A STUDY OF THE FACTORS INFLUENCING LAST MILE RESIDENTIAL FIXED BROADBAND PRICING IN KENTUCKY

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ABSTRACT

Ever since the first telegraph, a technology management challenge has existed to expand the availability of communication services farther into rural and unserved areas, while maintaining the affordability of those services to residential users. Over the years, that challenge has transformed from telegraph to broadband communications or high-speed Internet access. The challenge of affordable expansion of broadband services is seen all across the United States including the Commonwealth of Kentucky.

This study examined the extent to which community and provider-related supply and demand factors among last mile residential fixed broadband service areas impact the non-promotional advertised price of last mile broadband service throughout the 120 counties in the Commonwealth of Kentucky. The potential factors included population density, unemployment rate, provider count, broadband availability, middle mile, actual broadband speeds, technology deployed, provider type, maximum advertised download speeds, and maximum advertised upload speeds, with a goal to reveal if any have a correlation to the actual price of broadband seen by end users. In addition, this study attempted to create a model based on the significantly correlated factors.

Utilizing Pearson correlation and multiple regression analysis, this study found five variables with a significant correlation to the dependent variable, price per megabit, including a slight negative correlation with the count of middle mile providers, slight positive correlation with the technology deployed, slight negative correlation with the provider type, strong negative

correlation with the download speed tier, and strong negative correlation with the upload speed tier. Finally, a model was created to predict the price per megabit of broadband with three variables, technology used, provider type, and a joint variable representing the download and upload speeds tiers.

PREFACE

My interest in broadband and technology expansion has existed for most of my life. For more than two decades, I have been able to pursue that interest professionally, including efforts over the last fifteen years to expand broadband coverage in rural areas of the country. Most of that work has focused on access to broadband and the barriers to broadband expansion, not the actual price of broadband seen by the end users.

This dissertation has allowed me explore an area where more research is needed, applying technology management concepts to the field of broadband to consider how various supply and demand variables impact the price of last mile fixed broadband service to residential users.

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CHAPTER 1

INTRODUCTION

Since Samuel Morse created the first telegraph in 1844 (Morse & Morse, 2014), a challenge has existed to find ways to expand the availability of communication services further into rural and unserved areas, while maintaining the affordability of those services to residential consumers. When the telegraph transformed into the telephone, the communications challenge transformed, but the task of availability and service affordability remained. With the development of broadband, the communications challenge has transformed again to examine how broadband availability can be expanded into the unserved rural areas while maintaining the affordability of residential services. The communications challenge is ever present in the Commonwealth of Kentucky where 75 of the 120 counties in Kentucky are considered rural (Davis, 2009).

Broadband technology refers to high-speed Internet access, which is characterized as being much faster than the traditional dial-up Internet access (Federal Communications Commission, 2015d). Furthermore, residential broadband service emphasizes the last mile of broadband, meaning the final component of the larger broadband ecosystem. Last mile broadband service can utilize either fixed or mobile technologies but generally, uses fixed services for residential consumers. Fixed broadband service technologies provide broadband service to a particular location such as a home using wired or wireless technologies. Mobile

broadband service technologies provide broadband service to consumers on the move and typically delivered via wireless methods. The purpose of this research was to examine factors impacting the affordability of last mile residential fixed broadband pricing across the Commonwealth of Kentucky. Affordability was reviewed by considering ten factors and their implications on residential broadband pricing. The factors included population density, unemployment rate, provider count, broadband availability, middle mile, actual broadband speeds, technology deployed, provider type, maximum advertised download speeds, and maximum advertised upload speeds.

Broadband expansion requires significant planning and policy considerations. Challenges surround nearly all aspects of the broadband planning and policy continuum. Questions exist over the proper technology to use for broadband expansion (Federal Communications Commission, 2010a), the right amount of bandwidth to offer (Federal Communications Commission, 2015a), whether it should be managed like a government utility (Speta, 2003), methods for implementing broadband technologies in a technology and content-neutral manner (Hahn & Wallsten, 2006), and how differently rural and urban areas should be managed and regulated (McConnaughey, Goldberg, Neogi, & Brocca, 2013). Each of these challenges has been addressed at varying levels to date; however, one topic that has not been challenged is the economic impact of broadband (Ford & Koutsky, 2005; Gillett, Lehr, Osorio, & Sirbu, 2007; Holt & Jamison, 2009).

Background of Problem

Affordability of residential telecommunications/broadband services has been a consideration of policy makers, in Kentucky and across the United States, since the Communications Act of 1934 (1934) and has been reiterated many times including in the

American Recovery and Reinvestment Act of 2009 (2009). The Act directed the Federal Communications Commission (FCC) to create a detailed strategy for achieving affordability and increased utilization of broadband service. The goal of broadband affordability was reiterated by the Federal Communication Commission's National Broadband Plan (Federal Communications Commission, 2010a) by setting a goal of affordable residential broadband service to all Americans.

Broadband adoption has been connected to economic development by many organizations. A California-based study looked at whether policies to raise broadband availability would contribute to the local economic development of a community and found a positive relationship between broadband expansion and economic development of an area (Kolko, 2010), though the economic benefits to the residents were more limited when focusing on the residents alone. Even though Kolko's (2010) findings lean toward a causation, the methodology and data cannot definitively identify the cause of the growth. A study of Arab and emerging countries also found a positive impact on broadband uptake and economic growth (Badran, 2012). Additionally, Badran (2012) concluded that based on the results, a "one percent increase in broadband penetration would lead to 0.005% increase in the growth rate of the emerging and Arab countries covered." Badran (2012) also noted that competition in the telecom sector had a positive impact on economic growth.

Agreeing with the importance and impact of broadband, in 2009, the United States Congress instructed the FCC to develop a National Broadband Plan (NBP) and provided $7.2 billion to expand broadband infrastructure into unserved areas. (American Recovery and Reinvestment Act of 2009, 2009). The NBP included a plan for the expansion of broadband infrastructure, a plan for increased use among businesses and organizations, and a strategy for

affordability among other items. The NBP also included sections on policy reform, adoption programs, and broadband usage. Furthermore, the FCC acknowledged in the NBP that broadband was "changing how we educate our children, deliver healthcare, manage energy, ensure public safety, engage government and access, organize and disseminate knowledge" (Federal Communications Commission, 2010a).

Among the $7.2 billion in broadband-focused funding provided by Congress, $2.5 billion went to the Rural Utility Service (RUS) within the United States Department of Agriculture (USDA) for use in rural areas. In total for the broadband program, over $2.33 billion in grants and $1.19 billion in loans were made to 320 projects, totaling over $3.5 billion (Rural Utilities Service, 2013). Of the 320 projects, 297 were for infrastructure build-out (Rural Utilities Service, 2013). As of August 2013, RUS (Rural Utilities Service, 2013) funded projects had deployed 49,255 fiber miles in rural areas across the country.

Much of the funding, federal policy, and planning efforts have attempted to expand broadband coverage in rural areas. Prior research shows the differences between aspects of culture in urban and rural areas, especially as it relates to technology. De Blasio (2008) found that more urban consumers use the Internet than non-urban users. Whitacre and Mills (2010) found that infrastructure promotion alone fails to address other significant factors such as low demand and high-cost areas. Many organizations, federal, state, local, and non-governmental, have initiated efforts to impact broadband availability, adoption, and affordability. Glass and Stefanova (2012) found that "increasing capacity over existing broadband connections is subject to substantial economies of scale, but such economies diminish quickly as bandwidth capacity increases." (p. 100).

Some states such as the Commonwealth of Kentucky, are implementing large-scale networks trying to address last mile challenges and the middle mile pressure point as described by Glass and Stafanova. Announced in 2014, Kentucky's middle mile initiative called "KentuckyWired" is a public-private partnership with a goal of deploying over 3,000 fiber miles connecting each of the Commonwealth's 120 counties with fiber connectivity. According to KentuckyWired's website, the project will cost over $300 million including approximately $30 million in state bonds ("KentuckyWired," 2015). Kentucky's effort is similar to other state efforts, including Iowa ("ICN," 2015), Ohio ("OAR.net," 2015), and Vermont ("Vermont FiberConnect," 2015) which all created middle mile fiber networks to address broadband challenges, largely those seen by end users. These state projects, as with many broadband projects, have been met with varying degrees of success. For some of the unsuccessful projects, their failure may be due to inability to identify the correct underlying broadband challenge. In other cases, it may be due to unidentified challenges.

The FCC released an economic analysis of the broadband gap in 2010, which examined the network economics of broadband expansion based on various technologies, wired and wireless (Federal Communications Commission, 2010c). The analysis considered the costs of expanding broadband into unserved areas in a manner that was feasible for commercial deployment with a profitable business case. The effort was part of the NBP and indicated $23.5 billion would be required to expand availability to those across the United States without broadband at typical broadband speeds of the time (Federal Communications Commission, 2010a). The challenge of cost and pricing continues to exist, and researchers continue to seek a better understanding of the various factors involved.

As described in the literature review, there are many aspects of broadband technology and service to consider. This research focused on the pricing of last mile residential fixed broadband service. Each element in the phrase, residential fixed last mile broadband, provides an additional layer of specificity. Residential focuses the research specifically on the home users instead of commercial users. Fixed broadband service providers, meaning those serving a particular address, eliminates confusion and pricing differences in types of broadband service providers like mobile. Last mile broadband emphasizes those providers connecting to the end users instead of the providers connecting to other providers, which are called middle mile providers.

Statement of Purpose

The purpose of this research was to examine the extent to which community- and provider-related supply and demand factors among last mile residential fixed broadband service areas impact the non-promotional advertised price of last mile broadband service among the 120 counties in the Commonwealth of Kentucky. The examination of these potential factors would reveal if any have a correlation to the actual price of broadband seen by end users. Specifically, this research focused on determining which of the following factors have a significant correlation with advertised residential broadband price, including population density, unemployment rate, provider count, broadband availability, middle mile, actual broadband speeds, technology deployed, provider type, maximum advertised download speeds, and maximum advertised upload speeds.

Past broadband research has examined the possibility of usage-based pricing (D. A. Lyons, 2013), compared policy impact (Piot & Mourad, 2015), measured the cost of connectivity (Russo, Morgus, Morris, & Kehl, 2014) and evaluated the price of broadband (Greenstein, 2009).

Additionally, the FCC conducts an annual study examining the cost of broadband (Federal Communications Commission, 2015c). Policy disputes have surrounded government's role in setting the price (Davidson & Santorelli, 2014). Grubesic and Mack (2016) argue the pricing variable is an essential element to consider, and its omission from the National Broadband Map is a "clear and inexcusable weakness" (p. 249) of the map. While national regulation and legislation impact local pricing information, state policies and legislations may also affect the pricing of broadband at the local level. The proposed research will take a similar approach to existing research but add the pricing variable at the county-level across Kentucky.

Statement of Methodology

The research study used correlational analysis between the single dependent variable and multiple independent variables to assess the impact of a variety of factors on broadband pricing across the Commonwealth of Kentucky. Pearson correlation analysis and multiple linear regression were utilized in the analysis. The population was all fixed residential last mile broadband providers in Kentucky, as identified by the National Broadband Map (NBM) through its data collection process and updated by the FCC's annual data collection. The analysis included only providers with non-promotional advertised pricing publicly available. For the research, data collection was aggregated to the county level, due to the degree of detail of the various data sources utilized. The broadband availability data was validated to the census block, which is a small geographic area, potentially the size of a city block and much smaller than a county boundary (Federal Communications Commission, 2011a; Jayakar, 2011; "NBM - Technical Overview," 2014). County-level analysis eliminated any validation concerns for the data as census blocks do not cross county boundaries.

The dependent variable in the research project was the last mile fixed residential broadband non-promotional price of the maximum advertised broadband speed offered by each last mile broadband provider identified at the county level. Similar to other studies (Federal Communications Commission, 2011a; Russo et al., 2014), broadband pricing was analyzed on a price per megabit to normalize the differences in pricing between speeds and prices. Ten independent variables and one dependent variable were identified for this research and summarized in Table 1.

Table 1: Summary of Variables

Variable Name	Data Type	Description
Dollars per Megabit	Interval	Represents the price per megabit for the highest advertised broadband package (Dependent)
Population Density	Interval	Population per square mile throughout the county based on the U.S. Census Bureau
Unemployment Rate	Interval	County unemployment rate based on U.S. Department of Labor report
Provider Count	Interval	Count of fixed residential broadband providers
Broadband Availability	Interval	County level broadband availability
Middle Mile	Interval	Number of middle mile fiber providers within the county
Actual Broadband Speeds	Interval	Representation of the adopted broadband speeds based on Ookla data
Technology Deployed	Ordinal	Representation of technology type ordered based on the cost to deploy
Provider Type	Ordinal	Identifier as the type of provider.

Maximum Download Speeds	Ordinal	Maximum speed tier available for download based on the NBM
Maximum Upload Speeds	Ordinal	Maximum speed tier available for upload based on the NBM

Once data was collected and transformed into a usable format, each set of dependent and independent variables was analyzed using Pearson correlation coefficients analysis (Warner, 2013) within IBM SPSS software to determine which factors demonstrate a high degree of association. Multiple linear regression was utilized to assess the impact of each variable on the overall performance of the dependent variable to analyze the interactions between the independent variables and the dependent variable. As with any exploratory research, the initial set of independent variables would likely over-fit the model; therefore, stepwise regression techniques were utilized to develop more accurately a model that could predict the last mile fixed residential broadband price across the Commonwealth of Kentucky.

A pilot phase was conducted using the nine northwest counties of the State of Tennessee, also called the Northwest Tennessee Development District. The pilot phase was performed early on to ensure validation of the data, sources, and procedures. The collection and methods were utilized to analyze the validity of the variables and approach (Warner, 2013).

Statement of Problem

Over the last decade, the policy debate has centered on the topic of broadband growth and the factors that impact broadband expansion. Much of the research and related discussion has focused on the costs of broadband expansion. To date, little research has examined the impact of fixed last mile broadband pricing, meaning the pricing that a residential consumer would pay. Policy makers, researchers, industry experts, and broadband providers, without further

examination of any possible correlation or difference in value, have assumed there is a correlation between pricing and cost of broadband expansion. This research provided a correlational analysis of factors and their influence on last mile residential fixed broadband pricing. The factors included population density, unemployment rate, provider count, broadband availability, middle mile, actual broadband speeds, technology deployed, provider type, maximum advertised download speeds, and maximum advertised upload speeds.

Research Questions

As stated, the purpose of this research was to assess the impact of each identified factor on last mile residential fixed broadband non-promotional advertised price. The problem addressed in this research was to understand how the identified factors impact last mile residential fixed broadband pricing. Specifically, this dissertation sought to answer the following research questions:

Q1: Does the population density served by the provider impact the advertised price for last mile residential broadband service?

Q2: Does the unemployment rate of the county served by the provider impact the advertised price for last mile residential broadband service?

Q3: Does the number of providers within the county impact the advertised price for last mile residential broadband service?

Q4: Does the broadband availability within the county impact the advertised price for last mile residential broadband service?

Q5: Does the number of middle mile fiber providers offering service impact the advertised price for last mile residential broadband service?

Q6: Does the actual broadband speeds seen by users impact the advertised price for last mile residential broadband service?

Q7: Does the technology deployed by providers within the county impact the advertised price for last mile residential broadband service?

Q8: Does the provider type impact the advertised price for last mile residential broadband service?

Q9: Does the maximum advertised download speed impact the advertised price for last mile residential broadband service?

Q10: Does the maximum advertised upload speed impact the advertised price for last mile residential broadband service?

Q11: What are the contributions of different factors impacting last mile residential broadband to the overall advertised price for last mile residential broadband service?

Significance of Study

General significance of the research study can be found in the impact of broadband on the regions, states, and nations where broadband service is improved. Often cited by researchers and organizations is broadband's impact on economic development (Federal Communications Commission, 2010a; Ford & Koutsky, 2005; Gillett et al., 2007; Holt & Jamison, 2009; Qiang, 2010). Research has examined whether broadband impacts economic development, community growth or an increase in jobs. H. Gruber, Hätönen, & Koutroumpis (2014) considered the future economic benefits of broadband in the European Union in light of the Digital Agenda for Europe (European Commission, 2014), finding in the base case that the benefits of broadband infrastructure investment outweigh the costs by 32%. Rohman and Bohlin (2012) examined whether broadband speed matters for driving economic growth and found the estimated

broadband speed coefficient was statistically significant and determined that doubling broadband speed would contribute to 0.3% growth. Badran (2012) studied the impact of broadband infrastructure in emerging and Arab countries on economic growth, focusing on whether telecom investments and broadband competition within the 22 countries had a correlation to various factors including per capita income, primary school enrollment ratio, secondary school enrollment ratio, and population growth (Badran, 2012). Based on the models designed, Badran (2012) found a positive impact of broadband uptake on economic growth and developed a competition index which was statistically significant when controlled for foreign direct investment.

Peha (1999) examined Haiti's Internet development and its challenges, finding that government regulation of wireless spectrum was critical to the Internet development. A concern of artificially high prices for international telephone service made Internet expansion difficult since Internet telephony could negatively impact the revenues. Stenberg, Morehart, Vogel, Cromartie, Breneman, and Brown (2010) specifically analyzed broadband Internet's value to rural America by examining rural broadband use by consumers, the community, businesses, availability at the county level and the social, and economic effects of broadband on the community. Their results suggest that rural economies benefit from broadband availability, finding that those counties where broadband growth grew at faster rates saw greater economic growth, as well as higher nonfarm private earnings (Stenberg et al., 2010). Those higher growth counties would be considered more favorably on Roger's diffusion of innovation curve.

Specific importance of the findings from the research questions in this study can be found in the possible regression model to understand better last mile broadband pricing and the correlations between the variables, or even the lack of correlation between variables. Where

correlations of possible factors were identified in the study, future research can focus on determining the causal relationship between the specific factors. Alternatively, where the findings revealed no connection, it could also be important to understand better for decision-making among regulators, policy makers, and providers. For each of the potential factors, researchers and policy makers are taking actions and performing research based on the assumption of some level of correlation between the variable and availability or affordability of broadband (Federal Communications Commission, 2011b). If there is no correlational relationship to affordability or pricing, then alternative policy changes and management strategies may need to be considered.

Additional significance can be found in the regression analysis. If initial research can predict the non-promotional advertised price for last mile residential broadband service significantly, further research can be performed in areas that do not conform to the regression model. In cases where providers offer pricing much lower than the regression would predict, case study research could be performed to determine the cause. Conversely, where provider offerings are much higher, additional analysis could be conducted to determine what challenges are impacting pricing.

Definition of Terms

Advanced Telecommunications: The Telecommunications Act of 1996 defines advanced telecommunications as "high-speed, switched, broadband telecommunications capability" (Telecommunications Act of 1996, 1996) capable of transmitting data, voice, and video.

Broadband: Broadband is a high-speed Internet connection. The actual speed of broadband service may vary by organization and its purpose.

Broadband Over Powerline: Topology of broadband service delivery at high rates utilizing the electric distribution system

Cable Modem: Cable modem service allows cable providers, like Comcast or Charter Communications, to offer broadband service utilizing the same coaxial cables that deliver cable service to a residential or commercial location (Federal Communications Commission, 2015d).

Community Anchor Institution (CAI): CAIs are businesses and organizations in communities that facilitate greater use of broadband by vulnerable populations within the community, including schools, libraries, hospitals, and public safety groups (Federal Communications Commission, 2011c).

Digital subscriber line (DSL): DSL is a wireline transmission technology that allows data to be transmitted in a manner faster than previously available over traditional telephone line already installed to homes and businesses (Federal Communications Commission, 2015d). Typically, DSL can either be symmetric or asymmetric.

Fiber Optics: Fiber optic technology uses tiny strands of transparent glass fibers to send and receive data at extremely high speeds with beams of light (Federal Communications Commission, 2015d). Fiber deployments are deployable to the home (FTTH), to the neighborhood (FTTN), or to the curb (FTTC).

Fixed: Fixed broadband service technologies provide broadband service to a specific location, such as a home, using wired or wireless technologies.

Last Mile Provider: The last mile provider is a provider that connects the end user to the Internet via one or multiple technologies. Examples include AT&T and Comcast Corporation.

Middle Mile Provider: "relatively fast, large-capacity connections between the backbone and last mile" (Federal Communications Commission, 2000, p. 10)

Mobile: Mobile broadband service technologies provide broadband service to consumers on the move and are typically delivered via wireless methods.

Residential: Residential broadband refers to the segment of broadband services providing service to home broadband users, as opposed to commercial business customers.

Wireless: Wireless broadband connections link a home or organization to the Internet using wireless radio waves between the customer's location and the service provider's tower or facility (Federal Communications Commission, 2015d). Wireless can be deployed using fixed or mobile methods.

Assumptions, Limitations, and Delimitations

Assumptions

Multiple assumptions guided the research. The assumptions included:

1. The primary data source utilized in the study was the data collected through the National Broadband Map from the National Telecommunications and Information Administration (NTIA) and the FCC. Since all the information gathered through the process was validated per the data collection methodology, the data was assumed to be an accurate representation of broadband availability, maximum advertised speeds, and technology utilized by the provider when aggregated to the county level.
2. Broadband pricing data available on each last mile residential fixed broadband provider's website was an accurate representation of advertised pricing.
3. Pricing data presented included the non-promotional price advertised that a new customer would be expected to pay. In cases where a contract was required,

the price was evaluated as the average monthly non-promotional price over the duration of the contract.

4. Based on random checks and informal provider interviews, county geography was an accurate way to compare the pricing between the dependent and independent variables.
5. Advertised provider last mile fixed broadband pricing does not change across the local market. The pricing, not including special pricing, does not alter from within city limits to outside of city limits.

Limitations

Additionally, the study was limited by multiple elements including:

1. The broadband availability data was primarily based on a single snapshot in time and based on the last data submission for the National Broadband Map on June 30, 2014, and ongoing Federal Communications Commission broadband data collection.
2. Data collected and analyzed was for the last mile fixed broadband service. The collection does not include mobile or satellite provider data, which may also target last mile service.
3. Broadband data caps were limitations placed on users by broadband providers impacting large data users. Limitations of data caps were beyond the scope of the study.

Delimitations

Delimiting factors have also set boundaries around the study. The delimitations include:

1. The study area for the research was restricted to the Commonwealth of Kentucky, as economic and regulatory environment changes state by state. Therefore the boundaries of the research conclusions were limited to the Commonwealth of Kentucky.
2. Within the Commonwealth of Kentucky, the analysis looked at county level analysis. Many of the datasets were collected at the county level. Where data was collected at a smaller level, such as census block, the county level ensured the reliability of the data.
3. Some broadband providers may provide broadband service to multiple states. The analysis only considered the impact across the Commonwealth of Kentucky.

Chapter Summary

The chapter provided an introduction to the research problem, purpose, significance, and methodology. The research study examined factors impacting the affordability of last mile residential fixed broadband pricing across the Commonwealth of Kentucky. In the context of the research, affordability was examined by considering ten factors and their impact on residential broadband pricing across Kentucky. The factors included population density, unemployment rate, provider count, broadband availability, middle mile, actual broadband speeds, technology deployed, provider type, maximum advertised download speeds, and maximum advertised upload speeds.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

A number studies have examined broadband adoption, expansion, and affordability in a variety of settings. Consideration of a range of broadband policies and technologies along with consideration of the existing research is necessary to evaluate current broadband efforts appropriately. The literature review provides a survey of each area necessary to adequately evaluate the affordability of fixed broadband last mile residential services. The sections include a brief review of the history of telecommunications policy, the theoretical framework, an overview of the broadband technology, the impact of broadband pricing, challenges of broadband diffusion, a description of the search, and a literature review of the research factors organized by the overriding themes.

History of Telecommunications Policy

The current broadband research and policy reform find their origins through an examination of telecommunications policy history. Even though the Commonwealth of Kentucky and other states may have individual state regulations and legislations altering the broadband landscape, many of the underlying laws come from the federal level. A review of the federal policy, including its history, is worthy of consideration.

The original foundation for telecommunications regulation came by way of the Federal Radio Act of 1927 and the Mann-Elkins Act of 1910 as well as railroad case law (Benjamin, Lichtman, & Shelanski, 2001). Franklin D. Roosevelt signed the Communications Act of 1934 (Communications Act of 1934, 1934), establishing the Federal Communications Commission (FCC), replacing the Federal Radio Commission and reorganizing existing laws. The 1934 Act also first established the policy goal of: "regulating… to make available, so far as possible, to all the people of the United States a rapid, efficient, nationwide, and worldwide wire and radio communication service." (Communications Act of 1934, 1934). By approving the Act, the FCC received regulatory authority over telephone, telegraph, and radio operations. The Telecommunications Act of 1996 further modified the 1934 Act (Telecommunications Act of 1996, 1996). The 1996 Act increased the policy goal from the original act to include: "promot[ing] competition and reduc[ing] regulation in order to secure lower prices and higher quality services for American telecommunications consumers and encourage the rapid deployment of new telecommunications technologies." (Telecommunications Act of 1996, 1996).

The revisions to the original Act added terms and definitions for telecommunications service, advanced telecommunications service, and information service (Telecommunications Act of 1996, 1996). Telecommunications was typically considered a telephone service and regulated based on the Act. An information service was considered television service and not governed according to the Act. As previously noted, advanced telecommunications service was unclear and will be further discussed in a later section. Not included in the act were the terms *broadband*, *the Internet* or *network neutrality*.

When the Communications Act of 1934 passed, the Act included the concept of universal service as a cornerstone of its policy (Communications Act of 1934, 1934). That principle would ultimately be used to create the Universal Services Fund (USF), to support the deployment of telecommunication services in rural areas. The Telecommunications Act of 1996 expanded the USF goals "to include increased access to both telecommunications and advanced services—such as high-speed Internet—for all consumers at just, reasonable, and affordable rates" ("USF - FCC," 2014). The 1996 Act adopted a number of principles to guide its USF policy, including increasing quality services, increasing access to advanced telecommunications services, advancing availability of services to all consumers, supporting services to schools, libraries and healthcare facilities, and requiring "equitable and non-discriminatory contributions" from providers to support the fund ("USF - FCC," 2014).

Theoretical Framework

The theoretical framework directing this inquiry derives itself from a combination of Rogers's Diffusion of Innovation (Rogers, 2003) and the economic theory of supply and demand (Marshall, 1920). Policy decisions for technology adoption, and specifically, broadband availability and adoption, should be analyzed through a combination of these two theories with a host of data sources to make a fully informed decision. The Diffusion of Innovation provides a framework for how communities adopt innovations such as broadband technologies (Rogers, 2003). Broadband adoption, like many previous innovations, should be examined through the lens of the Rogers's process, an innovation that is communicated through channels over time within a preexisting social system (Rogers, 2003). Additionally, supporting the theoretical framework, Marshall's supply and demand theory considers the amount of a particular commodity and the desire for a consumer to purchase as factors involved in setting a specific

price (Marshall, 1920). Building upon these two fundamental theories is academic, industrial, and governmental research focused in the broadband area.

Whitacre (2010b) transformed the supply and demand equation to consider Internet technologies by highlighting the rural adoption challenges, examining the urban and rural divide, the adoption rates over time, and examination of the pricing of service. As indicated in the NBP, within the broadband industry, several variables can influence the supply-side while several additional variables may affect the demand-side (Federal Communications Commission, 2010c). For example, the density of a particular area can impact the number of customers and therefore limit the potential revenue (Federal Communications Commission, 2010c). Consequently, a provider may be required to raise the price of broadband service to make up that revenue. This inquiry will expand the impact of these variable types on the broadband service across the Commonwealth of Kentucky.

Augmenting the diffusion research, the area of broadband supply and demand research and analysis has been ongoing for nearly two decades in different socioeconomic and geographic settings. For example, supply and demand theory was used by Lyons (2014) to analyze significant influences on broadband demand in Ireland such as price, reliability, and quality of service as well as some customer characteristics. Likewise, from a supply perspective, the urban/rural divide was identified as the most significant factor of broadband availability (S. Lyons, 2014); however, data limitations prevent some conclusions from being drawn. Lyons (2014) suggested that if spatial data were available for the average price of broadband service offerings, research could potentially rule out bias due to the correlation between pricing and population density.

Rogers (2003) defined diffusion as the process by which "an innovation is communicated through certain channels over time among the members of a social system" (p. 5). Rogers described five categories of adopters: innovators, early adopters, early majority, late majority, and laggards, along with salient values, characteristics, behaviors, and social relationships (Rogers, 2003). Broadband, like many other previous innovations, should be examined through Rogers' process including an innovation that is communicated through channels over time among a social system (Rogers, 2003).

Research examining broadband as a diffusion of innovation has been observed in a variety of settings over the last 20 years. Lee, Marcu, and Lee (2011) utilized a logistic diffusion model to examine fixed and mobile broadband. Papacharissi and Zaks (2006) reviewed the diffusion of broadband and offered up regulatory recommendations. Gruber and Koutroumpis (2013) sought to use regulation to further the diffusion of innovation suggesting that regulatory access provisions dissipate after 3-4 years. Choudrie, Papazafeiropoulou, and Lee (2003) combined the diffusion of innovation theory with stakeholder theories to examine broadband diffusion in South Korea, while Yoo, Lyytinen, and Yang (2005) examined standard aspects of broadband diffusion in South Korea. LaRose, Gregg, Strover, Straubhaar, and Carpenter (2007) proposed a theory-based model to explain broadband utilization within the context of Rogers's diffusion model.

Several studies have examined the technology management challenge of how broadband pricing levels impact the willingness to adopt broadband studies. Haucap, Heimshoff, and Lange (2014) observed broadband pricing impact on broadband adoption, suggesting that broadband pricing and diversity of offerings is a more significant driver of fixed broadband adoption than diversity of broadband technology offerings. Conversely, Lin and Wu (2013) examined the

determinants in various stages of the diffusion process finding that for late adopters, the broadband price is the key determinant in the late majority and laggard stage.

Broadband Overview

Broadband policy finds its origins in federal law. However, federal law does not explicitly define broadband. Section 706 of the Telecommunications Act of 1996, directed the FCC to encourage the deployment of "advanced telecommunications capability" in a reasonable and timely basis to all Americans including elementary and secondary schools (Telecommunications Act of 1996, 1996). Furthermore, this Act directed the FCC to report annually on the availability of advanced telecommunications capability. However, the questions of whether broadband should be considered an advanced telecommunications service or not clearly defined in the Act and what the bandwidth is required for service to be considered broadband were not addressed.

Any examination of broadband requires a basic understanding of the entire broadband ecosystem, which includes the last mile, middle mile, and network core. The middle mile and network core are often referred to as backbone by some organizations. Last mile broadband links the residential user and the middle mile. Middle mile broadband providers support with "relatively fast, large-capacity connections between the backbone and last mile" (Federal Communications Commission, 2000, p. 10). Middle mile providers are aggregated and connected to core backbone providers, which provide ultra-high speed broadband services. The core providers are often called Tier 1 ISPs, which are privately owned, creating a network of Internet exchange (IX) points (Winther, 2006). According to Winther (2006), global tier 1 ISP providers include AboveNet, AT&T, Global Crossing, Level 3, Verizon, NTT Communications,

Savvis, Spring, and VSNL. All three aspects—last mile, middle mile, and network core—are required to distribute broadband to urban and rural areas.

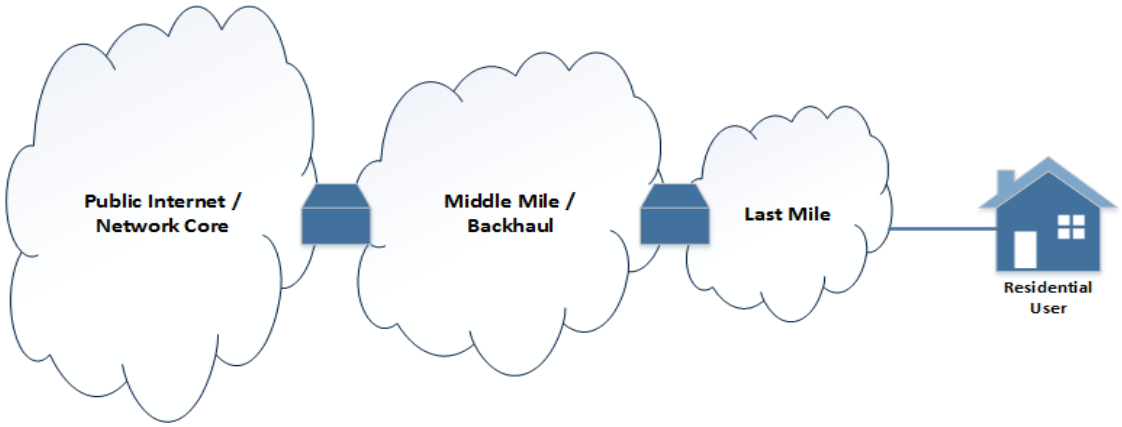

Figure 1: Internet Service Provider Network Diagram

In most examples, no ISP manages every aspect of the network infrastructure, last mile, middle mile and network core. Providers like AT&T may own aspects at each level, but still, don't own and manage the entirety of the ecosystem. As shown in the remaining sections of this chapter, challenges to the diffusion exist at multiple layers of the Internet and broadband ecosystem. Even though no single entity owns the entire network, some state-level efforts ("ICN," 2015, "KentuckyWired," 2015, "OAR.net," 2015, "Vermont FiberConnect," 2015) and public-private partnerships ("ALBI," 2016, "CK," 2016, "CTN," 2016) have addressed various aspects of the broadband ecosystem. Figure 1 (above) shows a diagram representing the ISP network from the end user to the public Internet including the last mile, middle mile, and network core. There are many middle mile connections to public Internet. However, the details around the public Internet and network core are outside the scope of the project. There are also many last mile connections that are aggregated for each middle mile connection.

The 1999 First Broadband Deployment Report defined an advanced telecommunications service as any technology with download bandwidth speed of more than 200 kilobits per second (kbps) in the last mile providing enough bandwidth for transmitting the most popular forms of broadband (Federal Communications Commission, 1999). By setting the speed at the 200 kbps speed threshold, the FCC ensured that broadband was faster than what the current 56 kbps dial-up phone line was capable of transmitting (Federal Communications Commission, 1999). By 2010, the definition of broadband or advanced telecommunications was redefined in the Sixth Broadband Deployment Report, in conjunction with the National Broadband Plan as 4 Megabit per second (Mbps) download and 1 Mbps upload speeds (Federal Communications Commission, 2010b). Referencing the advanced telecommunications term, the FCC altered the broadband speed definition again in the 2015 Broadband Progress Report changing the speed threshold for Internet service to be considered broadband to download speeds of at least 25 Mbps and actual upload speeds of at least 3 Mbps (Federal Communications Commission, 2015a). With three changes over 15 years, it would be valuable to analyze how the speed changes are translating into pricing structure as seen by the customer.

National Broadband Map/Plan

Leading up to the passage of the American Recovery and Reinvestment Act of 2009 (ARRA), researchers and organizations advocated for more centralized data collection and planning such as Flamm, Friedlander, Horrigan, & Lehr (2007), Whitacre (2010a), and Papacharissi and Zaks (2006). Flamm et al. (2007) suggested that data collection should be granular enough to permit regional analysis, should include a map capable of showing the availability of infrastructure, and should be conducted in a collaborative manner with researchers, non-profits, government, and the private sector. Researchers also correlated the

digital divide with specific factors, such as Stanton's (2004) assertion in 2004 that the digital divide was the widest among computer ownership and narrowest for broadband access. As part of the act, a National Broadband Map and Plan were to be created (American Recovery and Reinvestment Act of 2009, 2009). Each is explained further below.

National Broadband Map

The United States Congress directed the Department of Commerce to collect data to create a National Broadband Map (NBM) (American Recovery and Reinvestment Act of 2009, 2009). The map should be a "comprehensive nationwide inventory map of existing service capability and availability in the United States that depicts the geographic extent to which broadband service capability is deployed and available . . ." (American Recovery and Reinvestment Act of 2009, 2009).

Utilizing $293 million from the American Recovery and Reinvestment Act and data collected from 56 grantees including 50 states, 5 territories and the District of Columbia, the first National Broadband Map was released on February 17, 2011 ("NBM," 2014) by the National Telecommunications and Information Administration (NTIA) in conjunction with the FCC. Bernardi, Fenacci, Marina, and Pezaros (2014) defined broadband mapping as "the process of assessing broadband coverage, quality, and market for a given geographical region" (p. 344) and defined broadband coverage assessment as aiming to identify "locations not serviced by broadband access technology" (p. 344).

The National Broadband Map provided information at the census-block level of 3,400 broadband providers ("NBM - Technical Overview," 2014) and was updated on a biannual basis for five years, with the last update occurring in 2015. For each last mile provider service within a census block, the grantee was required to collect provider name, type of broadband service, and

maximum advertised speeds (download and upload), along with other information (Federal Communications Commission, 2011). The technology types included in the breakdown are Asymmetric xDSL; Symmetric xDSL; Other Copper Wireline; Cable Modem–DOCSIS 3.0; Cable Modem–Other; Optical Carrier/Fiber to the End User; Satellite; Terrestrial Fixed Wireless–Unlicensed; Terrestrial Fixed Wireless–Licensed; Terrestrial Mobile Wireless; Electric Power Line; and All Other (Federal Communications Commission, 2011). The 11 speed tiers representing download and upload speeds are:

- Tier 1: Less than 200 kbps
- Tier 2: Greater than 200 kbps and less than 768 kbps
- Tier 3: Greater than or equal to 768 kbps and less than 1.5 Mbps
- Tier 4: Greater than or equal to 1.5 Mbps and less than 3 Mbps
- Tier 5: Greater than or equal to 3 Mbps and less than 6 Mbps
- Tier 6: Greater than or equal to 6 Mbps and less than 10 Mbps
- Tier 7: Greater than or equal to 10 Mbps and less than 25 Mbps
- Tier 8: Greater than or equal to 25 Mbps and less than 50 Mbps
- Tier 9: Greater than or equal to 50 Mbps and less than 100 Mbps
- Tier 10: Greater than or equal to 100 Mbps and less than 1Gbps
- Tier 11: Greater than or equal to 1 Gbps

(Federal Communications Commission, 2011).

Data was collected at the census block level, as previously indicated. The use of census block data is more precise than previous national data collection efforts since it is at a smaller geographical dimension. However, the data collection method received criticism. Jayakar (2011) criticized previous FCC data collection where measurements were based on provider

companies who served just one customer in a ZIP code area, but the data was utilized due to the lack of anything better. Previously, Kolko (2010) used ZIP code level data but cited it as a limitation in his analysis, as well as speed and technology types. Even though the census level data was far more detailed, it still contained challenges. Ford (2011) suggested similar limitations including a census block with one customer would still be considered served. Additionally, Ford's research challenged the data quality due to the lack of a "robust data verification process" (Ford, 2011). Whitacre, Gallardo, and Strover (2014) utilized maximum advertised speeds and the number of providers but aggregated data to county level, concerned that providers may be incentivized to overstate their service areas. Grubesic (2012) critiqued the way that the NBM handled different sized segments.

Addressing the challenges represented by researchers and organizations, the National Telecommunications and Information Administration (NTIA) required each grantee to develop a data validation and verification process ("NBM - Technical Overview," 2014). The Commonwealth Office of Broadband Outreach and Development (OBOD), the Commonwealth of Kentucky's grantee, provided their *Data Development and Validation Methodologies White Paper* on October 1, 2014 ("Commonwealth of Kentucky," 2014). In Kentucky's verification methodology, OBOD included provider feedback, broadband market analysis, field data acquisition, independent third-party validation, and a reconciliation process ("Commonwealth of Kentucky," 2014), a sampling process to validate census blocks to +/- 4% margin of error at a 95% confidence level. The Commonwealth of Kentucky's ("Commonwealth of Kentucky," 2014) efforts resulted in:

- 246 total identified ISPs
- 121 confirmed broadband service providers

- 103 broadband service providers who supplied data
- 12 broadband service resellers
- 8 broadband service resellers who supplied data

National Broadband Plan

The United States Congress also directed the FCC to create a National Broadband Plan (NBP). The NBP had a goal of ensuring that all Americans had access to broadband capability. The plan was required to include (among other items): "a detailed strategy for achieving affordability of such service and maximum utilization of broadband infrastructure" (American Recovery and Reinvestment Act of 2009, 2009).

The FCC released the NBM on March 16, 2010 (Federal Communications Commission, 2010a) and included three primary parts: innovation and investment, inclusion, and national purposes.

The FCC identified four main opportunities for the government to impact the broadband ecosystem. These opportunities have been used to guide the FCC's actions. The first opportunity was to "design policies to ensure robust competition and, as a result, maximize consumer welfare, innovation, and investment" (Federal Communications Commission, 2010a). Within this opportunity, a sub-component included the requirement to "collect, analyze, benchmark, and publish detailed market-by-market information on broadband pricing and competition which will likely have direct impact on competitive behavior…" (Federal Communications Commission, 2010a).

As examined by Jayakar (2011), the NBM had a goal of providing 1 gigabit per second service to an anchor institution in every community (Federal Communications Commission, 2010a). Jayakar (2011) argues that funding for middle mile institutions be encouraged and even enforced through legislations. Based on his research, Jayakar contends consumers are not aware

of the benefits of broadband, funding may not be distributed cost-effectively, restrictions on access and usage prevent effective utilization of community or publicly owned networks, and universal service programs lack safeguards against fraud and abuse (Jayakar, 2011).

Broadband Pricing Policy

Several policy challenges exist across the United States and around the globe when trying to achieve higher broadband availability, affordability, adoption, and use in a manner that continues to be consistent in the public's interest. Piot and Mourad (2015) suggested that four types of policy exist including the policy that emphasizes infrastructures and networks (supply); policy focused on broadband wholesale offers (supply); policy related to awareness, trust, and usage capabilities (demand); and content and services (demand) policy. These four policy areas have a potential impact on one or more of the following sectors: increased coverage, quality of service improvement, price reduction, higher penetration, and usage stimulation (Piot & Mourad, 2015). The public challenge is how much the government regulators can direct, manage, or implement based on the identified areas.

The broadband debate and regulatory challenges center on three overarching policy and regulation questions. The first question asks, "How much regulation is necessary to preserve the Internet as intended when founded?" The second question asks, "How much regulation is required to ensure that investment continues in the broadband network deployment?" The third question queries, "How much regulation is necessary to foster innovation on the networks?" (Davidson & Santorelli, 2014). These questions frame much of the policy challenges described in the following sections. Answering these policy questions is further complicated by the lack of data. A fundamental principle of public policy making is that publicly available data should

direct decision making (Napoli & Karaganis, 2010). Though available data is improving, reliable data remains elusive for decision makers.

Challenges of Broadband Diffusion

Connecting the diffusion of innovation to the broadband landscape reveals a number of challenges. The National Broadband Plan highlighted three benchmarks that should be examined to measure the diffusion. The benchmarks were:

- *Access – The share of community or region with access to broadband services*
- *Adoption – Broadband adoption rates by local residents, businesses, and institutions*
- *Usage – Applications used by local residents, businesses, and institutions.*

(Federal Communications Commission, 2010a)

Typically, there is agreement by researchers, advocacy organizations, regulators, and providers of the challenges and benchmarks. The disputes arise in the prioritization of the challenges and the order in which to address them. For example, would it be more relevant to the public's interest to encourage adoption in the urban areas or to expand availability in the rural areas? In addition to the general benchmarks included above, the NBP suggests six long-term goals, including this goal: "Goal No. 1: At least 100 million U.S. homes should have affordable access to actual download speeds of at least 100 megabits per second and actual upload speeds of at least 50 megabits per second."
(Federal Communications Commission, 2010a)

Similar to the United States National Broadband Plan, the European Union's Broadband Commission identified three phases for their national broadband plan (Biggs, 2015). First, the deployment phase is concerned with broadband network availability with telecom-related

indicators. Second, the adoption phase is broadband access and capacity building for effective use which will use performance metrics as indicators. Third is the integration phase, where broadband is integrated into the economy and society with outcome and impact measures as indicators (Biggs, 2015).

Improvement in the broadband ecosystem is required to accomplish the long-term goal of broadband service. From a general standpoint, urban and rural areas are the two geographic diffusion challenge areas where interventions occur. Solving the challenges listed is not only in the public's interest, but also addresses a fundamental societal need such as economic development, education, and healthcare. Figure 2 depicts the challenges as access, adoption, use, utilization, price, and speed.

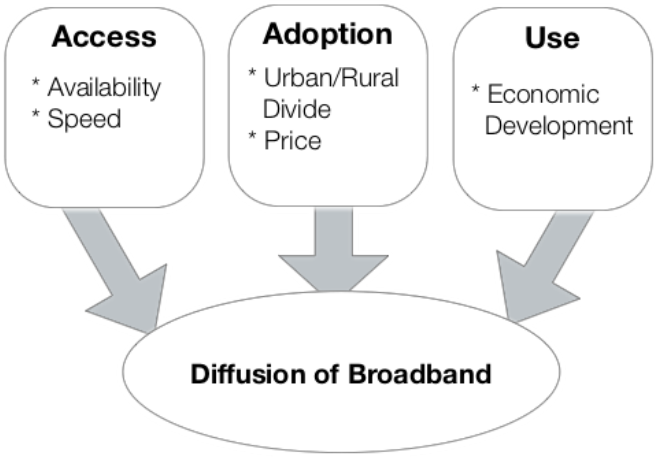

Figure 2: Challenges associated with the Diffusion of Broadband

The FCC and other federal advocacy groups have taken steps toward addressing the diffusion of broadband. One example, The Connect America Fund, was enacted in 2011 by the FCC as a way to transform the way that broadband services are funded in rural areas (Federal Communications Commission, 2011c). Under the new FCC Chairman Ajit Pai, broadband continues to be emphasized with examples including a proposal to transform 5G wireless

(Federal Communications Commission, 2017c), the business data services report (Federal Communications Commission, 2017a) and with the creation of a broadband advisory council (Federal Communications Commission, 2017b).

Search Description

As background and preparation, a thorough review of historical and current telecom and broadband policy from across the United States was undertaken to isolate potentials factors to further research. The FCC's National Broadband Plan solicited 23,000 public comments from more than 700 groups (Federal Communications Commission, 2010a). The plan, itself, along with the many comments became a reliable reference to recent policy and challenges to identify additional potential factors. The potential factors were assessed from three general categories, demographic characteristics, provider characteristics, and technology characteristics.

Following the initial analysis, an elaborate electronic search of academic journals was undertaken to find current and past research where the factors were used. Utilizing the online academic research library, key phrases noted from the national broadband plan, e.g., "broadband adoption" or "rural broadband speed availability," a large number of academic articles were identified to review. Based on the article review and analysis of references, the additional review was conducted evaluating other issues within the same journal, identifying additional items for consideration. Due to the impact and volume of work by nongovernment organizations, both independently and in response to the national broadband plan, an analysis of work, research, and surveys conducted by industry and government were included in the search.

The literature review confirmed some factors for inclusion in the current research. Other factors were eliminated as outside the scope of the current research. For example, there was a wealth of knowledge related to network neutrality (Faulhaber, 2012; Hahn & Wallsten, 2006;

Jordan & Ghosh, 2010; Wu, 2003). Even though it may be a potential barrier to broadband adoption, it was determined to be outside the scope as it is not directly measurable since the disclosures of network neutrality techniques must be identified.

Also, included in the review of literature was consideration of alternative research methodologies. This research study examines the current price of broadband service to the residential users. Other researchers and organizations have looked at it from the opposite angle (Federal Communications Commission, 2010c; Glass & Stefanova, 2012; Monath, Kristian, Cadro, Katsianis, & Varoutas, 2003; Rendon Schneir & Xiong, 2016), where they worked on an economic model to fit the environment. Though economic modeling is a significant component of research to consider, the current research seeks to add to the current modeling study by providing a current analysis of the pricing structure currently in use by broadband providers across the Commonwealth of Kentucky.

Research Review

Based on the search description, the factors, though independent, were often evaluated in thematic groups. Therefore, the review of factors is organized into five thematic clusters: digital divide, broadband availability, broadband adoption, broadband speed, and broadband pricing.

Digital Divide

Within broadband policy, a divide appears among urban-rural geographic areas in broadband adoption, in broadband availability, and even broadband use. These differences are typically referred to as the digital divide; however other gaps exist among broadband diffusion. In their July 2015 Issue Brief, the White House Council of Economic Advisors (Council of Economic Advisers Issue Brief, 2015) suggested that technology disparities exist among the older, less educated, and less affluent, along with the rural populations. As seen with USDA

funding and USF, the rural divide is the gap most prioritized with funding and research. Armenta, Serrano, Caberra, and Conte (2012) examined the digital divide and suggested grassroots participation based on a confluence of factors including the digital divide (Abramson, 2006) incorporation of socioeconomic and regulatory factors as defined by Dimaggio and Hargittai (2001) and Servon (2008), human development factors as described by Buente and Robbin (2008) and Dimaggio and Hargittai (2001), and a numer of best practices. McConnaughey, Goldberg, Neogi, and Brocca (2013) examined the digital divide in the United States and Canada and advocate for a two-pronged approach: supporting infrastructure build-out and addressing adoption and non-adoption issues. As with other researchers, McConnaughey, et al. found that the availability challenge between rural and urban increases as broadband speed increases (McConnaughey et al., 2013) and found the challenges associated with data and definitions of broadband.

Utilizing the FCC, the United States Census Bureau, and a telecommunications wire center database, Prieger (2003) analyzed the unequal access among poor, minority, and rural households. Prieger found rurality decreases availability while market size, education, Spanish language use, commuting distance, and the presence of a Bell operating company increases availability. Prieger suggested that relevant cost considerations are the fixed deployment costs, subscriber density, and type of broadband infrastructure (J. E. Prieger, 2003). The variance in average fixed costs among regions is indirectly controlled by including subscribership (J. E. Prieger, 2003).

Prieger (2013) examined the impact of the digital divide by examining FCC and U.S. Census Bureau data, finding that for faster, fixed broadband services, availability and provider numbers are lower in rural areas, a gap exists between fixed broadband usage rates between

urban and rural areas, and usage rate gaps are more proportionally greater with low-income households. Whitacre, Strover, and Gallardo (2015) estimated the difference in adoption to be approximately 38%, with 52% of the difference attributed to the differences in education and income.

A divide exists among middle mile infrastructure as well. Glass & Stefanova (2012) analyzed data from more than 500 rural local exchange carriers to determine if economies of scale existed. Glass and Stefanova (2012) found that "increasing capacity over existing broadband connections is subject to substantial economies of scale, but such economies diminish quickly as bandwidth capacity increases," (p.100). As national efforts focusing on broadband build-out in rural areas continue, one should continue to examine those points that are of most concern and limiting additional broadband expansion. If avenues could be identified to improve the middle mile, then broadband expansion could take place in geographic localities, not possible today due to middle mile pressures.

Another aspect of the digital divide is the use of broadband and Internet, not just the availability or the adoption. The Pew Research Center's Internet project offers insight into Internet use and adoption of a variety of social categories including home broadband adoption, privacy, Internet sharing, adult use of dating sites and apps, online gaming, searching for work and several others (Pew Research Center, 2016), and even opening their data to academic researchers. Buente and Robbin (2008) examined broadband use in everyday life, arguing that if the Internet is viewed as an information source and used to help facilitate transactions, then the Internet impact on daily life is more likely to result in significant changes and opportunities.

Broadband Availability

The bulk of the government funding has focused on broadband availability and infrastructure projects. In the American Recovery and Reinvestment Act, the United States Department of Agriculture awarded $2.5 billion in funds (American Recovery and Reinvestment Act of 2009, 2009). Furthermore, the NTIA awarded $3.94 billion in projects through their BTOP program including $3.48 billion in infrastructure projects and $452 million in non-infrastructure projects (National Telecommunications and Information Administration, 2010). Research has focused on the impact of such infrastructure efforts and identified ongoing barriers.

Similar to the loan program utilized in the American Recovery and Reinvestment Act, USDA has offered broadband loans since the U.S. Congress authorized a pilot broadband loan program in 2000 and expanded in 2002 (Kandilov & Renkow, 2010). Kandilov & Renkow (2010) suggested that the pilot loan projects had a substantial positive impact on employment, annual payroll, and the number of businesses in communities receiving awards but could not find the same in the full loan program, perhaps due to the time elapsed between award, build-out, and growth.

Jayakar and Park (2013) examined unemployment levels at the county level across the United States based on broadband availability. Using speed combo, download speed, wire availability, and competition as independent variables from the National Broadband Map, the authors found that broadband availability had a positive relationship on unemployment and was stronger when coupled with positive results on employment generation (Jayakar & Park, 2013).

Renkow (2011) examined broadband availability at a county level in Kentucky and North Carolina to analyze the urban-rural divide, trying to determine the accuracy of Parker's (1990) assertion of the "rural penalty" based on the increase in transport cost and low density. Among

the findings, Renkow examined six rural breakdowns: (1) rural, not adjacent to a metro county, (2) rural, adjacent to a metro county, (3) metro, (4) rural with urban population < 2,500, (5) rural with urban population of 2,500 to 20,000, and (6) rural with urban population > 20,000; findings showed that availability increases correlated to a county's urbanized population when focused on a rural county (Renkow, 2011).

Whitacre (2010a) examined both broadband availability and adoption in rural areas of Oklahoma using ZIP code data, which revealed that 99% of the most populated ZIP codes in Oklahoma had broadband access. Even in the least populated ZIP code areas, it is reported that 96.2% have access to broadband, highlighting the challenges of broadband availability data sources in rural areas (Whitacre, 2010a). As noted by the researcher, at the time of publication, there was no precise data representation on exact locations in Oklahoma (Whitacre, 2010a), which continues to be a challenge among data sources, even with more accurate data (Ford, 2011).

As seen in other research, stronger availability data can be coupled to reveal interesting information. Boik (2016) coupled broadband availability data from the NBM with data from four other sources to analyze entry subsidies for high-speed broadband in North Carolina, revealing a universal service policy would be too costly and may not result in universal adoption.

Broadband Adoption

Efforts by public and private sector organizations have attempted to address demand-stimulus programs. Programs typically focus on the barriers to adoption, such as the three identified by Horrigan (2010) as cost, digital literacy, or relevance. Prieger and Hauge (2015) identified four general types of demand-stimulus programs that include programs to mitigate as a barrier to broadband service, programs to alleviate lack of computer ownership as an obstacle to

broadband service, programs to alleviate lack of digital literacy as a barrier to broadband service, and programs to mitigate perceived lack of value as a barrier to broadband service. Research has focused on the impact of these programs as well as the importance of adoption to diffusion of broadband technology.

Briglauer (2014) examined the impact of regulation and competition on the adoption of fiber-based broadband services among European Union members. Briglauer found that next-generation fiber-based access (NGA adoption) is negatively influenced by the effectiveness of wholesale broadband regulation; mobile competition is nonlinear to NGA adoption; a replacement of first-generation broadband infrastructure had an effect; and substantial network effects give rise to an endogenous NGA adoption process (Briglauer, 2014).

Lee and Brown (2008) examined the most influential factors of global broadband adoption, including platform competition, broadband (information communication technology) use, broadband speed, income, population density, price, and bundling aspects. Using regression, Lee and Brown found that platform competition was a significant factor in broadband adoption (Lee & Brown, 2008).

Dobson, Jackson, and Gengatharen (2013) examined the Australian government broadband project implementation and argued the individual reflexivity in explaining the adoption decision and barriers. Specifically, the researchers suggested that universal availability in Australia will require urban broadband users to subsidize the rural areas where adoption is lower (Dobson et al., 2013). Based on the examination of data from 30 OECD countries, Cava-Ferreruela and Alabau-Muñoz (2006) found that in poorly developed markets with low broadband availability affordability, consumer's predisposition, and skills were key motivators for obtaining broadband.

On behalf of the Small Business Administration, Pociask (2005) examined broadband use by rural small businesses finding that rural small businesses are less likely to use broadband services. Pociask suggested that rural consumers subscribe to broadband at lower levels causing small businesses not to demand it at high levels or that demographics and cultural characteristics may account for the differences (Pociask, 2005). Whitacre, Gallardo, and Strover (2013) inspected the impact of broadband adoption on the economic health of rural areas, finding a positive causation between broadband adoption and income growth between 2001 and 2010, as well as a negative influence on broadband and unemployment growth.

Broadband Speed

As seen in the broadband overview section, another aspect of the broadband equation is the continued examination and changing benchmark for broadband speeds. Broadband speed is a moving target because the applications and requirements have evolved from low-quality audio using 56 kbps download speeds to streaming audio at 1 Mbps to high definition television at 30 Mbps (Barnes, 2010). In an analysis of speed in rural America, Barnes (2010) indicated that U.S. consumers paid more for slow speeds and lower adoption. Backing Barnes's assertion, Turner (2005) examined broadband upload and download speeds among the largest DSL and Cable Modem providers along with the monthly fees and startup costs, which revealed that U.S. Consumers paid more for slower speeds than in other areas.

To understand broadband speed, one must consider the complexities associated with speed. Advertised speed focuses on the capacity of service or potential throughput (Bauer, Clark, & Lehr, 2010). Another description of speed is actual speed or average speed. It is the average speed that is experienced by the end-user (Bauer et al., 2010). The difference between the two terms is a utilization gap among end users. If a user has a maximum advertised service

speed of 100 Mbps available but only subscribes to a package for 25 Mbps, then the user should not expect the maximum speeds. Due to overhead, bottlenecks, and interference associated with broadband, the advertised and actual may not match as well (Bauer et al., 2010).

An additional concern with broadband speed measurements is determining what or how to measure broadband speed. A tester must determine where in the network the actual testing will occur to measure broadband speed. Figure 1 (Page 24) shows a diagram representing the ISP network from the end user to the public Internet. An ISP does not have the ability to manage every aspect of the network, rather only their portion of the last mile presenting problems for typical speed tests.

In the analysis of different broadband speed testing tools, Bauer, Clark, and Lehr (Bauer et al., 2010) found that the broadband speed testing tool from Ookla's Speedtest.net tool typically resulted in greater data rates than other speed testing techniques, but the Speedtest.net was the best method to measure ISP's broadband access service speeds of those available (Bauer et al., 2010). Ookla measures "the maximum sustainable throughput between the user's computer and the nearest server selecting a file size based on a bit test estimate of connection speed" (Federal Communications Commission, 2016, p. 136). By measuring the closest server Ookla attempts, to the extent possible, to measure the last mile portion of the broadband ecosystem. Additionally, it becomes the difference between the maximum broadband speed tier available from a particular provider and the utilized broadband speed by the end user. Due to the previously stated overhead and a consumer not purchasing the maximum available broadband speed tier, the actual download speed is lower. According to the FCC's Fifth International Broadband Data Report (Federal Communications Commission, 2016), Speedtest.net revealed an average download broadband speed for the last mile of 26.68 Mbps.

Initially published in 2011, the FCC issued the Measuring Broadband America Fixed Broadband Report each year since (Federal Communications Commission, 2015b). According to their methodology, the FCC attempts to measure actual broadband and upload speeds, latency, and packet loss at a state level (Federal Communications Commission, 2015b) using Form 477 data. Appendix B summarizes the most recent Form 477 data. Based on their new definition of broadband, the report measures broadband technologies at lower speeds than the 25 Mbps threshold and examines how the country is progressing toward that goal.

Through the Akamai Intelligent Platform ("Akamai," 2015b) handling two trillion Internet transactions a day, Akamai has tracked Internet speeds, mobile connectivity, and situational performance, among others, with typical reporting at a state or nation level (Akamai, 2015a). In the Fourth Quarter State of the Internet report, Akamai found that global average connection speed was 5.6 Mbps download while the United States had an average download speed of 14.2 Mbps and South Korea was the fastest with 26.7 Mbps download speed.

Broadband Pricing

When considering broadband pricing, the NTIA (National Telecommunications and Information Administration, 2013) definition of broadband "does not specifically include price . . . " (p. 2); however, it may be considered essential to the diffusion process. Multiple researchers and organizations have examined the area of broadband pricing. Bernardi et al. (2014) suggest that choice and cost are items of interest and should be included with any broadband mapping project, particularly for consumers and regulators. Data collection in research has occurred in a variety of manners, some of which are very different. Communications Chambers (Communications Chambers, 2014) analyzes visits to operator websites; Russo et al. (2014) survey providers in the largest cities in the world; Boik (2016) used web scraping. There are

multiple factors affecting broadband pricing including the competitive structure of the market, degree of regulatory intervention, the existing infrastructure of incumbents, competing technologies and indirect competitive pressure from neighboring countries (Phillippa Biggs & Tim Kelly, 2006)

The Open Technology Institute publishes an annual study on *The Cost of Connectivity*, publishing for the first time in 2012 (Hussain, Kehl, Lucey, & Russo, 2013; Russo et al., 2014) comparing the pricing and offerings of the main cities around the world. *The Cost of Connectivity* studies have collected download and upload speeds, monthly costs, data caps and penalties, activation and installation fees, equipment rentals, and contract lengths (Russo et al., 2014). The study utilized the non-promotional price for service and covered the average cost over an entire contract when pricing differs over time. Among the survey's analysis is a tabulation of different speed tiers showing price, download speed, upload speed, network technology and data cap. With the findings, the researchers can demonstrate price for the maximum speed, as well as the fast download speed available for a price point (Russo et al., 2014). For example, the study revealed that Seoul, Hong Kong, Tokyo, Paris, and Bucharest all offer home broadband deals under $40 with at least 1000 Gbps download speed.

In the FCC's international analysis of broadband speed and pricing, the FCC used price per Gbps and found the United States had the fourth least expensive broadband price at $0.33 with speeds of greater than 25 Mbps (Federal Communications Commission, 2016). The FCC developed a formula to account for all the inclusive prices, which is considered the contract term price. The formula included promotional price, the number of months for promotion, standard price, contract term, installation fee, activation fee, modem fee, and rebates (Federal Communications Commission, 2016).

Wallsten and Mallahan (2010) analyzed the new FCC dataset to explore the state of broadband competition in the U.S. and its relationship of speed, penetration, and pricing. Results suggested that broadband subscription pricing is lower where competition exists, particularly at lower broadband speeds such as DSL (S. Wallsten & Mallahan, 2010). However, the researchers do suggest that quality of data within the 477 Forms make it difficult to draw firm conclusions. Understanding those results, Bates, Malakoff, and Kane (2012) advocate that an affordable price for broadband service would be a barrier to adoption citing a 2010 survey which found the average user has a broadband bill of $40.68 per month.

The Organization for Economic Co-operation and Development (OECD) operates a broadband portal, providing national-level data from the 34 OECD countries on broadband penetration, usage, coverage, prices, services and speeds ("OECD," 2016b). Pricing methodology included equipment rental but does not contain telephone, cable pricing, or discounts ("OECD," 2016a). Additionally, OECD considered the following fixed broadband technologies: DSL, cable, fiber, satellite, terrestrial fixed wireless, and broadband over powerline ("OECD," 2016a).

In an analysis of broadband pricing between U.S. and European countries, the data showed that U.S. broadband pricing was lower than European prices for services up to 12 Mbps (C. S. Yoo, 2014). Between 12 Mbps and 30 Mbps, the differences between the geographic areas were relatively small; however, when considering speed tiers over 30 Mbps, the U.S. pricing was significantly higher than those in the European countries. The study found that pricing for 30+ Mbps service in the EU was only $37 while the U.S. comparable service was $61. As seen in other recent studies, the data utilized in Yoo's study provides an additional level of detail that was not previously available.

Wallsten and Riso (2014) examined pricing determinants by analyzing consumer prices, metering, changes over time, and pricing from an examination of all OECD countries. The results suggest that an unlimited data plan would cost approximately 27% more than a plan with a 10 GB plan (S. J. Wallsten & Riso, 2014). Similarly, Galperin and Ruzzier (2013) examined the retail prices in Latin America and Caribbean area finding that a 10% reduction in pricing would result in approximately 22% increase in broadband adoption, which is inconsistent with OECD countries.

Greenstein and McDevitt (2009) attempted to measure broadband Internet's impact on U.S. GDP by creating an Internet-access consumer price index. The challenges identified by the researchers were how to measure technical progress and how to handle broadband speed updates. One example of the challenge cited in the pricing measurement was that it was unable to account for a provider who upgrades broadband speed without raising the price to the consumers (Greenstein & McDevitt, 2009).

In a Progressive Policy Institute's Policy Brief advocating for new regulations, Litan and Singer (Litan & Singer, 2014) calculated a potential annual increase of broadband pricing using a flat monthly wireline cost plus the government fees. Meanwhile, Davidson and Santorelli (Davidson & Santorelli, 2014) compared cable modem and DSL service by examining dollars per megabits, finding that cable modem service cost $1.10/Mbps in 2013 while DSL service cost $3.32/Mbps.

In addition to the analysis of current pricing, other research has focused on potential alternatives to existing pricing schemes. Nevo, Turner, and Williams (2015) suggested that usage-based pricing would improve the overall welfare of the Internet. Malone, Nevo, and

Williams (2015) suggested changes to the way broadband is priced based on an examination of over-the-top video and those users that have eliminated home cable service.

Chapter Summary

In summary, the literature review revealed a large amount of research had been conducted on broadband and broadband has long been a consideration of lawmakers, but the review also indicates that broadband pricing and costing studies are still lacking. Broadband expansion, the role of government, and the economic impact of broadband have been examined. Specifically, there are very few studies that look at the comparison of broadband pricing across urban and rural areas, specifically in the small geographic area, such as a county. When considering a particular state like the Commonwealth of Kentucky, there is a void in the available research.

CHAPTER 3

METHODOLOGY

Introduction

This research study used Pearson correlation, ANOVA, and regression analysis to examine and determine potential relationships between last mile broadband pricing and various potential technical and demographic predictors. This chapter describes the research methodology that was utilized in the study. Specifically, it includes the study's design, the chosen statistical technique, a description of the population and sample, data collection method, analysis techniques, validity aspects, and ethical considerations.

Research Method

Analytical Methods

The analytical method used in this research was correlational analysis between the single dependent variable and multiple independent variables. Pearson correlation analysis, analysis of variance (ANOVA), and multiple linear regression were utilized in the analysis. In the analysis, ANOVA provided the test of significance for the overall regression with the null hypothesis: H_0: $R = 0$. Multiple regression was used to determine if multiple independent variables can be used to predict the dependent variable. Furthermore, for each independent variable (individually, grouped or combination), the multiple regression would show the statistical significance accounted for in the dependent variable (Hayden, 2008). Pearson correlation was used to test the

relationships among the variables and determine if any variables should be removed before testing the model.

Multiple regression and ANOVA are both characterized by the general linear model (GLM), and both could be considered as the method for analyzing the variables within the research questions. However, multiple regression is more appropriate based on multiple factors. Due to the number tests that would be required if using ANOVA, the family-wise Type I error (alpha) would be inflated. Even with a Bonferroni calculated error rate, the alpha (α) would grow to a level not acceptable to reach a significant conclusion (Hayden, 2008, p. 37). Multiple regression is appropriate to use and has been utilized by researchers in similar analysis (Angolia, 2013; Gulati & Yates, 2012; Lee & Brown, 2008; Rosenthal, 2002).

In this study, ten independent variables were selected making multiple linear regression appropriate. However, with a larger number of independent variables, identifying the most suitable model becomes problematic. Stepwise variable selection was utilized in the analysis to address the most suitable model. The stepwise approach combined backward elimination and forward selection to calculate the "best" equation by entering various combinations and orders of independent variables (Vogt & Johnson, 2011). Though some statisticians are against using the stepwise approach, it is appropriate in exploratory research such as this one (Vogt & Johnson, 2011).

Null Hypothesis and Alternative Hypothesis

To effectively analyze the advertised price for last mile residential broadband price, the following null and alternative hypotheses tested and were based on the research questions provided in Chapter 1. Questions 1-10 and resulting hypotheses were created to test each individual variable relationship with the dependent variable. The final question and hypothesis

was included to examine whether an overarching model could be developed using the variables from the prior hypotheses.

1. $H_0$1: There will be no statistically significant difference between the advertised price for last mile residential broadband service and population density.

   H_A1: There will be a statistically significant difference between the advertised price for last mile residential broadband service and population density.

2. $H_0$2: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the unemployment rate.

   H_A2: There will be a statistically significant difference between the advertised price for last mile residential broadband service and unemployment rate.

3. $H_0$3: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the number of providers.

   H_A3: There will be a statistically significant difference between the advertised price for last mile residential broadband service and the number of providers.

4. $H_0$4: There will be no statistically significant difference between the advertised price for last mile residential broadband service and broadband availability.

   H_A4: There will be a statistically significant difference between the advertised price for last mile residential broadband service and broadband availability.

5. $H_0$5: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the number of middle mile fiber providers.

   H_A5: There will be a statistically significant difference between the advertised price

for last mile residential broadband service and the number of middle mile fiber providers.

6. $H_0$6: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the actual broadband speeds.

   H_A6: There will be a statistically significant difference between the advertised price for last mile residential broadband service and the actual broadband speeds.

7. $H_0$7: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the technology deployed.

   H_A7: There will be a statistically significant difference between the advertised price for last mile residential broadband service and the technology deployed.

8. $H_0$8: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the provider type.

   H_A8: There will be a statistically significant difference between the advertised price for last mile residential broadband service and the provider type.

9. $H_0$9: There will be no statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised download speed.

   H_A9: There will be a statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised download speed.

10. $H_0$10: There will be no statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised upload speed.

    H_A10: There will be a statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised upload speed.

11. $H_0$11: There will be no statistically significant relationship between the advertised price for last mile residential broadband service and one or more independent variable.

    H_A11: There will be a statistically significant relationship between the advertised price for last mile residential broadband service and one or more independent variable.

Multiple Linear Regression Assumptions

To accurately apply multiple linear regression, the variables must be set up appropriately. The dependent (or outcome) variable and independent (or predictor) variables were assumed to be measured without error. The independent variable must be a quantitative variable measured on a continuous scale and normally distributed. The independent (or predictor) normally distributed variables should be continuous or ordinal variable and may be dichotomous. Each set of dependent and independent variables should have a linear relationship, as well as the dependent variable and the collective set of independent variables. In addition to including variables properly set up, a number of additional assumptions are required (Hayden, 2008; Warner, 2013):

1. The variables should have independence of observation, meaning that no independent variable should have any undue influence on another.
2. The data should show homoscedasticity, which is the "assumption that the error term has a constant variance across each of the levels of independent variable" (Vogt & Johnson, 2011, p. 171).
3. The independent variables should not show multicollinearity, meaning that the variables should not be correlated.

4. The residual of the difference between the value of the dependent variable and the predicted value of the dependent variable should be normally distributed.
5. The data should not contain significant outliers.

Univariate frequency distribution for each individual variable and bivariate scatter plot for each pair of variables would be sufficient to generally assess possible violations (Warner, 2013).

Selection of Variables

A variety of factors were considered to determine the appropriate variables. The dependent variable is inferred in the research question and validated as a research need based on the review of the literature. The selection of independent variables required two additional steps: (1) selecting variables for the model and (2) selecting independent variables that will remain in the model once completed (Hayden, 2008). As described in the literature review, the variable selection began with an analysis of existing research relating to broadband pricing, analysis of current government policy and studies, and informal interviews with broadband providers and industry professionals. Due to the distinct goals between the three differing groups of broadband professionals, triangulation of the data was important. The triangulation of the three research types served to validate the analysis and reveal some overarching concerns and considerations.

The first consideration was to determine the appropriate level of analysis, census block, ZIP code, or county, based on research appropriateness and data availability. The second consideration was to determine which variables would be correlated with the dependent variable. The review of the investigation concluded that there were three general categories of potential independent variables as depicted in Figure 3 with their potential impact on the dependent variable. Each general category contained aspects of supply and demand.

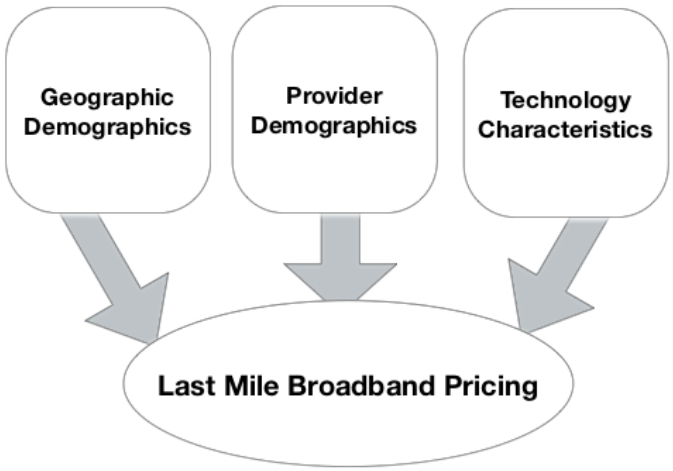

Figure 3: Sources of Independent Variables

Based on the literature review, several independent variables were identified originating from each of the categories. As previously stated, all data in this research was analyzed at the county level. County level geographic variables included county population density, unemployment rate, broadband availability, actual broadband speeds, the number of providers within the county, and the number of middle mile providers. Unemployment rate was chosen over average income and poverty level as the independent variable to measure the community's ability to pay since the literature review found several examples of previous related research using unemployment rate as the variable of choice. Also considered were education attainment, average age, and percent of the population in the rural area; however, these factors were rejected as potential variables based on the literature review showing the variables were significantly correlated. Also rejected were broadband adoption and community anchor institution data, because the data sources were not reliable enough.

Company demographic and technology characteristics were closely related and overlapped. The company demographic variables selected are the type of technology deployed at a county level, provider type, and pricing information. There may be more than one

technology deployed at a county level. Additionally, provider type allows the impact of telecommunications regulation to examined for its potential relationship to the dependent variable. The pricing variable, which was used to create the dependent variable, includes three sub-variable components: (1) non-promotional advertised price of the highest residential speed tier available; (2) the number of years for any potential contract that must be signed; and (3) the data cap limit for the selected package.

Table 2: Summary of Community Demographic Variables

Variable Name	Data Type	Data Source
Dollars per Megabit	Interval	Web Scrapping
Population Density	Interval	U.S. Census Bureau
Unemployment Rate	Interval	U.S. Department of Labor
Provider Count	Interval	NBM
Broadband Availability	Interval	NBM
Middle Mile	Interval	Web Scrapping
Actual Broadband Speeds	Interval	FCC/Ookla Speedtest.net
Technology Deployed	Ordinal	NBM
Provider Type	Ordinal	NBM
Maximum Download Speeds	Ordinal	NBM
Maximum Upload Speeds	Ordinal	NBM

Company technology variables selected were maximum download speed and maximum upload speed, both calculated based on the speed tiers utilized in the NBM. Also collected was the highest advertised speed package, which was incorporated into the dependent variable. In Table 2 (above), the variables with data sources are summarized.

Population and Sample

The population is the group that one is trying to describe or generalize while a sample is a representative group from the larger population meant to have the same characteristics as the population (Vogt & Johnson, 2011). Much has been written and researched regarding the process and considerations for determining the population and sample (Creswell, 2014). A sample is typically required due to the cost and time to collect data from all members of the population (Warner, 2013).

The research question examined the population of fixed last mile residential broadband providers within the Commonwealth of Kentucky. Due to differences in state and federal laws, as well as geographic and population demographic differences, without additional research, it was not reasonable to assume the population would be representative of any other state within the United States or any other country. For the study, mobile and satellite broadband providers were excluded because both provider types are outside of the research question. Additionally, resellers were also excluded from the study as they have a different set of economics and would confuse the data. Excluding those types of providers as well as those providers that were no longer providing service, the population of fixed last mile residential providers in Kentucky is approximately 114 providers ("Commonwealth of Kentucky," 2014). Listings of broadband providers, based on the National Broadband Map and FCC Form 477 data are available in Appendix A and Appendix B, respectively.

For an ideal research problem, there exists an actual population of interest with all members of the population being identifiable. True random sampling would be conducted from that actual population (Warner, 2013). The sampling would be required due to a large population size. In this research study, data was collected at the county level as described in the Data

Collection Method section to answer the research question. Even with 120 counties in Kentucky, most of the 114 providers only service a small number of counties. Therefore, sampling was not necessary since it was not unreasonable, too costly, or time-consuming to collect data from the entire population of last mile residential fixed broadband providers.

Data Collection Method

Research data came from five separate data sources. The first data source was the NBM, which collects provider availability at a census-block level. Available provider information includes the availability, technology type, and maximum bandwidth available. Review of the provider dataset was conducted to remove duplicates, affiliates, providers no longer in business, merged providers, and mobile providers. For nonparticipating providers, meaning those who did not participate in the data collection process, data was manually collected, if possible. Nonparticipating providers account for less than ten providers in Kentucky out of a total of more than 120 providers. Data was aggregated at the county level. Pricing information was the second source of data collected by researching each provider's website to identify the advertised price for the maximum advertised speed tier. The third source of data was the latest data releases from the relevant government agencies, census information from the United State Census Bureau will be used to determine population density, calculated as a population per square mile (United States Census Bureau, 2017), and unemployment rate from the most recent United States Department of Labor report (United States Department of Labor, 2017). The fourth source of data was the count of fiber middle mile providers and will be collected from web scrapping and utilizing data from various data collection services. The fifth data source was speed testing information gathered from Ookla's Speedtest.net, an online broadband testing service used by

the FCC (2016). Given that the research in this study was exploratory in nature, multiple items were included to measure their potential as an independent or controlling factor.

Based on the data sources indicated above, data collection occurred through four different steps. First, the initial population of broadband providers was determined and collected from publicly available data within the National Broadband Map program and FCC Form 477 data—all ex-post facto downloadable information. Second, the data regarding county density and unemployment rates was collected through publicly available data collected by the United States Census Bureau. Third, data regarding the actual broadband speed was gathered using OOKLA's Speedtest.net online speed test. Fourth, web scrapping was utilized to collect middle mile information beyond that available in the National Broadband Map.

The dependent variable was a combination of the maximum advertised speed and non-promotional publicly advertised price. To collect the required information web scrapping of the providers' websites was utilized. Some provider websites require an address to be used to determine available speed tiers and pricing. For those providers, an address close to the center of a town in the community where service is available from the provider was utilized. In cases where information is missing from a provider's website, a follow-up phone call was conducted to ask for the publicly advertised price and speed of service.

Analysis Procedures

Once data was collected and initial formatting completed, the procedure was as follows:

1. Data Import: The raw data was analyzed with an appropriate GIS program, QGIS, a free and open source GIS program, to allow the data to be transformed into a county level and imported into IBM SPSS Statistics Version 21.

2. Data Review: An initial data review was conducted to determine if all records are valid including the identification of any record that contains obvious flaws, missing information, or is a duplicate.
3. Data Preparation: Once the initial review was completed, additional preparation was required to ensure that data properties are correct. Since the dependent variable was shown in dollars per megabit, manipulation of the data field containing the advertised speed and the field containing advertised speed was required.
4. Assumption Check: All assumptions for multiple linear regression were verified using procedures within IBM SPSS and described previously in the chapter.
5. Descriptive Statistics: Descriptive statistics were calculated for all variables to examine for normality.
6. Correlational Analysis: All pairs of variables were checked for correlation. Pairs of dependent and independent variables exhibiting no correlation were flagged for possible exclusion from the model.
7. Regression Analysis: Utilizing SPSS Statistics, the following procedure is the steps required to run the regression:

    Analyze -> Regression -> Linear…

    Choose the dependent and independent variables

    Select appropriate additional linear regression statistical options

Once the procedures were completed, analysis of the regression values and resulting data were analyzed and reported in Chapter 4.

Design and Validity

The research design is the art and science of planning procedures for conducting research studies to obtain the most valid results. In research design, validity is the quality and accuracy of the information. In other words, *does the study measure what it claims to measure?* (Vogt & Johnson, 2011; Warner, 2013). Several internal and external threats to validity need to be accounted for in the design of the research including history, selection, instrumentation, interaction of selection, and the setting (Creswell, 2014). The construct validity should be designed to ensure the convergent, discriminant, concurrent, and predictive validity of the design to address the threats posed to validity (Warner, 2013).

Due to the nature of the research design, several validity concerns were not applicable. The design is not qualitative. Therefore, the design avoids the concerns focused on the validity of qualitative methods. The research design does not include a survey or test. Therefore, additional validity concerns were not relevant. Content, criterion-oriented, and convergent validity were not applicable due to the lack of a survey or test.

Data was checked for discriminant validity, meaning items that should not correlate, and concurrent validity, meaning the data correlates with other valid data, by examining the fields from the data sources that are not being utilized for the analysis (Warner, 2013). Predictive validity is the extent that the design predicts subsequent performance. Predictive validity was verified post facto by testing various broadband providers.

To further ensure the validation of the data, sources, and procedures, a pilot phase was conducted using the nine northwest counties of the State of Tennessee, also called the Northwest Tennessee Development District. The collection and procedures was utilized to analyze the validity of the variables and approach (Warner, 2013). Following completion of the pilot phase

and full research, the results were validated using data from providers both inside and outside of Kentucky.

Ethical Considerations

All research was conducted with ethical considerations in mind. No personally identifiable information was collected. In addition to the technical reasons for data collection at the county level, the aggregation of data at the county level ensured that no personal information will be revealed. The research plan was executed with consideration of Indiana State University Institutional Review Board (IRB) standards to ensure that all ethical considerations were contemplated and handled appropriately.

The researcher involved in this research plan has worked with broadband providers across Kentucky for more than a decade with pre-existing relationships with many of the providers. As a project manager with the public-private partnership, ConnectKentucky, and the executive director of the public-private partnership, Connected Tennessee, the researcher worked with broadband providers to expand broadband coverage in rural areas, improve broadband adoption, and increase use of broadband technology in a manner that would encourage private sector investment.

The researcher's organization has been a member of the Kentucky Telecommunications Association for approximately ten years, which comprising most rural telephone and DSL providers across Kentucky. Before the researcher's hire, the organization was a grantee of the Commonwealth Office of Broadband Outreach & Development (OBOD) and tasked with leading Kentucky higher education institutions to provide broadband field validation for broadband providers ("Commonwealth of Kentucky," 2014). Following the researcher's hire, the

organization was the recipient of a community broadband planning project to provide digital literacy training to four rural counties in Western Kentucky.

Chapter Summary

As described in the chapter, a detailed methodology has been selected to examine the relationship between the dependent and independent variables. The study used correlational analysis between the single dependent variable and multiple independent variables to assess the impact of a variety of factors on broadband pricing across the Commonwealth of Kentucky. Pearson correlation analysis and multiple linear regression was utilized in the analysis. As described, the population was all fixed residential last mile broadband providers in Kentucky, as identified by the National Broadband Map in its data collection process and updated by the FCC's annual data collection.

CHAPTER 4

DATA ANALYSIS AND FINDINGS

Introduction

The purpose of this research was to analyze the factors influencing last mile residential fixed broadband pricing in Kentucky. This chapter presents the results of the data collection, data preparations, and statistical analysis. Data was stored in Microsoft Access during data collection. Once collected, all data was analyzed using IBM SPSS 21 Statistical Software. A complete listing of data collected is available in Appendix C.

Research Questions and Null/Alternate Hypotheses

The research statements with their corresponding null and alternate hypotheses are stated below.

Q1: Does the population density served by the provider impact the advertised price for last mile residential broadband service?

$H_0 1$: There will be no statistically significant difference between the advertised price for last mile residential broadband service and population density.

$H_A 1$: There will be a statistically significant difference between the advertised price for last mile residential broadband service and population density.

Q2: Does the unemployment rate of the county served by the provider impact the advertised price for last mile residential broadband service?

H_02: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the unemployment rate.

H_A2: There will be a statistically significant difference between the advertised price for last mile residential broadband service and unemployment rate.

Q3: Does the number of providers within the county impact the advertised price for last mile residential broadband service?

H_03: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the number of providers.

H_A3: There will be a statistically significant difference between the advertised price for last mile residential broadband service and the number of providers.

Q4: Does the broadband availability within the county impact the advertised price for last mile residential broadband service?

H_04: There will be no statistically significant difference between the advertised price for last mile residential broadband service and broadband availability.

H_A4: There will be a statistically significant difference between the advertised price for last mile residential broadband service and broadband availability.

Q5: Does the number of middle mile fiber providers offering service impact the advertised price for last mile residential broadband service?

H_05: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the number of middle mile fiber providers.

H_A5: There will be a statistically significant difference between the advertised price for last mile residential broadband service and the number of middle mile fiber providers.

Q6: Does the actual broadband speeds seen by users impact the advertised price for last mile residential broadband service?

$H_0$6: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the actual broadband speeds.

H_A6: There will be a statistically significant difference between the advertised price for last mile residential broadband service and the actual broadband speeds.

Q7: Does the technology deployed by providers within the county impact the advertised price for last mile residential broadband service?

$H_0$7: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the technology deployed.

H_A7: There will be a statistically significant difference between the advertised price for last mile residential broadband service and the technology deployed.

Q8: Does the provider type impact the advertised price for last mile residential broadband service?

$H_0$8: There will be no statistically significant difference between the advertised price for last mile residential broadband service and the provider type.

H_A8: There will be a statistically significant difference between the advertised price for last mile residential broadband service and the provider type.

Q9: Does the maximum advertised download speed impact the advertised price for last mile residential broadband service?

$H_0$9: There will be no statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised download speed.

H_A9: There will be a statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised download speed.

Q10: Does the maximum advertised upload speed impact the advertised price for last mile residential broadband service?

H_010: There will be no statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised upload speed.

H_A10: There will be a statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised upload speed.

Q11: What are the contributions of different factors impacting last mile residential broadband to the overall advertised price for last mile residential broadband service?

H_011: There will be no statistically significant relationship between the advertised price for last mile residential broadband service and one or more independent variable.

H_A11: There will be a statistically significant relationship between the advertised price for last mile residential broadband service and one or more independent variable.

Data Collection and Preparation

Data collection was conducted through a number of steps. External data sources were used to identify the provider population. As shown in Appendix A and Appendix B, broadband provider listings were collected by the National Broadband Map collection and the FCC's Form 477 process, respectively. The listings of providers included broadband providers from both fixed and mobile providers. Once the initial population of providers were identified, a number of validation checks to ensure only the targeted population is considered. The research questions excluded mobile providers. An initial data validation check of providers was conducted to exclude mobile technology types. Some providers utilize mobile and fixed technology types. In

those cases, the providers were included for the fixed technology component only. Twenty-two provider with mobile or satellite technology types were excluded based on the validation check.

A second validation check of data was conducted to ensure they offered last mile broadband service, operated their own infrastructure, and offered services to residential customers. The analysis separated those providers who were middle mile providers versus last mile providers, excluding 30 providers in the process. The validation check also excluded those providers who only resell another provider's services, excluding 14 providers. The validation check excluded those providers without residential service offerings, which eliminated 5 additional providers from the population. As with the initial check, the second validation check only excluded the component of a provider's service offerings that fell outside the scope of the research questions.

A third validation check was conducted to identify those providers that have merged with another company, eliminated the service offering that related to the research questions or were no longer in business. The third check required ongoing validation throughout the data collection process. Some broadband providers merged with other providers but were still required to report to state and federal entities utilizing their previous organization name. In cases where the validation check did not identify the merger up front, the ongoing validation caught them when pricing data was collected.

A fourth validation check examined the broadband speed available through the FCC datasets, which utilized the speedtest.net speed testing tool. The researcher had past experience with the OOKLA speedtest.net data, examining broadband speeds data at the county level across the State of Tennessee, providing a level of confidence in the quality of data. Based on the experience, the researcher expected data would be granular enough to examine broadband speeds

at the provider and county level. Datasets were available for each month in 2016, from January to August. Each dataset was between 2 GB and 8 GB. The file size of the datasets was very large, requiring a great deal of computing processor power to examine. Each month of data was stored as compressed SQL data files with each one stored as comma separated values (CSV)("Raw Data - Measuring Broadband America 2016," 2016). There was a large number of records for each state in the country, including the primary state, Kentucky, and the pilot area in Tennessee. Data was download, imported into a MySQL database and analyzed over multiple weeks to validate the data and determine how the data could be used to address the research question.

Each month's dataset included several tables with each table examining separate aspects of the speed test process including DNS, HTTP GET, HTTP Post, Ping, UDP Jitter, latency, video stream, etc. After careful examination and validation, it was determined that broadband speeds could be taken down to the county level, determining broadband speeds by county. Even though there was an extremely large amount of data, the examination determined that it would not be possible to take broadband speed data down to the provider and county level for all providers. Question 6 required a separate average broadband download speed value for each provider in each county where service is provided. While data was available for the larger providers, the FCC dataset was not sufficient for the smaller providers, nor able to provide for county specific data for all of the larger providers. Therefore, the actual broadband speed data was excluded from the analysis leaving research question Q6 unanswered in this inquiry.

During the data collection process, providers were required to have pricing information available for review. Two additional providers were excluded from the analysis because broadband pricing information was not available. Based on all reviews and data collection, 75

broadband providers were identified. Most of the identified broadband providers provided service in multiple counties and many utilized more than one technology. After combining all records, 811 records were identified for analysis. As described in Chapter 2, the technology types utilized for analysis are based on the broadband technology types utilized in the National Broadband Map and listed below:

- 10 – Asymmetric xDSL
- 20 – Symmetric DSL
- 30 – Other Copper
- 40 – Cable Modem – DOCSIS 3.0
- 41 – Cable Modem – Other
- 50 – Fiber to the End User
- 70 – Terrestrial Fixed – Unlicensed
- 71 – Terrestrial Fixed Wireless – Licensed

Figure 4 shows the breakdown of record count by technology type.

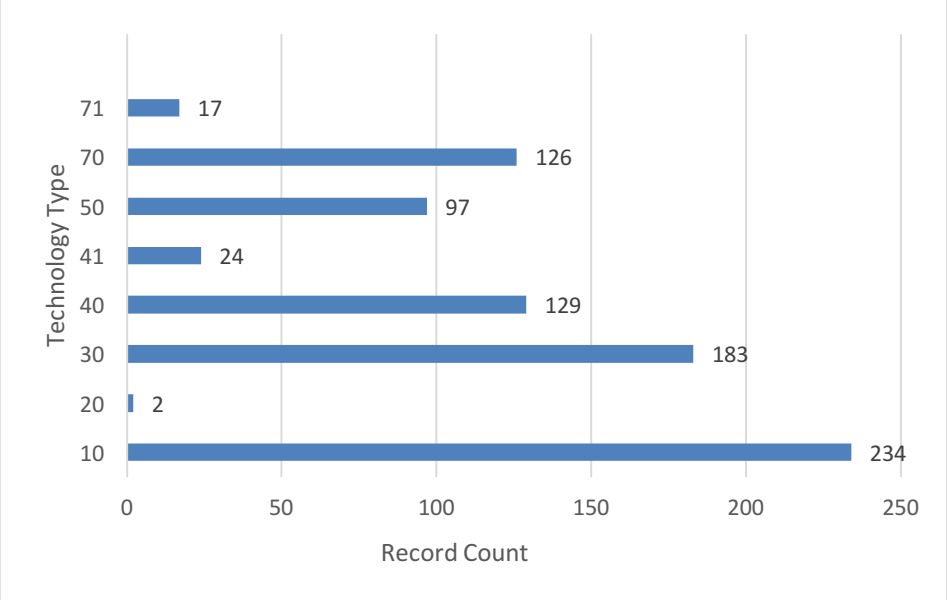

Figure 4: Count of records by technology type

As stated, broadband providers typically provide service to multiple counties. Only 19 providers in Kentucky provided service using a single technology in a single county. Conversely, each of the 120 counties in the Commonwealth of Kentucky contain multiple providers, ranging from 2 providers to 6 providers. Figure 5 shows the breakdown of the number of counties with each number of last mile fixed broadband providers. Based on the figure, one county has two providers, 20 counties have 3 providers, 40 counties have 4 providers, 52 counties have 5 providers and 7 counties have 6 providers.

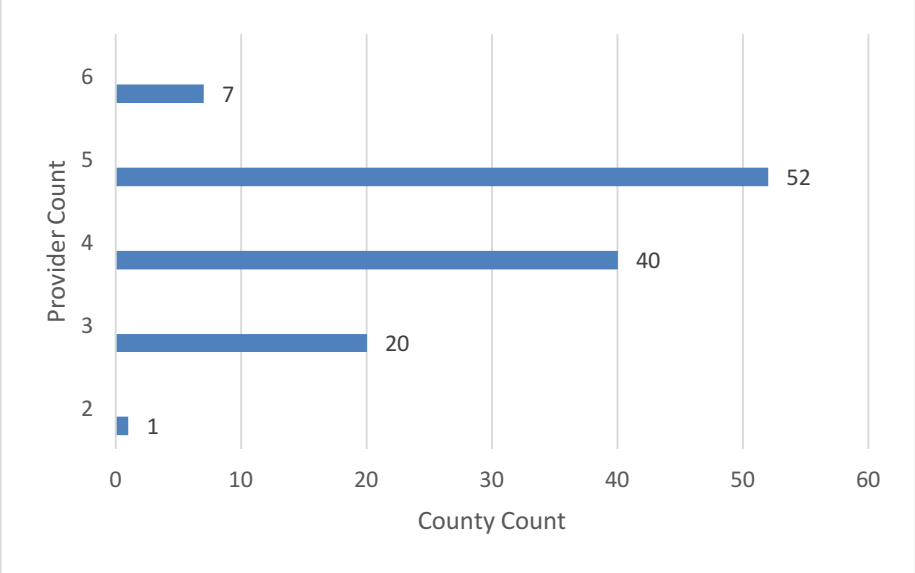

Figure 5: County count by number of providers

Provider Type data was collected from the National Broadband Map and National Broadband Plan (Federal Communications Commission, 2010a). The data was broken down into multiple categories based on the type and regulation and ordered from 1 to 6, based on the level of government regulation and its potential to influence pricing. Figure 6 shows the breakdown of provider types as described in the literature review and listed below:

- 6 – Large Corporation with some FCC regulation
- 5 – Large Corporation with FCC regulation
- 4 – Small-medium sized enterprises with FCC oversight
- 3 – Small-medium sized enterprises with no FCC oversight
- 2 – Municipal utility
- 1 – Telecommunications cooperative corporation

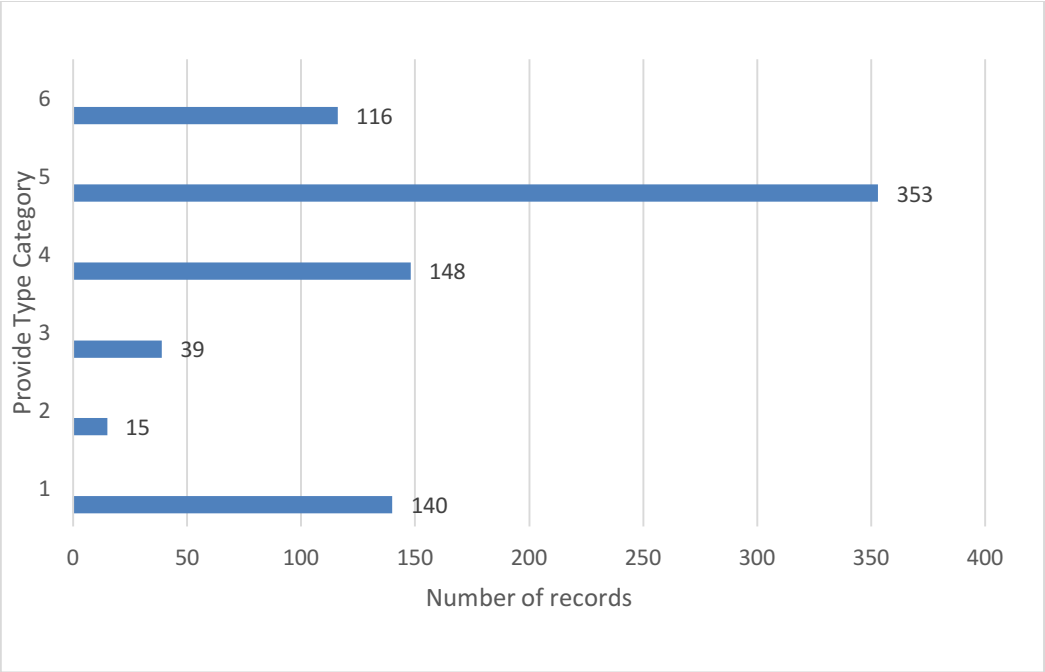

Figure 6: Count of records by provider type

Data Transformation

Based on the data validation and visual analysis of the pilot broadband data collected, it was determined that a skewness of data was present and likely present in the primary dataset as well. An additional check was conducted to analyze the assumption of homoscedasticity. Utilizing a plot of the regression standardized residuals plotted against the regression standardized predicted values revealed a likely violation (Kutner, Nachtsheim, Neter, & Li, 2004). If the assumption of homoscedasticity is violated, a data transformation may be warranted (Kleinbaum, Kupper, & Muller, 1988). The three primary reasons for data transformation are to stabilize the "variance of the dependent variable," "to normalize the normality assumption," and "to linearize the regression model" (Kleinbaum et al., 1988, p. 251). Based on the review of the pilot data, each are appropriate in this case. Furthermore, the log transformation, which is used here, is appropriate to use to stabilize the variance of Y, also true in the present data (Kleinbaum et al., 1988).

The data analysis, of both the pilot and primary dataset, suggested that the dependent variable—Broadband Price, and one of the independent variables—Population Density, would be appropriate for data transformation. Figure 8 and Figure 10 show the normality curves before and after the log transformation for the dependent variable, broadband price. Figure 9 and Figure 10 show the normality curves before and after the log transportation for the independent variable, population density. The equation of the new transformed variable is: New Variable = Log (Old Variable).

Transformed Broadband Price = Log (Original Broadband Price)

Transformed Population Density = Log (Original Population Density)

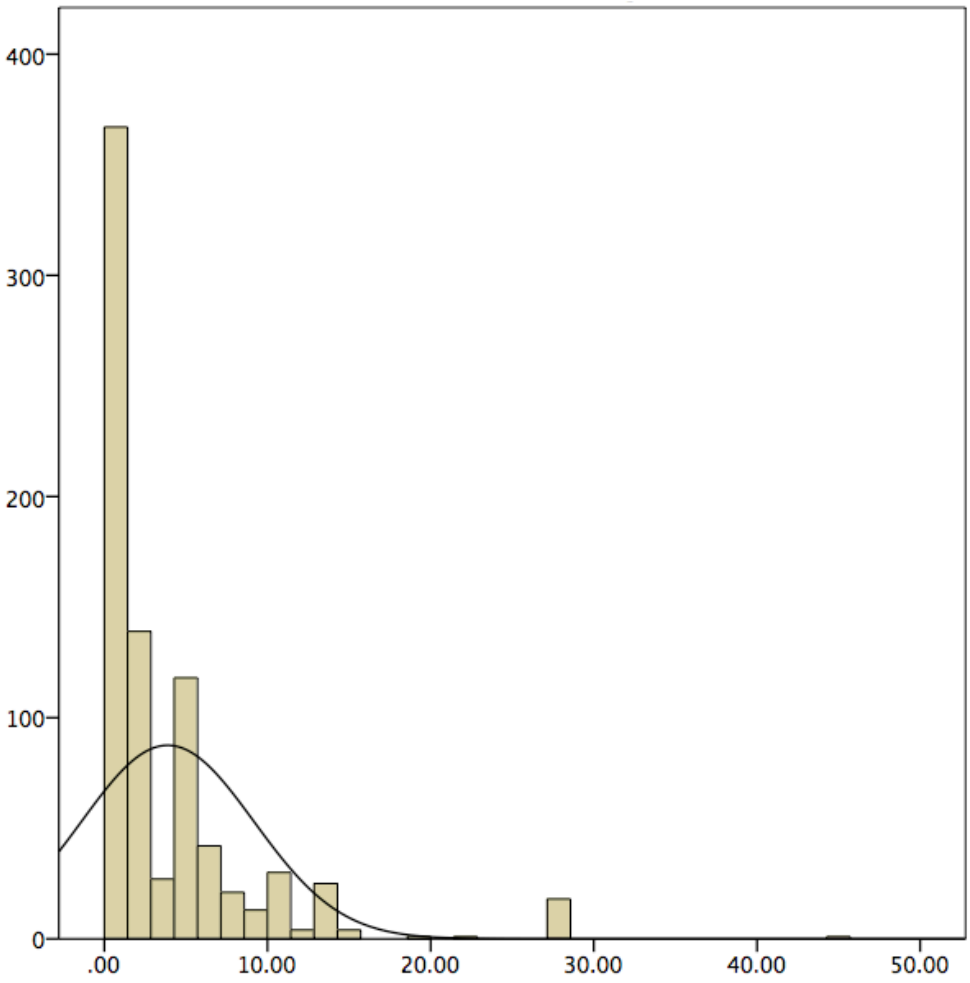

Figure 7: Distribution of broadband price before the log transformation

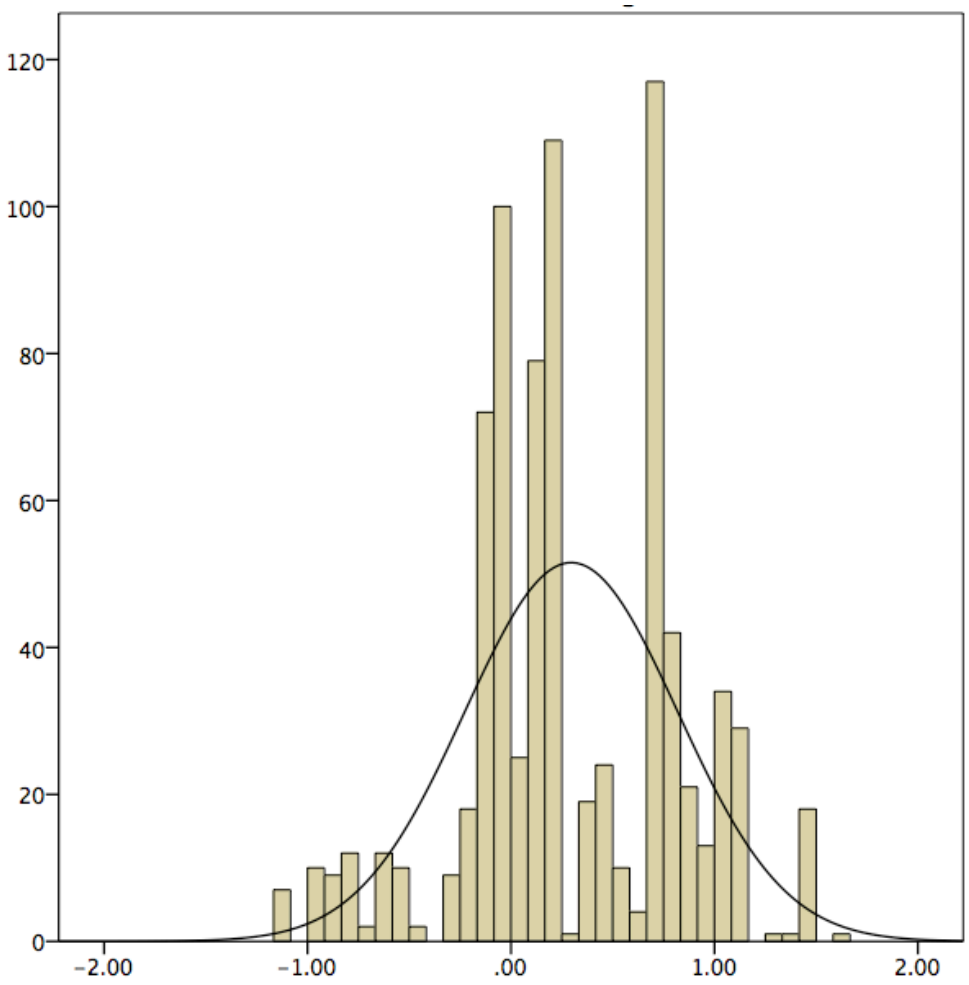

Figure 8: Distribution of broadband price after the log transformation

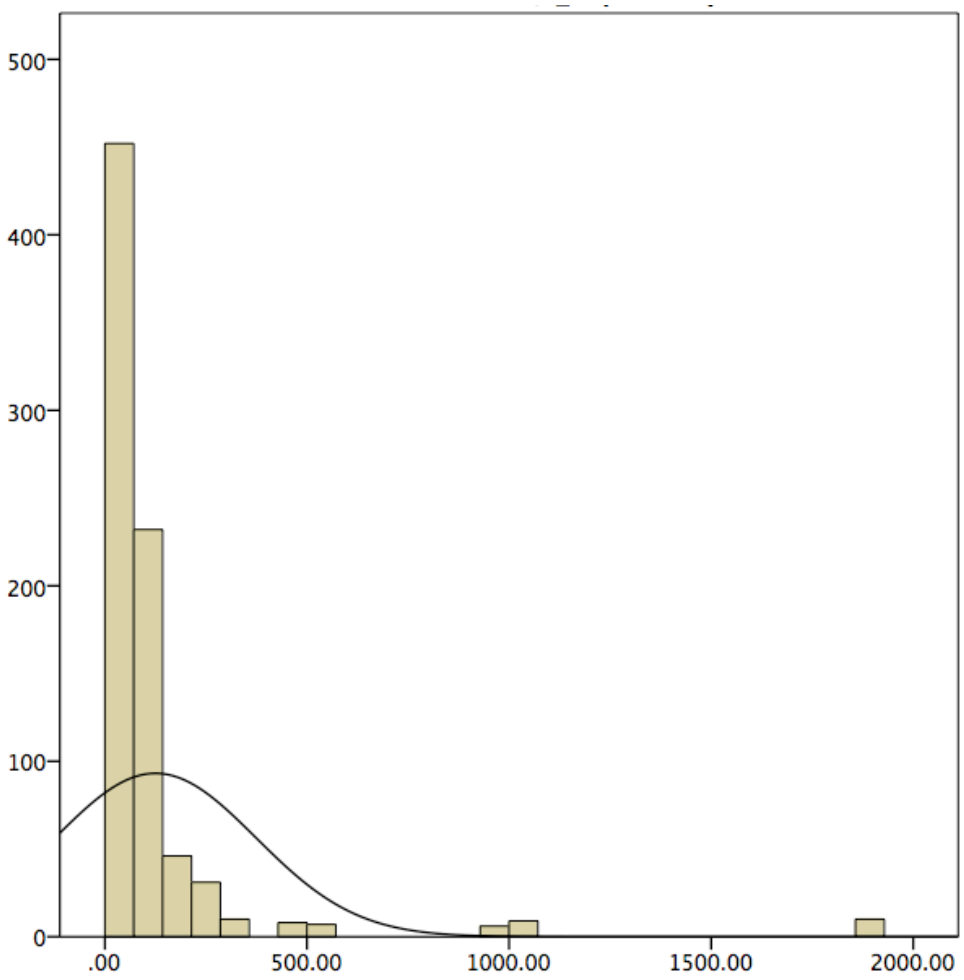

Figure 9: Distribution of population density before the log transformation

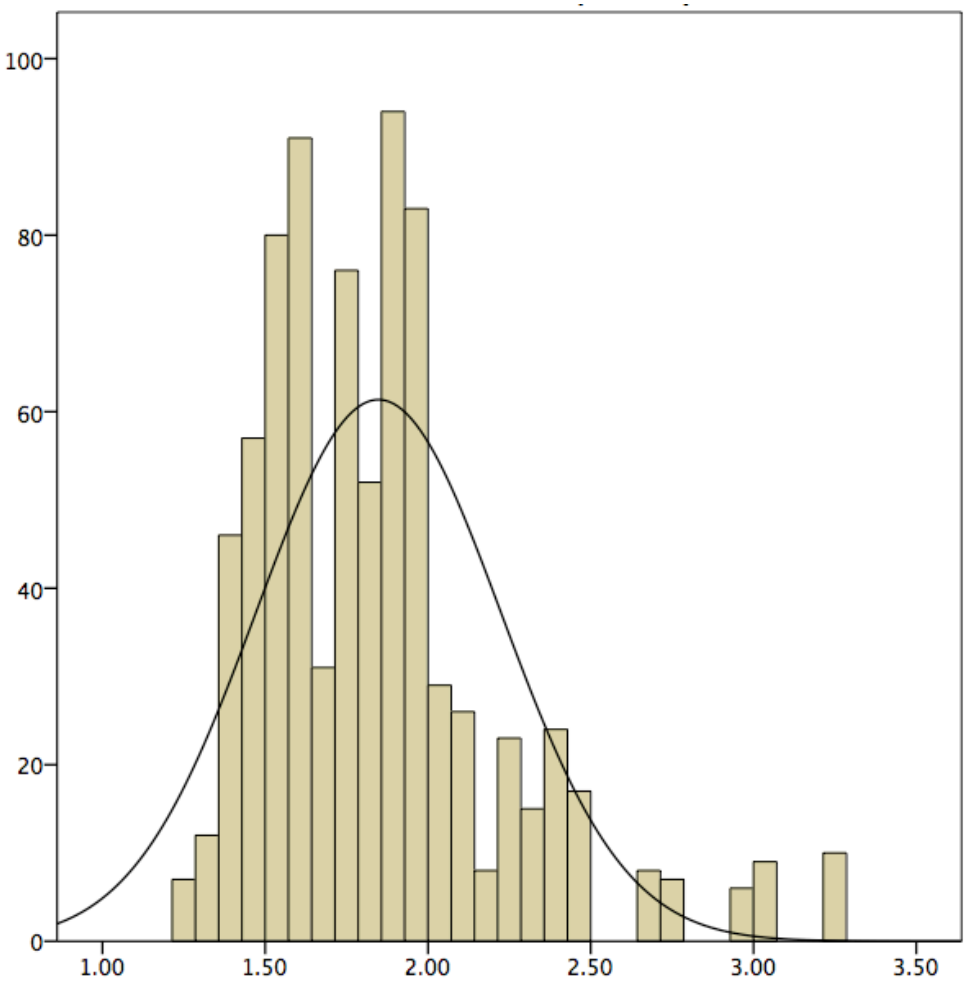

Figure 10: Distribution of population density after the log transformation

Descriptive Statistics

Descriptive statistics were generated for all dependent and independent variables. All data was based on the 811 cases. For the variables transformed, only transformed data was included throughout the results. The data is summarized in the following sections. The Frequency distribution and box plot were examined for each variable. The graphs reveal no significant violations of normality assumptions but do reveal potential concerns. A strict significance level was used in the analysis to ensure the validity of results.

PricePerMb (Dependent)

Descriptive statistics were conducted on the dependent variable, PricePerMb. Based on the 811 cases, the mean for PricePerMb was 0.2962 (SD=.5231). Table 3 shows the additional descriptive statistics PricePerMb, along with the scores for skewness and kurtosis.

Table 3: Descriptive Statistics for PricePerMb

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
PricePerMb	811	-1.10	1.65	0.2962	0.52307	-0.143	0.086	0.048	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was created for the variable as well as a boxplot. Both are found in Figure 11 and Figure 12, respectively. The boxplot revealed a few potential outliers, but based on the normality curve and previous analysis, the data was kept in the dataset. The data represented actual and accurate data points of PricePerMb from the population analyzed. In this instance, the outliers are the cases with very low broadband pricing on a per megabit basis. For example, in the case where a provider offers one gigabit broadband service for a comparable overall price to a provider offering fifty megabit service would be an outlier.

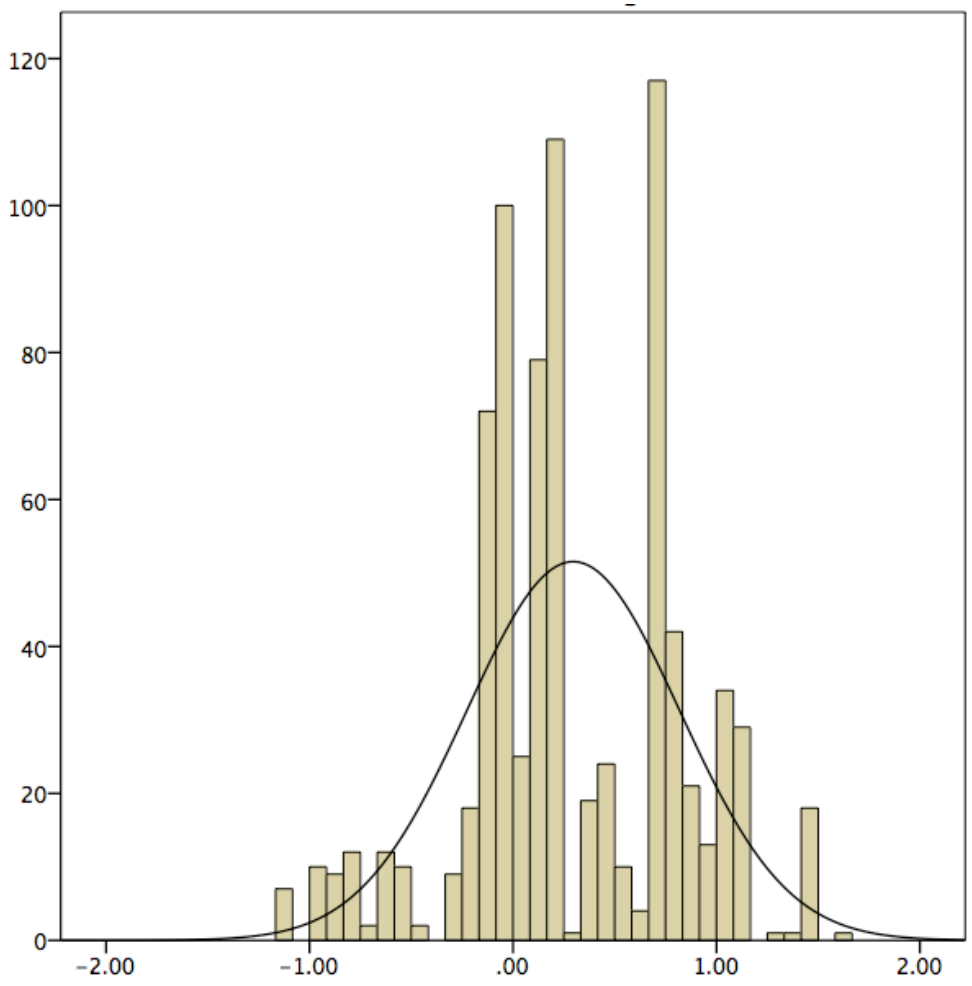

Figure 11: Histogram for PricePerMb

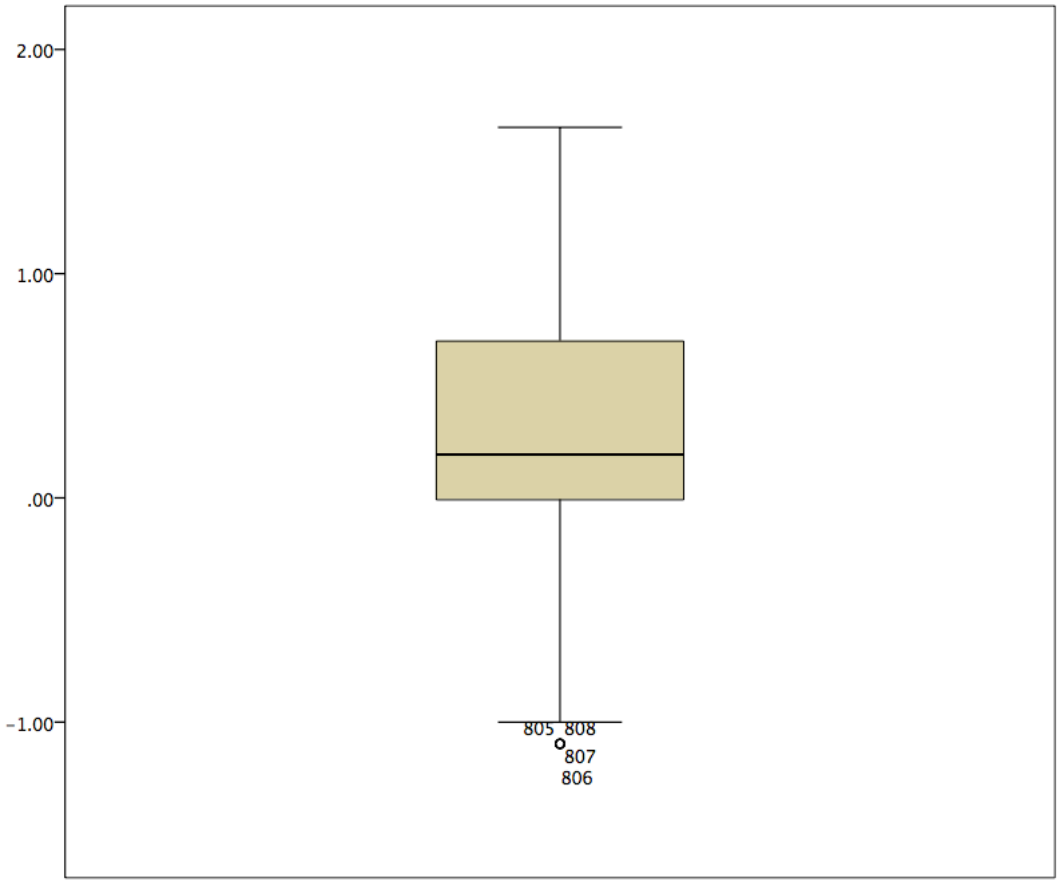

Figure 12: Boxplot for PricePerMb

PopDensity (Independent)

Descriptive statistics were conducted on the independent variable, PopDensity. Based on the 811 cases, the mean for PopDensity was 1.8479 (SD=.3766). Table 4 shows the additional descriptive statistics for PopDensity, along with the scores for skewness and kurtosis.

Table 4: Descriptive Statistics for PopDensity

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
PopDensity	811	1.2404	3.2736	1.8479	0.3766	1.396	0.086	2.526	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was created for the variable as well as a boxplot. Both are found in Figure 13 and Figure 14, respectively. The boxplot revealed a few potential outliers, but based on the normality curve and previous analysis, the data was kept in the dataset. The data represented actual and accurate data points of PopDensity from the population analyzed. In this instance, it was cases from counties where population density is very high.

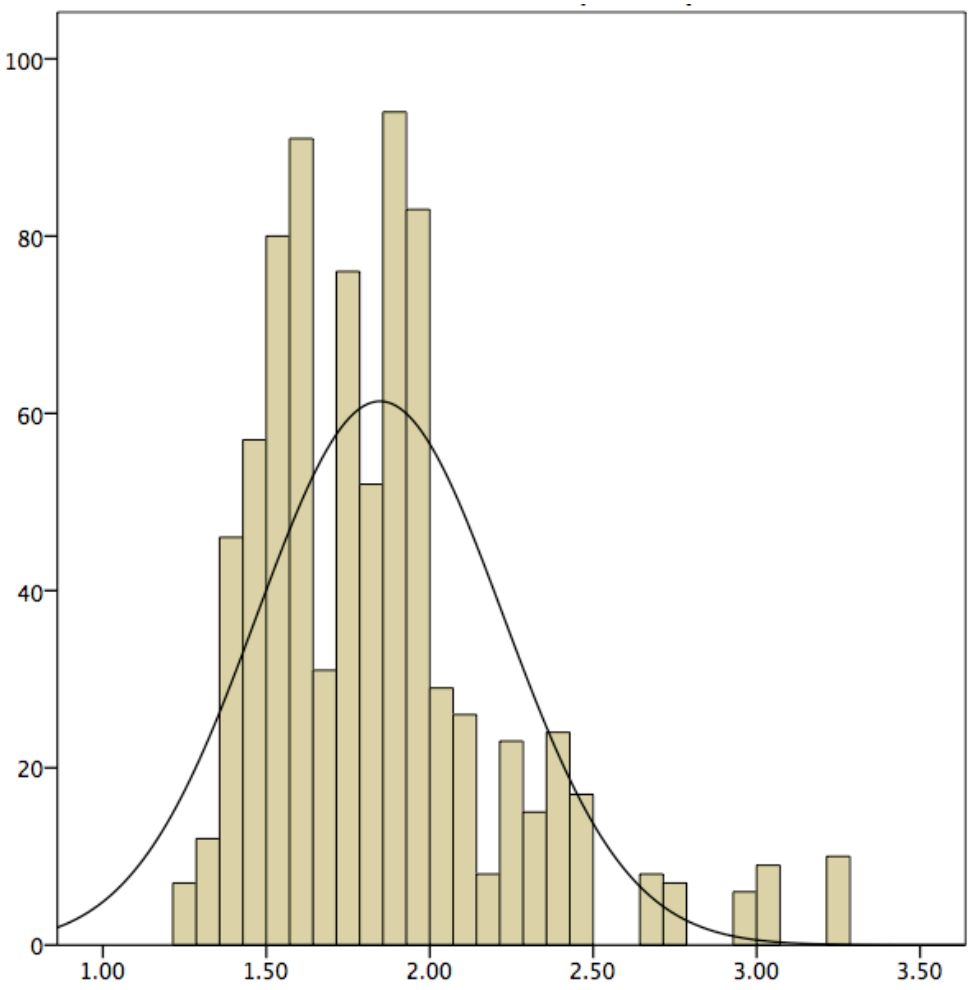

Figure 13: Histogram for PopDensity

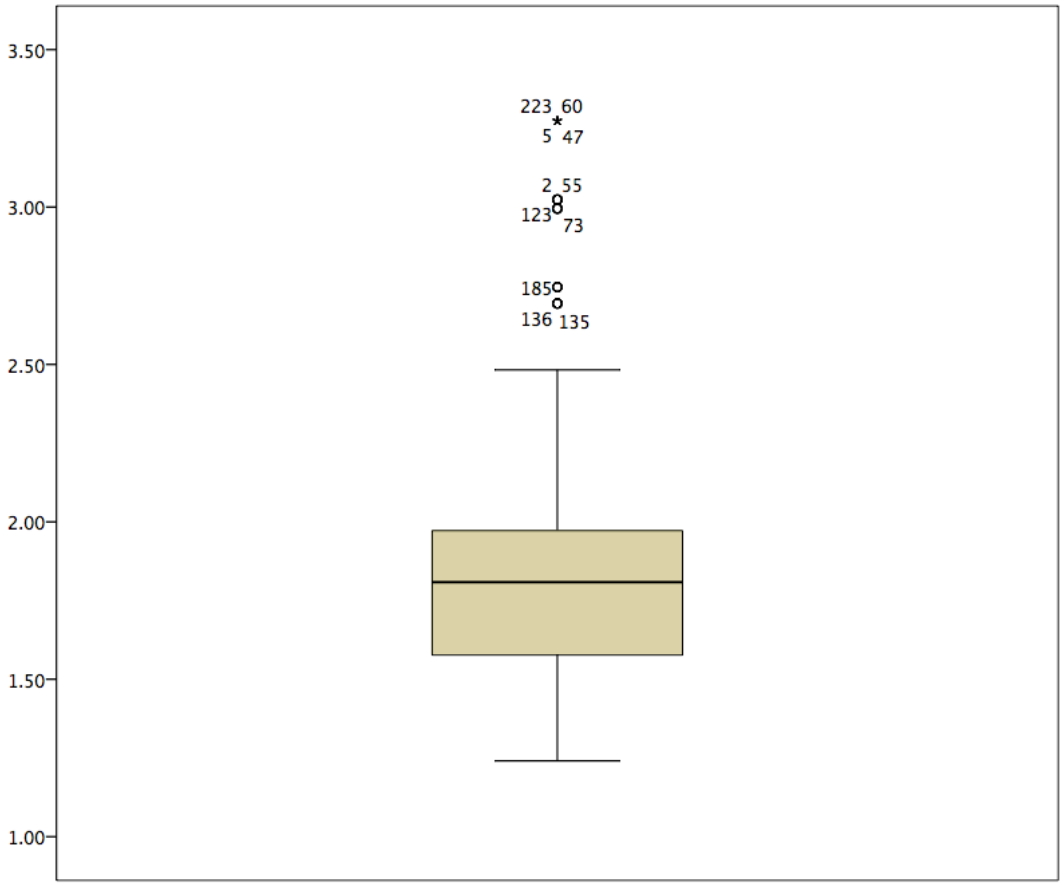

Figure 14: Box plot for PopDensity

Unemployment (Independent)

Descriptive statistics were conducted on the independent variable, Unemployment. Based on the 811 cases, the mean for Unemployment was 0.5.578 (SD=1.9145). Table 5 shows the additional descriptive statistics along with the scores for skewness and kurtosis.

Table 5: Descriptive Statistics for Unemployment

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Unemployment	811	2.90	13.50	5.578	1.9145	0.976	0.086	0.542	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was created for the variable, unemployment, as well as a boxplot. Both are found in Figure 15 and Figure 16, respectively. The boxplot revealed a few potential outliers, but based on the normality curve and previous analysis, the data was kept in the dataset. The data represented actual and accurate representation of unemployment from the population analyzed. In this instance, it was cases from counties where the unemployment rate was very high.

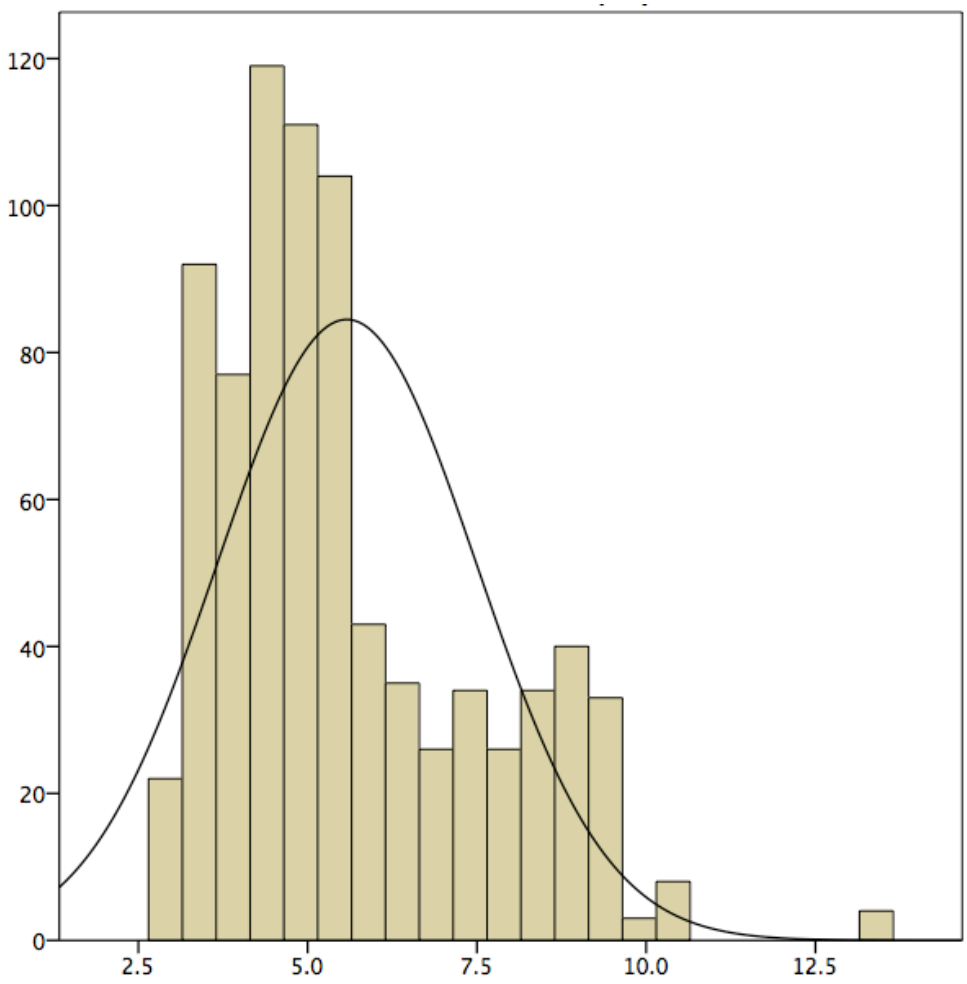

Figure 15: Histogram for Unemployment

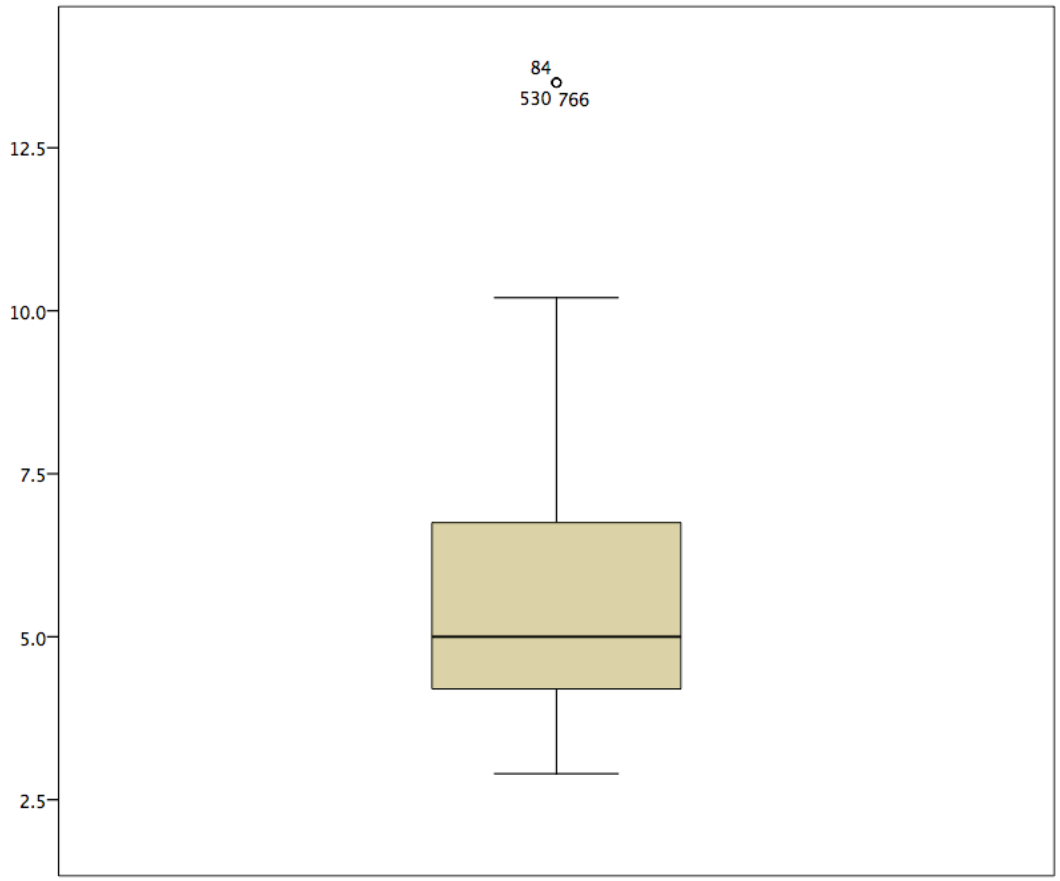

Figure 16: Box plot for Unemployment

ProviderCount (Independent)

Descriptive statistics were conducted on the dependent variable, ProviderCount. Based on the 811 cases, the mean for ProviderCount was 4.94 (SD= 1.578). Table 6 shows the additional descriptive statistics along with the scores for skewness and kurtosis.

Table 6: Descriptive Statistics for ProviderCount

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
ProviderCount	811	2	10	4.94	1.578	.710	0.086	0.851	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was conducted for the variable as well as a boxplot. Both are found in Figure 17 and Figure 18, respectively. The boxplot revealed a few potential outliers, but based on the normality curve and previous analysis, the data was kept in the dataset. The data represented actual and accurate representation of ProviderCount from the population analyzed. In the case of ProviderCount, it represents cases from areas with high broadband competition.

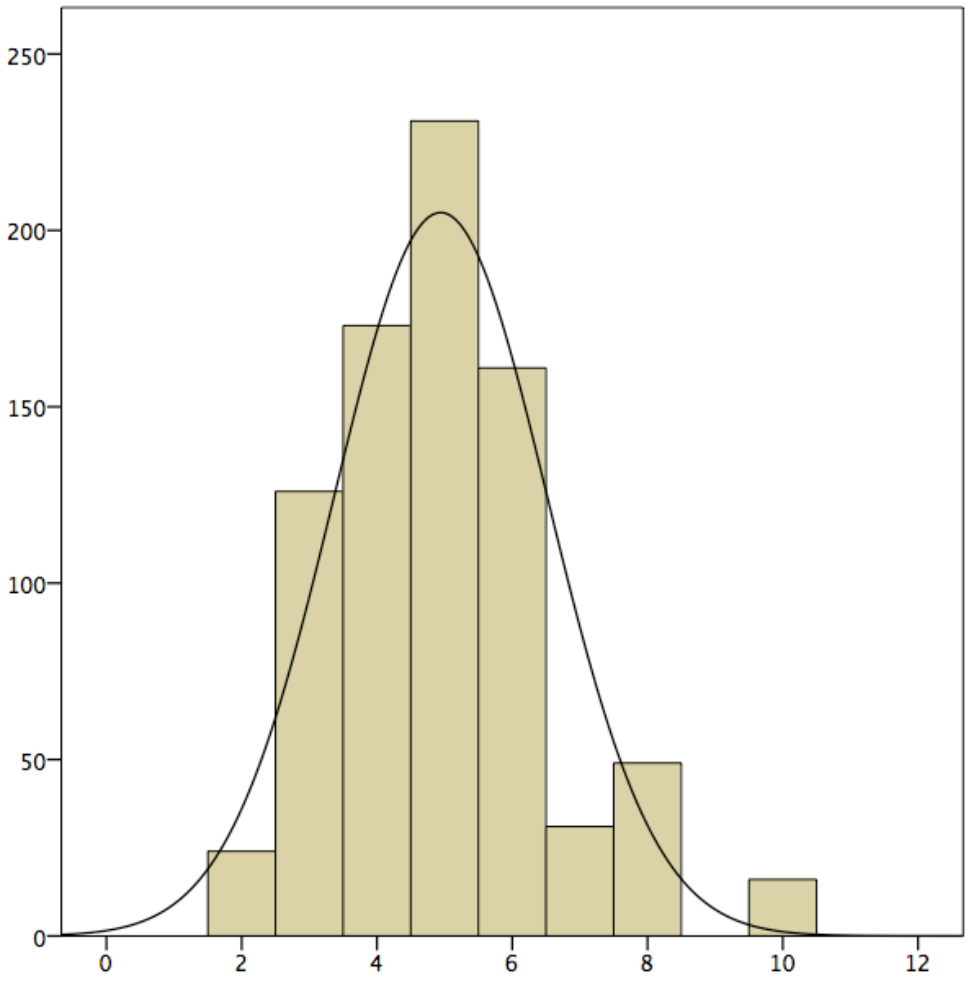

Figure 17: Histogram for ProviderCount

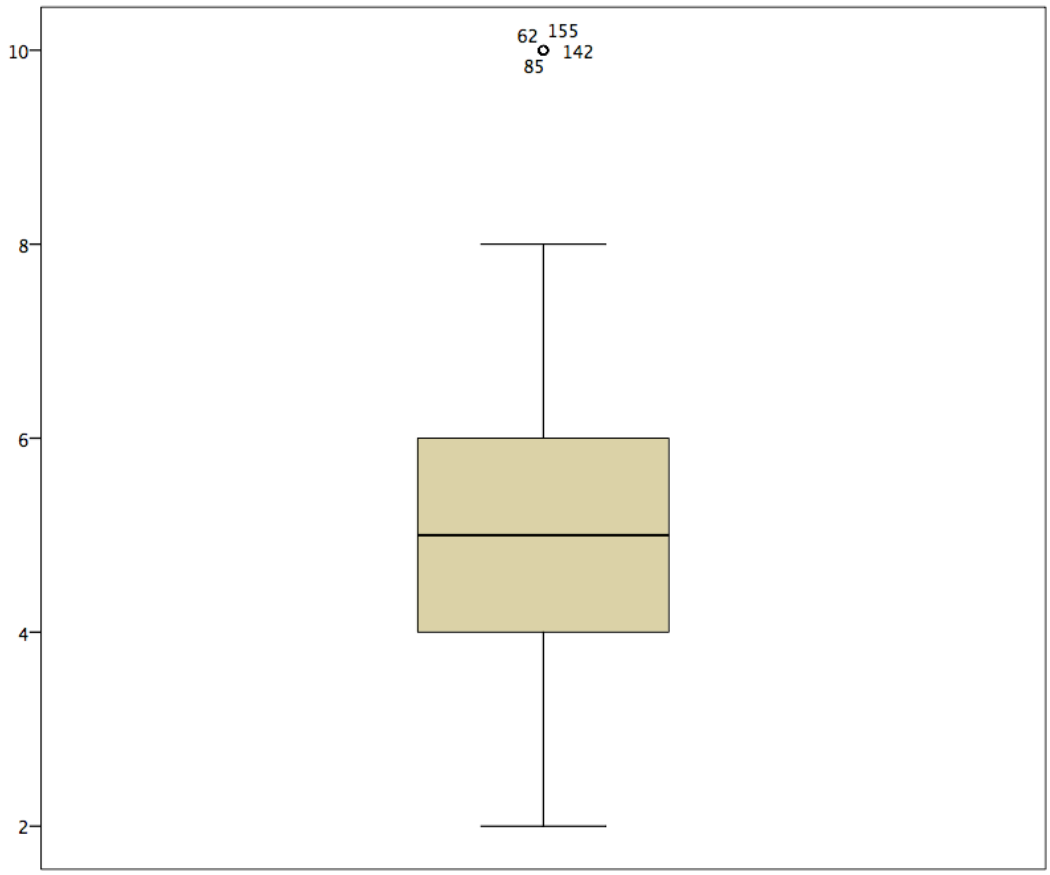

Figure 18: Box plot for ProviderCount

BBAvail (Independent)

Descriptive statistics were conducted on the independent variable, BBAvail. Based on the 811 cases, the mean for BBAvail was .92143 (SD=.1126). Table 7 shows the additional descriptive statistics along with the scores for skewness and kurtosis.

Table 7: Descriptive Statistics for BBAvail

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
BBAvail	811	0.304	1.000	0.9214	0.1126	-2.112	0.086	5.275	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was conducted for the variable as well as a boxplot. Both are found in Figure 19 and Figure 20, respectively. The boxplot revealed a few potential outliers, but based on the normality curve and previous analysis, the data was kept in the dataset. The data represented actual and accurate representation of BBAvail from the population analyzed. For broadband availability, there are a large number of cases near 100% and several cases with much lower broadband availability.

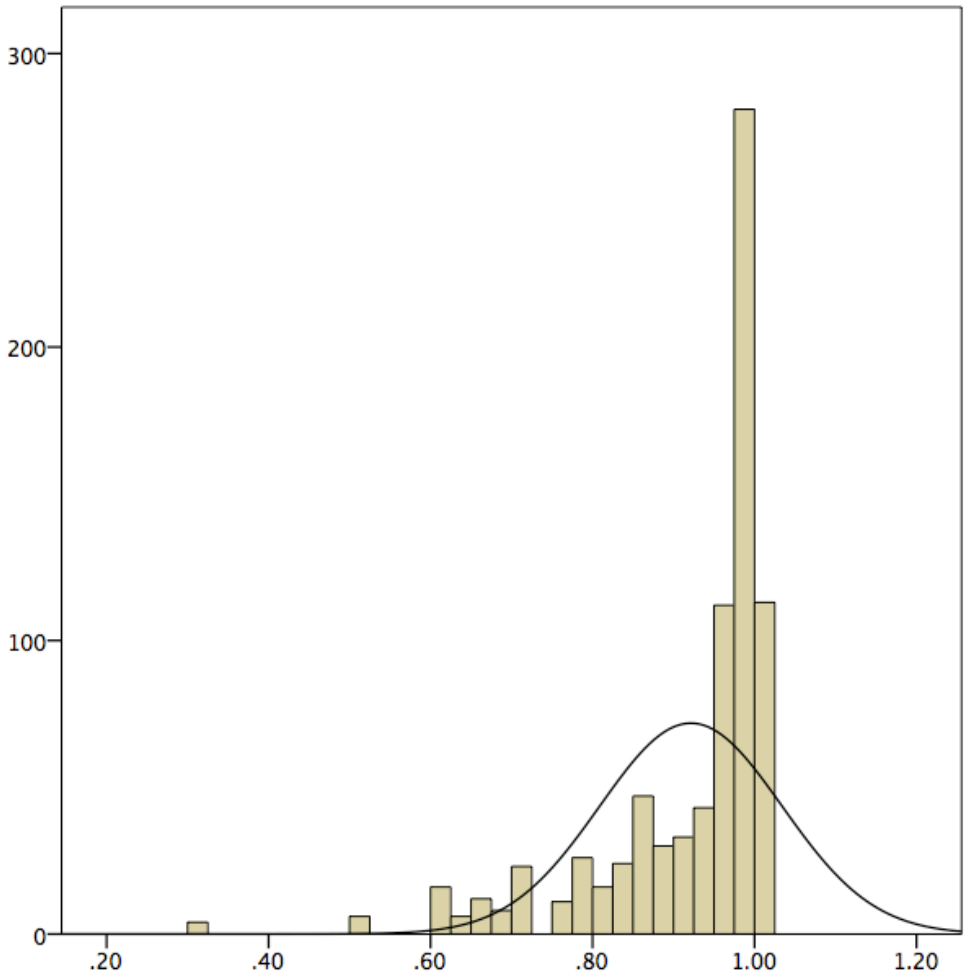

Figure 19: Histogram for BBAvail

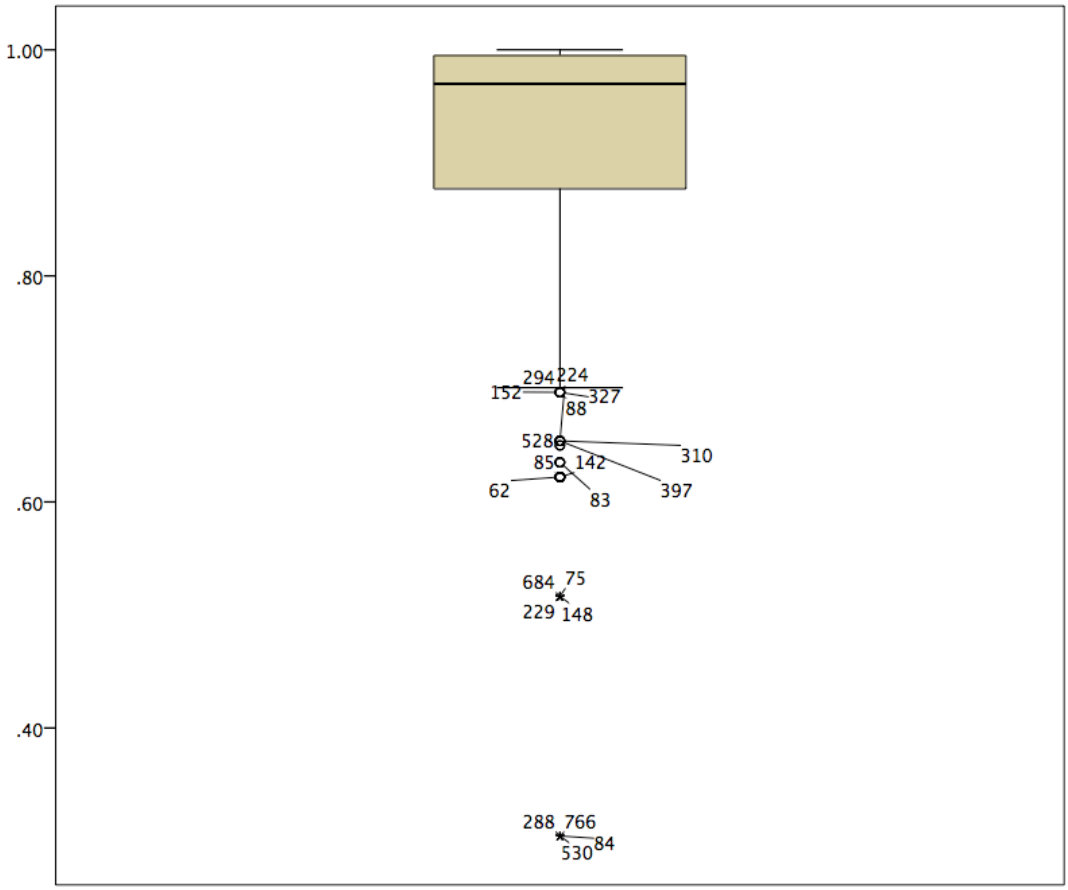

Figure 20: Box plot for BBAvail

MMCount (Independent)

Descriptive statistics were conducted on the dependent variable, MMCount. Based on the 811 cases, the mean for MMCount was 4.00 (SD=1.125). Table 8 shows the additional descriptive statistics along with the scores for skewness and kurtosis.

Table 8: Descriptive Statistics for MMCount

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
MMCount	811	2.00	8.00	4.00	1.250	0.942	0.086	1.474	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was conducted for the variable as well as a boxplot. Both are found in Figure 21 and Figure 22, respectively. The boxplot revealed no potential outliers.

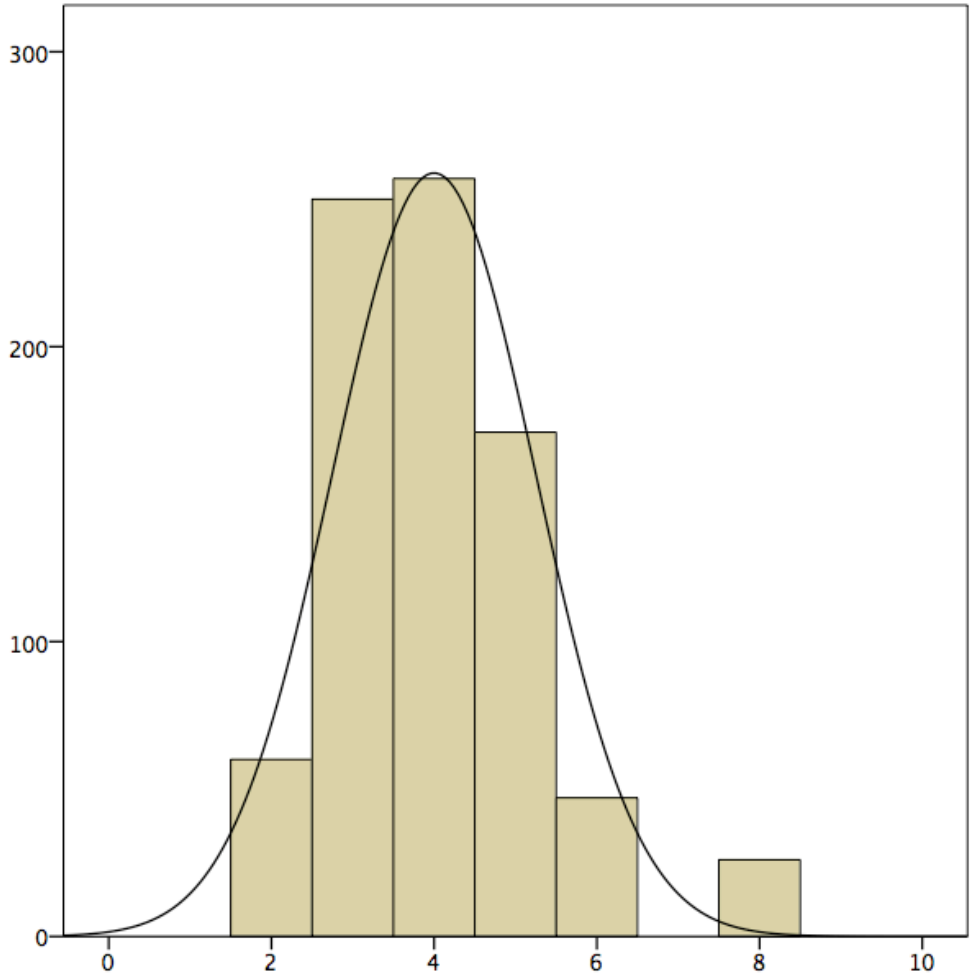

Figure 21: Histogram for MMCount

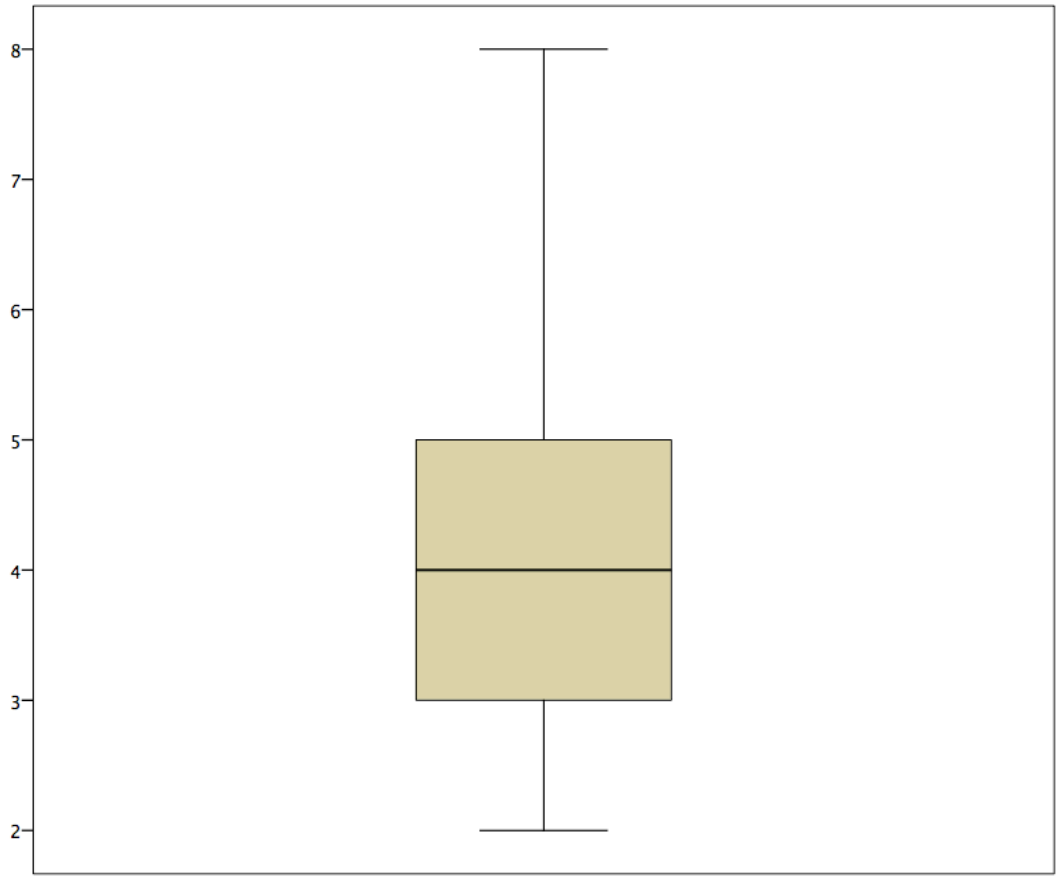

Figure 22: Box plot for MMCount

TechUsed (Independent)

Descriptive statistics were conducted on the dependent variable, TechUsed. Based on the 811 cases, the mean for TechUsed was 4.90 (SD= 2.518). Table 9 shows the additional descriptive statistics along with the scores for skewness and kurtosis.

Table 9: Descriptive Statistics for TechUsed

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
TechUsed	811	2.00	10.00	4.899	2.518	0.467	0.086	-0.979	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was created for the variable as well as a boxplot. Both are found in Figure 23 and Figure 24, respectively. The boxplot revealed no potential outliers.

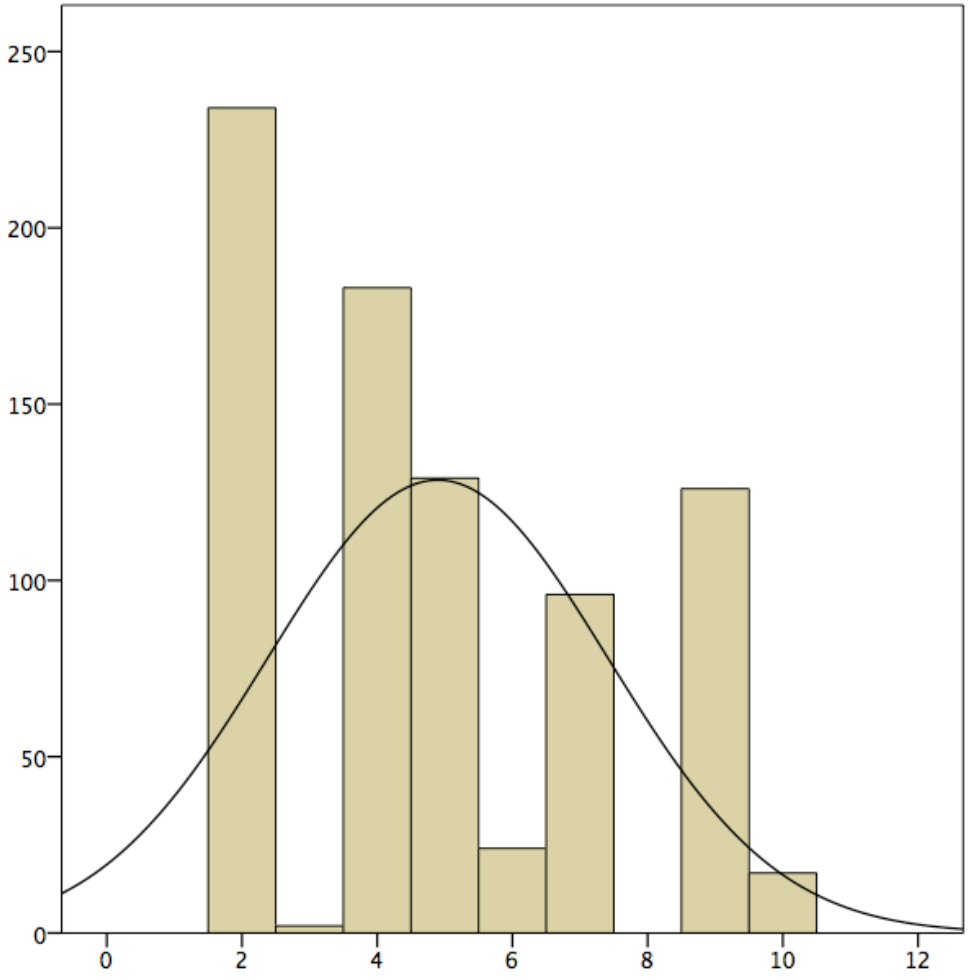

Figure 23: Histogram for TechUsed

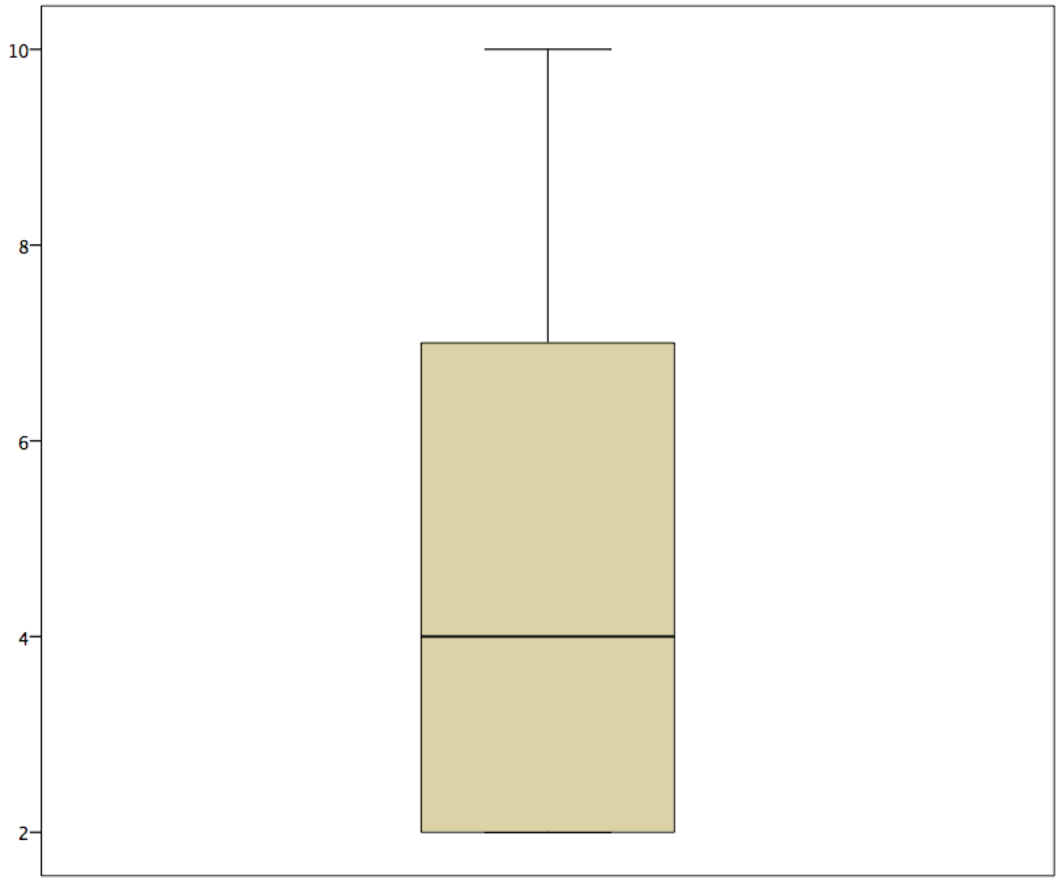

Figure 24: Box plot for TechUsed

ProviderType (Independent)

Descriptive statistics were conducted on the independent variable, ProviderType. Based on the 811 cases, the mean for ProviderType was 4.12 (SD=1.635). Table 10 shows the additional descriptive statistics along with the scores for skewness and kurtosis.

Table 10: Descriptive Statistics for ProviderType

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
ProviderType	811	1.00	6.00	4.12	1.635	-0.971	0.086	-0.352	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was created for the variable as well as a boxplot. Both are found in Figure 25 and Figure 26, respectively. The boxplot revealed a few potential outliers, but based on the normality curve and previous analysis, the data was kept in the dataset. The data represented actual and accurate representation of ProviderType from the population analyzed. In this instance, there are few cases with broadband providers of those types.

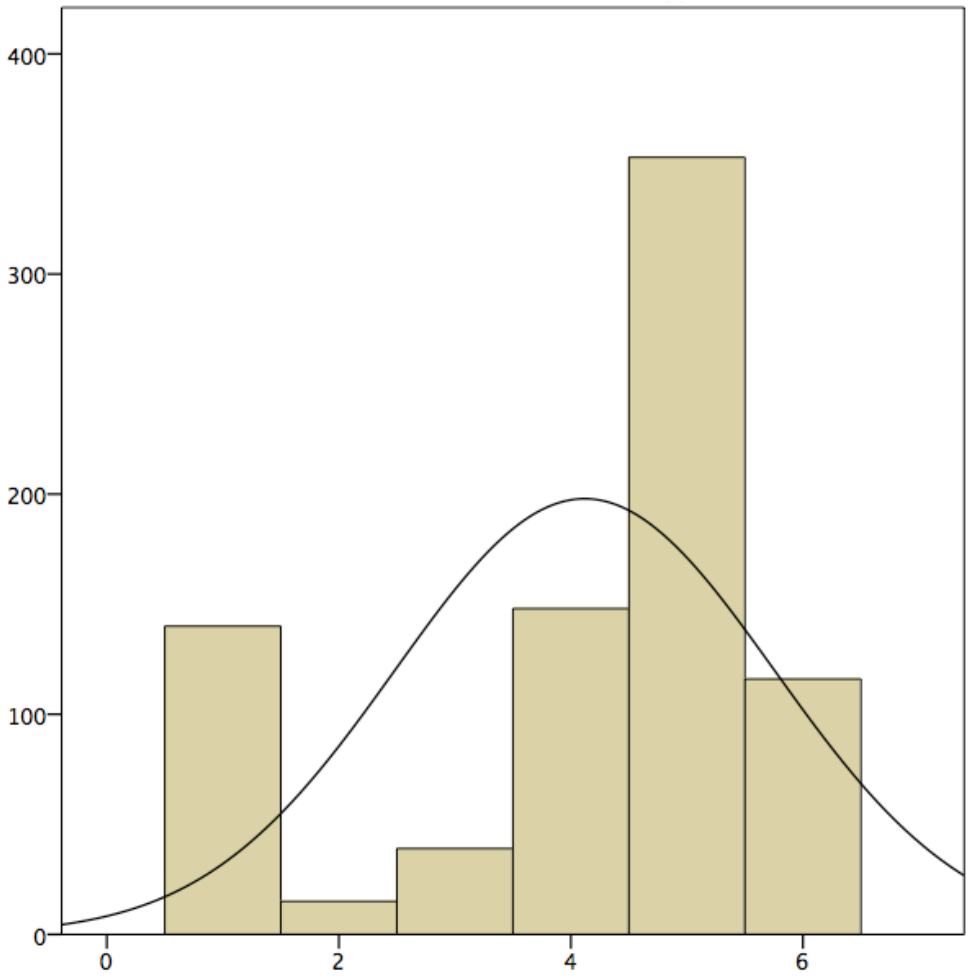

Figure 25: Histogram for ProviderType

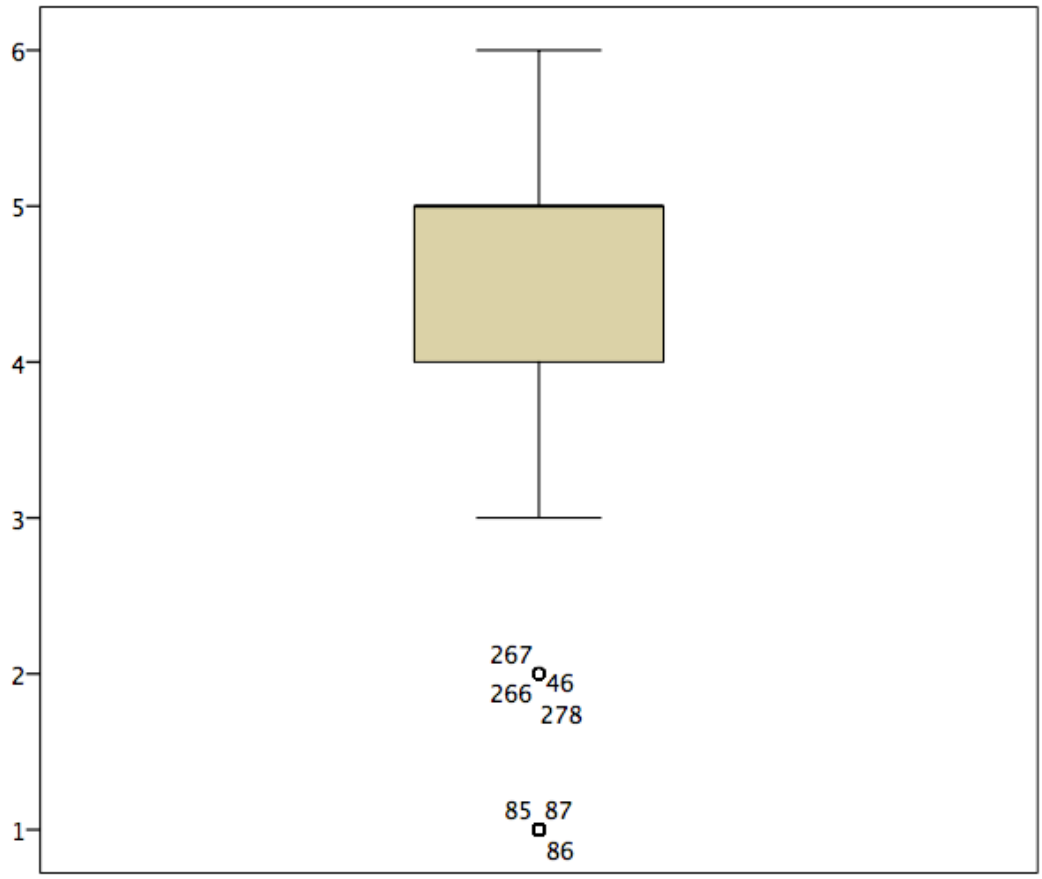

Figure 26: Box plot for ProviderType

DownloadSpeedTier (Independent)

Descriptive statistics were conducted on the dependent variable, DownloadSpeedTier. Based on the 811 cases, the mean for DownloadSpeedTier was 7.52 (SD= 1.823). Table 11 shows the additional descriptive statistics along with the scores for skewness and kurtosis.

Table 11: Descriptive Statistics for DownloadSpeedTier

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
DownloadSpeed Tier	811	3.00	11.00	7.52	1.823	-0.362	0.086	-1.036	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was created for the variable as well as a boxplot. Both are found in Figure 27 and Figure 28, respectively. The boxplot revealed no potential outliers.

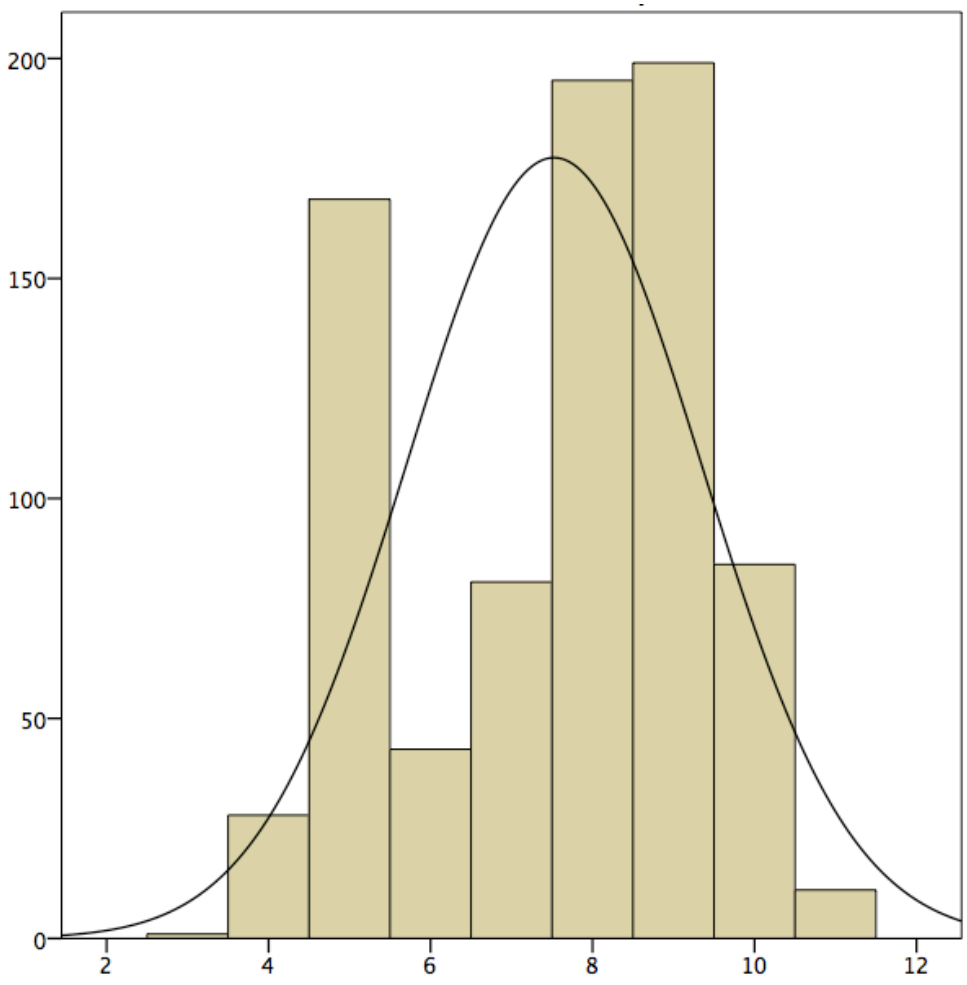

Figure 27: Histogram for DownloadSpeedTier

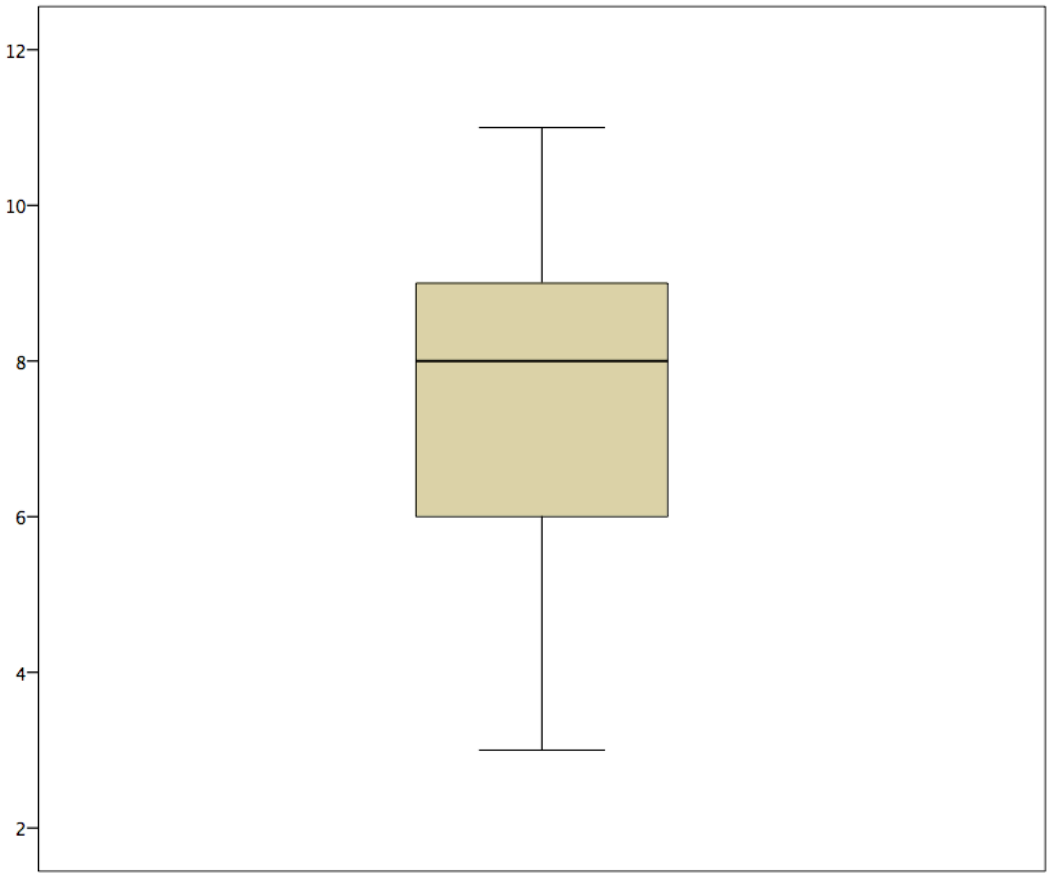

Figure 28: Box plot for DownloadSpeedTier

UploadSpeedTier (Independent)

Descriptive statistics were conducted on the independent variable, UploadSpeedTier. Based on the 811 cases, the mean for UploadSpeedTier was 4.43 (SD= 2.223). Table 12 shows the additional descriptive statistics along with the scores for skewness and kurtosis.

Table 12: Descriptive Statistics for UploadSpeedTier

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
UploadSpeed Tier	811	1.00	11.00	4.43	2.223	1.321	0.086	1.040	0.171
Valid N (listwise)	811								

Additionally, a frequency chart with a normality curve overlaid was created for the variable as well as a boxplot. Both are found in Figure 29 and Figure 30, respectively. The boxplot revealed a few potential outliers, but based on the normality curve and previous analysis, the data was kept in the dataset. The data represented actual and accurate representation of UploadSpeedTier from the population analyzed. For UploadSpeedTier, the outliers are from those cases where the advertised upload speed is much higher than the typical provider.

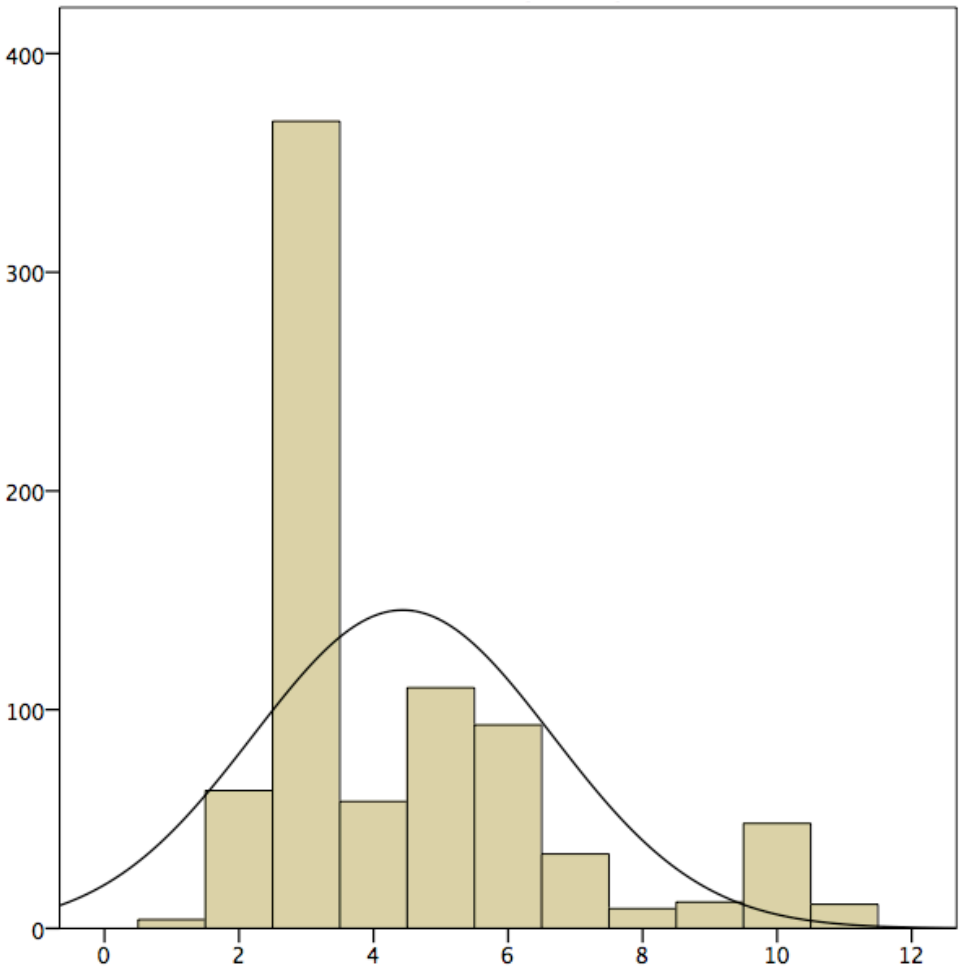

Figure 29: Histogram for UploadSpeedTier

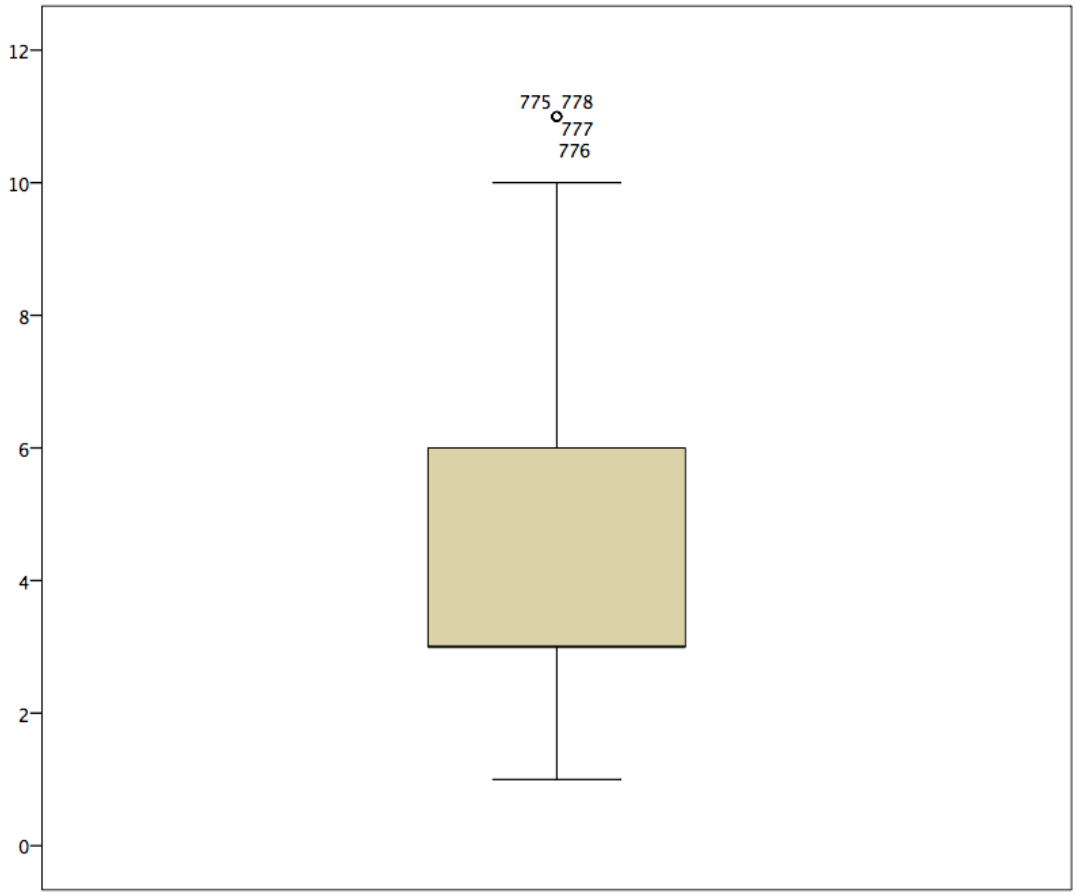

Figure 30: Box plot for UploadSpeedTier

Correlation Analysis

A Pearson product-moment correlation coefficient was computed for each setup to assess the relationship between each independent variable and the dependent variable. For each set of variables, a scatter plot was created to represent the potential relationship visually. These tests address the research questions Q1-Q10. The following section provides the results for each set of correlation tests.

Q1: Advertised price for last mile versus population density

A Pearson product-moment correlation coefficient was computed between the dependent variable, PricePerMb, and the independent variable PopDensity, assessing the relationship of the

price of last mile residential broadband service and the population density of a county. The analysis corresponds to Research Question 1. The results revealed no significant correlation at the 0.01 confidence level between the two variables with r = -0.014, n = 811, p = 0.698. The correlation results are shown in Table 13. Additionally, the scatterplot between the two variables is shown in Figure 31, which summarizes the results.

Table 13: Correlation Results for PricePerMb v. PopDensity

		PricePerMb	PopDensity
PricePerMb	Pearson Correlation	1	-0.014
	Sig. (2-tailed)		0.698
	N	811	811
PopDensity	Pearson Correlation	-0.014	1
	Sig. (2-tailed)	0.698	
	N	811	811

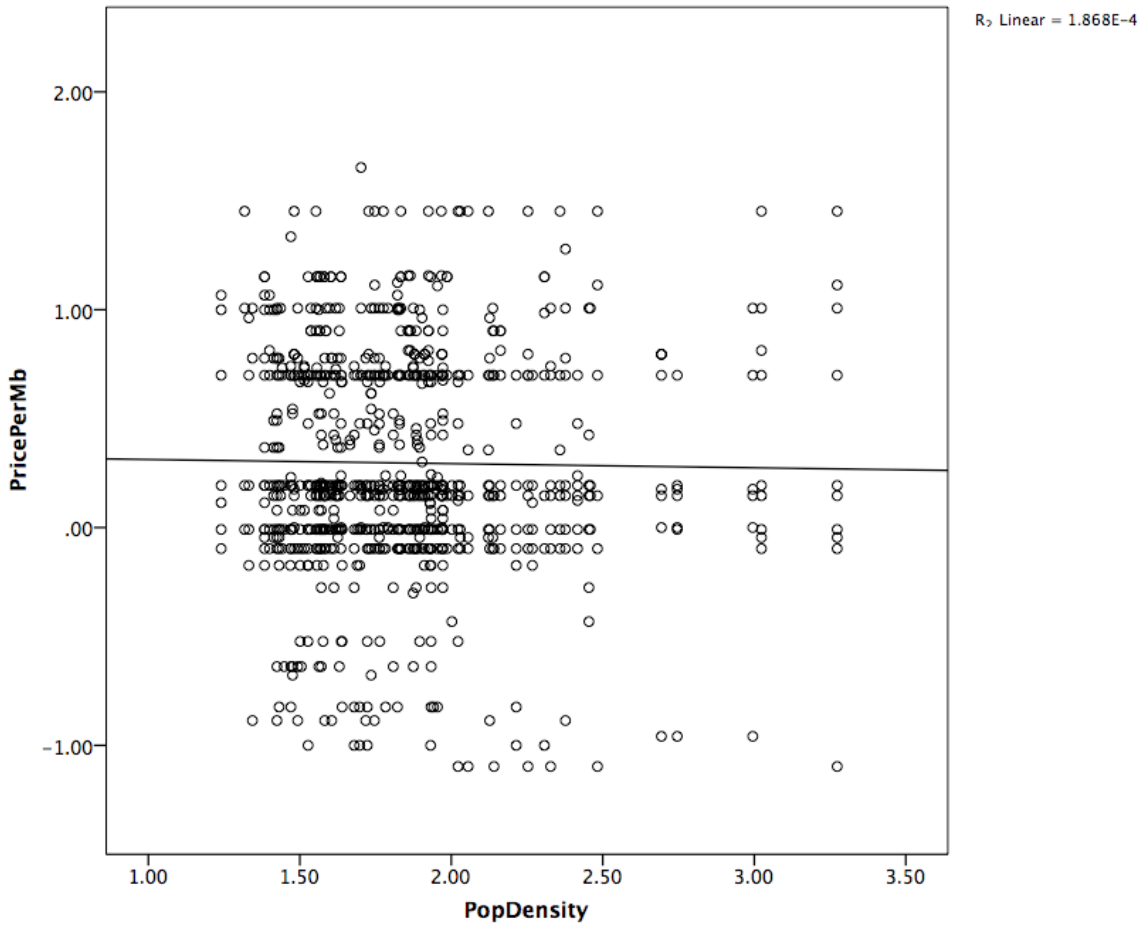

Figure 31: Scatterplot of PricePerMb v. PopDensity

Q2: Advertised price for last mile versus Unemployment

A Pearson product-moment correlation coefficient was computed between the dependent variable, PricePerMb, and the independent variable Unemployment, assessing the relationship of the price of last mile residential broadband service and the unemployment rate of a county. The analysis corresponds to Research Question 2. The results revealed no significant correlation at the 0.01 confidence level between the two variables with r = -0.066, n = 811, p = 0.062. The correlation results are shown in Table 14. Additionally, the scatterplot between the two variables is shown in Figure 32, which summarizes the results.

Table 14: Correlation Results for PricePerMb v. Unemployment

		PricePerMb	Unemployment
PricePerMb	Pearson Correlation	1	-0.066
	Sig. (2-tailed)		0.062
	N	811	811
Unemployment	Pearson Correlation	-0.066	1
	Sig. (2-tailed)	0.062	
	N	811	811

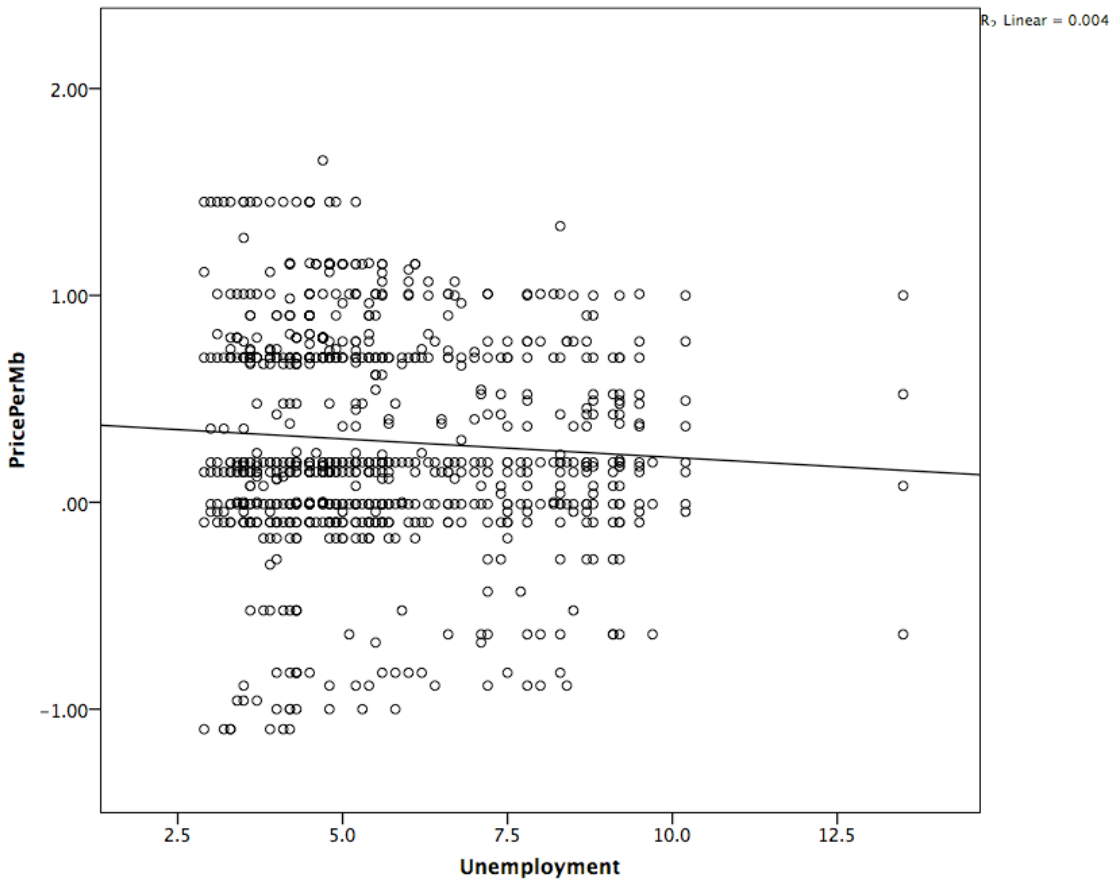

Figure 32: Scatterplot of PricePerMb v. Unemployment

Q3: Advertised price for last mile versus ProviderCount

A Pearson product-moment correlation coefficient was computed between the dependent variable, PricePerMb, and the independent variable ProviderCount, assessing the relationship of the price of last mile residential broadband service and the number of broadband providers in a county. The analysis corresponds to Research Question 3. The results revealed no significant correlation at the 0.01 confidence level between the two variables with r = 0.082, n = 811, p = 0.02. The correlation results are shown in Table 15. Additionally, the scatterplot between the two variables is shown in Figure 33, which summarizes the results.

Table 15: Correlation Results for PricePerMb v. ProviderCount

		PricePerMb	ProviderCount
PricePerMb	Pearson Correlation	1	0.082
	Sig. (2-tailed)		0.020
	N	811	811
ProviderCount	Pearson Correlation	0.082	1
	Sig. (2-tailed)	0.020	
	N	811	811

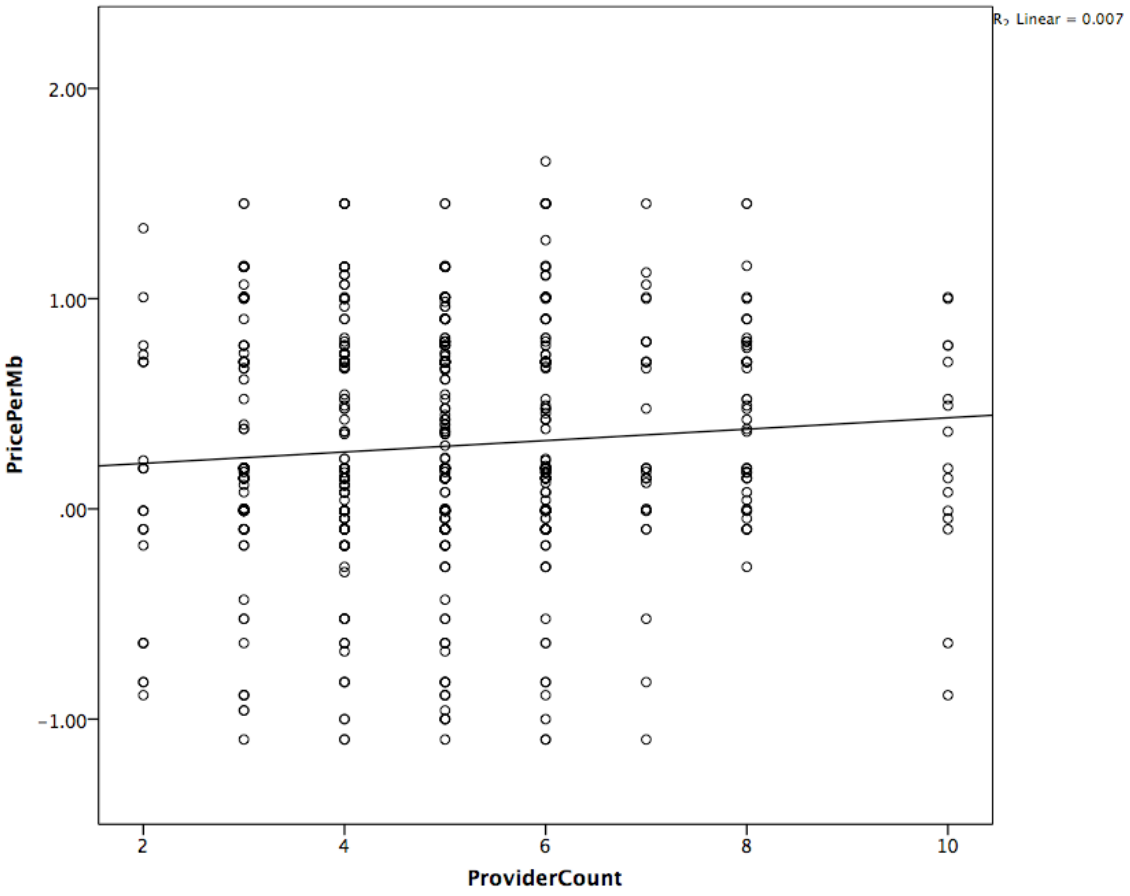

Figure 33: Scatterplot of PricePerMb v. ProviderCount

Q4: Advertised price for last mile versus BBAvail

A Pearson product-moment correlation coefficient was computed between the dependent variable, PricePerMb, and the independent variable BBAvail, assessing the relationship of the price of last mile residential broadband service and the broadband availability in a county. The analysis corresponds to Research Question 4. The results revealed no significant correlation at the 0.01 confidence level between the two variables with r = 0.045, n = 811, p = 0.199. The correlation results are shown in Table 16. Additionally, the scatterplot between the two variables is shown in Figure 34, which summarizes the results.

Table 16: Correlation Results for PricePerMb v. BBAvail

		PricePerMb	BBAvail
PricePerMb	Pearson Correlation	1	0.045
	Sig. (2-tailed)		0.199
	N	811	811
BBAvail	Pearson Correlation	0.045	1
	Sig. (2-tailed)	0.199	
	N	811	811

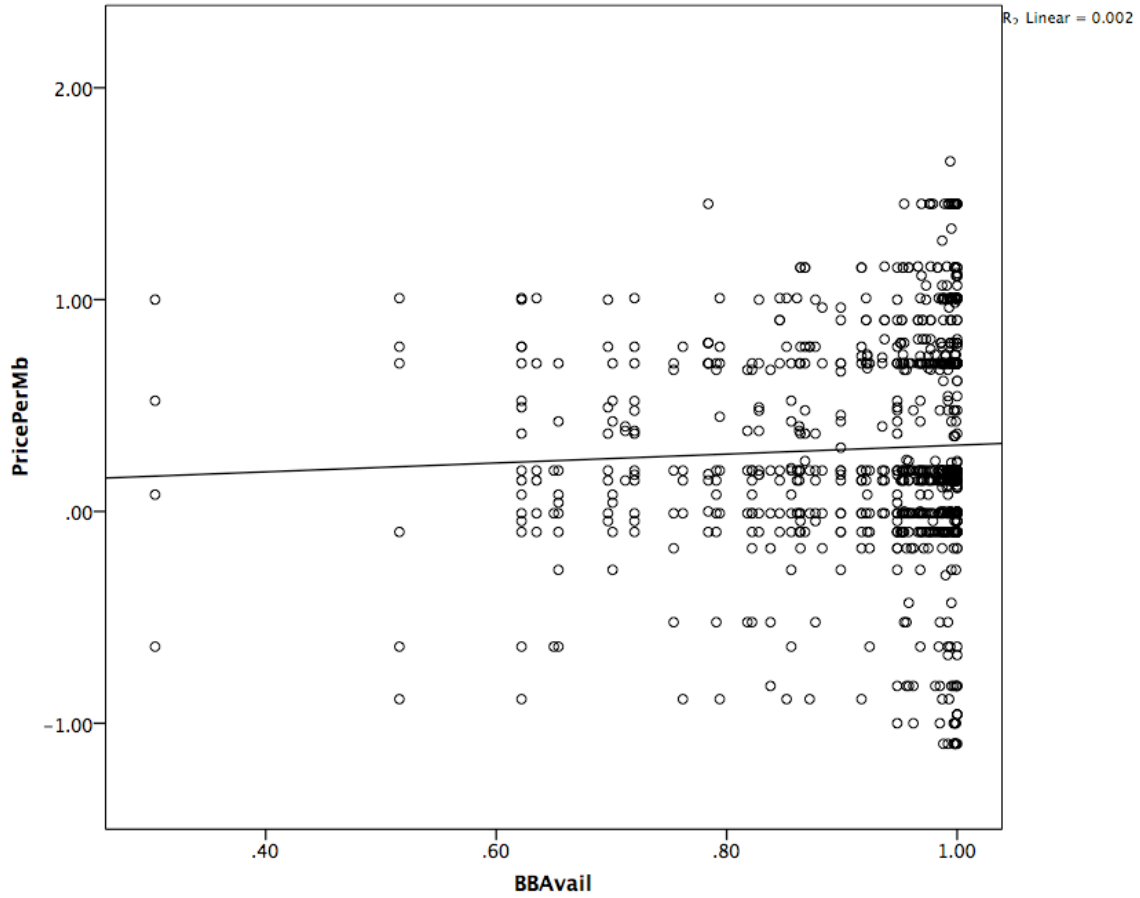

Figure 34: Scatterplot of PricePerMb v. BBAvail

Q5: Advertised price for last mile versus MMCount

A Pearson product-moment correlation coefficient was computed between the dependent variable, PricePerMb, and the independent variable MMCount, assessing the relationship of the

price of last mile residential broadband service and the number of middle mile broadband providers in a county. The analysis corresponds to Research Question Q5. The results revealed a statistically significant correlation at the 0.01 confidence level with a slight negative correlation between the two variables, $r = -0.129$, $n = 811$, $p < 0.001$. The correlation results are shown in Table 17. With a coefficient of determination (R^2) value of just 0.017, the two variables have only a very slight correlation at 1.7%. Additionally, the scatterplot between the two variables is shown in Figure 35, which summarizes the results.

Table 17: Correlation Results for PricePerMb v. MMCount

		PricePerMb	MMCount
PricePerMb	Pearson Correlation	1	-0.129
	Sig. (2-tailed)		0.000
	N	811	811
MMCount	Pearson Correlation	-0.129	1
	Sig. (2-tailed)	0.000	
	N	811	811

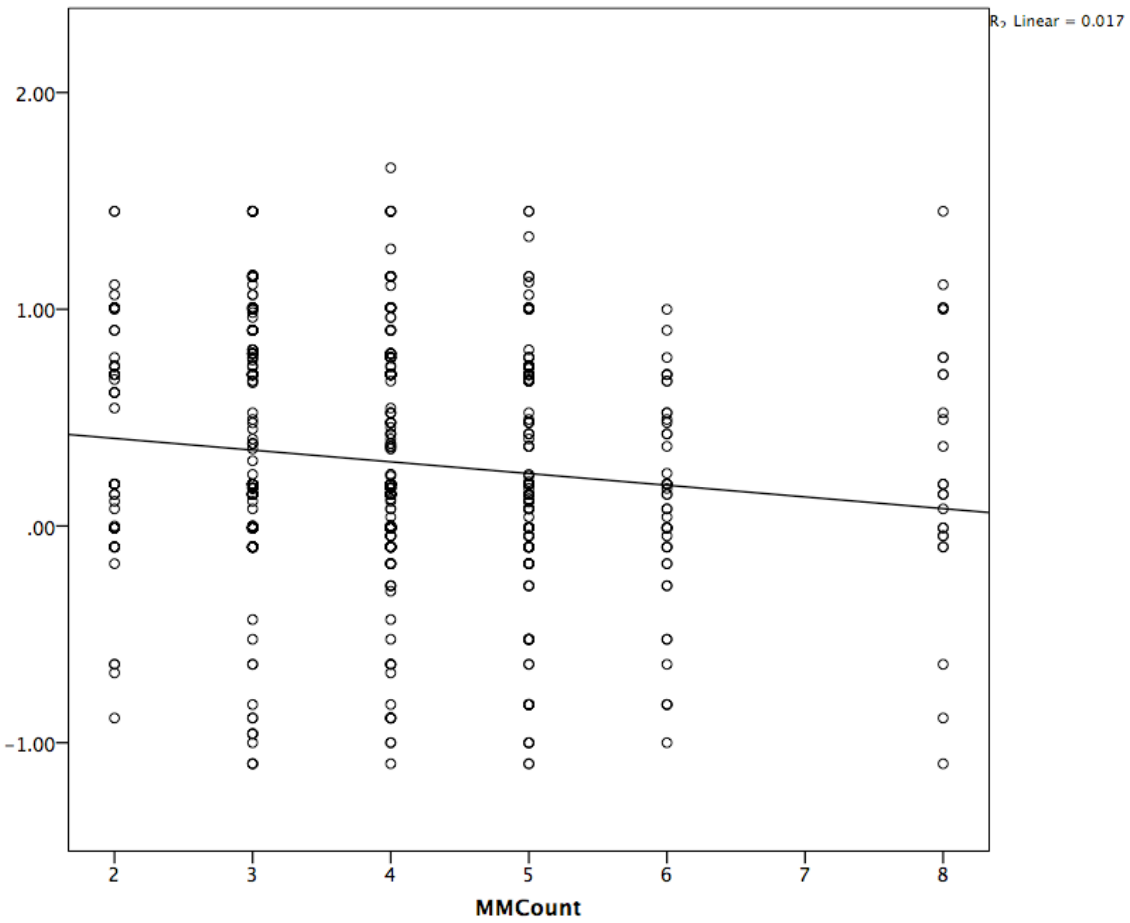

Figure 35: Scatterplot of PricePerMb v. MMCount

Q6: Advertised price for last mile versus Actual Broadband Speeds

As previously stated, Research Question Q6 was eliminated due to lack of data across all providers and counties in Kentucky.

Q7: Advertised price for last mile versus TechUsed

A Pearson product-moment correlation coefficient was computed between the dependent variable, PricePerMb, and the independent variable TechUsed, assessing the relationship of the price of last mile residential broadband service and the technology deployed by a provider. The analysis corresponds to Research Question Q7. The results revealed a statistically significant correlation at the 0.01 confidence level between the two variables with a slight positive

correlation, r = 0.187, n = 811, p < 0.001. The correlation results are shown in Table 18. With a R^2 value of just 0.035, the two variables have only a slight correlation at 3.5%. Additionally, the scatterplot between the two variables is shown in Figure 36, which summarizes the results.

Table 18: Correlation Results for PricePerMb v. TechUsed

		PricePerMb	TechUsed
PricePerMb	Pearson Correlation	1	0.187
	Sig. (2-tailed)		0.000
	N	811	811
TechUsed	Pearson Correlation	0.187	1
	Sig. (2-tailed)	0.000	
	N	811	811

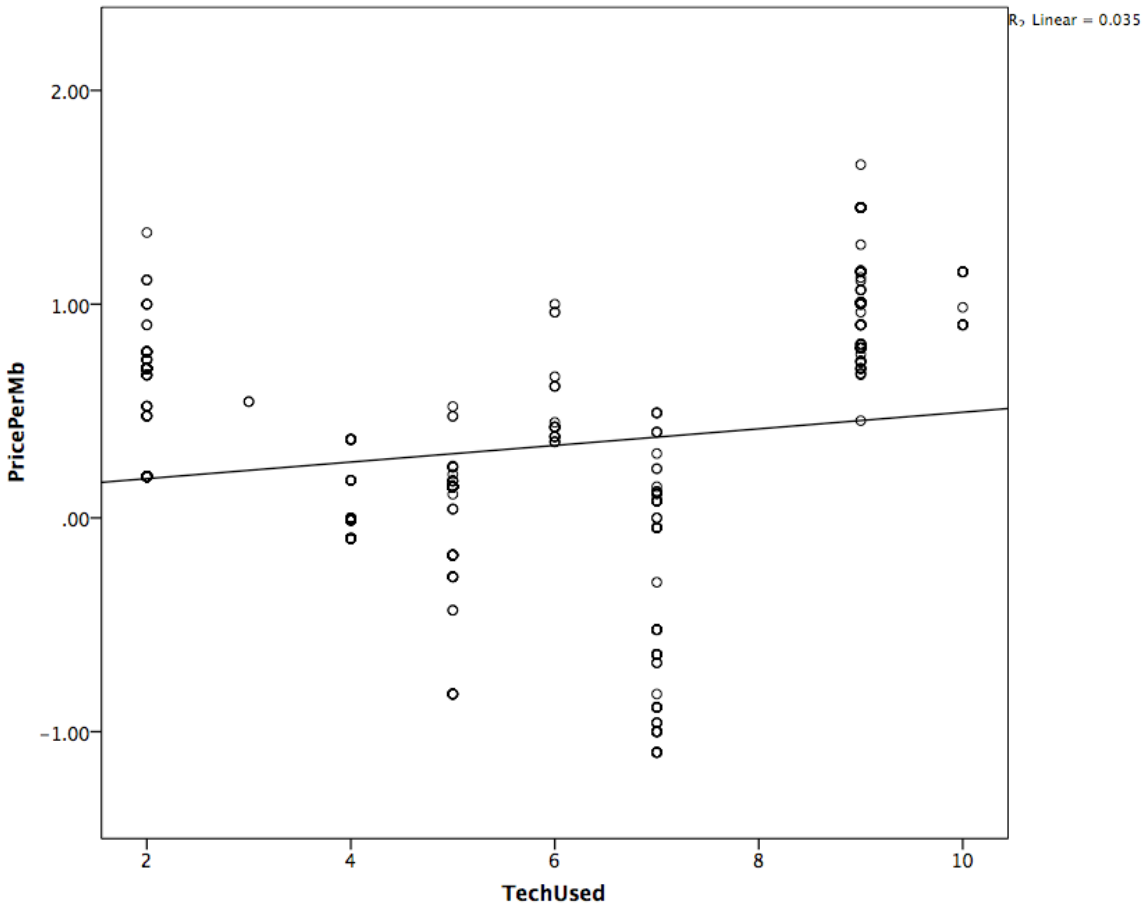

Figure 36: Scatterplot of PricePerMb v. TechUsed

Q8: Advertised price for last mile versus ProviderType

A Pearson product-moment correlation coefficient was computed between the dependent variable, PricePerMb, and the independent variable ProviderType, assessing the relationship of the price of last mile residential broadband service and the type of provider. The analysis corresponds to Research Question Q8. The results revealed a statistically significant correlation at the 0.01 confidence level between the two variables with a slight negative correlation, r = -0.102, n = 811, p = 0.004. The correlation results are shown in Table 19. With a R^2 value of just 0.010, the two variables have only a very slight correlation at 1.0%. Additionally, the scatterplot between the two variables is shown in Figure 37, which summarizes the results.

Table 19: Correlation Results for PricePerMb v. ProviderType

		PricePerMb	ProviderType
PricePerMb	Pearson Correlation	1	-0.102
	Sig. (2-tailed)		0.004
	N	811	811
ProviderType	Pearson Correlation	-0.102	1
	Sig. (2-tailed)	0.004	
	N	811	811

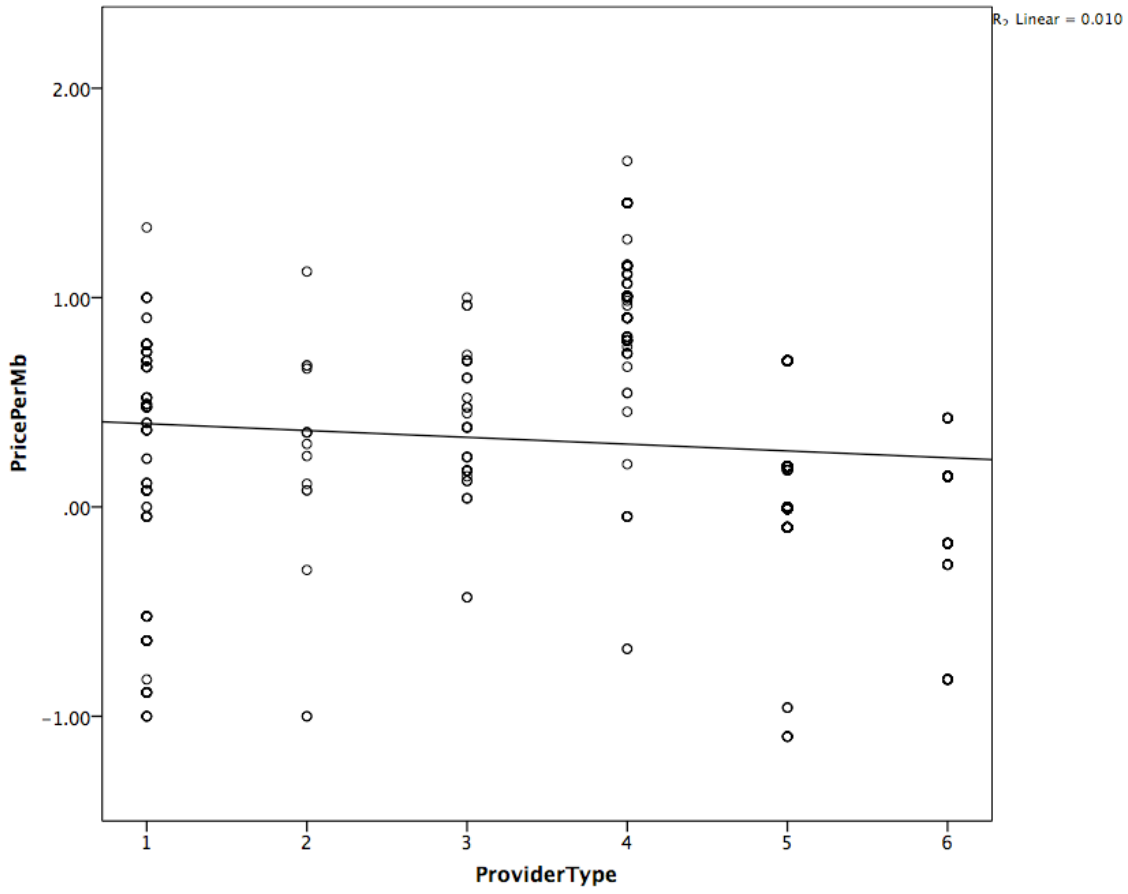

Figure 37: Scatterplot of PricePerMb v. ProviderType

Q9: Advertised price for last mile versus DownloadSpeedTier

A Pearson product-moment correlation coefficient was computed between the dependent variable, PricePerMb, and the independent variable DownloadSpeedTier, assessing the

relationship of the price of last mile residential broadband service and the download broadband speed tier offered by the provider. The analysis corresponds to Research Question Q9. The results revealed a statistically significant correlation at the 0.01 confidence level between the two variables with a strong negative correlation, $r = -0.927$, $n = 811$, $p < 0.001$. The correlation results are shown in Table 20. With a R^2 value of just 0.859, the two variables have a strong correlation at 85.9%. Additionally, the scatterplot between the two variables is shown in Figure 38, which summarizes the results.

Table 20: Correlation Results for PricePerMb v. DownloadSpeedTier

		PricePerMb	DownloadSpeedTier
PricePerMb	Pearson Correlation	1	-0.927
	Sig. (2-tailed)		0.000
	N	811	811
DownloadSpeedTier	Pearson Correlation	-0.927	1
	Sig. (2-tailed)	0.000	
	N	811	811

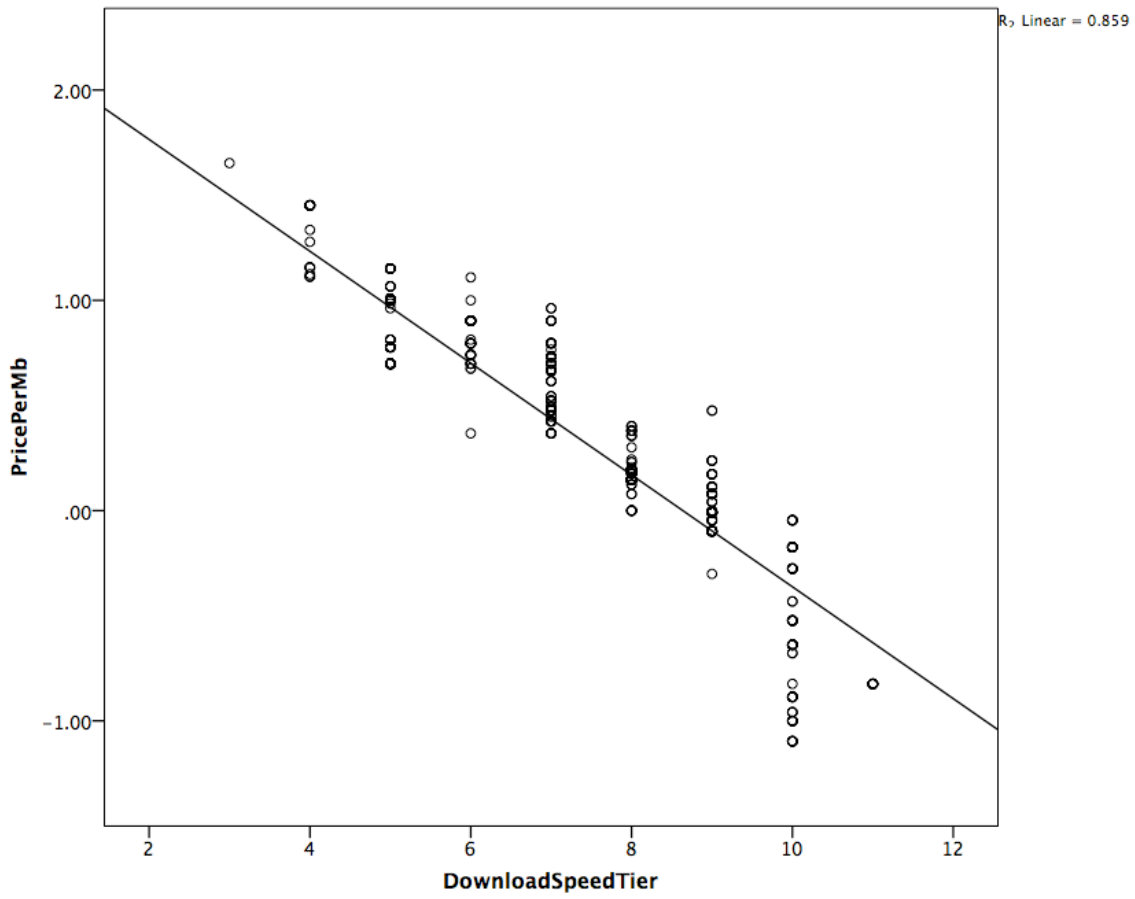

Figure 38: Scatterplot of PricePerMb v. DownloadSpeedTier

Q10: Advertised price for last mile versus UploadSpeedTier

A Pearson product-moment correlation coefficient was computed between the dependent variable, PricePerMb and the independent variable UploadSpeedTier, assessing the relationship of the price of last mile residential broadband service and the upload broadband speed tier offered by the provider. The analysis corresponds to Research Question Q10. The results revealed a statistically significant correlation at the 0.01 confidence level between the two variables with a strong negative correlation, $r = -0.741$, $n = 811$, $p < 0.001$. The correlation results are shown in Table 21. With a R^2 value of just 0.549, the two variables have a strong

correlation at 54.9%. Additionally, the scatterplot between the two variables is shown in Figure 39, which summarizes the results.

Table 21: Correlation Results for PricePerMb v. UploadSpeedTier

		PricePerMb	UploadSpeedTier
PricePerMb	Pearson Correlation	1	-0.741
	Sig. (2-tailed)		0.000
	N	811	811
UploadSpeedTier	Pearson Correlation	-0.741	1
	Sig. (2-tailed)	0.000	
	N	811	811

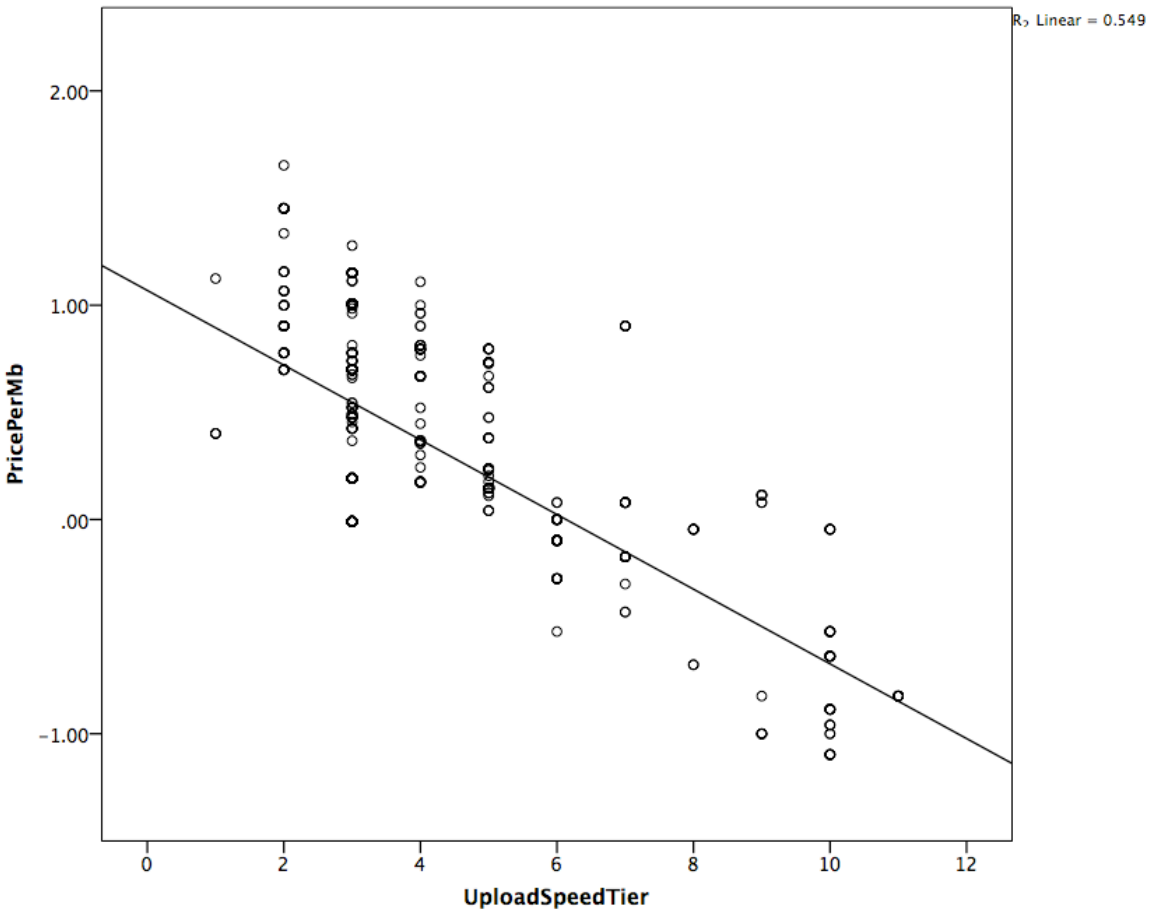

Figure 39: Scatterplot of PricePerMb v. UploadSpeedTier

Regression Analysis

Research Question 11 investigated the contributions to PricePerMb from each of the independent variables, found to have a significant correlation between itself and the dependent variable. Stepwise multiple linear regression was utilized to predict PricePerMb, the dependent variable, from the group of independent variables.

As previously noted, there was a concern with the model fit, which was addressed by transforming the PricePerMb, dependent variable, and PopDensity, independent variable. An additional concern with the regression assumptions was that the variables DownloadSpeedTier and UploadSpeedTier were correlated. To alleviate that concern, a new variable was created called SpeedTier, which was a simple sum of the two variables.

A scatter plot was created to verify the assumption of homoscedasticity comparing the regression standardized predicted value to the regression standardized residuals. The scatterplot reveals no overarching patterns to cause concern and the regression analysis can continue, as shown in Figure 40.

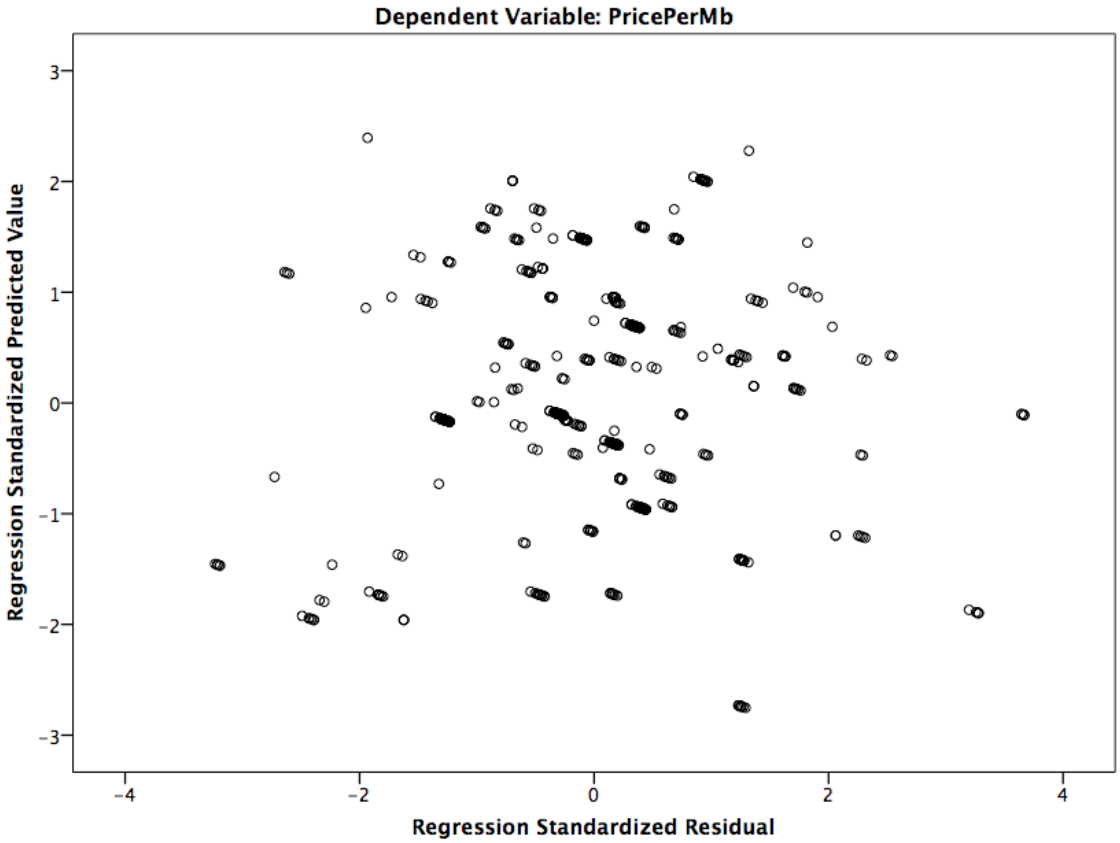

Figure 40: Scatterplot of standardized predicted value v. residuals

The model summary is shown below in Table 22 and ANOVA information in Table 23. Utilizing Model Number 3, a significant regression model was found ($F(3, 807) = 2011.520$, $p < 0.001$, with an R^2 of 0.882. The model included the following variables: SpeedTier, TechUsed, and ProviderType. The R^2 and adjusted R^2 value reveals that 88.2% of the dependent variable PricePerMb can be predicted from the four independent variables used.

Table 22: Regression Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.898*	0.807	0.807	0.23008
2	0.935**	0.875	0.875	0.18523
3	0.939***	0.882	0.882	0.17998

* Predictors: (Constant), SpeedTier

** Predictors: (Constant), SpeedTier, TechUsed

*** Predictors: (Constant), SpeedTier, TechUsed, ProviderType

**** Dependent Variable: PricePerMb

Table 23: ANOVA Results

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	178.794	1	178.794	3377.371	0.000*
	Residual	42.828	809	0.053		
	Total	221.622	810			
2	Regression	193.899	2	96.950	2825.682	0.000**
	Residual	27.723	808	0.034		
	Total	221.622	810			
3	Regression	195.480	3	65.160	2011.52	0.000***
	Residual	26.142	807	0.032		
	Total	221.622	810			

* Predictors: (Constant), SpeedTier

** Predictors: (Constant), SpeedTier, TechUsed

*** Predictors: (Constant), SpeedTier, TechUsed, ProviderType

**** Dependent Variable: PricePerMb

The coefficients for the model are summarized in Table24. Using Model Number 3, the constant for PricePerMb is 1.707. The contribution from SpeedTier is -0.130, from TechUsed is 0.051 and from ProviderType is -0.027. The proposed model is included in Chapter 5.

Table 24: Model Coefficient Contributions

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.809	0.027		66.371	0.000	1.755	1.862
	SpeedTier	-0.126	0.002	-0.898	-58.115	0.000	-0.131	-0.122
2	(Constant)	1.578	0.025		64.328	0.000	1.530	1.626
	SpeedTier	-0.129	0.002	-0.92	-73.658	0.000	-0.133	-0.126
	TechUsed	0.054	0.003	0.262	20.982	0.000	0.049	0.059
3	(Constant)	1.707	0.030		56.581	0.000	1.648	1.767
	SpeedTier	-0.130	0.002	-0.921	-75.897	0.000	-0.133	-0.125
	TechUsed	0.051	0.003	0.248	20.150	0.000	0.046	0.056
	ProviderType	-0.027	0.004	-0.086	-6.986	0.000	-0.035	-0.200

* Dependent Variable: PricePerMb

Chapter Summary

The chapter presented the statistical results corresponding to the research questions. There were statistically significant correlations found for the variables: MMCount, TechUsed, ProviderType, DownloadSpeedTier, and UploadSpeedTier. The results revealed a regression model using three variables: TechUsed, ProviderType, and a combined variable, SpeedTier.

CHAPTER 5

CONCLUSIONS AND DISCUSSION

Introduction

This research project examined the last mile price of residential fixed broadband across the 120 counties in the Commonwealth of Kentucky. The objective was to examine the extent to which community and provider-related supply and demand factors impact non-promotional advertised price of last mile broadband service. Furthermore, the goal was to reveal if any have a correlation to the actual price of broadband seen by users and whether a potential model can be developed to predict the price of broadband.

Conclusions on the Research Hypotheses

Null Hypothesis 1

There will be no statistically significant difference between the advertised price for last mile residential broadband service and population density.

Conclusion 1

Pearson Correlation results, shown in Chapter 4, indicate that there is no statistically significant correlation between the last mile price of broadband service and population density. The results revealed no significant correlation at the 0.01 confidence level between the two variables with $r = -0.014$, $n = 811$, $p = 0.698$. Therefore, Null Hypothesis 1 is accepted.

Null Hypothesis 2

There will be no statistically significant difference between the advertised price for last mile residential broadband service and the unemployment rate.

Conclusion 2

Pearson Correlation results, shown in Chapter 4, indicate that there is no statistically significant correlation between the last mile price of broadband service and the unemployment rate. The results revealed no significant correlation at the 0.01 confidence level between the two variables with $r = -0.066$, $n = 811$, $p = 0.062$. Therefore, Null Hypothesis 2 is accepted.

Null Hypothesis 3

There will be no statistically significant difference between the advertised price for last mile residential broadband service and the number of providers.

Conclusion 3

Pearson Correlation results, shown in Chapter 4, indicate that there is no statistically significant correlation between the last mile price of broadband service and the number of providers. The results revealed no significant correlation at the 0.01 confidence level between the two variables with $r = 0.082$, $n = 811$, $p = 0.02$. Therefore, Null Hypothesis 3 is accepted.

Null Hypothesis 4

There will be no statistically significant difference between the advertised price for last mile residential broadband service and broadband availability.

Conclusion 4

Pearson Correlation results, shown in Chapter 4, indicate that there is no statistically significant correlation between the last mile price of broadband service and broadband

availability. The results revealed no significant correlation at the 0.01 confidence level between the two variables with $r = 0.045$, $n = 811$, $p = 0.199$. Therefore, Null Hypothesis 4 is accepted.

Null Hypothesis 5

There will be no statistically significant difference between the advertised price for last mile residential broadband service and the number of middle mile fiber providers.

Conclusion 5

Pearson Correlation results, shown in Chapter 4, indicate that there is a statistically significant correlation between the last mile price of broadband service and the number of middle mile fiber providers. The results revealed a slight negative correlation at the 0.01 confidence level between the two variables with $r = -0.129$, $n = 811$, $p < 0.001$. With an R^2 value of just 0.017, the two variables have only a very slight correlation at 1.7%. Therefore, Null Hypothesis 5 is rejected.

Null Hypothesis 6

There will be no statistically significant difference between the advertised price for last mile residential broadband service and the actual broadband speeds.

Conclusion 6

As previously stated, Research Question Q6 was eliminated due to lack of data across all providers and counties in Kentucky. Therefore, there is no conclusion for this null hypothesis.

Null Hypothesis 7

There will be no statistically significant difference between the advertised price for last mile residential broadband service and the technology deployed.

Conclusion 7

Pearson Correlation results, shown in Chapter 4, indicate that there is a statistically significant correlation between the last mile price of broadband service and the technology deployed. The results revealed a slight positive correlation at the 0.01 confidence level between the two variables with $r = 0.187$, $n = 811$, $p < 0.001$. With an R^2 value of just 0.035, the two variables have only a slight correlation at 3.5%. Therefore, Null Hypothesis 7 is rejected.

Null Hypothesis 8

There will be no statistically significant difference between the advertised price for last mile residential broadband service and the provider type.

Conclusion 8

Pearson Correlation results, shown in Chapter 4, indicate that there is a statistically significant correlation between the last mile price of broadband service and the provider type. The results revealed a slight negative correlation at the 0.01 confidence level between the two variables with $r = -0.102$, $n = 811$, $p = 0.004$. With an R^2 value of just 0.010, the two variables have only a very slight correlation at 1.0%. Therefore, Null Hypothesis 8 is rejected.

Null Hypothesis 9

There will be no statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised download speed.

Conclusion 9

Pearson Correlation results, shown in Chapter 4, indicate that there is a statistically significant correlation between the last mile price of broadband service and the maximum advertised download speed. The results revealed a strong negative correlation at the 0.01 confidence level between the two variables with $r = -0.927$, $n = 811$, $p < 0.001$. With an R^2 value

of just 0.859, the two variables have a strong correlation at 85.9%. Therefore, Null Hypothesis 9 is rejected.

Null Hypothesis 10

There will be no statistically significant difference between the advertised price for last mile residential broadband service and maximum advertised upload speed.

Conclusion 10

Pearson Correlation results, shown in Chapter 4, indicate that there is a statistically significant correlation between the last mile price of broadband service and the maximum advertised upload speed. The results revealed a strong negative correlation at the 0.01 confidence level between the two variables with $r = -0.741$, $n = 811$, $p < 0.001$. With a R^2 value of just 0.549, the two variables have a strong correlation at 54.9%. Therefore, Null Hypothesis 10 is rejected.

Null Hypothesis 11

There will be no statistically significant relationship between the advertised price for last mile residential broadband service and one or more independent variable.

Conclusion 11

The stepwise linear regression results, shown in Chapter 4, indicate that there is a statistically significant model that could be developed between the advertised price for last mile residential price of broadband service and one or more independent variables. Therefore, Null Hypothesis 11 is rejected. Furthermore, the variables considered for the model were SpeedTier, TechUsed, and ProviderType with the SpeedTier variable being a combination of the DownloadSpeedTier and UploadSpeedTier variable. The model is described below.

PricePerMb = 1.707 - .130 (SpeedTier) + .051 (TechUsed)

– 0.027 (ProviderType)

where SpeedTier is a number (2 – 22)

TechUsed is a number (10 – 71)

ProviderType is a number (1 – 6)

PricePerMb is the logarithm of the actual advertised price for last mile residential broadband service

Based on the model described above and results show in Chapter 4, the null hypothesis that no statistically significant relationship between the advertised price for last mile residential broadband service and one or more independent variables would be rejected.

Discussion of Results

Over the last decade, significant funding has focused on broadband growth and the factors impacting broadband expansion. Much of the research and related discussion has concentrated on the costs of broadband expansion. To date, little research has examined the impact of fixed last mile broadband pricing, meaning the pricing that a residential consumer would pay. Policy makers, researchers, industry experts, and broadband providers, without further examination of any possible correlation or difference in value, have assumed there is a correlation between pricing and cost of broadband expansion.

The study found significant, but slight negative correlations between the price per megabit and the number of middle mile providers and provider type, while a slight positive correlation was found between the price per megabit and provider type. Though the correlations may be slight, the dependent variable is a logarithm of the actual price of broadband. The slight correlations will have larger overall impact of the price per megabit. For example, the log

(PricePerMb) where the original price is $28.32 is 1.45 and the original price of $3.50 the transformed value is 0.54.

The study also found strong positive correlations between the price per megabit and the download speed tier and the upload speed tier. Significance of the research can be seen in three ways. First, there is significance in the areas where correlations were found. Second, there is significance found in the areas where correlations were not found. Third, there is also significance in a possible model to help with the planning of broadband in communities.

The findings further the knowledge of what is known in regard to broadband expansion in pricing. Broadband availability was found to have a significant correlation with unemployment rates by Jayakar and Park (2013). However, this research indicates that the relationship doesn't translate into the residential last mile price of broadband service. Furthermore, Parker (1990) found a rural penalty for broadband availability based on a county's density; however, there was no significant correlation between density and residential last mile price of broadband service. The policy assumptions built into the affordability as discussed by Wallsten and Mallahan (2010) does not appear to be present in the Commonwealth of Kentucky when comparing the price of broadband with the number of providers in a county.

Recommendations Based on Findings

This study's results provide data to further our understanding of broadband pricing across the Commonwealth of Kentucky. Based on this study, it would be recommended that broadband providers be encouraged to increase broadband speeds for both download speeds and upload speeds, as a most significant way to lower the price of broadband for last mile residential fixed broadband price in Kentucky.

Additionally, the study implies that efforts to address broadband pricing based on unemployment rates, population density, broadband availability, and number of providers would not have the desired impact as no significant correlation was present. Such efforts may address other aspects of broadband policy such as increased availability, but would not be appropriate to address the price of broadband.

Finally, the study provides a model that could be used to learn from providers. Using the 95% confidence levels, if a provider's broadband price fell outside of those levels, then additional analysis could provide insight into the price. For example, if a provider's price is outside the 95% level on the low side, further examination may reveal lessons that could help other providers to lower price. Also, if a provider's price is outside the 95% level on the high side, further examination may reveal a pressure point that could help the provider lower its price of broadband.

Limitations of Findings

The results from this study provided significant results. However, it had some limitations. The research limitations are below.

1. The results and conclusions are limited to the Commonwealth of Kentucky. Other states may have a policy environment that creates different correlations with regards to broadband pricing.
2. The analysis was limited to county-level data. Though there may be challenges with the quality of data, presenting a different challenge, an examination of data at a more granular level may produce more granular results.

3. The normality of the data warranted a smaller significance level. The conclusions are limited to the data collected. A larger population, including additional states, may have data that better fits the normality curve.
4. The study did not include broadband resellers in the population. The impact of resellers on broadband price is outside the scope of the project.

Recommended Future Research

The following recommendations are suggested for future research based on the experience, knowledge gained, and analysis performed from this research project.

1. Additional states could be examined to determine if the correlations found in this study can be transposed to other states. Based on the impact that state-by-state policies may have on broadband pricing, additional states should be considered. Additionally, a sample of many states could provide a larger conclusion.
2. Each independent variable could be further examined to understand its relationships with broadband pricing better. For example, a middle mile provider count in the specific footprint of a provider as opposed to within a county may provide additional insight into the impact of middle mile provider count on last mile broadband pricing.
3. Mobile broadband was not considered in this research project, but could be included in further analysis. Pricing of mobile broadband is structured differently than wired broadband. Further analysis will require a different research methodology due to the differences in broadband pricing.
4. Federal funding was not a factor included in the analysis. Some providers receive funding support from multiple federal agencies such as USDA or the FCC. The amount of grants, loans, and/or subsidies may have an impact on the last mile price of broadband.

5. The dataset for actual broadband speeds was not at a usable level and could not be utilized for analysis. If an alternative dataset were available, it may provide useful insight into broadband pricing by analyzing potential relationships with the actual download/upload speeds realized by the end users and worth consideration of a future study.
6. This study examined the maximum advertised speed tier. It would be interesting to also examine if the lowest speed tier or the middle speed tier offered by the last mile residential fixed broadband service would reveal the same results. A correlation of the various speed tiers may be helpful in planning for broadband expansion.
7. The study examined broadband pricing normalized to price per megabit. The analysis was conducted in order to normalize the discrepancies in broadband pricing from provider to provider. It would be interesting to consider if there are other ways to examine broadband pricing. For example, is there an additional way to compare broadband plans where Provider A offers DSL at 3 Mbps for $19.99 per month versus Provider B who offers fiber-to-the-home service at 1 Gbps for $99.99 per month.
8. The study only considered the non-promotional price of broadband. Promotional pricing and contract pricing was not taken into account. An examination of additional pricing variables, including contract terms, promotional pricing, or data limitations, could provide insight into the management practices of broadband pricing.

Conclusion

The study examined a number of factors that impact the last mile price of fixed residential broadband service and found five variables with a significant correlation, while four others were not found to be significantly correlated. Between the significant correlations

identified and the regression model developed, the study furthers the body of knowledge known about broadband pricing in the Commonwealth of Kentucky and provides some potential next steps for additional research.

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APPENDIX A: KENTUCKY PROVIDER LISTING BASED ON NBM

Below is the listing of broadband providers from Kentucky based on data submitted by the Kentucky's Commonwealth Office of Broadband Outreach and Development to the National Broadband Map Effort.

- Access Cable Television, Inc.
- ALTIUS Broadband
- Appalachian Wireless
- Armstrong Utilities
- AT&T Kentucky
- Avolutia, LLC
- Axon Access
- Ballard Telephone Cooperative
- Barbourville Online
- Bardstown Cable TV
- BGMU
- Big Sandy Broadband, Inc.
- Birch Communications
- Blazing Speeds LLC
- Blue Zoom Wifi
- Bluegrass Cellular

- BluegrassNet
- Bracken Cablevision
- Brandenburg Telecom LLC
- Brandenburg Telephone Company
- Broadlinc Wireless
- Broadvox, LLC
- CBW of Kentucky
- Chapel Communications Inc.
- Cincinnati Bell Telephone
- City of Williamstown, Cable & Internet Service
- ClearLinc Broadband
- Coalfields Telephone Company, Inc.
- Cogent Communications
- Comcast
- Community Telecom Services
- Community Wireless
- ConnectLink, Inc.
- Conterra Broadband Services (DBA Detel)
- Cricket Wireless
- Crystal Broadband Network
- Duo County Telephone Cooperative, Inc.
- EarthLink, Inc.

- Eastern Cable Corp
- Egan Technology Services
- EPBNET
- FastNet
- Foothills Broadband
- Frankfort Plant Board
- Franklin Municipal FiberNET
- Galaxy Cablevision
- Glasgow Electric Plant Board
- Harlan Community Television, Inc.
- Heavenwire.net
- Henderson Municipal Power & Light Company
- Highland Telephone Cooperative
- Hopkinsville Electric System
- HughesNet
- Inside Connect Cable
- Integrated Networks, Inc.
- Inter Mountain Cable, Inc.
- Irvine Community Television, Inc.
- Ken-Tenn Wireless, LLC
- Kentucky OnLine, Inc. (KYOL)
- Kentucky Telephone Company

- Kentucky WiMAX
- Kentucky Wireless
- Kudu Systems
- KYWIFI
- Level 3 Communications, LLC
- Liberty Communications, Inc.
- Lightyear Network Solutions, Inc.
- Limestone Cablevision
- Logan Telephone Cooperative, Inc.
- Lumos Networks
- Lycom Communications, Inc.
- Mediacom
- MegaPath Corporation
- megaWi
- MEWS
- Mikrotec CATV, LLC
- Mountain Telephone
- MST Wireless
- Murray Electric Systems
- North Central Communications
- NTELOS
- OMU

- PowerNet Global Communications
- Princeton Electric Plant Board
- PRTC
- QKY Wireless
- QX.net
- SignalPoint Communications
- Skycasters
- South Central Rural Telephone
- Sprint
- StarBand Communications Inc.
- Suddenlink Communications
- T-Mobile
- T.V. Service
- TDS Telecom
- Thacker-Grigsby Telephone
- Time Warner Cable
- tw telecom of kentucky llc
- US Cellular
- VCI Internet
- Verizon Wireless
- Vortex Wireless
- WildBlue Communications, Inc.

- WiMAX Express
- Win.net Internet
- Windstream Kentucky East, LLC
- WK&T Telecommunications Cooperative
- World View Resources (WVR)
- WWGapTel
- XO Communications
- Your Telecommunications Co.
- Zito Media

APPENDIX B: KENTUCKY PROVIDER LISTING BASED ON FCC FORM 477

Below is the listing of broadband providers accurate as of June 15, 2015, based FCC Form 477 data, including all providers fixed and mobile with broadband speeds over 200 kbps

- 2Geton Net, Inc.
- Access Cable
- Access One Communications
- Aero Communications, LLC
- ALTIUS Broadband
- APXnet
- Armstrong Utilities, Inc.
- AT&T Kentucky
- Ballard Rural Telephone Cooperative Corporation, Inc.
- Barbourville Online
- Battles Xtreme Networks
- BGMU Fiber
- Big Sandy Broadband, Inc.
- Bluegrass Cellular Inc.
- Bluegrass Wireless LLC
- Bracken Cable
- Brandenburg Telecom LLC

- Broadlinc Communications LLC
- Broadview Networks, Inc.
- Cavalier Business Communications
- Cavalier Telephone
- Cincinnati Bell Any Distance Inc.
- Cincinnati Bell Telephone Company, LLC
- City of Russellville Electric Plant Board
- City of Williamstown
- Citynet
- Coalfields Telephone Company
- Cogent Communications
- Comcast
- COMMUNITY TELECOM SERVICES
- Cornerstone Telephone Company
- Crystal Broadband Networks Inc.
- Dialog Telecommunications
- dishNET Satellite Broadband LLC
- DoveTel Communications LLC
- Duo County Telephone
- Duo County Telephone
- e-Tel
- EarthLink Business

- Eastern Cable Corp.
- Evolve Business Solutions LLC
- Fibertech Networks, LLC
- Foothills Broadband
- Frankfort Plant Board
- GCI Communications Corp.
- Glasgow Electric Plant Board
- Global Capacity LLC
- Harlan Community Television Inc.
- Henderson Municipal Power & Light
- HIGHLAND TELEPHONE COOPERATIVE, INC.
- Hopkinsville Electric System
- HughesNet
- Info-Ed, Inc.
- Inmarsat Mobile Networks, Inc.
- Inside Connect
- InterMountain Cable
- Irvine Cable
- Ken-Tenn Wireless
- Kentucky WiMAX
- King Street Wireless L.P.
- Kudu Systems

- Level 3 Communications, LLC
- Limestone Cable
- Logan Telephone Cooperative Inc.
- Lycom
- Maximum Broadband
- Mayfield Electric & Water
- MCI
- McLeod USA Telecommunications Services LLC
- Mediacom Southeast LLC
- MegaPath Corporation
- Mikrotec CATV LLC
- Mobile Communications Services of Bowling Green Inc.
- Mountain Rural Telephone Coop
- Murray Electric System
- Network Telephone Corporation
- North Central Telephone Cooperative
- Owensboro Municipal Utilities
- PAETEC Communications Inc.
- Peoples Rural Telephone Coop Corp
- Princeton Electric Plant Board
- QWirelessLLC
- QX.net

- Rapid Systems Corporation
- SEI Data
- Shelby Broadband
- Skycasters
- SkyNet Communications of Kentucky LLC
- SOUTH CENTRAL TELCOM
- Spectrotel
- Steelville Tele
- SUDDENLINK COMMUNICATIONS
- T V Service Inc.
- Talk America Inc.
- TDS TELECOM
- Thacker-Grigsby Telephone Co.
- The Other Phone Company Inc.
- THE T1 COMPANY, LLC
- Time Warner Cable Inc.
- tw telecom
- UNSi
- US LEC of Tennessee LLC
- US Signal Company, L.L.C.
- ViaSat Inc.
- Vocal IP Networx

- Windstream Kentucky East, LLC
- Windstream Kentucky West, LLC
- Windstream Norlight, Inc.
- Windstream NuVox, Inc.
- WK&T Telecommunications Incorporated
- XO Communications
- Zito Media LP

APPENDIX C: COMPLETE DATASET OF VARIABLES

(Ordered based on the dependent variable)

PricePerMb	PopDensity	Unemployment	ProviderCount	BBAvail	MMCount	TechUsed	ProviderType	DownloadSpeedTier	UploadSpeedTier	SpeedTier
-1.1	2.14095	4.2	3	0.988	3	7	5	10	10	20
-1.1	3.273634	3.9	6	1	8	7	5	10	10	20
-1.1	2.022189	4.1	7	0.992	5	7	5	10	10	20
-1.1	2.482509	2.9	4	0.999	3	7	5	10	10	20
-1.1	2.253119	3.3	6	0.997	3	7	5	10	10	20
-1.1	2.055548	3.2	4	0.998	4	7	5	10	10	20
-1.1	2.327933	3.3	5	0.998	5	7	5	10	10	20
-1	1.722746	4.3	6	0.985	6	7	1	10	9	19
-1	1.697446	5.8	4	0.962	5	7	1	10	9	19
-1	2.214347	4.2	5	0.997	5	7	1	10	9	19
-1	1.931828	4.8	4	0.998	4	7	1	10	9	19
-1	1.527292	5.3	5	0.948	4	7	1	10	9	19
-1	1.679487	4	5	0.999	5	7	2	10	10	20
-1	2.307349	4.2	5	0.998	3	7	2	10	10	20

-0.96	2.693517	3.4	5	1	3	7	5	10	10	20
-0.96	2.745726	3.5	3	1	3	7	5	10	10	20
-0.96	2.995026	3.7	3	1	3	7	5	10	10	20
-0.89	1.424462	7.8	10	0.622	8	7	1	10	10	20
-0.89	1.605202	8.4	3	0.872	4	7	1	10	10	20
-0.89	1.746297	5.2	5	0.794	3	7	1	10	10	20
-0.89	1.582163	6.4	3	0.762	3	7	1	10	10	20
-0.89	2.126621	5.4	5	0.993	4	7	1	10	10	20
-0.89	1.493029	7.2	5	0.516	4	7	1	10	10	20
-0.89	2.376754	3.5	6	0.987	4	7	1	10	10	20
-0.89	1.343718	8	2	0.852	2	7	1	10	10	20
-0.89	1.717625	4.8	3	0.917	4	7	1	10	10	20
-0.82	1.679487	4	5	0.999	5	7	1	10	9	19
-0.82	1.954359	5.6	6	1	4	5	6	11	11	22
-0.82	1.470564	8.3	2	0.995	5	5	6	11	11	22
-0.82	1.933224	4.3	5	0.956	6	5	6	11	11	22
-0.82	1.822275	6	7	1	5	5	6	11	11	22
-0.82	1.697446	5.8	4	0.962	5	5	6	11	11	22
-0.82	2.214347	4.2	5	0.997	5	5	6	11	11	22
-0.82	1.639632	4.3	4	0.838	5	5	6	11	11	22
-0.82	1.722746	4.3	6	0.985	6	5	6	11	11	22
-0.82	1.431721	7.5	5	0.948	6	5	6	11	11	22

-0.82	1.782944	6.2	4	0.981	5	5	6	11	11	22
-0.82	1.941706	4.5	2	0.958	3	5	6	11	11	22
-0.68	1.735434	5.5	5	1	2	7	4	10	8	18
-0.68	1.475992	7.1	4	0.992	4	7	4	10	8	18
-0.64	1.630455	6.6	5	0.994	4	7	1	10	10	20
-0.64	1.424462	7.8	10	0.622	8	7	1	10	10	20
-0.64	1.808404	9.1	5	0.968	6	7	1	10	10	20
-0.64	1.448567	9.7	2	0.65	2	7	1	10	10	20
-0.64	1.57078	9.2	6	0.856	5	7	1	10	10	20
-0.64	1.493029	7.2	5	0.516	4	7	1	10	10	20
-0.64	1.562808	13.5	3	0.304	3	7	1	10	10	20
-0.64	1.470473	8	2	0.924	2	7	1	10	10	20
-0.64	1.475992	7.1	4	0.992	4	7	1	10	10	20
-0.64	1.874682	5.1	4	0.984	4	7	1	10	10	20
-0.64	1.504875	9.1	2	1	3	7	1	10	10	20
-0.64	1.933505	8.3	6	0.654	5	7	1	10	10	20
-0.52	1.636888	5.9	3	0.954	4	7	1	10	10	20
-0.52	1.895785	8.5	4	0.877	5	7	1	10	6	16
-0.52	1.763953	3.6	5	0.791	5	7	1	10	10	20
-0.52	1.933224	4.3	5	0.956	6	7	1	10	10	20
-0.52	1.57674	4.2	3	0.818	3	7	1	10	10	20
-0.52	1.639632	4.3	4	0.838	5	7	1	10	10	20

-0.52	1.722746	4.3	6	0.985	6	7	1	10	10	20
-0.52	1.526861	3.9	4	0.754	5	7	1	10	10	20
-0.52	1.500899	3.8	4	0.822	5	7	1	10	10	20
-0.52	2.022189	4.1	7	0.992	5	7	1	10	10	20
-0.43	2.001992	7.7	3	0.958	3	5	3	10	7	17
-0.43	2.454235	7.2	5	0.995	4	5	3	10	7	17
-0.3	1.874196	3.9	4	0.99	4	7	2	9	7	16
-0.28	1.884285	8.7	6	0.899	4	5	6	10	6	16
-0.28	1.679487	4	5	0.999	5	5	6	10	6	16
-0.28	1.933505	8.3	6	0.654	5	5	6	10	6	16
-0.28	1.972096	8.8	8	0.948	6	5	6	10	6	16
-0.28	1.612577	7.4	4	0.701	4	5	6	10	6	16
-0.28	1.57078	9.2	6	0.856	5	5	6	10	6	16
-0.28	1.808404	9.1	5	0.968	6	5	6	10	6	16
-0.28	2.454235	7.2	5	0.995	4	5	6	10	6	16
-0.17	1.933224	4.3	5	0.956	6	5	6	10	7	17
-0.17	1.527292	5.3	5	0.948	4	5	6	10	7	17
-0.17	1.556251	4.8	6	0.917	5	5	6	10	7	17
-0.17	1.930312	4	4	1	5	5	6	10	7	17
-0.17	1.972234	5.2	6	0.975	5	5	6	10	7	17
-0.17	1.688751	6.1	3	0.96	4	5	6	10	7	17
-0.17	1.383622	5	5	0.864	4	5	6	10	7	17

-0.17	1.33177	5	4	0.883	4	5	6	10	7	17
-0.17	1.578022	5.4	3	0.971	4	5	6	10	7	17
-0.17	1.697446	5.8	4	0.962	5	5	6	10	7	17
-0.17	2.214347	4.2	5	0.997	5	5	6	10	7	17
-0.17	1.639632	4.3	4	0.838	5	5	6	10	7	17
-0.17	1.910833	4.9	4	0.987	5	5	6	10	7	17
-0.17	1.431721	7.5	5	0.948	6	5	6	10	7	17
-0.17	2.267673	5.7	4	1	4	5	6	10	7	17
-0.17	1.526861	3.9	4	0.754	5	5	6	10	7	17
-0.17	1.500899	3.8	4	0.822	5	5	6	10	7	17
-0.17	1.468647	5.4	2	0.924	2	5	6	10	7	17
-0.1	1.763953	3.6	5	0.791	5	4	5	9	6	15
-0.1	2.029643	3.5	4	0.979	4	4	5	9	6	15
-0.1	1.863429	7.5	3	0.822	3	4	5	9	6	15
-0.1	1.83354	4.5	6	1	3	4	5	9	6	15
-0.1	2.162503	4.5	5	0.97	3	4	5	9	6	15
-0.1	1.424462	7.8	10	0.622	8	4	5	9	6	15
-0.1	1.527292	5.3	5	0.948	4	4	5	9	6	15
-0.1	2.416695	3.7	6	1	4	4	5	9	6	15
-0.1	1.469998	4.9	3	0.953	3	4	5	9	6	15
-0.1	1.556251	4.8	6	0.917	5	4	5	9	6	15
-0.1	1.930312	4	4	1	5	4	5	9	6	15

-0.1	1.878371	4.7	5	0.951	3	4	5	9	6	15
-0.1	1.972234	5.2	6	0.975	5	4	5	9	6	15
-0.1	2.14095	4.2	3	0.988	3	4	5	9	6	15
-0.1	1.383622	5	5	0.864	4	4	5	9	6	15
-0.1	2.307349	4.2	5	0.998	3	4	5	9	6	15
-0.1	3.02368	3.1	6	1	5	4	5	9	6	15
-0.1	1.972096	8.8	8	0.948	6	4	5	9	6	15
-0.1	2.358804	3.5	5	0.997	3	4	5	9	6	15
-0.1	1.400138	6.3	4	0.973	3	4	5	9	6	15
-0.1	1.822275	6	7	1	5	4	5	9	6	15
-0.1	1.635921	5.2	5	0.868	4	4	5	9	6	15
-0.1	2.214347	4.2	5	0.997	5	4	5	9	6	15
-0.1	1.762366	9.5	8	0.72	4	4	5	9	6	15
-0.1	1.775696	4.5	6	0.989	4	4	5	9	6	15
-0.1	1.986002	4.8	3	1	3	4	5	9	6	15
-0.1	1.727394	3.7	4	0.954	3	4	5	9	6	15
-0.1	1.240435	5.6	4	0.991	2	4	5	9	6	15
-0.1	1.910833	4.9	4	0.987	5	4	5	9	6	15
-0.1	3.273634	3.9	6	1	8	4	5	9	6	15
-0.1	1.933505	8.3	6	0.654	5	4	5	9	6	15
-0.1	1.903471	6.8	5	0.899	3	4	5	9	6	15
-0.1	1.722746	4.3	6	0.985	6	4	5	9	6	15

-0.1	2.126621	5.4	5	0.993	4	4	5	9	6	15
-0.1	1.57078	9.2	6	0.856	5	4	5	9	6	15
-0.1	1.493029	7.2	5	0.516	4	4	5	9	6	15
-0.1	1.829103	9.2	6	0.828	3	4	5	9	6	15
-0.1	1.857658	5.4	6	0.966	3	4	5	9	6	15
-0.1	1.431721	7.5	5	0.948	6	4	5	9	6	15
-0.1	1.679487	4	5	0.999	5	4	5	9	6	15
-0.1	1.441878	6.6	2	0.968	3	4	5	9	6	15
-0.1	2.376754	3.5	6	0.987	4	4	5	9	6	15
-0.1	1.565983	4	4	0.952	3	4	5	9	6	15
-0.1	2.267673	5.7	4	1	4	4	5	9	6	15
-0.1	1.612577	7.4	4	0.701	4	4	5	9	6	15
-0.1	1.735434	5.5	5	1	2	4	5	9	6	15
-0.1	1.954359	5.6	6	1	4	4	5	9	6	15
-0.1	1.833342	4.6	4	0.958	3	4	5	9	6	15
-0.1	1.931828	4.8	4	0.998	4	4	5	9	6	15
-0.1	1.924642	4.5	8	0.977	3	4	5	9	6	15
-0.1	2.136966	5.5	5	1	4	4	5	9	6	15
-0.1	1.782944	6.2	4	0.981	5	4	5	9	6	15
-0.1	2.022189	4.1	7	0.992	5	4	5	9	6	15
-0.1	1.55319	4.9	6	0.995	3	4	5	9	6	15
-0.1	1.602784	6.1	3	0.953	3	4	5	9	6	15

-0.1	2.482509	2.9	4	0.999	3	4	5	9	6	15
-0.1	1.4814	4.3	8	0.784	4	4	5	9	6	15
-0.1	1.884285	8.7	6	0.899	4	4	5	9	6	15
-0.1	1.826348	6.6	5	0.635	3	4	5	9	6	15
-0.1	2.253119	3.3	6	0.997	3	4	5	9	6	15
-0.1	2.055548	3.2	4	0.998	4	4	5	9	6	15
-0.1	1.874196	3.9	4	0.99	4	4	5	9	6	15
-0.1	1.967108	3.6	3	0.976	3	4	5	9	6	15
-0.1	1.514868	3.6	4	0.922	2	4	5	9	6	15
-0.1	1.468647	5.4	2	0.924	2	4	5	9	6	15
-0.1	1.74715	4.8	4	0.969	2	4	5	9	6	15
-0.1	1.566392	5.6	4	0.998	3	4	5	9	6	15
-0.1	2.327933	3.3	5	0.998	5	4	5	9	6	15
-0.1	1.5866	3.6	5	0.846	2	4	5	9	6	15
-0.1	1.580503	5	3	0.983	4	4	5	9	6	15
-0.1	1.888002	5.7	5	0.863	4	4	5	9	6	15
-0.1	1.504875	9.1	2	1	3	4	5	9	6	15
-0.05	1.431721	7.5	5	0.948	6	7	1	9	8	17
-0.05	1.383622	5	5	0.864	4	7	1	9	8	17
-0.05	1.413759	10.2	4	0.697	5	7	1	9	8	17
-0.05	1.895785	8.5	4	0.877	5	7	1	9	8	17
-0.05	1.762366	9.5	8	0.72	4	7	1	9	8	17

-0.05	1.424462	7.8	10	0.622	8	7	1	9	8	17
-0.05	1.625428	8.7	4	1	5	7	1	9	8	17
-0.05	2.029643	3.5	4	0.979	4	7	4	10	10	20
-0.05	2.136966	5.5	5	1	4	7	4	10	10	20
-0.05	2.122534	3	5	0.998	4	7	4	10	10	20
-0.05	2.055548	3.2	4	0.998	4	7	4	10	10	20
-0.05	3.02368	3.1	6	1	5	7	4	10	10	20
-0.05	3.273634	3.9	6	1	8	7	4	10	10	20
-0.01	2.253119	3.3	6	0.997	3	4	5	9	3	12
-0.01	1.941706	4.5	2	0.958	3	4	5	9	3	12
-0.01	1.566392	5.6	4	0.998	3	4	5	9	3	12
-0.01	2.327933	3.3	5	0.998	5	4	5	9	3	12
-0.01	1.5866	3.6	5	0.846	2	4	5	9	3	12
-0.01	1.618884	7	5	0.935	5	4	5	9	3	12
-0.01	1.888002	5.7	5	0.863	4	4	5	9	3	12
-0.01	2.122534	3	5	0.998	4	4	5	9	3	12
-0.01	1.636888	5.9	3	0.954	4	4	5	9	3	12
-0.01	1.763953	3.6	5	0.791	5	4	5	9	3	12
-0.01	2.029643	3.5	4	0.979	4	4	5	9	3	12
-0.01	1.933224	4.3	5	0.956	6	4	5	9	3	12
-0.01	1.630455	6.6	5	0.994	4	4	5	9	3	12
-0.01	1.863429	7.5	3	0.822	3	4	5	9	3	12

-0.01	1.83354	4.5	6	1	3	4	5	9	3	12
-0.01	2.454235	7.2	5	0.995	4	4	5	9	3	12
-0.01	2.162503	4.5	5	0.97	3	4	5	9	3	12
-0.01	1.598113	5.6	3	0.988	2	4	5	9	3	12
-0.01	1.424462	7.8	10	0.622	8	4	5	9	3	12
-0.01	1.527292	5.3	5	0.948	4	4	5	9	3	12
-0.01	1.469998	4.9	3	0.953	3	4	5	9	3	12
-0.01	1.556251	4.8	6	0.917	5	4	5	9	3	12
-0.01	2.745726	3.5	3	1	3	4	5	9	3	12
-0.01	1.383609	6.7	3	0.987	3	4	5	9	3	12
-0.01	1.808404	9.1	5	0.968	6	4	5	9	3	12
-0.01	1.536414	4.5	5	0.921	4	4	5	9	3	12
-0.01	1.972234	5.2	6	0.975	5	4	5	9	3	12
-0.01	1.605202	8.4	3	0.872	4	4	5	9	3	12
-0.01	1.688751	6.1	3	0.96	4	4	5	9	3	12
-0.01	1.383622	5	5	0.864	4	4	5	9	3	12
-0.01	1.33177	5	4	0.883	4	4	5	9	3	12
-0.01	1.578022	5.4	3	0.971	4	4	5	9	3	12
-0.01	1.448567	9.7	2	0.65	2	4	5	9	3	12
-0.01	1.746297	5.2	5	0.794	3	4	5	9	3	12
-0.01	3.02368	3.1	6	1	5	4	5	9	3	12
-0.01	1.618911	5.2	3	0.996	3	4	5	9	3	12

-0.01	1.972096	8.8	8	0.948	6	4	5	9	3	12
-0.01	2.358804	3.5	5	0.997	3	4	5	9	3	12
-0.01	1.400138	6.3	4	0.973	3	4	5	9	3	12
-0.01	1.864714	4.2	5	0.937	3	4	5	9	3	12
-0.01	1.969315	4.7	7	0.986	4	4	5	9	3	12
-0.01	1.822275	6	7	1	5	4	5	9	3	12
-0.01	1.697446	5.8	4	0.962	5	4	5	9	3	12
-0.01	1.57674	4.2	3	0.818	3	4	5	9	3	12
-0.01	2.001992	7.7	3	0.958	3	4	5	9	3	12
-0.01	2.214347	4.2	5	0.997	5	4	5	9	3	12
-0.01	1.762366	9.5	8	0.72	4	4	5	9	3	12
-0.01	1.639632	4.3	4	0.838	5	4	5	9	3	12
-0.01	1.240435	5.6	4	0.991	2	4	5	9	3	12
-0.01	1.910833	4.9	4	0.987	5	4	5	9	3	12
-0.01	1.582163	6.4	3	0.762	3	4	5	9	3	12
-0.01	3.273634	3.9	6	1	8	4	5	9	3	12
-0.01	2.458989	3.4	3	0.998	3	4	5	9	3	12
-0.01	1.933505	8.3	6	0.654	5	4	5	9	3	12
-0.01	1.625428	8.7	4	1	5	4	5	9	3	12
-0.01	1.903471	6.8	5	0.899	3	4	5	9	3	12
-0.01	1.722746	4.3	6	0.985	6	4	5	9	3	12
-0.01	2.126621	5.4	5	0.993	4	4	5	9	3	12

-0.01	1.57078	9.2	6	0.856	5	4	5	9	3	12
-0.01	1.413759	10.2	4	0.697	5	4	5	9	3	12
-0.01	1.829103	9.2	6	0.828	3	4	5	9	3	12
-0.01	1.436496	8.3	3	0.861	3	4	5	9	3	12
-0.01	1.857658	5.4	6	0.966	3	4	5	9	3	12
-0.01	1.431721	7.5	5	0.948	6	4	5	9	3	12
-0.01	1.679487	4	5	0.999	5	4	5	9	3	12
-0.01	2.376754	3.5	6	0.987	4	4	5	9	3	12
-0.01	1.565983	4	4	0.952	3	4	5	9	3	12
-0.01	2.267673	5.7	4	1	4	4	5	9	3	12
-0.01	1.735434	5.5	5	1	2	4	5	9	3	12
-0.01	1.954359	5.6	6	1	4	4	5	9	3	12
-0.01	1.470473	8	2	0.924	2	4	5	9	3	12
-0.01	1.924642	4.5	8	0.977	3	4	5	9	3	12
-0.01	1.526861	3.9	4	0.754	5	4	5	9	3	12
-0.01	1.500899	3.8	4	0.822	5	4	5	9	3	12
-0.01	1.475992	7.1	4	0.992	4	4	5	9	3	12
-0.01	2.022189	4.1	7	0.992	5	4	5	9	3	12
-0.01	1.55319	4.9	6	0.995	3	4	5	9	3	12
-0.01	1.702025	4.7	6	0.994	4	4	5	9	3	12
-0.01	1.895785	8.5	4	0.877	5	4	5	9	3	12
-0.01	1.884285	8.7	6	0.899	4	4	5	9	3	12

-0.01	1.826348	6.6	5	0.635	3	4	5	9	3	12
-0.01	1.967477	4.8	3	0.991	3	4	5	9	3	12
-0.01	1.317795	5.2	3	0.993	2	4	5	9	3	12
-0.01	1.717625	4.8	3	0.917	4	4	5	9	3	12
-0.01	1.874682	5.1	4	0.984	4	4	5	9	3	12
-0.01	1.791156	8.2	3	0.968	2	4	5	9	3	12
-0.01	2.416695	3.7	6	1	4	4	5	9	3	12
0	1.636888	5.9	3	0.954	4	7	1	9	6	15
0	1.791156	8.2	3	0.968	2	7	1	9	6	15
0	2.693517	3.4	5	1	3	4	5	8	6	14
0	2.745726	3.5	3	1	3	4	5	8	6	14
0	1.912195	4.7	5	0.994	4	4	5	8	6	14
0	1.969315	4.7	7	0.986	4	4	5	8	6	14
0	1.775696	4.5	6	0.989	4	4	5	8	6	14
0	2.995026	3.7	3	1	3	4	5	8	6	14
0	1.4814	4.3	8	0.784	4	4	5	8	6	14
0	1.702025	4.7	6	0.994	4	4	5	8	6	14
0.04	1.933505	8.3	6	0.654	5	5	3	9	5	14
0.04	1.972096	8.8	8	0.948	6	5	3	9	5	14
0.04	1.612577	7.4	4	0.701	4	5	3	9	5	14
0.08	1.763953	3.6	5	0.791	5	7	1	9	9	18
0.08	1.424462	7.8	10	0.622	8	7	1	9	7	16

0.08	1.808404	9.1	5	0.968	6	7	1	9	7	16
0.08	1.972096	8.8	8	0.948	6	7	1	9	7	16
0.08	1.933505	8.3	6	0.654	5	7	1	9	7	16
0.08	1.57078	9.2	6	0.856	5	7	1	9	7	16
0.08	1.562808	13.5	3	0.304	3	7	1	9	7	16
0.08	1.612577	7.4	4	0.701	4	7	1	9	7	16
0.08	1.475992	7.1	4	0.992	4	7	1	9	7	16
0.08	1.500899	3.8	4	0.822	5	7	1	9	9	18
0.08	1.972234	5.2	6	0.975	5	7	2	8	6	14
0.08	1.514868	3.6	4	0.922	2	7	2	8	6	14
0.11	1.930312	4	4	1	5	7	1	9	9	18
0.11	2.267673	5.7	4	1	4	7	1	9	9	18
0.11	1.383609	6.7	3	0.987	3	7	1	9	9	18
0.11	1.240435	5.6	4	0.991	2	7	1	9	9	18
0.11	1.930312	4	4	1	5	5	2	9	5	14
0.12	2.022189	4.1	7	0.992	5	7	3	8	5	13
0.12	2.416695	3.7	6	1	4	7	3	8	5	13
0.15	1.969315	4.7	7	0.986	4	7	3	8	5	13
0.15	3.273634	3.9	6	1	8	5	6	8	5	13
0.15	1.763953	3.6	5	0.791	5	5	6	8	5	13
0.15	2.029643	3.5	4	0.979	4	5	6	8	5	13
0.15	1.630455	6.6	5	0.994	4	5	6	8	5	13

0.15	1.863429	7.5	3	0.822	3	5	6	8	5	13
0.15	2.693517	3.4	5	1	3	5	6	8	5	13
0.15	1.83354	4.5	6	1	3	5	6	8	5	13
0.15	2.454235	7.2	5	0.995	4	5	6	8	5	13
0.15	1.424462	7.8	10	0.622	8	5	6	8	5	13
0.15	2.162503	4.5	5	0.97	3	5	6	8	5	13
0.15	2.416695	3.7	6	1	4	5	6	8	5	13
0.15	1.556251	4.8	6	0.917	5	5	6	8	5	13
0.15	2.745726	3.5	3	1	3	5	6	8	5	13
0.15	1.878371	4.7	5	0.951	3	5	6	8	5	13
0.15	1.808404	9.1	5	0.968	6	5	6	8	5	13
0.15	1.536414	4.5	5	0.921	4	5	6	8	5	13
0.15	1.972234	5.2	6	0.975	5	5	6	8	5	13
0.15	2.14095	4.2	3	0.988	3	5	6	8	5	13
0.15	2.307349	4.2	5	0.998	3	5	6	8	5	13
0.15	1.578022	5.4	3	0.971	4	5	6	8	5	13
0.15	3.02368	3.1	6	1	5	5	6	8	5	13
0.15	1.618911	5.2	3	0.996	3	5	6	8	5	13
0.15	2.358804	3.5	5	0.997	3	5	6	8	5	13
0.15	1.912195	4.7	5	0.994	4	5	6	8	5	13
0.15	1.864714	4.2	5	0.937	3	5	6	8	5	13
0.15	1.969315	4.7	7	0.986	4	5	6	8	5	13

0.15	2.001992	7.7	3	0.958	3	5	6	8	5	13
0.15	1.762366	9.5	8	0.72	4	5	6	8	5	13
0.15	1.775696	4.5	6	0.989	4	5	6	8	5	13
0.15	1.986002	4.8	3	1	3	5	6	8	5	13
0.15	1.727394	3.7	4	0.954	3	5	6	8	5	13
0.15	1.910833	4.9	4	0.987	5	5	6	8	5	13
0.15	1.582163	6.4	3	0.762	3	5	6	8	5	13
0.15	2.458989	3.4	3	0.998	3	5	6	8	5	13
0.15	2.995026	3.7	3	1	3	5	6	8	5	13
0.15	1.625428	8.7	4	1	5	5	6	8	5	13
0.15	1.903471	6.8	5	0.899	3	5	6	8	5	13
0.15	1.722746	4.3	6	0.985	6	5	6	8	5	13
0.15	2.126621	5.4	5	0.993	4	5	6	8	5	13
0.15	1.413759	10.2	4	0.697	5	5	6	8	5	13
0.15	1.436496	8.3	3	0.861	3	5	6	8	5	13
0.15	1.857658	5.4	6	0.966	3	5	6	8	5	13
0.15	2.376754	3.5	6	0.987	4	5	6	8	5	13
0.15	1.565983	4	4	0.952	3	5	6	8	5	13
0.15	1.665479	6.5	3	0.712	3	5	6	8	5	13
0.15	1.833342	4.6	4	0.958	3	5	6	8	5	13
0.15	1.931828	4.8	4	0.998	4	5	6	8	5	13
0.15	1.924642	4.5	8	0.977	3	5	6	8	5	13

0.15	2.136966	5.5	5	1	4	5	6	8	5	13
0.15	2.022189	4.1	7	0.992	5	5	6	8	5	13
0.15	1.55319	4.9	6	0.995	3	5	6	8	5	13
0.15	1.602784	6.1	3	0.953	3	5	6	8	5	13
0.15	2.482509	2.9	4	0.999	3	5	6	8	5	13
0.15	1.4814	4.3	8	0.784	4	5	6	8	5	13
0.15	1.702025	4.7	6	0.994	4	5	6	8	5	13
0.15	1.895785	8.5	4	0.877	5	5	6	8	5	13
0.15	1.826348	6.6	5	0.635	3	5	6	8	5	13
0.15	1.967477	4.8	3	0.991	3	5	6	8	5	13
0.15	1.717625	4.8	3	0.917	4	5	6	8	5	13
0.15	1.874682	5.1	4	0.984	4	5	6	8	5	13
0.15	2.253119	3.3	6	0.997	3	5	6	8	5	13
0.15	2.055548	3.2	4	0.998	4	5	6	8	5	13
0.15	1.967108	3.6	3	0.976	3	5	6	8	5	13
0.15	1.74715	4.8	4	0.969	2	5	6	8	5	13
0.15	1.566392	5.6	4	0.998	3	5	6	8	5	13
0.15	2.327933	3.3	5	0.998	5	5	6	8	5	13
0.15	1.5866	3.6	5	0.846	2	5	6	8	5	13
0.15	1.618884	7	5	0.935	5	5	6	8	5	13
0.15	1.580503	5	3	0.983	4	5	6	8	5	13
0.15	1.888002	5.7	5	0.863	4	5	6	8	5	13

0.15	2.122534	3	5	0.998	4	5	6	8	5	13
0.17	1.972096	8.8	8	0.948	6	5	3	9	4	13
0.17	1.625428	8.7	4	1	5	5	3	9	4	13
0.17	1.829103	9.2	6	0.828	3	5	3	9	4	13
0.17	1.884285	8.7	6	0.899	4	5	3	9	4	13
0.17	1.762366	9.5	8	0.72	4	5	3	9	4	13
0.17	1.829103	9.2	6	0.828	3	5	3	9	4	13
0.18	2.693517	3.4	5	1	3	4	5	8	4	12
0.18	2.745726	3.5	3	1	3	4	5	8	4	12
0.18	1.912195	4.7	5	0.994	4	4	5	8	4	12
0.18	1.969315	4.7	7	0.986	4	4	5	8	4	12
0.18	1.775696	4.5	6	0.989	4	4	5	8	4	12
0.18	2.995026	3.7	3	1	3	4	5	8	4	12
0.18	1.4814	4.3	8	0.784	4	4	5	8	4	12
0.18	1.702025	4.7	6	0.994	4	4	5	8	5	13
0.19	2.253119	3.3	6	0.997	3	2	5	8	3	11
0.19	1.941706	4.5	2	0.958	3	2	5	8	3	11
0.19	1.566392	5.6	4	0.998	3	2	5	8	3	11
0.19	2.327933	3.3	5	0.998	5	2	5	8	3	11
0.19	1.5866	3.6	5	0.846	2	2	5	8	3	11
0.19	1.618884	7	5	0.935	5	2	5	8	3	11
0.19	1.888002	5.7	5	0.863	4	2	5	8	3	11

0.19	2.122534	3	5	0.998	4	2	5	8	3	11
0.19	1.636888	5.9	3	0.954	4	2	5	8	3	11
0.19	1.763953	3.6	5	0.791	5	2	5	8	3	11
0.19	2.029643	3.5	4	0.979	4	2	5	8	3	11
0.19	1.933224	4.3	5	0.956	6	2	5	8	3	11
0.19	1.630455	6.6	5	0.994	4	2	5	8	3	11
0.19	1.863429	7.5	3	0.822	3	2	5	8	3	11
0.19	1.83354	4.5	6	1	3	2	5	8	3	11
0.19	2.454235	7.2	5	0.995	4	2	5	8	3	11
0.19	2.162503	4.5	5	0.97	3	2	5	8	3	11
0.19	1.598113	5.6	3	0.988	2	2	5	8	3	11
0.19	1.424462	7.8	10	0.622	8	2	5	8	3	11
0.19	1.527292	5.3	5	0.948	4	2	5	8	3	11
0.19	1.469998	4.9	3	0.953	3	2	5	8	3	11
0.19	1.556251	4.8	6	0.917	5	2	5	8	3	11
0.19	2.745726	3.5	3	1	3	2	5	8	3	11
0.19	1.383609	6.7	3	0.987	3	2	5	8	3	11
0.19	1.808404	9.1	5	0.968	6	2	5	8	3	11
0.19	1.536414	4.5	5	0.921	4	2	5	8	3	11
0.19	1.972234	5.2	6	0.975	5	2	5	8	3	11
0.19	1.605202	8.4	3	0.872	4	2	5	8	3	11
0.19	1.688751	6.1	3	0.96	4	2	5	8	3	11

0.19	1.383622	5	5	0.864	4	2	5	8	3	11
0.19	1.33177	5	4	0.883	4	2	5	8	3	11
0.19	1.578022	5.4	3	0.971	4	2	5	8	3	11
0.19	1.448567	9.7	2	0.65	2	2	5	8	3	11
0.19	1.746297	5.2	5	0.794	3	2	5	8	3	11
0.19	3.02368	3.1	6	1	5	2	5	8	3	11
0.19	1.618911	5.2	3	0.996	3	2	5	8	3	11
0.19	1.972096	8.8	8	0.948	6	2	5	8	3	11
0.19	2.358804	3.5	5	0.997	3	2	5	8	3	11
0.19	1.400138	6.3	4	0.973	3	2	5	8	3	11
0.19	1.864714	4.2	5	0.937	3	2	5	8	3	11
0.19	1.969315	4.7	7	0.986	4	2	5	8	3	11
0.19	1.822275	6	7	1	5	2	5	8	3	11
0.19	1.697446	5.8	4	0.962	5	2	5	8	3	11
0.19	1.57674	4.2	3	0.818	3	2	5	8	3	11
0.19	2.001992	7.7	3	0.958	3	2	5	8	3	11
0.19	2.214347	4.2	5	0.997	5	2	5	8	3	11
0.19	1.762366	9.5	8	0.72	4	2	5	8	3	11
0.19	1.639632	4.3	4	0.838	5	2	5	8	3	11
0.19	1.240435	5.6	4	0.991	2	2	5	8	3	11
0.19	1.910833	4.9	4	0.987	5	2	5	8	3	11
0.19	1.582163	6.4	3	0.762	3	2	5	8	3	11

0.19	3.273634	3.9	6	1	8	2	5	8	3	11
0.19	2.458989	3.4	3	0.998	3	2	5	8	3	11
0.19	1.933505	8.3	6	0.654	5	2	5	8	3	11
0.19	1.625428	8.7	4	1	5	2	5	8	3	11
0.19	1.903471	6.8	5	0.899	3	2	5	8	3	11
0.19	1.722746	4.3	6	0.985	6	2	5	8	3	11
0.19	2.126621	5.4	5	0.993	4	2	5	8	3	11
0.19	1.57078	9.2	6	0.856	5	2	5	8	3	11
0.19	1.413759	10.2	4	0.697	5	2	5	8	3	11
0.19	1.829103	9.2	6	0.828	3	2	5	8	3	11
0.19	1.436496	8.3	3	0.861	3	2	5	8	3	11
0.19	1.857658	5.4	6	0.966	3	2	5	8	3	11
0.19	1.431721	7.5	5	0.948	6	2	5	8	3	11
0.19	1.679487	4	5	0.999	5	2	5	8	3	11
0.19	2.376754	3.5	6	0.987	4	2	5	8	3	11
0.19	1.565983	4	4	0.952	3	2	5	8	3	11
0.19	2.267673	5.7	4	1	4	2	5	8	3	11
0.19	1.735434	5.5	5	1	2	2	5	8	3	11
0.19	1.954359	5.6	6	1	4	2	5	8	3	11
0.19	1.470473	8	2	0.924	2	2	5	8	3	11
0.19	1.924642	4.5	8	0.977	3	2	5	8	3	11
0.19	1.526861	3.9	4	0.754	5	2	5	8	3	11

0.19	1.500899	3.8	4	0.822	5	2	5	8	3	11
0.19	1.475992	7.1	4	0.992	4	2	5	8	3	11
0.19	2.022189	4.1	7	0.992	5	2	5	8	3	11
0.19	1.55319	4.9	6	0.995	3	2	5	8	3	11
0.19	1.702025	4.7	6	0.994	4	2	5	8	3	11
0.19	1.895785	8.5	4	0.877	5	2	5	8	3	11
0.19	1.884285	8.7	6	0.899	4	2	5	8	3	11
0.19	1.826348	6.6	5	0.635	3	2	5	8	3	11
0.19	1.967477	4.8	3	0.991	3	2	5	8	3	11
0.19	1.317795	5.2	3	0.993	2	2	5	8	3	11
0.19	1.717625	4.8	3	0.917	4	2	5	8	3	11
0.19	1.874682	5.1	4	0.984	4	2	5	8	3	11
0.19	1.791156	8.2	3	0.968	2	2	5	8	3	11
0.19	2.416695	3.7	6	1	4	2	5	8	3	11
0.2	1.57078	9.2	6	0.856	5	5	4	8	5	13
0.23	1.470564	8.3	2	0.995	5	7	1	8	5	13
0.23	1.954359	5.6	6	1	4	7	1	8	5	13
0.24	1.933224	4.3	5	0.956	6	5	2	8	4	12
0.24	1.782944	6.2	4	0.981	5	5	3	9	5	14
0.24	1.833342	4.6	4	0.958	3	5	3	9	5	14
0.24	2.416695	3.7	6	1	4	5	3	9	5	14
0.24	1.635921	5.2	5	0.868	4	5	3	9	5	14

0.3	1.903471	6.8	5	0.899	3	7	2	8	4	12
0.36	2.358804	3.5	5	0.997	3	6	2	8	4	12
0.36	2.055548	3.2	4	0.998	4	6	2	8	4	12
0.36	2.122534	3	5	0.998	4	6	2	8	4	12
0.37	1.431721	7.5	5	0.948	6	4	1	7	4	11
0.37	1.383622	5	5	0.864	4	4	1	7	4	11
0.37	1.635921	5.2	5	0.868	4	4	1	6	3	9
0.37	1.413759	10.2	4	0.697	5	4	1	7	4	11
0.37	1.895785	8.5	4	0.877	5	4	1	7	4	11
0.37	1.762366	9.5	8	0.72	4	4	1	7	4	11
0.37	1.424462	7.8	10	0.622	8	4	1	7	4	11
0.37	1.625428	8.7	4	1	5	4	1	7	4	11
0.38	1.57674	4.2	3	0.818	3	6	3	8	5	13
0.38	1.762366	9.5	8	0.72	4	6	3	8	5	13
0.38	1.829103	9.2	6	0.828	3	6	3	8	5	13
0.38	1.665479	6.5	3	0.712	3	6	3	8	5	13
0.38	1.888002	5.7	5	0.863	4	6	3	8	5	13
0.4	1.665479	6.5	3	0.712	3	7	1	8	1	9
0.4	1.618884	7	5	0.935	5	7	1	8	1	9
0.4	1.888002	5.7	5	0.863	4	7	1	8	1	9
0.42	1.884285	8.7	6	0.899	4	6	6	7	3	10
0.42	1.679487	4	5	0.999	5	6	6	7	3	10

0.42	1.933505	8.3	6	0.654	5	6	6	7	3	10
0.42	1.972096	8.8	8	0.948	6	6	6	7	3	10
0.42	1.612577	7.4	4	0.701	4	6	6	7	3	10
0.42	1.57078	9.2	6	0.856	5	6	6	7	3	10
0.42	1.808404	9.1	5	0.968	6	6	6	7	3	10
0.42	2.454235	7.2	5	0.995	4	6	6	7	3	10
0.45	1.746297	5.2	5	0.794	3	6	3	7	4	11
0.45	1.884285	8.7	6	0.899	4	9	4	7	3	10
0.48	1.931828	4.8	4	0.998	4	2	1	7	3	10
0.48	1.527292	5.3	5	0.948	4	2	1	7	3	10
0.48	2.214347	4.2	5	0.997	5	2	1	7	3	10
0.48	2.416695	3.7	6	1	4	2	1	7	3	10
0.48	1.635921	5.2	5	0.868	4	2	1	7	3	10
0.48	1.697446	5.8	4	0.962	5	2	1	7	3	10
0.48	1.722746	4.3	6	0.985	6	2	1	7	3	10
0.48	2.022189	4.1	7	0.992	5	2	1	7	3	10
0.48	1.762366	9.5	8	0.72	4	5	3	9	5	14
0.48	1.829103	9.2	6	0.828	3	5	3	9	5	14
0.49	1.424462	7.8	10	0.622	8	7	1	7	3	10
0.49	1.972096	8.8	8	0.948	6	7	1	7	3	10
0.49	1.413759	10.2	4	0.697	5	7	1	7	3	10
0.49	1.829103	9.2	6	0.828	3	7	1	7	3	10

0.52	1.424462	7.8	10	0.622	8	2	1	7	3	10
0.52	1.808404	9.1	5	0.968	6	2	1	7	3	10
0.52	1.972096	8.8	8	0.948	6	2	1	7	3	10
0.52	1.57078	9.2	6	0.856	5	2	1	7	3	10
0.52	1.562808	13.5	3	0.304	3	2	1	7	3	10
0.52	1.612577	7.4	4	0.701	4	2	1	7	3	10
0.52	1.475992	7.1	4	0.992	4	2	1	7	3	10
0.52	1.762366	9.5	8	0.72	4	5	3	7	4	11
0.54	1.735434	5.5	5	1	2	3	4	7	3	10
0.54	1.475992	7.1	4	0.992	4	3	4	7	3	10
0.62	1.598113	5.6	3	0.988	2	6	3	7	5	12
0.62	1.735434	5.5	5	1	2	6	3	7	5	12
0.62	1.735434	5.5	5	1	2	6	3	7	5	12
0.66	1.903471	6.8	5	0.899	3	6	2	7	3	10
0.67	1.636888	5.9	3	0.954	4	2	1	7	4	11
0.67	1.763953	3.6	5	0.791	5	2	1	7	4	11
0.67	1.933224	4.3	5	0.956	6	2	1	7	4	11
0.67	1.57674	4.2	3	0.818	3	2	1	7	4	11
0.67	1.639632	4.3	4	0.838	5	2	1	7	4	11
0.67	1.722746	4.3	6	0.985	6	2	1	7	4	11
0.67	1.526861	3.9	4	0.754	5	2	1	7	4	11
0.67	1.500899	3.8	4	0.822	5	2	1	7	4	11

0.67	2.022189	4.1	7	0.992	5	2	1	7	4	11
0.67	1.924642	4.5	8	0.977	3	9	4	7	5	12
0.68	1.972234	5.2	6	0.975	5	9	2	6	3	9
0.68	1.514868	3.6	4	0.922	2	9	2	6	3	9
0.7	1.636888	5.9	3	0.954	4	2	1	7	3	10
0.7	1.536414	4.5	5	0.921	4	2	1	7	3	10
0.7	1.688751	6.1	3	0.96	4	2	1	7	3	10
0.7	1.33177	5	4	0.883	4	2	1	7	3	10
0.7	1.526861	3.9	4	0.754	5	2	1	7	3	10
0.7	1.791156	8.2	3	0.968	2	2	1	7	3	10
0.7	1.618884	7	5	0.935	5	2	1	7	3	10
0.7	1.969315	4.7	7	0.986	4	9	3	6	3	9
0.7	1.775696	4.5	6	0.989	4	9	3	6	3	9
0.7	2.253119	3.3	6	0.997	3	9	3	6	3	9
0.7	1.4814	4.3	8	0.784	4	9	3	6	3	9
0.7	1.702025	4.7	6	0.994	4	9	3	6	3	9
0.7	2.693517	3.4	5	1	3	2	5	5	2	7
0.7	2.745726	3.5	3	1	3	2	5	5	2	7
0.7	1.912195	4.7	5	0.994	4	2	5	5	2	7
0.7	1.969315	4.7	7	0.986	4	2	5	5	2	7
0.7	1.775696	4.5	6	0.989	4	2	5	5	2	7
0.7	2.995026	3.7	3	1	3	2	5	5	2	7

0.7	1.4814	4.3	8	0.784	4	2	5	5	2	7
0.7	1.702025	4.7	6	0.994	4	2	5	5	2	7
0.7	1.763953	3.6	5	0.791	5	2	5	5	3	8
0.7	2.029643	3.5	4	0.979	4	2	5	5	3	8
0.7	1.863429	7.5	3	0.822	3	2	5	5	3	8
0.7	1.83354	4.5	6	1	3	2	5	5	3	8
0.7	2.162503	4.5	5	0.97	3	2	5	5	3	8
0.7	1.424462	7.8	10	0.622	8	2	5	5	3	8
0.7	1.527292	5.3	5	0.948	4	2	5	5	3	8
0.7	2.416695	3.7	6	1	4	2	5	5	3	8
0.7	1.469998	4.9	3	0.953	3	2	5	5	3	8
0.7	1.556251	4.8	6	0.917	5	2	5	5	3	8
0.7	1.930312	4	4	1	5	2	5	5	3	8
0.7	1.878371	4.7	5	0.951	3	2	5	5	3	8
0.7	1.972234	5.2	6	0.975	5	2	5	5	3	8
0.7	2.14095	4.2	3	0.988	3	2	5	5	3	8
0.7	1.383622	5	5	0.864	4	2	5	5	3	8
0.7	2.307349	4.2	5	0.998	3	2	5	5	3	8
0.7	1.746297	5.2	5	0.794	3	2	5	5	3	8
0.7	3.02368	3.1	6	1	5	2	5	5	3	8
0.7	1.972096	8.8	8	0.948	6	2	5	5	3	8
0.7	2.358804	3.5	5	0.997	3	2	5	5	3	8

0.7	1.400138	6.3	4	0.973	3	2	5	5	3	8
0.7	1.822275	6	7	1	5	2	5	5	3	8
0.7	1.635921	5.2	5	0.868	4	2	5	5	3	8
0.7	2.214347	4.2	5	0.997	5	2	5	5	3	8
0.7	1.762366	9.5	8	0.72	4	2	5	5	3	8
0.7	1.775696	4.5	6	0.989	4	2	5	5	3	8
0.7	1.986002	4.8	3	1	3	2	5	5	3	8
0.7	1.727394	3.7	4	0.954	3	2	5	5	3	8
0.7	1.240435	5.6	4	0.991	2	2	5	5	3	8
0.7	1.910833	4.9	4	0.987	5	2	5	5	3	8
0.7	3.273634	3.9	6	1	8	2	5	5	3	8
0.7	1.933505	8.3	6	0.654	5	2	5	5	3	8
0.7	1.903471	6.8	5	0.899	3	2	5	5	3	8
0.7	1.722746	4.3	6	0.985	6	2	5	5	3	8
0.7	2.126621	5.4	5	0.993	4	2	5	5	3	8
0.7	1.57078	9.2	6	0.856	5	2	5	5	3	8
0.7	1.493029	7.2	5	0.516	4	2	5	5	3	8
0.7	1.829103	9.2	6	0.828	3	2	5	5	3	8
0.7	1.857658	5.4	6	0.966	3	2	5	5	3	8
0.7	1.431721	7.5	5	0.948	6	2	5	5	3	8
0.7	1.679487	4	5	0.999	5	2	5	5	3	8
0.7	1.441878	6.6	2	0.968	3	2	5	5	3	8

0.7	2.376754	3.5	6	0.987	4	2	5	5	3	8
0.7	2.267673	5.7	4	1	4	2	5	5	3	8
0.7	1.612577	7.4	4	0.701	4	2	5	5	3	8
0.7	1.735434	5.5	5	1	2	2	5	5	3	8
0.7	1.954359	5.6	6	1	4	2	5	5	3	8
0.7	1.833342	4.6	4	0.958	3	2	5	5	3	8
0.7	1.931828	4.8	4	0.998	4	2	5	5	3	8
0.7	1.924642	4.5	8	0.977	3	2	5	5	3	8
0.7	2.136966	5.5	5	1	4	2	5	5	3	8
0.7	1.782944	6.2	4	0.981	5	2	5	5	3	8
0.7	2.022189	4.1	7	0.992	5	2	5	5	3	8
0.7	1.55319	4.9	6	0.995	3	2	5	5	3	8
0.7	1.602784	6.1	3	0.953	3	2	5	5	3	8
0.7	2.482509	2.9	4	0.999	3	2	5	5	3	8
0.7	1.4814	4.3	8	0.784	4	2	5	5	3	8
0.7	1.884285	8.7	6	0.899	4	2	5	5	3	8
0.7	1.826348	6.6	5	0.635	3	2	5	5	3	8
0.7	2.253119	3.3	6	0.997	3	2	5	5	3	8
0.7	2.055548	3.2	4	0.998	4	2	5	5	3	8
0.7	1.874196	3.9	4	0.99	4	2	5	5	3	8
0.7	1.967108	3.6	3	0.976	3	2	5	5	3	8
0.7	1.514868	3.6	4	0.922	2	2	5	5	3	8

0.7	1.468647	5.4	2	0.924	2	2	5	5	3	8
0.7	1.74715	4.8	4	0.969	2	2	5	5	3	8
0.7	1.566392	5.6	4	0.998	3	2	5	5	3	8
0.7	2.327933	3.3	5	0.998	5	2	5	5	3	8
0.7	1.5866	3.6	5	0.846	2	2	5	5	3	8
0.7	1.580503	5	3	0.983	4	2	5	5	3	8
0.7	1.888002	5.7	5	0.863	4	2	5	5	3	8
0.7	1.504875	9.1	2	1	3	2	5	5	3	8
0.7	2.122534	3	5	0.998	4	2	5	5	3	8
0.73	1.618884	7	5	0.935	5	9	3	7	5	12
0.73	1.874196	3.9	4	0.99	4	9	4	7	5	12
0.73	1.556251	4.8	6	0.917	5	9	4	7	5	12
0.73	1.972234	5.2	6	0.975	5	9	4	7	5	12
0.73	1.514868	3.6	4	0.922	2	9	4	7	5	12
0.73	1.441878	6.6	2	0.968	3	9	4	7	5	12
0.74	1.679487	4	5	0.999	5	2	1	6	3	9
0.74	1.469998	4.9	3	0.953	3	2	1	6	3	9
0.74	1.874196	3.9	4	0.99	4	2	1	6	3	9
0.74	1.782944	6.2	4	0.981	5	2	1	6	3	9
0.74	1.514868	3.6	4	0.922	2	2	1	6	3	9
0.74	2.327933	3.3	5	0.998	5	2	1	6	3	9
0.77	1.924642	4.5	8	0.977	3	9	4	7	4	11

0.78	1.424462	7.8	10	0.622	8	2	1	5	3	8
0.78	1.431721	7.5	5	0.948	6	2	1	5	2	7
0.78	1.383622	5	5	0.864	4	2	1	5	2	7
0.78	1.635921	5.2	5	0.868	4	2	1	5	2	7
0.78	1.605202	8.4	3	0.872	4	2	1	5	3	8
0.78	1.582163	6.4	3	0.762	3	2	1	5	3	8
0.78	1.493029	7.2	5	0.516	4	2	1	5	3	8
0.78	2.376754	3.5	6	0.987	4	2	1	5	3	8
0.78	1.343718	8	2	0.852	2	2	1	5	3	8
0.78	1.717625	4.8	3	0.917	4	2	1	5	3	8
0.78	1.413759	10.2	4	0.697	5	2	1	5	2	7
0.78	1.895785	8.5	4	0.877	5	2	1	5	2	7
0.78	1.762366	9.5	8	0.72	4	2	1	5	2	7
0.78	1.424462	7.8	10	0.622	8	2	1	5	2	7
0.78	1.625428	8.7	4	1	5	2	1	5	2	7
0.78	1.605202	8.4	3	0.872	4	2	1	5	2	7
0.78	2.126621	5.4	5	0.993	4	2	1	5	3	8
0.78	1.746297	5.2	5	0.794	3	2	1	5	3	8
0.8	1.912195	4.7	5	0.994	4	9	4	6	4	10
0.8	1.969315	4.7	7	0.986	4	9	4	6	4	10
0.8	1.878371	4.7	5	0.951	3	9	4	6	4	10
0.8	2.693517	3.4	5	1	3	9	4	6	4	10

0.8	2.693517	3.4	5	1	3	9	4	6	4	10
0.8	1.878371	4.7	5	0.951	3	9	4	6	4	10
0.8	1.912195	4.7	5	0.994	4	9	4	6	4	10
0.8	1.969315	4.7	7	0.986	4	9	4	6	4	10
0.8	1.4814	4.3	8	0.784	4	9	4	6	4	10
0.8	2.693517	3.4	5	1	3	9	4	7	5	12
0.8	1.912195	4.7	5	0.994	4	9	4	7	5	12
0.8	1.878371	4.7	5	0.951	3	9	4	7	5	12
0.8	1.727394	3.7	4	0.954	3	9	4	7	5	12
0.8	1.4814	4.3	8	0.784	4	9	4	7	5	12
0.8	1.969315	4.7	7	0.986	4	9	4	7	5	12
0.8	2.253119	3.3	6	0.997	3	9	4	7	5	12
0.8	1.4814	4.3	8	0.784	4	9	4	6	4	10
0.81	1.400138	6.3	4	0.973	3	9	4	6	3	9
0.81	1.864714	4.2	5	0.937	3	9	4	5	4	9
0.81	1.857658	5.4	6	0.966	3	9	4	5	4	9
0.81	2.162503	4.5	5	0.97	3	9	4	5	4	9
0.81	3.02368	3.1	6	1	5	9	4	5	4	9
0.81	1.924642	4.5	8	0.977	3	9	4	5	4	9
0.9	1.972096	8.8	8	0.948	6	2	1	6	4	10
0.9	1.884285	8.7	6	0.899	4	2	1	6	4	10
0.9	1.536414	4.5	5	0.921	4	9	4	6	2	8

0.9	2.136966	5.5	5	1	4	9	4	7	7	14
0.9	1.630455	6.6	5	0.994	4	9	4	7	7	14
0.9	1.83354	4.5	6	1	3	9	4	7	7	14
0.9	2.14095	4.2	3	0.988	3	9	4	7	7	14
0.9	1.55319	4.9	6	0.995	3	9	4	7	7	14
0.9	1.857658	5.4	6	0.966	3	9	4	6	2	8
0.9	1.864714	4.2	5	0.937	3	9	4	6	2	8
0.9	2.162503	4.5	5	0.97	3	9	4	6	2	8
0.9	1.924642	4.5	8	0.977	3	9	4	6	2	8
0.9	1.5866	3.6	5	0.846	2	9	4	6	2	8
0.9	1.565983	4	4	0.952	3	9	4	6	2	8
0.9	2.162503	4.5	5	0.97	3	10	4	6	2	8
0.9	1.536414	4.5	5	0.921	4	10	4	6	2	8
0.9	1.864714	4.2	5	0.937	3	10	4	6	2	8
0.9	1.857658	5.4	6	0.966	3	10	4	6	2	8
0.9	1.565983	4	4	0.952	3	10	4	6	2	8
0.9	1.924642	4.5	8	0.977	3	10	4	6	2	8
0.9	1.5866	3.6	5	0.846	2	10	4	6	2	8
0.96	1.903471	6.8	5	0.899	3	6	3	7	4	11
0.96	2.126621	5.4	5	0.993	4	6	3	7	4	11
0.96	1.33177	5	4	0.883	4	9	4	5	3	8
0.98	2.307349	4.2	5	0.998	3	10	4	5	3	8

1	1.424462	7.8	10	0.622	8	2	1	5	3	8
1	1.895785	8.5	4	0.877	5	2	1	5	3	8
1	1.972096	8.8	8	0.948	6	2	1	5	3	8
1	1.413759	10.2	4	0.697	5	2	1	5	3	8
1	1.829103	9.2	6	0.828	3	2	1	5	3	8
1	1.562808	13.5	3	0.304	3	6	3	6	4	10
1	1.400138	6.3	4	0.973	3	9	4	5	2	7
1	1.240435	5.6	4	0.991	2	9	4	5	2	7
1	1.383609	6.7	3	0.987	3	9	4	5	2	7
1	1.822275	6	7	1	5	9	4	5	2	7
1.01	3.02368	3.1	6	1	5	9	4	5	3	8
1.01	1.702025	4.7	6	0.994	4	9	4	5	3	8
1.01	1.83354	4.5	6	1	3	9	4	5	3	8
1.01	2.454235	7.2	5	0.995	4	9	4	5	3	8
1.01	1.822275	6	7	1	5	9	4	5	3	8
1.01	3.273634	3.9	6	1	8	9	4	5	3	8
1.01	1.55319	4.9	6	0.995	3	9	4	5	3	8
1.01	1.424462	7.8	10	0.622	8	9	4	5	3	8
1.01	1.618911	5.2	3	0.996	3	9	4	5	3	8
1.01	1.536414	4.5	5	0.921	4	9	4	5	3	8
1.01	1.5866	3.6	5	0.846	2	9	4	5	3	8
1.01	1.317795	5.2	3	0.993	2	9	4	5	3	8

1.01	1.630455	6.6	5	0.994	4	9	4	5	3	8
1.01	1.874682	5.1	4	0.984	4	9	4	5	3	8
1.01	1.343718	8	2	0.852	2	9	4	5	3	8
1.01	2.136966	5.5	5	1	4	9	4	5	3	8
1.01	1.775696	4.5	6	0.989	4	9	4	5	3	8
1.01	1.735434	5.5	5	1	2	9	4	5	3	8
1.01	2.995026	3.7	3	1	3	9	4	5	3	8
1.01	1.762366	9.5	8	0.72	4	9	4	5	3	8
1.01	1.493029	7.2	5	0.516	4	9	4	5	3	8
1.01	1.598113	5.6	3	0.988	2	9	4	5	3	8
1.01	2.376754	3.5	6	0.987	4	9	4	5	3	8
1.01	2.458989	3.4	3	0.998	3	9	4	5	3	8
1.01	1.746297	5.2	5	0.794	3	9	4	5	3	8
1.01	1.436496	8.3	3	0.861	3	9	4	5	3	8
1.01	1.791156	8.2	3	0.968	2	9	4	5	3	8
1.01	2.327933	3.3	5	0.998	5	9	4	5	3	8
1.01	1.826348	6.6	5	0.635	3	9	4	5	3	8
1.07	1.400138	6.3	4	0.973	3	9	4	5	2	7
1.07	1.240435	5.6	4	0.991	2	9	4	5	2	7
1.07	1.383609	6.7	3	0.987	3	9	4	5	2	7
1.07	1.822275	6	7	1	5	9	4	5	2	7
1.11	1.954359	5.6	6	1	4	9	4	6	4	10

1.11	3.273634	3.9	6	1	8	2	4	4	3	7
1.11	2.482509	2.9	4	0.999	3	2	4	4	3	7
1.11	1.74715	4.8	4	0.969	2	2	4	4	3	7
1.12	1.822275	6	7	1	5	9	2	4	1	5
1.15	1.527292	5.3	5	0.948	4	9	4	5	3	8
1.15	1.383622	5	5	0.864	4	9	4	5	3	8
1.15	2.307349	4.2	5	0.998	3	9	4	5	3	8
1.15	1.556251	4.8	6	0.917	5	9	4	5	3	8
1.15	1.931828	4.8	4	0.998	4	9	4	5	3	8
1.15	1.635921	5.2	5	0.868	4	9	4	5	3	8
1.15	1.833342	4.6	4	0.958	3	9	4	5	3	8
1.15	1.602784	6.1	3	0.953	3	9	4	5	3	8
1.15	1.566392	5.6	4	0.998	3	9	4	5	3	8
1.15	1.986002	4.8	3	1	3	9	4	5	3	8
1.15	1.580503	5	3	0.983	4	9	4	5	3	8
1.15	1.986002	4.8	3	1	3	10	4	5	3	8
1.15	1.833342	4.6	4	0.958	3	10	4	5	3	8
1.15	1.602784	6.1	3	0.953	3	10	4	5	3	8
1.15	1.566392	5.6	4	0.998	3	10	4	5	3	8
1.15	1.580503	5	3	0.983	4	10	4	5	3	8
1.15	1.556251	4.8	6	0.917	5	10	4	5	3	8
1.15	1.383622	5	5	0.864	4	10	4	5	3	8

1.15	2.307349	4.2	5	0.998	3	10	4	5	3	8
1.15	1.635921	5.2	5	0.868	4	10	4	5	3	8
1.16	1.857658	5.4	6	0.966	3	9	4	4	2	6
1.16	1.924642	4.5	8	0.977	3	9	4	4	2	6
1.16	1.967477	4.8	3	0.991	3	9	4	4	2	6
1.16	1.864714	4.2	5	0.937	3	9	4	4	2	6
1.28	2.376754	3.5	6	0.987	4	9	4	4	3	7
1.34	1.470564	8.3	2	0.995	5	2	1	4	2	6
1.45	3.02368	3.1	6	1	5	9	4	4	2	6
1.45	2.029643	3.5	4	0.979	4	9	4	4	2	6
1.45	1.83354	4.5	6	1	3	9	4	4	2	6
1.45	3.273634	3.9	6	1	8	9	4	4	2	6
1.45	2.253119	3.3	6	0.997	3	9	4	4	2	6
1.45	1.55319	4.9	6	0.995	3	9	4	4	2	6
1.45	2.358804	3.5	5	0.997	3	9	4	4	2	6
1.45	2.022189	4.1	7	0.992	5	9	4	4	2	6
1.45	1.727394	3.7	4	0.954	3	9	4	4	2	6
1.45	1.317795	5.2	3	0.993	2	9	4	4	2	6
1.45	2.122534	3	5	0.998	4	9	4	4	2	6
1.45	2.055548	3.2	4	0.998	4	9	4	4	2	6
1.45	1.775696	4.5	6	0.989	4	9	4	4	2	6
1.45	1.967108	3.6	3	0.976	3	9	4	4	2	6

1.45	1.74715	4.8	4	0.969	2	9	4	4	2	6
1.45	1.4814	4.3	8	0.784	4	9	4	4	2	6
1.45	1.924642	4.5	8	0.977	3	9	4	4	2	6
1.45	2.482509	2.9	4	0.999	3	9	4	4	2	6
1.65	1.702025	4.7	6	0.994	4	9	4	3	2	5