of 1,000 Mega-bits per second (Mbps) download and upload speeds (Maniscalo, 2014). According to Gold (2015) the average speed for U.S. households in 2011 was 10 Mbps and by 2015 it grew to 31 Mbps. Gigabit broadband networks offer 3,000% faster speeds than the average download speed. According to

Belson (2014), the U.S. ranked 17th in average global connection speeds. The World Bank (2016) ranked the U.S. 18th in Internet users per 100 people.

In the United States the Federal Communications Commission (FCC) establishes the required connection speeds in order to label an Internet service, broadband. In 2015, the FCC increased the minimum connection speeds by 400% to label a service as broadband (Singleton, 2015). There are a number of infrastructures, such as fiber optic cables, coaxial cables, DSL and satellite that provide quality broadband service. In 2013 the FCC established a goal for 2015 to have at least one gigabit connection in all 50 states (Engebretson, 2016). They fell short of the 50 state goal but plans have been put into place to have at least one network fully operational in all states by the end of 2016 (Engebretson, 2016). FCC chairman Tom Wheeler stated their goal is, "to do everything within their power to ensure that the United States has the world's most dynamic and competitive broadband ecosystem with a virtuous cycle of new investment, new innovations and new services" (FCC, 2014, p. 6).

Applications and streaming media drive the need for connection speed. In 2014 over 60% of peak-time downloads consisted of streaming audio and video content, and the FCC expects by 2019 an increase to 90% (FCC, 2014). Gigabit broadband networks have the potential to impact the greater U.S. economy. Genchowski (2013), the former chairman of the FCC, outlined how broadband impacts everything including (1) genetic sequencing for cancer patient treatment, (2) access to immersive and creative software to support lifelong learning from home, and (3) small businesses through taking advantage of big data to analyze their customer base. In 2015, Accenture surveyed 2,000 businesses with the purpose of finding out how the digital world impacts businesses' investments (Daugherty et. al., 2015). They found 62% of the businesses invested in digital technologies and 35% of them made the investments part of their overall business strategy (Daugherty et. al., 2015). These percentages reflected how digital technologies are an important component of any business plan.

There are three main ways communities have brought gigabit broadband networks to their locality. The first is by building the network themselves, as did Chattanooga, Tennessee. Chattanooga attracted technology talent/businesses, provided public schools with high-speed Internet connection, and increased civic participation (Remy, 2013). The second way was through public private partnerships. Google through their fiber infrastructure deployment is defining both the way communities connect to the Internet and network partnerships (Trogdon, 2013). Google can help communities through provision of faster speeds and cheaper subscription costs than the incumbent Internet Service Provider (ISP), prompting cities to make it easier and more affordable to build the network through the provision of right of way for infrastructure deployment (Trogdon, 2013). The third way is through the private model or an ISP fully deployed and managed network (Hovis & Afflerbach, 2014). Google Fiber created a competition with the large incumbent ISPs to improve speeds and prices, or risk losing out on market share (Wallsten, 2013). In an effort to compete with Google, in 2015 ISPs of Cox Communications, Comcast, Time Warner Cable and AT&T began offering access to gigabit speeds (Paul, 2015).

The U.S. government identified gigabit broadband networks as vital to the future. President Obama supported two major programs focusing on the need to create gigabit connections to ensure the future competitiveness of the U.S. Information Technology sector. In 2011, Gig U, a nonprofit organization, received funding from the Federal government to help develop next generation ultra-high speed network applications and services (Gig U, 2014). Thirty-seven research universities across the country form Gig U and these universities have network access that allows for gigabit Internet connection speeds (Gig U, 2014). Gig U works with these higher education institutions and provides the opportunity for collaboration and funding to continue gigabit network research (Engebretson, 2014). The second initiative, U.S. Ignite, focuses on the development of next generation gigabit applications (U.S. Ignite, 2015). By 2020, U.S. Ignite plans to provide over 60 next generation gigabit applications, 200 community test beds and forums for collaboration (Kalil & Maynard, 2011). These two initiatives demonstrate how the U.S. government embraces the future of network capabilities.

2.3 Economic Well-Being

Decker (2015) in his Economic Indicator Report stated, "when it comes to economic indicators, there is no single number that provides a comprehensive measure of a region's economic health or addresses all of a community's concerns . . . to answer questions about economic health, it is typically necessary to evaluate multiple economic indicators that help you understand different pieces of the economy" (p. 1). Stiglitz (2009) and the U.K. Office of National Statistics (2014) described economic well-being as multifaceted and multidimensional covering a broad variety of indicators. Indicators of the economic well-being of a metropolitan statistical area include, GDP per capita, median income, median home value, and educational attainment as well certain industries' employment.

GDP per Capita

The Center for the Advancement of the Steady State Economy (2015) defined economic growth for a region as the "increase in production and consumption of goods and services" (p. 1). Gross domestic product (GDP) is one of the key components of measuring an economy as it examines the growth of consumption and regional employment (CASSE, 2015). In 2007 the Bureau of Economic Analysis (BEA) began reporting GDP at the metropolitan level (Panek et. al., 2007). The BEA wanted to create a way to analyze different metropolitan areas' economic growth to determine trends across the nation (Panek et. al., 2007). Private and public sectors use these statistics to determine the overall size and economic growth/ health of a metropolitan economy (BEA, 2015).

Stiglitz (2009) pointed to inherent problems using GDP as an indicator on the macro scale. GDP provides a macroeconomic picture of the metropolitan area. However, because change in GDP relates to population growth, it might not reflect the true economic health of an MSA (ONS, 2014). GDP per capita provides a more comprehensive look at how GDP is working to define economic growth, as it measures production over population (Stiglitz, 2009).

Income/ Housing

Vigna (2013) using the example of 2007 housing collapse described the importance of wages/ income as a metric for economic well-being of communities. In the 2000s wages remained stagnant as housing values increased (Vigna, 2013). The housing market could not continue to outpace wages exponentially and the 2007 housing collapse showed housing prices were not the sole measure of economic well-being (Vigna, 2013). Wages of workers is one of the strongest ways to document economic well-being for MSAs as consumer spending relates to personal and drives U.S. economy (Summers & Lanfranco, 2012).

The Milken Institute (2014) in their review of metropolitan economies cited wages related to the economic strength of metropolitan areas because the spending power of residents can help drive local employment opportunities (Milken Institute, 2014). Furthermore, wages are one of the variables helping to attract talent to a region and impact the quality of life (Milken, 2014). However, wages can be a deceiving indicator as things like inflation and cost of living play a role in determining employment wages (Summers & Lanfranco, 2012). Baumohl (2012) states that one of the ways to avoid this trap is through use of median income data from the Bureau of Economic Analysis, which accounts for all the different incomes people receive (i.e.

social security, unemployment, and welfare). For analysis of gigabit networks relationship to a MSA's economy the use of the median income is a strong indicator of economic well-being.

Straszheim (1975) pointed to the housing market as an economic indicator because "metropolitan development patterns are determined principally by the location of the decisions of firms and households" (p. 2). Rightmove Research (2014) surveyed 3,000 people in the U.K. and found broadband ranked as a more important feature to home buyers than transportation or nearby schools. BBC property expert Henry Pryor (2014) said, "Broadband speeds are now regarded as the 'fourth utility' after gas, water and electricity" (Perry, 2014, para. 5). Perry (2014) found homes without the least standard of broadband connectivity, could be worth up to 20% less than comparable property. A collaborative study in the U.S. by Broadbandchoices and independent real estate agents found properties that included broadband speeds attracted twice as many viewing requests (Onlincolnshire, 2016). The best way to measure the relationship between housing and economic well-being is through median price of the home, because median price of the home reflects the wealth of citizens (Barnes, 2016).

Educational Attainment

Regions can build a strong local economy through focusing on providing quality education and attracting educated individuals (Berger & Fisher, 2013). The new economy requires an educated workforce (Berger & Fisher, 2013). Area Development Online (2013) used the amount of the workforce with a bachelor's degree or higher, as a metric for determining the economic health of a region. They found a correlation between educational attainment and a stronger local economy (AreaDevelopment, 2013).

Industry Health

Malecki (1984), before the Internet and home computing had become a part of everyday life, conducted one of the first studies to analyze the relationship between high technology jobs and local economic output. He found areas with more high tech jobs experienced greater economic output. These jobs had a positive impact in the present and he predicted high technology jobs would become the highest paying jobs (Malecki, 1984).

The new economy includes a "globalization effect" which through technologies more efficiently connects countries allowing for easier international trade (Chong & Yuen, 2002). Stiglitz (2009) reported Information Technology (IT) jobs changed the structure of production and IT assets gained importance as capital goods (Stiglitz, 2009). IT became important in nearly every aspect of business and manufacturing, the larger share of IT professionals reflected the extent to which the local economy was a leader in the transition to the new economy (Buress et. al., 2004). Successful and innovative metropolitan economies do not need to compete in every segment of high tech or cutting edge industry but they generally do need to compete in some of those segments (Buress et. al., 2004).

2.4 Broadband Research

Sosa (2014) examined MSAs to determine the impact the gigabit broadband networks had on GDP per capita. He used Form 477 data for the information on gigabit penetration percentages and selected his accompanying MSAs. The study compared 54 MSAs with greater than 50% gigabit penetration with populations of under 1 million people and other equivalent MSAs located in the same states. He found that MSAs with high gigabit broadband household penetration percentage had a 1.1% increase in GDP per capita than MSAs without at least 50% gigabit broadband penetration (Sosa, 2014).

Hardy (1980) found a significant impact of tele-density on GDP per capita in both developing and developed countries. Anusua and Agarwal (2004), found statistically significant and positively correlated growth between GDP per capita and telecommunication infrastructure at the country level. Koutroumpis (2009) found a positive correlation between GDP per capita growth and a country's investment in broadband infrastructure. These early studies focused on inter-country comparisons.

In comparing countries World Bank (2009) found as median income increased so did broadband penetration. Ericsson (2014) reached the same conclusion. Ericsson examined at the inter country level comparing OECD and BID countries by speeds and income levels. One of the limitations in this study was the categorization of speeds into three categories; 0-512 KB, 2MB, and 4 MB +. This preliminary research showed on small scale the positive and statistically significant relationship between connection speeds and median income. It is difficult to use the Ericsson study to analyze the relationship between median income and gigabit broadband due to the exponential speed difference between 4 Mbps and the 1,000 Mbps.

To study the relationship between income and home access to broadband, Horrigan (2009) used a regression model with income data from the Census Bureau and FCC form 477 data. He found a relationship between higher median income and access to higher speeds. Using income data from the U.S. Census Bureau and broadband penetration data from the FCC, Lee et al. (2011) found income played a role in broadband diffusion. Whitcare et al. (2014) found median income grew with greater broadband penetration.

Lee and Brown (2008) examined the role educational attainment played in broadband adoption at the international level. Their regression analysis found broadband adoption was more likely with the increase in individual education level (Lee & Brown, 2008). Savage and Waldman (2005) and Chadudhuri et. al. (2005) both used ACS 5 year estimates data on educational attainment and found a positive relationship to broadband adoption. Clements and Abramowitz (2006) used the same data and found a positive relationship between of percentage of the population 25 years and older holding at least a Bachelor’s degree and broadband adoption. The Government Accountability Office (2006) in their report to Congress pointed out citizens with a college degree were more likely to demand quality connection speeds when adopting broadband service. Horrigan (2009) found a positive correlation between broadband adoption and educational attainment.

Grubesic (2003) focused on the early deployment of broadband technologies and factors related with the early deployment initiatives. He studied median home value and data collected from the U.S. Census Bureau’s ACS 5 year estimates. He found through regression analysis a relationship between the two but warned as the technology evolves the phenomenon needs more study. Blake (2009) examined the impact of median home value in North Carolina counties and the relationship to broadband. The North Carolina Department of Commerce provided the most accurate statistics on median home value in North Carolina. Running a regression analysis the researchers found the higher the price of the home the more likely for broadband adoption. Dutz et al. (2009) found a positive relationship between the price of homes and the accessibility to broadband.

Majumdar (2008) found that both total jobs and IT sector jobs grew with the first generation of broadband deployment between 1998-2001. Crandall et al. (2003) examined the first generation of broadband speeds on employment and found a positive relationship between IT industry growth and broadband network penetration. Gillet et al. (2006) found broadband penetration levels positively and statistically impacted the amount of IT jobs in a local community.

Katz (2009) of the Brookings Institute studied President Obama’s Administrative Broadband Stimulus Plan to determine if new jobs would be created and what industries would be most impacted through implementation of the plan. He found the White House's plan not only increased total jobs but added substantial jobs to the IT sector. Katz et al (2010) studied the relationship between broadband and the German economy and found IT industries experienced employment and GDP growth with greater broadband penetration.

Kolko (2010) examined the relationship early broadband technologies had on the number of different industries at the zip code level in the United States. Using data collected through NETS and the NAICS codes he identified and compared 20 different industries' employment growth to broadband deployment between 1999- 2006. He found 18 of the industries experienced positive growth associated with broadband deployment and only mining and public administration job growths were not statistically significant (Kolko, 2010).

2.5 Identifying the Gaps

Gaps in the literature exist, specifically in gigabit broadband research. Since the gigabit speed capability is a newer technology, researchers have not determined the relationships between local economies and gigabit broadband networks. While there is a vast amount of existing broadband research, the overwhelming majority deals with the low broadband speeds or analyzes the relationship at the international level. The gigabit network speed has been shown to be exponentially faster and the results of gigabit broadband research do not explain the relationship between next generation speeds and local economies. Sosa (2014) researched gigabit broadband networks but only in the early development period and only using one economic indicator. Research on the relationship between local economic strength and gigabit broadband networks requires studying more economic indicators, and larger sample sizes. Building off of previous broadband research, this study addressed these gaps, through studying the relationships between economic well-being of MSAs in the U.S. and gigabit broadband network penetration.

2.6 Research Questions

(1) What is the relationship between gigabit broadband network penetration and a locality's economic well-being?

(2) What is the relationship between gigabit broadband penetration and different industry employment?

The research protocol to answer these questions is in Chapter 3.

3. Research Design and Methodological Approach

3.1 Introduction

Chapter two provided the definition of gigabit broadband networks, identification of variables affecting economic well-being and a review of broadband research. Answering the research question "what is the relationship between gigabit broadband network penetration and a locality's economic well-being?" involves: (1) developing the research design; (2) identifying measures and variables; (3) collecting data; and (4) statistical analysis.

3.2 Description of Study Area

The research design involved identifying MSAs, procuring Gigabit broadband percentage from FCC Form 477 and collecting data on economic well-being variables from U.S. Census Bureau. Previous research (Sosa, 2014) used MSAs as a basis for studying the economic relationship between localities and gigabit broadband networks. The Office of Management and Budget (OMB) defines the core based statistical areas and makes adjustments when more social and economic integration takes place between communities in geographic proximity. In 2014 the OMB identified 388 MSAs in the United States. Between 2012–2013 the OMB drew geographic boundaries around MSAs and changed what municipalities they encompassed. Inclusion criteria for this research consisted of MSAs whose borders were consistent between

2011 and 2014. Twenty-one MSAs were not included in this analysis due to boundary changes between 2011 and 2014. Figure 1 shows all of the mainland United States MSAs used in this study.

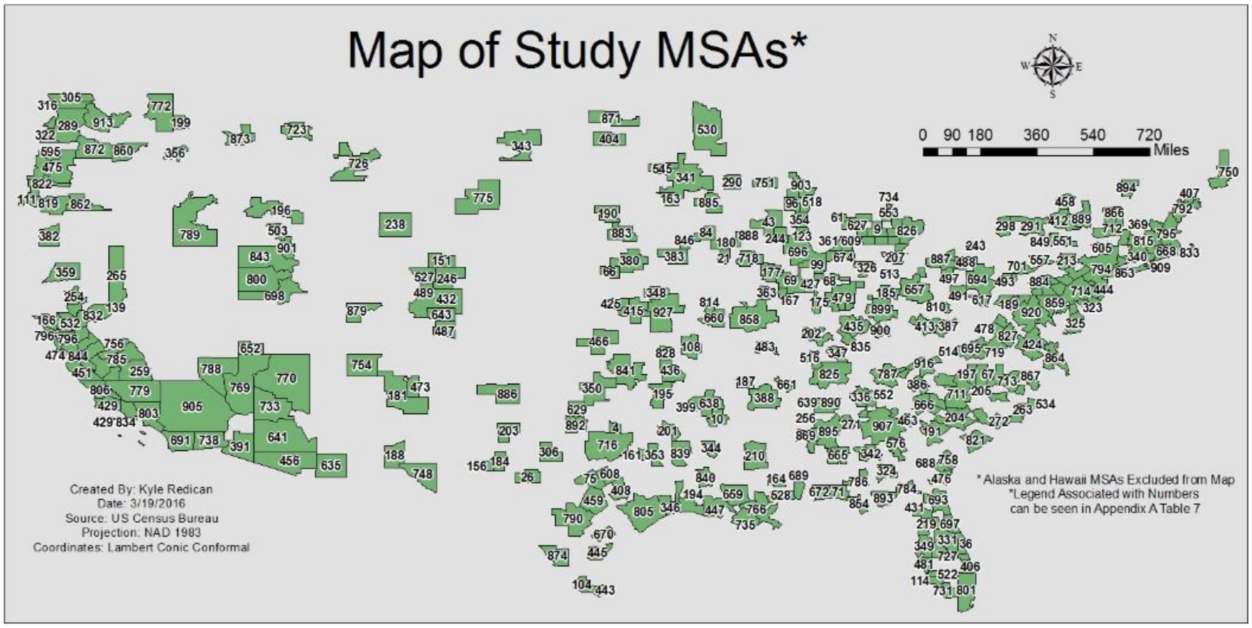

Figure 1: Map of All MSAs Included in the Study

3.3 Measures and Variables

Gigabit broadband penetration data came from the aggregation of FCC Form 477 by the National Telecommunications and Information Administration (NTIA). Grubesic (2012) pointed out that the coverage data comes from the infrastructure carriers, who may overstate their coverage areas because of industry competition. Ford (2011) points to the measurement errors, and selection bias as further issues. He states that there cannot be any strong causal conclusions derived from the data set but it is the most accurate source for broadband penetration data. GAO (2010) echoed the concerns about the data, but still point to it as the strongest source of data for broadband penetration. The NTIA's aggregated FCC Form 477 included data on gigabit broadband network penetration percentage at the household level with network access for the years 2011, 2012, 2013, and 2014.

This study included 13 different variables analyzed to determine the relationship between gigabit broadband penetration and an MSA's economic well-being. The study categorized the variables into four different groups: time, geography, economy, and employment. Table 1 shows the grouping of the variables.

Table 1: Variable Overview Table

Category	**Variable**	**Variable Name**	**Years Collected**	**Source**
Broadband Penetration	*Gigabit Broadband Penetration (HHU %)*	GigBP	2011-2014	Form 477 FCC data, used through the Analyze table of the data from the NTIA
Time	*Year*	Year	2011-2014	
Geography	*Population Density*	PopDen	2011-2014	U.S. Census Bureau: ACS 5 years estimates (with GIS analysis)
	MSA Size	Small, Mid, Large	2011-2014	U.S. Census Bureau: ACS 5 years estimates
Economy	*GDP per Capita*	GDPPC	2011-2014	Bureau of Economic Analysis, Survey of Business Statistics 5 year collection
	Median Income	MHInc	2011-2014	U.S. Census Bureau: ACS 5 years estimates
	Educational Attainment	Education	2011-2014	U.S. Census Bureau: ACS 5 years estimates
	Median Home Value	MHVal	2011-2014	U.S. Census Bureau: ACS 5 years estimates
Employment	*Agriculture, Forestry, Fishing, Hunting, Mining*	Agri	2011-2014	U.S. Census Bureau: ACS 5 years estimates
	Whole Sale Trade	Whole	2011-2014	U.S. Census Bureau: ACS 5 years estimates

	Information	Info	2011-2014	U.S. Census Bureau: ACS 5 years estimates
	Finance, Insurance, Real Estate, Rental, Leasing	Fin	2011-2014	U.S. Census Bureau: ACS 5 years estimates
	Professional Scientific, Management, Administrative, and Waste Management Services	ProfSM	2011-2014	U.S. Census Bureau: ACS 5 years estimates
	Transportation and Warehousing	Trans	2011-2014	U.S. Census Bureau: ACS 5 years estimates

The time group includes an ordinal variable accounting for each data point's year: 2011, 2012, 2013 or 2014. The geography group includes data from the U.S. Census Bureau ACS 5 year estimates. Population data of MSAs from the U.S. Census Bureau provides both of the population size variables; small and large. The small variable accounts for all MSAs with a population of less than 500,000, which consisted of 252 MSAs. The large variable accounts for MSAs with a population greater than one million, which consisted of 51 MSAs. MSA geographic data determined the size in square miles. Due to 2014 being the only available geographic area data, the study used 2014 area to calculate population density for 2011 to 2013.

The economy variables included GDP per capita, median household income, educational attainment and median home value because the literature review documented them as economic indicators. Median household income (Horrigan, 2009; Lee et. al., 2011; Whitcare et al., 2014), educational attainment (Savage & Waldman, 2005; Chadudhuri et. al., 2005; Clements & Abramowitz, 2006), and median housing value (Dutz et. al., 2009; Browne, 2014) came from the

U.S. Census Bureau's ACS 5 year estimates. The educational attainment variable refers to percentage of the population 25 years and older holding a bachelor's degree or higher. The Bureau of Economic Analysis provided data on the GDP per capita at the MSA level.

The employment group includes six different industries that either act as an indicator for economic well-being or previous literature pointed out a relationship between the industry and broadband. This study collected industry employment percentage from the U.S. Census Bureau ACS 5 year estimates. The data provided 13 different industries (Agriculture, Forestry, Fishing, Hunting, Mining; Construction; Manufacturing; Wholesale Trade; Retail Trade; Transportation, Warehousing, Utilities; Information; Finance, Insurance, Real Estate, Rental, Leasing; Professional Scientific, Management, Administrative, Waste Management Services; Educational Services, Health Care, Social Assistance; Arts, Entertainment, Recreation, Accommodation, Food Services, Public Administration; Other Services) and used selected industries with previously identified relationships to gigabit broadband penetration (Katz, 2009; Kolko, 2010).

3.4 Data Collection

Data for all the variables analyzed came from multiple sources including the NTIA analyze table database, the American Fact Finder database, and the Bureau of Economic Analysis' yearly reports. The U.S. Census Bureau only provided data for the 2014 size of MSAs through GIS shapefiles; therefore, this study used the 2014 available data to calculate population density. Because geographic size data was limited to 2014, and population density for all years was based on these data, 2011–2013 population densities may over- or underestimate actual population density for those years.

3.5 Analytical Challenges

Previous broadband research studies used various regression analyses to investigate the effects of broadband on different economic indicators. Regression analyses evaluate predictive models, using the independent variables to predict the rate of change in dependent variables. Sosa (2014) used a fixed-effects regression model to study the impact of gigabit broadband networks on GDP per capita because it controlled for idiosyncratic differences over time. Koutroumpis (2009) and Czernich et al. (2009) used multiple regression methods to investigate the impact broadband penetration had on GDP. Kolko (2010) used regression analysis to analyze the impact broadband had on industry employment. Using the FCC Form 477 data in a regression model is problematic, as Ford (2011) described the data as imperfect, thus causal links should not be derived from these data. Additionally, including all of the variables that may be related to gigabit broadband penetration could lead to issues with multicollinearity and over-paramaterization of models. While regression analysis seems to be the accepted approach for analyzing these data, correlation analyses can identify multicollinearity and potential significant relationships between variables. The researcher can then use these identified relationships to build models that represent *a priori* hypotheses about the effects of different economic variables on gigabit broadband penetration.

Literature supports use of correlation research in answering the research question on the relationship between economic well-being and gigabit broadband network penetration. Maiwada and Okey (2015) pointed to correlation research as an important tool in quantitative research to investigate the nature of relationships between variables, as it can be used to inform model building for regression analyses. Duncan (1966) describes correlation research as vital to the development and testing of theoretical models because important relationships can be targeted for further investigation, while irrelevant variables can be eliminated. Correlation research identifies important variables and allows for the creation of a model to predict the role economic well-being plays in gigabit broadband network penetration.

3.5 Operationalization of Research Question

To answer the research question about the relationship between gigabit broadband penetration and economic well-being, the study used Pearson's correlation coefficient (r) test. The Pearson's test establishes the relationship between the variables and shows the degree of strength and the directionality of the relationships (Maiwada & Okey, 2015). A positive r coefficient shows a positive relationship between the variables. Negative r coefficients show an inverse relationship. The results of the Pearson's correlation test create a correlation matrix, which shows the relationship between the variables and addresses multicollinearity. Holgado-Tello et. al., (2011) describes the use of a correlation matrix as important for studying the validity of data in factor analysis, and Barnes (2012) considers interpreting the correlation matrix to be one of the first steps in analysis.

The end result of this analysis is a correlation matrix, which provides a 14 by 14 table with all of the chosen variables showing the r coefficient and the p-value. The r coefficient shows the direction and strength of the relationship, and the p value shows whether the relationship is significantly different than zero. Correlational analysis of the variables should show a relationship between economic well-being and gigabit broadband network penetration. This descriptive analysis will lay the foundation for the researcher to develop an *a priori* candidate set of models representing different hypotheses about the interactions of these variables and how they affect gigabit broadband penetration. This study analyzed the data in SAS version 9.4 using the CORR procedure (SAS Institute, Cary, NC, USA).

4. Results

4.1 Introduction

As discussed in Chapter 3, multiple reports and other sources provided data to answer the questions (1) what is the relationship between gigabit broadband network penetration and economic well-being, and (2) what is the relationship between gigabit broadband network penetration and industry employment. In Chapter 4 the descriptive statistics of the data showed the expected direction of the r coefficients, and Pearson's correlation test analyzed the relationships among variables. The results showed four variable relationships to gigabit broadband network penetration (GBNP)—time, GDP per capita, education, and information industry employment—require further analysis and discussion.

4.2 Descriptive Statistics/ Sign Expectations

Descriptive statistics included number of observations, mean of each variable, standard deviation, sum of all the variable data, minimum and maximum thresholds, percentage change between 2011 and 2014 and expected directionality. The study calculated the percentage change in different ways depending on the variable. For example, the percentage change for gigabit broadband network penetration (GBNP) used the difference between the 2011 and 2014 data, while the economic grouped variables took the difference of value between 2011 and 2014 then divided by the 2011 data to find the percentage change. The expected sign came from a combination of the literature review and statistics on the rate of change between 2011 and 2014.

Table 2 contains the descriptive statistics. While Table 2 includes much data,

the n column shows there will be 1,428 observations in the study. The mean value shows the data points average measured across all the observations. The min and max columns give the size ranges for each of the variables. The sum is not a relevant column as it is adding up the totals for the each variable not providing any new information. The percentage change column calculated percentage change in the variables to help show the expected the r coefficient sign. The expected r coefficient sign allows for testing of the relationships. The expected r coefficient directionality works in conjunction with the correlation matrix to determine the accuracy of the direction of the expected relationships between GBNP and economic well-being.

Table 2: Descriptive Statistics of the Data

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	2011 to 2014 Percentage Change	Expected Sign
Gigabit Broadband Penetration (HHU%)	1428	0.1	0.2	87.4	0.0	0.9	+7.85%[1]	
Year	1428	2013.0	1.1	2873850.0	2011.0	2014.0	n/a	+
Small MSA	1428	0.7	0.5	1011.0	0.0	1.0	n/a	+
Large MSA	1428	0.1	0.4	213.0	0.0	1.0	n/a	+
Population Density	1428	311.7	351.3	445130.0	8.1	3026.0	+1.43%	+
Median Household Income	1428	50252.0	8701.0	71759518.0	32156.0	92960.0	+2.09%[2]	+
GDP per Capita	1428	41599.0	12750.0	59402692.0	17009.0	162786.0	+1.46%[2]	+
Education	1428	7.9	3.3	11269.0	0.9	18.4	+6.49%[2]	+
Median Home Value	1428	173731.0	84682.0	248088500.0	75200.0	674800.0	-2.30%[2]	+
Agriculture	1428	2.4	2.9	3463.0	0.2	20.7	+7.52%[3]	-
Wholesale	1428	2.7	0.7	3788.0	0.5	6.3	-6.16%[3]	-
Information	1428	2.6	1.6	3733.0	0.6	11.3	-9.06%[3]	+
Finance	1428	4.3	2.0	6184.0	1.0	21.3	-3.26%[3]	+
Professional Scientific Services	1428	7.8	2.0	11146.0	3.7	19.5	+3.20%[3]	+

Transportation	1428	4.7	1.1	6679.0	2.1	13.8	-1.53%[3]	-

[1]Calculated by 2014 average gigabit broadband penetration at household level by 2011 average gigabit broadband penetration at the household level shows the increase in average gigabit broadband network penetration between 2011 and 2014.

[2]Calculated by [(Average of variable in 2014)- (average of variable in 2011)]/(Average of variable in 2011)*100 shows the percentage change in employment percentage between 2011 and 2014.

[3]Average of industry employment percentage in 2014)- (Average of industry employment percentage in 2011)/ (Average of industry employment 2011)*100 shows the percentage change in employment percentage between 2011 and 2014.

The finding of a positive relationship between GDP per capita and broadband penetration by Sosa (2014), and Koutroumpis (2009) and the 1.46 percentage growth of GDP per capita between 2011 and 2014 led to the expectation of a positive relationship between GDP per capita and GBNP. This study (I) expects a positive relationship between median household income and GBNP because Horrigan (2009) found a positive correlation between the two variables and median household income grew by 2.09% between 2011 to 2014. Multiple studies point to the relationship between education and broadband penetration, and the 6.49 percentage growth in education between 2011 and 2014 led to the expectation of a positive relationship between education and GBNP (Lee & Brown, 2008; Chadudhuri et. al, 2005; Savage & Waldman, 2005; Clements & Abramowitz, 2006). Perry (2014) pointed to the broadband playing a role in the housing market and the study expected median home value would be positively correlated with GBNP.

Kolko (2010) showed negative relationships between the agriculture industry employment and broadband penetration, and between wholesale industries and broadband, therefore this study expected negative relationships. Multiple studies pointed to the positive relationship between the information industry and broadband (Majumdar, 2008; Crandall et. al, 2003; Gillet et. al, 2006; Kolko, 2010; Katz, 2009), and Kolko (2010) showed a positive relationship between the finance industry and broadband penetration. Despite the decreases in information and finance industry employment between 2011 and 2014, the study expected a positive relationship between these industries and GBNP. Kolko (2010) found the professional sciences industry had a positive relationship to broadband, and a positive relationship between broadband and the transportation industry, leading to positive r coefficient expectations.

4.3 Correlational Matrix Results

The result of the culmination of each individual Pearson's correlation test is the correlation matrix in Table 7. The correlation matrix provides both the strength of the relationship through the r coefficient and statistical significance through the p value. Reading the results of statistically significant variables shows the relationship between gigabit broadband network penetration and different economic well-being variables between 2011 and 2014. The correlation matrix is a tool to compare the expected relationship to the actual observations.

Table 3: Correlation Matrix of all Pearson's Correlation Tests

	GigBC	*Year*	*Small*	*Large*	*PDen*	*MHI*	*GDPPC*	*Edu*	*MHV*	*Agri*	*Whole*	*Info*	*Fin*	*ProfSM*	*Trans*
Gigabit Broadband Penetration	**1.00**														
Year	**0.204** (<0.001)**	**1.00**													
MSA (Small)	**-0.011 (0.683)**	**0.002 (0.938)**	**1.00**												
MSA (Large)	**0.001 (0.977)**	**-0.003 (0.921)**	**-0.652** (<0.001)**	**1.00**											
Population Density	**-0.007 (0.796)**	**0.004 (0.867)**	**-0.493** (<0.001)**	**0.512** (<0.001)**	**1.00**										
Median Household Income	**0.026 (0.324)**	**0.027 (0.309)**	**-0.355** (<0.001)**	**0.365** (<0.001)**	**0.474** (<0.001)**	**1.00**									
GDP Per Capita	**0.134** (<0.001)**	**0.017 (0.518)**	**-0.048 (0.071)**	**0.034 (0.196)**	**0.001 (0.966)**	**-0.024 (0.362)**	**1.00**								
Education	**0.119** (<0.001)**	**-0.007 (0.783)**	**-0.066** (0.012)**	**0.108** (<0.001)**	**0.047 (0.074)**	**0.012 (0.661)**	**0.549** (<0.001)**	**1.00**							
Median Housing Value	**-0.044 (0.096)**	**-0.082** (0.002)**	**-0.041 (0.125)**	**0.026 (0.325)**	**-0.02 (0.449)**	**-0.063** (0.018)**	**0.399** (<0.001)**	**0.307** (<0.001)**	**1.00**						
Agriculture Industry	**-0.029 (0.263)**	**-0.001 (0.983)**	**0.068** (0.002)**	**-0.082** (0.002)**	**-0.062 (0.26)**	**-0.061** (0.021)**	**-0.015 (0.578)**	**-0.383** (<0.001)**	**0.027 (0.303)**	**1.00**					
Wholesale Industry	**-0.063** (0.017)**	**-0.019 (0.482)**	**0.082** (<0.001)**	**-0.109** (<0.001)**	**-0.008 (0.767)**	**-0.059** (0.027)**	**0.09** (<0.001)**	**-0.163** (<0.001)**	**-0.046 (0.079)**	**0.305** (<0.001)**	**1.00**				
Information Industry	**0.077** (0.004)**	**-0.017 (0.894)**	**-0.03 (0.261)**	**0.008 (0.775)**	**-0.006 (0.829)**	**-0.009 (0.733)**	**0.302** (<0.001)**	**0.316** (<0.001)**	**0.193** (<0.001)**	**-0.244** (<0.001)**	**0.255** (<0.001)**	**1.00**			
Finance Industry	**0.024 (0.363)**	**-0.016 (0.536)**	**-0.007 (0.80)**	**0.018 (0.486)**	**0.009 (0.736)**	**-0.024 (0.361)**	**-0.11** (<0.001)**	**-0.089** (<0.001)**	**-0.091** (<0.001)**	**0.031 (0.247)**	**-0.169** (<0.001)**	**-0.617** (<0.001)**	**1.00**		
Professional Scientific Services Industry	**0.056** (0.035)**	**-0.02 (0.461)**	**-0.05 (0.064)**	**0.081** (0.002)**	**0.002** (0.930)**	**-0.053** (0.047)**	**0.143** (<0.001)**	**0.195** (<0.001)**	**0.282** (<0.001)**	**-0.079** (0.003)**	**-0.187** (<0.001)**	**-0.154** (<0.001)**	**0.31** (<0.001)**	**1.00**	
Transportation Industry	**0.006 (0.836)**	**0.03 (0.259)**	**0.04 (0.132)**	**-0.075** (0.004)**	**0.013 (0.627)**	**0.057** (0.033)**	**-0.037 (0.172)**	**-0.316** (<0.001)**	**-0.122** (<0.001)**	**0.095** (<0.001)**	**0.338** (<0.001)**	**0.058** (0.278)**	**-0.136** (<0.001)**	**-0.259** (<0.001)**	**1.00**

()= Number in parenthesis is p-value

**= Statistically significant at the 95% confidence interval

N= 1,42

4.4 Relationships of Gigabit Broadband Network Penetration

Pearson's correlation test showed the most important variable determining the percentage of households that have access to gigabit broadband network connections was year ($r = 0.204$, $p = <0.001$). The correlation coefficient of 0.204 was the highest coefficient of all the variables. This supported this study's expectation of the variable's statistical significance and the positive relationship to GBNP. These results suggest that as technology continues to evolve, the penetration levels of gigabit broadband network deployment will continue to grow.

Against the expectations of the study, gigabit broadband network penetration (GBNP) did not relate to any of the geography and population variables of the MSAs. The population density and small and large MSA variables were not significantly correlated with gigabit broadband network penetration (Population Density: $r = -0.007$, $p = 0.769$; Small: $r = -0.011$, $p = 0.681$; Large: $r = 0.001$, $p = 0.98$). This shows no relationship between the population of an MSA and GBNP, meaning there are other drivers that relate to GBNP.

The economic grouped variables of median household income and median home value did not correlate to GBNP. The study incorrectly expected the relationship between median household income and GBNP, as the study observed no significant relationship ($r = 0.026$, $p = 0.324$). Literature pointed to information technology jobs having higher earnings than other fields (Hardy, 1980), but GBNP does not clarify the gap between the two. The study incorrectly expected the statistical significance of median home value and GBNP, as the variables did not correlate ($r = -0.044$, $p = 0.096$). The observed relationship between the two did not show GBNP as a driver of the housing market. Perry (2014) pointed to broadband impacting the price of homes but next generation network connections did not share the same relationship.

The study correctly expected the significance and sign of the relationship of GBNP and GDP per capita (r = 0.134, p = <0.001). The relationship is positive and shows GDP per capita growth with greater GBNP. GBNP provides one of the key tools for firms' success in the "new economy" and allows for them to be more productive. This productivity translates into greater output raising the amount of money coming in, which in turn raises the GDP of the MSA. If the greater output is not based solely around a growth in MSA population then the GDP per capita of the MSA grows. The statistically significant relationship between GBNP and GDP per capita shows that GBNP may be driving some economic growth.

Education showed a statistically significant relationship to GBNP (Education; r = 0.119, p =<0.001). The study correctly expected the relationship's statistical significance and directionality. The relationship could show evidence for the demand of educated individuals for faster speeds or the growth of industries requiring more educated individuals and faster connection speeds. The relationship between education and the information industry highlight the latter (r =0.316, p = <0.001), as there is a correlation between these variables.

For the industry employment percentage variables the expectations on statistical significance and directionality showed some correct and some incorrect outcomes. The study incorrectly expected the statistical significance of the relationship of GBNP and agriculture industries (r = -0.029, p = 0.263). This shows that there is essentially no relationship between GBNP and agriculture industry employment. The study incorrectly expected the relationship between Finance, insurance, real estate, rental and leasing industry employment and GBNP (r = 0.024, p = 0.363). Networks and access to technology were expected to help the finance industry but the relationship was shown to not exist. Gigabit broadband networks do not play a role in finance industry employment. The study incorrectly expected the statistical significance of the relationship between GBNP and the transportation and warehousing industries employment percentage (r = 0.006, p = 0.836). There was no relationship between GBNP and transportation industry employment.

The study correctly expected the negative correlation between wholesale industry and GBNP (r = -0.063, p = 0.017), indicating a negative relationship between the industry employment and GBNP. Albeit the small correlation, the relationship shows as gigabit broadband network penetration grows, the wholesale industry employment falls. The study correctly expected the positive correlation between the professional scientific, management, administrative and waste management services industry employment and GBNP (r = 0.056, p = 0.035). The positive relationship shows that as GBNP grows so does the employment percentage of the professional scientific industries.

The study correctly expected the positive correlation between the Information employment percentage and GBNP (r = 0.077, p = 0.004). Access to fast Internet connections is important to the information industry and the results show that as GBNP grows, so does information industry employment.

4.5 Other Relationships of Note

The results of the geography variable group showed statistically significant correlation in the relationships between the small and large variables (r =-0.652, p = <0.001), and the relationship between the small and large variables and population density (Small: r = -0.493, p = <0.001; Large: r = 0.512, p = <0.001). The relationship between all the geography variables was to be expected as the data making up the variables relates to each other. Small and large MSA variables showed an inverse relationship to population density and each other, as they extracted different MSAs using the same population data, and the r coefficients are almost equal with the exception of the sign direction.

The year variable correlated with the median housing value, which decreased with year (r = -0.082, p = <0.001). This is an important relationship to analyze as it shows that the housing market was on the decline between 2011 and 2014. The decrease in the housing market could be a bi product of the housing bubble bursting in 2007, and it seems that the impacts of the housing crash still impact the home value seven years later. Identification of the drivers determining the housing market require further study to explain the observation.

Median household income had statistically significant relationships to all three of the geography variables (Small: r = -0.355, p = <0.001; Large: r = 0.365, p = <0.001, Population Density: r = 0.474, p = <0.001). The results showed that there was a negative correlation between small MSAs and median home income but a positive correlation between the large MSAs. The relationship to the geography variables of median household income shows that with greater population size or density there is likely to be a higher median income, due to the cost of living and required wages for living being higher in metropolitan areas compared to rural ones.

The relationships between median household income and the agriculture industry (r = -0.062, p = 0.021), the professional sciences industry (r = -0.053, p = 0.047), and the transportation industries (r = 0.057, p = 0.033) show the impact that different employment has on wages. Agriculture is negatively correlated with median home income showing that many of the agriculture industry positions garner lower wages than other industries. The negative correlation between median home income and the professional sciences industry employment shows there are diminishing returns in the industry employment to median household income compared to other industries employment. The relationship with the other variables show there are other drivers to median household income rather than GBNP.

GDP per capita was significantly and positively correlated with median home value ($r = 0.399$, $p = <0.001$) and education ($r = 0.549$, $p = <0.001$). The relationship between median home value and GDP per capita shows that homes increase in value in MSAs where there is greater GDP per capita. The strong relationship of GDP per capita to education shows that the talent provided from education helps with the productivity of firms. The productivity directly relates to the increase in GDP.

Education surprisingly showed a positive relationship to the agriculture industry ($r =0.383$, $p =<0.001$). The agriculture industry has the stigma of not requiring as strong of education backgrounds as others and the relationship between the two would need more analysis. Further surprising results were the statistically significant relationship but negative directionality between education and the finance industry employment ($r = -0.089$, $p = <0.001$). There is a perception that finance jobs require a strong educational background but the relationship shows that finance employment is less reliant on education than the agriculture employment. Education had strong and statistically significant relationship between professional scientific services industry employment ($r = 0.195$, $p = <0.001$) and the transportation industry ($r =0.122$, $p = <0.001$). Showing that employment in these industries relates to an individual holding a bachelor's degree or higher. Education had statistically significant relationships with median home value ($r = 0.307$, $p = <0.001$). Greater education leads to higher paying jobs, which in turn could be the driver for the housing market.

Agriculture showed statistically significant relationships with wholesale industry employment ($r = 0.305$, $p = <0.001$). Wholesale industries and agriculture showed the largest positive relationship between industries. These industries are closely tied in practice and often work together, thus a strong positive correlation between these variables might be expected. Furthermore, wholesale industry correlated with the information industry employment (r = 0.255, p = <0.001). The relationship to the information industry employment shows positive growth with wholesale employment.

The information industry employment showed statistically significant relationships to GDP per capita (r = 0.302, p = <0.001), education (r = 0.316, p = <0.001), and median home value (r = 0.193, p = <0.001).   As information industry employment percentage grows GDP per capita, education and median home value grows. The presence of the information industry creates better, higher paying jobs within the area and requires a more educated work force, thus with a greater percentage of information employment, the other economic variables will grow as well. Furthermore information negatively correlated with the agriculture industry (r = -0.244, p = <0.001), the finance industry (r = -0.617, p = <0.001) and the professional scientific industry (r = -0.154, p = <0.001). The negative relationship to agriculture is to be expected as the two industries do not work together and provide different services. The finance industry had the largest r coefficient showing the negative relationship between the two variables. The factors impacting this relationship would require further research. The professional scientific industry also showed a diminishing relationship between the two variables. The relationship was unexpected due to the overlap of coverage and further research is needed to understand the relationship.

The relationship between the professional scientific industry and the transportation industry gave surprising results (r = -0.259, p = <0.001). The relationship was negative and showed as the transportation industry grows the professional scientific industry employment will fall.

4.6 Summary of Results

The descriptive statistics provided basis for the expectations in statistical significance and directionality of the r coefficient. The Pearson's correlation test showed that six out of the 14 variables were positively correlated to GBNP. Table 3 is a summary showing all the statistical significance found between the variables, the expected sign and the observed sign. Further review of the importance of the positive relationships of GBNP to GDP per capita, education, and the information industry will be discussed in Chapter 5.

Table 4: Summary of Findings

Category	Variable	Statistically Significant	Expected Sign	Actual Sign
Time	*Year***	Yes	(+)	(+)
Geographic	*Population Density*	No	(+)	(-)
	MSA Size	No	(+)	(-)
Economic	*GDP per Capita***	Yes	(+)	(+)
	Median Income	No	(+)	(+)
	*Educational Attainment***	Yes	(+)	(+)
	Median Home Value	No	(+)	(-)
Employment	*Agriculture, Forestry, Fishing, Hunting, Mining*	No	(-)	(+)
	*Whole Sale Trade***	Yes	(-)	(-)
	*Information***	Yes	(+)	(+)
	Finance, Insurance, Real Estate, Rental, Leasing	No	(+)	(+)
	*Professional Scientific, Management, Administrative, and Waste Management Services***	Yes	(+)	(+)
	Transportation and Warehousing	No	(+)	(+)

N= 1,428

***= statistically significant at the 95% confidence interval*

5. Discussion

5.1 Introduction

The purpose of the Chapter 5 is to discuss the implications of the relationship between gigabit broadband network penetration in the context of a localities economic well-being. The synthesis and interpretation of the results provides the real world implications of the findings and addresses any unexpected findings. The limitations of the study point to where simple research design changes could benefit future gigabit broadband network research. The discussion also examines what the relationships between different economic well-being indicators and GBNP means for localities across the United States.

5.2.1 Geography

Gigabit broadband network penetration did not relate to any of the geography and population variables of the MSAs (Population Density: $r = -0.007$, $p = 0.769$; Small: $r = -0.011$, $p = 0.681$; Large: $r = 0.001$, $p = 0.98$). One reason that these results were observed could be the level of geography. Ericsson (2014) found that the geography and population variables played a role in broadband diffusion at the county level. The MSA as a geographic unit might be too large of a unit for this analysis, as regional and small-scale variation may have been masked at the MSA level. Using the FCC Form 477 data and U.S. Census Bureau data the county level, geographic parameters and population data would have less variance and allow for a more detailed analysis to show the true nature of the relationships between geography variables and GBNP.

5.2.2 Economic

The study expected to find positive and statistically significant relationships between GBNP and all of the economy grouped variables. The economy grouped variables of median household income and median home value showed unexpected non-statistical significance and did not correlate to GBNP (Median Home Income: r = 0.026, p = 0.324; Median Home Value: r = -0.044, p = 0.096). The non-statistically significant relationships between the variables and GBNP show none of the variables are drivers for each other to grow or diminish. However, median household income had correlations to the geography grouped variables (Small: r = -0.355, p = <0.001; Large: r = 0.365, p = <0.001, Population Density: r = 0.474, p = <0.001). The relationship to the geography variables shows that location is potentially a better driver of median household income than GBNP or any of the employment variables. Indeed, the cost of living and the metropolitan status of an area are important factors that determine the median household income.

Median home value showed no relationship to GBNP but negative correlations with GDP per capita and education (GDP per Capita: r = 0.399, p = <0.001, Education: r =0.307, p = <0.001). The directionality of the relationship shows that as GDP per capita and education levels rise, the median price of the home falls. Perry (2014) showed that homebuyers place premiums on buying homes with broadband accessibility, but this study showed that while homebuyers may be looking for gigabit broadband access, it does not relate to the home value. Vigna (2014) pointed out that the housing market has fallen since the 2007 housing collapse, making the market predictors unreliable. The drivers of the housing market are different from factors influencing GBNP and further research needs to look into what relationships drive home prices.

The study expected and found a positive significant relationship between GBNP and GDP per capita. The study showed that as GDP per capita grows so does GBNP. The small relationship at the MSA level reflects the findings of Sosa (2014) of a 1.1% increase in GDP per capita with greater GBNP. The MSA level of geography might be able to explain the weak correlation, as other studies examining it at the international level found a stronger relationship

(Koutroumpis, 2009; Anusua & Agarwal, 2004; Hardy, 1980). The international level of geography provided more variance between both broadband penetration levels and GDP, because country designation is not formed around co-operating economies like MSAs but have other socio-political factors in their formation. The Office of Management and Budget creates the MSAs because of the economic influence and reliance different areas in geographic proximity have to each other, making less variance between economies across the U.S.

GDP measures the gross domestic product of a defined area, showing the production of firms. The new economy relies on access to technology and networks because the productivity of firms increases as they connect and sell their products without the place of production being an important feature (Bai & Yuen, 2002). GBNP represents the future of network technologies and access by firms gives them advantage for productivity with the fastest connections. The fastest Internet connection speeds allows for the development of new technologies and increasing productivity. The increase in production in turn impacts the output, which increases GDP. The increase in GDP is beneficial for local economies as it shows an increase in money for a locality, and in turn could represent better locality employment.

Education showed a statistically significant positive relationship to GBNP. The relationship was weak at the MSA level but statistically significant nonetheless. The relationship shows that the more educated a populace is, the more likely there is to be greater GBNP. These findings reflect the statements from the U.S. Governmental Accountability Office (GAO, 2006; 2008) in their reports to Congress on the state of broadband, which pointed to education as the determining factor in people’s demand for high speed connections. The relationship was smaller at the MSA level than the relationship at the international level found in numerous studies (Clements & Abramowitz, 2006; Lee & Brown, 2008; Chadudhuri et. al., 2005; Savage &

Waldman, 2005). The smaller level of analysis provided the smaller coefficient. Education strongly related to GDP per capita and the relationship shows, the relationship is the strongest drivers are each other, in this research (r = 0.549, p = <0.001).

5.2.3 Employment

The study expected positive relationships between GBNP and the information industry employment, the finance industry employment, the professional scientific industry employment and the transportation industry employment, but only found positive and statistically significant correlations between GBNP and the information, and professional scientific industry employment (Information: r = 0.077, p = 0.004; Professional Scientific: r = 0.056, p = 0.035). The study expected negative relationships between agriculture industry employment and wholesale industry employment and GBNP but only the wholesale industry employment was statistically significant (Wholesale: r = -0.063, p = 0.017).

The strongest relationship between industry employment and GBNP was the relationship with information industry employment. The positive relationship showed that they both grow together. Information jobs are reliant on Internet connectivity and they should be interrelated. The study correctly expected the positive correlation between the Information employment percentage and GBNP (r = 0.077, p = 0.004). Access to fast Internet connections is important to the information industry and the results show that as GBNP grows, so does information industry employment. These results showed that the relationship between information industry employment and GBNP was weaker than the relationships shown in studies conducted at the international level (Hardy, 1980; Stiglitz, 2009; Majumdar, 2008). Additionally, Kolko (2010) showed a stronger relationship between the information industry and GBNP at the county level. The low r coefficient could be related to the level of analysis. Further, the information industry had stronger positive relationships to GDP per captia and education than to GBNP. These are stronger drivers for industry employment, but the relationship still exists with GBNP.

5.3 Limitations

During the course of this analysis the revealed limitations and issues relating to the level of geography, correlation research, data validity, and unanswered questions related to the relationship between economic well-being and GBNP.

Future studies would benefit from changing the locality designation from the MSA level to something smaller. MSAs vary in size and coverage but attempting to scale all the economic variables to the MSA level might have resulted in a loss of resolution in the data. Since MSAs encompass a number of counties and different areas, their aggregate numbers might not be the truest reflection of the total health of local economies, industries, etc. The trends experienced at the MSA level are linear in nature and the outliers are few and far between. To help avoid this issue in future studies, the opportunity exists to break down the MSA into the county, or city level then they might be able to see more statistically significant results, as the data will have more variance between points.

Building off the original correlation research would potentially be able to improve the statistical significance of the results. Correlational research has limited capabilities to identify important variable interactions. The correlational research in this study identified strong relationships between the population variables, and the interaction between these variables causes a need for a new model that works with the interactions to show the relationship. Future research could benefit from transitioning the data into model building and analyses. Modelling different interactions, non-linear terms, and random effects may help capture variability not explained by the relationships of the variables tested and GBNP.

The study was limited by amount of data that could be collected for the research. The phenomenon of gigabit Internet speeds is relatively new, and long-term datasets do not exist for exploring the relationship between GBNP and other variables over many years. For instance, as seen through the data collection issues, startups and other companies recently gained access to the new connectivity speeds, thus it may take time for the effects to scale up to the MSA level. As the networks begin to get higher penetrations at the household level there will be a stronger relationship between GBNP and local economies.

During the research other questions arose that this study was unable to answer, but still are pertinent questions in determining the relationship between economic well-being and GBNP. The question of home adoption of gigabit broadband and what causes individuals to demand and adopt the new networks would show where the demand is coming from helping form the causality of the relationships. The question of whether the networks provide a return on investment for the creators would need to be answered, to determine whether or not investment in a GBN would be financially prosperous for the community. Finally, questions of how many service providers impact a local economy could help explain the role of network choices in a localities economic development. The questions raised show that more explanatory variables need to be added to the research to answer the question about the relationship of GBNP to economic well-being. Further research would answer all of these questions while using the same data sources as this study, add other explanatory variables, and create a new model to effectively explain the relationship of GBNP to localities economic well-being.

5.4 Future Research Designs

Future research can build off of this study to understand the relationship between economic well-being and gigabit broadband network penetration. The initial steps of finding significant variables in the economic well-being model have been presented and other research efforts can focus on these variables in greater depth. . Future research is informed that the MSA level across the entire United States is not showing the variance necessary for a high r explaining the relationship of the phenomenon. Breaking the level of analysis down to fewer MSAs or the county or city level is predicted to show more significant results.

Furthermore on the variance issue future research would benefit from having more years of data. Since gigabit broadband networks have only been around for a short period of time, many of the MSAs penetration levels were extremely low. These low numbers did not provide the separation between the MSAs that would have been necessary to have the results have higher coefficients. One fix to this problem would have been to re run the study in a couple of years after the penetration levels are higher among MSAs giving even more observations. Finally this research offers the opportunity for future research through the use of this base correlation research to build from when choosing a regression analysis to predict the impact of the relationships. Choosing a predictive model that will work to adjust for multicollinearity would be able to impact the results and might provide a stronger answer to the research questions.

5.5 Answering the Research Questions for Community Implications

The results of the study answered both of the research questions posed. First there was a positive and statistically relationship between GBNP and different economic variables. As expected the variables of time, GDP per capita, education, information industry employment, and professional scientific industry employment showed a positive relationship exists to GBNP and found unexpected results of a non-statistically significant relationships between GBNP and small MSA, large MSA, population density, median household income, median home value, agriculture industry employment, finance industry employment, and transportation industry employment. For the statistically significant variables the r coefficient was low and the relationship weak when looking at the MSA level, yet the relationship still exists.

The study answered the second research question about the relationship between GBNP and industry employment through showing the statistically significant and positive/ negative relationships. Industry employment was higher in information, and professional scientific employment with greater GBNP. The wholesale industry showed a negative relationship to GBNP, meaning that the industry employment declines with GBNP. Communities looking to build up employment in these industries can use these relationships to determine if attracting a GBN would accomplish their goals. The r coefficients for the industries coefficients were small and further research would need to address this to show causality for locality's use.

6 Conclusion

6.1 Introduction

The study set out to explore the relationship of a locality's economic well-being and GBNP, for the purpose of informing localities around the United States about the potential for economic development by embracing the next generation networks. The study also sought to examine the relationship between different industry employment and GBNP, for the purpose of informing U.S. localities about the potential to attract different industries through provision of next generation networks. The literature focuses on looking early deployment network speeds and does not deal with speeds 4,000% greater. The study sought to add to the literature on the relationship between greater networks speeds and local economies through answering these two questions:

1. What is the relationship between gigabit broadband network penetration and a locality's economic well-being?

2. What is the relationship between gigabit broadband network penetration and a locality's different industry employment?

6.2 Empirical Findings

Answering both of the research questions provided both expected and unexpected results. The relationship of GBNP to economic well-being showed positive and statistically relationships between GBNP and GDP per capita, education, information industry employment, and professional scientific industry employment. Unexpected results were the non-statistically significant relationships between GBNP and small MSA, large MSA, population density, median household income, median home value, agriculture industry employment, finance industry employment, and transportation industry employment.

Answering the second research question about the relationship between GBNP and industry employment showed both expected and unexpected results. As expected relationships existed between information industry employment, wholesale industry employment, and professional scientific industry employment with GBNP. The unexpected results showed that no statistically significant relationship exists between GBNP and the agriculture industry employment, finance industry employment and transportation industry employment.

6.3 Theoretical and Policy Implications

The relationships identified in this research have implications for localities across the United States. The positive relationships between GBNP and GDP per capita and education show that one potential way to raise the productivity of firms and attract a more educated populace would be to focus on the creation or attraction of a gigabit broadband network. The small r coefficient of the relationships shows that there is no guarantee that either GDP or education will change with greater deployment but the opportunity exists. The relationship to the information and professional scientific industry employment show that fields requiring network access are larger in places with greater coverage. The relationships show potential and further research would help determine the causal relationship between the variables that in turn communities could use to grow their local economies.

6.4 Future research

The study identified and provided a number of options for how to conduct further research into the relationship between GBNP and a locality's economic well-being. Future research should focus on changing the level of geography, adding additional explanatory variables, changing the model to work with the interactive variables, and with more years of data points on GBNP. A future study using regression analysis could predict the impact of GBNP on the economic well-being indicator variables. The new model could change the level of geography to something smaller than an MSA and all the sources of data used in this study provide the same data but at the city, county, or town level. Future research identifying these relationships and the prediction of the impacts would help inform communities on how gigabit broadband networks can be used as tool to stimulate the locality's economic well-being.

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