Mobile Broadband Adoption and Its Role in the U.S. Digital Divide

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DEDICATION

To Johannes Gutenberg
for his vision that information should be available to the masses

and

Guglielmo Marconi
who gave us the technology to connect wirelessly.

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To my Committee Chair, Siona Listokin for her patience and thoughtful questions throughout the fields and dissertation process. She showed me the way, kept me on track, questioned the unknown, and guided me each step of the way.

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To my children, who have all been in school while I chased this dream. What a wonderful experience to share with all of you.

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LIST OF ABBREVIATIONS

Broadband Technology Opportunities Program .... BTOP
American Community Survey .... ACS
Broadband Technology Opportunities Program .... BTOP
Community Population Survey .... CPS
Computer and Internet Use .... CIU
Diffusion of Innovation .... DoI
Digital Subscriber Line .... DSL
Distributed Antenna Systems .... DAS
European Union .... EU
Federal Communications Commission .... FCC
Fifth Generation 5G
First Generation 1G
Fixed to Mobile Substitution .... FMS
Fourth Generation 4G
Gigabits per second .... Gbps
Global Positioning System .... GPS
Gross Domestic Product .... GDP
International Telecommunication Union .... ITU
Kilobits per second .... Kbps
Long Term Evolution .... LTE
Megabits per second .... Mbps
Model of Adoption of Technology in Households .... MATH
National Telecommunications and Information Administration .... NTIA
Non-Governmental Organization .... NGO
Office of Personnel Management .... OPM
Older Adults Technology Services .... OATS
Organization for Economic Cooperation and Development .... OECD
Problematic Internet Use .... PIU
Second Generation 2G
Social Cognitive Theory .... SCT
Technology Acceptance Model .... TAM
Theory of Reasoned Action .... TRA
Third Generation 3G
Unified Theory of the Acceptance and Use of Technology .... UTAUT
Wireless Access Protocol .... WAP
Wireless Technology Acceptance Model .... MWTAM

ABSTRACT

MOBILE BROADBAND ADOPTION AND ITS ROLE IN THE U.S. DIGITAL DIVIDE

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In the U.S., high-speed internet service, or broadband, is considered essential to expanded job training for the unemployed and under-employed, access to educational resources within schools, extension of medical services to rural areas (allowing broader reach for more specialized expertise), and the ability for small businesses to expand and reach national and international markets.   A great deal of research has been devoted to the impact of fixed broadband on economic growth. Federal, state and local government have focused significant resources to subsidize and encourage industry to invest in building out broadband infrastructure to bridge the "digital divide" among rural and poor areas of the U.S. However, in recent years the emergence of mobile broadband, made possible through the introduction of the "smartphone" and high-speed digital (3G+) networks, has rapidly changed the way we live and work. This study explores the patterns or adoption for mobile broadband and its relationship with fixed broadband.

With widespread mobile broadband adoption and availability of recent datasets, this study uniquely explores the implications and potential role in closing the digital divide. The key findings of this research are that the traditional determinants of adoption hold true for both fixed and mobile broadband and that mobile is used as a substitute for fixed broadband in rural, low-income communities. Further, the analysis showed that households with children have a positive impact on mobile adoption. Consistent with technology adoption theory on consumer intrinsic behavior and beliefs, access at work, school or travel is a strong determinant of both fixed and mobile adoption. Finally, this study could not definitively find support for the impact of private and security concerns on fixed or mobile broadband. As fixed broadband penetration slows, mobile broadband's accelerated adoption could help to bridge the divide where fixed struggles to serve. Key differences in both extrinsic factors (coverage, form/function, ease of use, and mobility) and intrinsic factors (social norms and values) may create a differentiated role for mobile broadband going forward. Its rapid adoption and the future of greater functionality and higher capacity networks promise a still greater functional role in our lives.

Depriving a citizen of access to the Internet is a violation of the human right to "seek, receive and impart information and ideas of all kinds, regardless of frontiers."

– United Nations, Article 19 of the Declaration of Human Rights (2014)[1]

"It is unacceptable that here, in the country that invented the Internet, we fell to 15th in the world in broadband deployment. When kids in downtown Flint or rural Iowa can't afford or access high-speed Internet, that sets back America's ability to compete. As President, I will set a simple goal: every American should have the highest speed broadband access – no matter where you live, or how much money you have. We'll connect schools, libraries and hospitals. And we'll take on special interests to unleash the power of wireless spectrum for our safety and connectivity."

– President Barak Obama
June 16, 2008[2]

There is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new order of things."

– Niccolò Machiavelli, The Prince (1513)[3]

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1 United Nations. 2014. "The Universal Declaration of Human Rights." Article 19.

2 Barack Obama: "Remarks at Kettering University in Flint, Michigan," June 16, 2008. Online by Gerhard Peters and John T. Woolley, *The American Presidency Project*.

3 Machiavelli, Niccolò. 2005. *The Prince*. Vol. Webster's Thesaurus. San Diego: Icon Group International, Inc.

Chapter 1: Introduction

The telegraph, telephone, radio, television, internet, cellphone, high-speed "broadband," and now mobile broadband have each been transformative in the way we communicate, interact with one another and share and receive information. It has changed the way we bank, shop, and the way we conduct our lives. Each technology wave offers greater enhancements and presents new opportunities. Some technologies disrupt, changing the evolution of existing technologies. Others converge, building a symbiotic relationship that extends the life cycle of both. The challenge for policy makers is to ensure all citizens are allowed equal access to these resources, to prevent anti-competitive behavior, and to foster new technology development. With the emergence of mobile broadband in the past decade, it offers new opportunities to connect to internet resources in ways different than the traditional fixed broadband. Understanding the relationship between fixed and mobile broadband is essential to policymakers going forward.

This dissertation contributes to the body of research regarding mobile broadband adoption. It identifies and analyzes how mobile broadband interacts with the traditional determinants of broadband adoption. It compares adoption patterns of fixed broadband with those of mobile broadband, and looks for opportunities for adoption among communities on the other side of the digital divide. This study uses Diffusion of

Innovation Theory and Social Cognitive Theory to understand consumer behavior associated with technology adoption.

This study analyzes the demographic divide and compares patterns of adoption for fixed and mobile broadband, looking for both similarities and contrasting patterns that could offer opportunity to close the gap associated with the digital divide. This research will study household life cycle stages – from young to old households, to those with and without children. It will explore the intrinsic factors that influence adoption, such as relative advantage (understanding the functions utilized for each of the access technologies), observational and enabled learning (through access to broadband outside the home, handling complexity (learning to master the technology), and compatibility with current norms and attitudes (challenges to control beliefs by privacy and security concerns).

Why Broadband?

High-speed internet, or "broadband" represents the next generation of internet – going from low-speed connections that could support text-based messaging and simple browsing to high-speed service capable of image and video transfer, large file downloads and complex functions. Once a luxury, broadband is now considered a global "universal right."[4] Broadband is associated with increasing the potential for business growth,

[4] United Nations. 2014. "The Universal Declaration of Human Rights." Article 19.

productivity, and output.[5] It is accepted as being essential in knowledge-based economies.[6] International studies show a direct return on investment in broadband in terms of GDP growth, but only after reaching a "critical mass" (about 30 percent of the infrastructure serving roughly half the population).[7] Figure 1 shows the rapid advancement of broadband in the U.S.

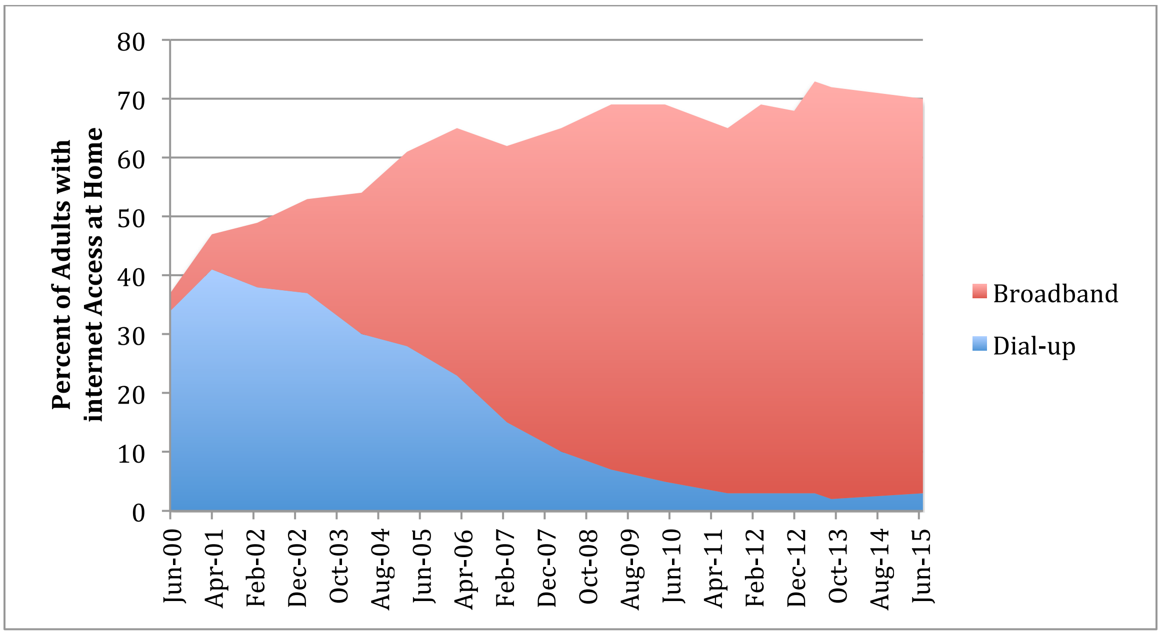

Figure 1 – Broadband vs. Dial-up Adoption Over Time[8]

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5 National Telecommunications and Information Administration (NTIA). 2010. "Broadband Technology Opportunities Program (BTOP)." *BroadbandUSA: Connecting America's Communities*.

6 Cava-Ferreruela, Inmaculada, and Antonio Alabau-Muñoz. 2006. "Broadband Policy Assessment: A Cross-national Empirical Analysis." *Telecommunications Policy* 30 (8–9) (September): 445–463.

7 Koutroumpis, Pantelis. 2009. "The Economic Impact of Broadband on Growth: A Simultaneous Approach." *Telecommunications Policy* 33 (9) (October): 471–485.

8 Wormald, Benjamin. 2015. "Broadband vs. Dial-up Adoption Over Time." *Pew Research Center: Internet, Science & Tech*. June 10.

In the U.S., broadband is seen as having a strong return on investment. It is considered essential for access to educational resources within and outside schools,[9] extension of medical services to rural areas (allowing broader reach for more specialized expertise), expanded job creation and productivity,[10] expanded job training for the unemployed and under-employed, and the ability for small businesses to expand and reach national and international markets.[11]

Similar to the electric grid, broadband is considered a key enabler of other infrastructures and services that provide both economic and personal benefits. The interdependence of multiple parallel ecosystems with broadband has increased the essential role of a high-speed, high capacity physical infrastructure. Systems such as public safety, health care, transportation, education, energy, entertainment and the consumer marketplace are increasingly dependent on a robust end-to-end infrastructure. The "Internet of things" promises to increase the human-machine and machine-machine interfaces and further demand higher bandwidth. Regulation and governance for all of these infrastructures and industries is split among many stakeholders from both government and industry. As these technologies evolve, they become more interdependent and distinctions become

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[9] National Telecommunications and Information Administration (NTIA). 2015a. "California Broadband Workshop Shows Work Still Needed to Close Digital Divide." NTIA. *BroadandUSA*. November 15.

[10] Taxalli, Sandeep. 2015. "Broadband Infrastructure Case Studies Released – How Broadband Changes the Game." NTIA Blog. *BroadbandUSA*. April 13.

[11] National Telecommunications and Information Administration (NTIA). 2014. "Broadband Technology Opportunities Program (BTOP) Quarterly Program Status Report." Report to U.S. Congress. Washington, D.C.

imprecise, necessitating an integrated approach across multiple stakeholders (across and within federal, state and local) to ensure a cogent regulatory strategy.

The Digital Divide

The United States still has a digital divide where a significant number of citizens have limited or no access to affordable digital services, specifically broadband internet. While the gap is narrowing, it has been slow to close as internet providers cope with high entry costs associated with difficult or remote geographies and insufficient demand at current commercial rates.

The U.S. has lagged behind many developed countries in fixed broadband connectivity, speed and subscriber costs. In speaking regarding universal service in October 2011, Julius Genachowski, then Chairman of the FCC, stated that "Broadband has gone from being a luxury to a necessity for full participation in our economy and society."[12] In 2012, President Obama signed an Executive Order declaring that broadband is "essential to U.S. global competitiveness in the 21st century, driving job creation, promoting innovation, and expanding markets for American businesses." The Order also stated "too many areas still lack adequate access to this crucial resource."[13]

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[12] Genachowski, Julius. 2011. "Connecting America: A Plan To Reform and Modernize the Universal Service Fund and Intercarrier Compensation System." Prepared Remarks, Washington, D.C., Oct. 6

[13] "Executive Order -- Accelerating Broadband Infrastructure Deployment." 2012. *Whitehouse.gov*. June 14.

Significant investment by both industry and government has been made on fixed broadband supply – connecting every household in the U.S. With the Government now closing in on its "100 squared" target (100 Mbps in 100 million households), the focus has shifted from supply to demand. Most government demand-side programs focus on enablement – making broadband more affordable and training consumers on the requisite technical skills. These programs are predicated on the premise that consumers prefer access to services but just lack the resources or digital skills necessary to subscribe and use these services. While significant resources have been spent on these programs, they remain underutilized and some studies suggest that financial assistance has little effect on adoption.[14] In fact, only one-third of those eligible for federal assistance programs for installation and recurring costs (Link-Up and Lifeline) actually enroll for the subsidy.[15]

Despite improved access to fixed high speed internet, many have never adopted, some have discontinued use, and some consumers have chosen alternate means of access (through work, schools, community centers or mobile devices). Rural and low-income populations and the elderly are most often those that disconnect or never connect, due to high cost or lack of compelling need. A persistent digital divide can have significant implications as society increasingly relies on the internet for education, public safety, economic opportunity, social connection, and other critical infrastructures such as banking, health and commerce. Those that have disconnected are more likely to be

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[14] Gideon, Carolyn, and David Gabel. 2011. "Disconnecting: Understanding Decline in Universal Service." *Telecommunications Policy* 35 (8): pp.740.

[15] Ibid. p.740

isolated and marginalized as they may find it increasingly difficult to participate in societal and civic engagement and interaction.[16]

In a recent survey of 2000 households, the Pew Research Center showed a growing number of Americans representing whites and minorities at all income and education levels choosing to disconnect from fixed broadband. [17] They go off the grid completely or access services through smartphones. Figure 2 shows the widening gap within no internet households that state that it less about affordability and computer resources, but more that they do not see the need or are uninterested. For these households, they miss opportunities to exploit new digital resources and emerging dependent systems such as public safety, health care, transportation, education, energy, entertainment, and the consumer marketplace.

Several factors may contribute to the digital divide challenges, representing both external market and intrinsic consumer factors. Access has traditionally been the focus of market and industry with the premise that "if you build it, they will come." However as we reach saturation for fixed infrastructure, the last mile to remote areas becomes more difficult and expensive.

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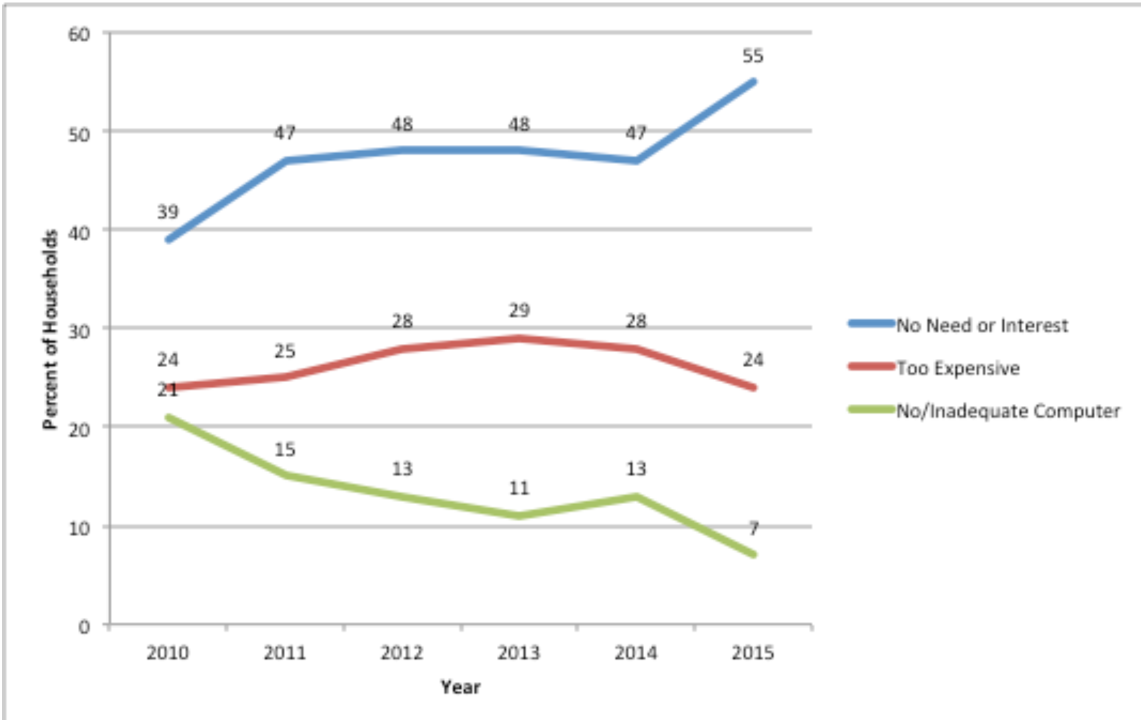
[16] Lee, HyunJoo, Namsu Park, and Yongsuk Hwang. 2015. "A New Dimension of the Digital Divide: Exploring the Relationship between Broadband Connection, Smartphone Use and Communication Competence." *Telematics and Informatics* 32 (1): p. 47

[17] Horrigan, John B., and Maeve Duggan. 2015. "Home Broadband 2015." Pew Research Center: Internet, Science & Tech. December 21.



Data Source: Pew Research Surveys, 2010-2015

Figure 2: Selected Main Reasons for Not Using the Internet at Home
Percent of Households Not Online at Home, 2010-2015

While the divide persists, some of these challenged communities have increasingly adopted mobile broadband technologies. Several surveys show the growing role of mobile devices (i.e., smartphones) as the primary means of connection for subscribers.[18]

Consumer Choice

With broadband digital infrastructure now reaching its goal of saturation – reaching nearly every household – the focus has shifted from access to enablement. Most government demand-side programs focus on making broadband more affordable and

[18] McHenry, Giulia. 2016. "Evolving Technologies Change the Nature of Internet Use." *NTIA*. April 16.

training consumers on the requisite skills. Multiple programs focus on lowering cost and building literacy to serve those who already have an interest in gaining access to broadband.

Some surveys solicit consumer preferences and reasons for adoption or non-adoption. It is difficult to determine the relative utility of different factors that comprise consumer trade-offs and decision-making. It is also unclear if non-adopters have sufficient exposure and experiences to make informed decisions regarding adoption. In areas with affordable access to fixed or mobile broadband internet services, consumers must perceive that the benefits outweigh the risks. Consumers must see the advantages of adoption in areas such as lifestyle improvement, education, convenience, or timeliness. They must also be able to value these benefits over the cost and potential risks - privacy, security, and safety - associated with adoption.

Organization of this Dissertation

This research is intended to contribute to the general body of knowledge in technology adoption theory, specifically regarding the patterns of mobile broadband adoption. Mobile broadband "smartphones" offer a low cost entry into internet services (lower device costs, lower subscription rates, and inexpensive applications) and require a lower technical skill set through "apps." Simplified apps increase consumer exposure and confidence to master varied social and productivity applications. Mobile broadband represents a potential alternative in areas where fixed broadband is unaffordable or unavailable (or both). This research determines the key demographic patterns for mobile adoption and identifies areas that may present opportunities for policy-makers to influence adoption.

By applying fundamental tenets of technology adoption theories, this research also determines how technology adoption theory components affect consumer broadband internet adoption. While some consumer preferences could be rooted in belief systems and risk tolerance, technology exposure through work or school enhances observational or enabled learning, boosting consumer confidence to adopt. Using existing datasets, this study utilizes empirical methods augmented by selective field interviews to identify potential information gaps and consumer beliefs that influence technology adoption. It concludes with a discussion of potential implications to policy makers.

Chapter 2 presents the relevant research question and associated hypotheses to help frame the research. Chapter 3 discusses the state of the literature regarding the role of mobile broadband in providing internet services and the emerging literature on technology adoption models, and some of the potentially relevant factors that could influence broadband internet adoption. Chapter 4 describes the research strategy and data, and presents the data analysis methods and model specification. Analysis includes an assessment of the impact of demographics and household life cycle, and a longitudinal analysis of mobile broadband adoption across select demographic communities. Intrinsic factors are also examined, specifically consumer exposure through outside the home (e.g., work, schools, libraries) that allows observational or enabled learning, and builds technical skills.   Chapter 5 presents the empirical results and significance of findings. Chapter 6 concludes with a summary of hypotheses results and a description of potential impact of research findings on policies and programs for broadband internet adoption. Finally, Chapter 7 discusses the implications for policy-makers and directions for further research.

CHAPTER 2: RESEARCH QUESTION & HYPOTHESES

Government programs have focused extensive resources on providing fixed broadband infrastructure to each home, particularly in unserved and underserved areas (low-income and rural areas). Federal grants have been awarded to state and local government organizations to build awareness, educate, and foster adoption of fixed broadband services. However, while these programs have made progress in closing the digital divide, they did not address growing availability of mobile broadband that could offer an alternate method of access. Mobile broadband technologies became a reality with the introduction of the smartphone in 2007 and the rollout of 3G networks that reached critical mass in 2010. Technology disruption from mobile broadband creates a new opportunity to rethink supply-side regulation and research the implication of this new means of alternative access. It has implications for bridging the digital divide and could impact existing fixed broadband adoption programs. However, mobile's role in broadband adoption and its implications regarding fixed broadband adoption is not well understood.

> ***Research Question:*** *How does the emergence of mobile broadband change household broadband adoption?*

The Relationship Between Fixed and Mobile Broadband

Mobile broadband is an access technology, connected to internet resources through the Wireless Access Protocol (WAP), the global standard for accessing internet services on mobile smartphones. While fixed and mobile access the internet differently, operating system and application developers are working to diminish the differences between the fixed and mobile experience, often referred to as *service convergence*. [19]

Networks are continuing to advance in capacity and "smart" mobile devices are keeping pace. New smartphones, tablets, wearable devices (e.g., glasses, watches, fitness trackers, and health monitoring devices), and emerging artificial intelligence-enabled devices (e.g., Google Home, Amazon Echo, Microsoft Cortana) are all making significant inroads in the internet world once dominated by PCs.[20] As mobile broadband networks and devices proliferate, does their adoption affect the traditional determinants and patterns of fixed broadband adoption, or are they different?

> *H1: The patterns of adoption for mobile broadband are the same as fixed broadband.*

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[19] Studer, Bruno. 2001. "Fixed Mobile Internet Convergence (FMIC)." *Telematics and Informatics*, Mobile Computing and Networking Technologies, 18 (2–3): p.139.

[20] Nour, Mohamed Abdalla. 2014. "An Empirical Study of the Effect of Internet Services on the Preferential Adoption of Mobile Internet." *International Journal of E-Business Research (IJEBR)* 10 (1): p. 68.

Until the introduction of the smartphone and the maturation of 3G networks, much of the literature had focused on cellphone adoption, specifically Fixed to Mobile Substitution (FMS). FMS primarily addressed voice telephony service – i.e. replacing a home phone with a mobile phone. Research on FMS concludes that as mobile networks mature they become substitutes for the fixed networks and "ultimately can lead to their demise."[21] It is not certain this holds true for mobile and fixed broadband.

While FMS is focused on voice telephony, mobile broadband offers a somewhat differentiated service. Mobile broadband developments could change the market dynamics of FMS.[22] Although limited in speed compared to fixed networks and typically more usage-sensitive, mobile broadband offers a different value proposition than fixed broadband services. Mobile broadband service has a lower cost of entry (a smartphone vs. a computer), requires lower technical proficiency, and offers greater flexibility (allowing them to connect nearly anywhere, anytime). It can also be used to tether to a computer or tablet to allow internet access (in some cases, the mobile access is built into the device). The ability to connect through simple, easy to use "apps" has created widespread consumer adoption. Today, there are over 2 million apps available for both iOS and Android mobile devices.[23]

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[21] Vogelsang, Ingo. 2010. "The Relationship between Mobile and Fixed-Line Communications: A Survey." *Information Economics and Policy*, Wireless Technologies, 22 (1): p. 5
[22] Ibid p. 15
[23] "The 2017 Mobile App Market: Statistics, Trends, and Analysis." 2017. *Business 2 Community*. Accessed February 27.

For those with fixed service at home, consumers can diversify their access, adopting mobile broadband as a complementary service. For those without fixed service at home, mobile is a potential alternative to fixed access (where fixed infrastructure is limited or household members require greater mobility). Low-income households may find it difficult to afford having both services and are more likely to adopt one or the other.

Rural areas are often targeted for fixed broadband programs that subsidize or incentivize providers to install cable/fiber the last mile to remote households. While significant progress has been made, it is increasingly difficult for carriers to provide service where distances are great or terrain is challenging. Mobile broadband services are often a more efficient alternate for connection for households in these rural areas (see Note [24]).

> *H2: Low-income and rural households with lower incomes are more likely to adopt mobile technologies as an alternative or substitute to fixed broadband services.*

Consumer Intrinsic Factors and Mobile Broadband Adoption

The choice to adopt fixed or mobile broadband or disconnect completely is not strictly an availability or economic decision. Even with affordable access, many consumers do not

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[24] While many households may be outside the footprint of mobile broadband coverage, some households with mobile broadband devices routinely go into local towns, workplaces or schools that are in coverage areas to permit access.

see the relative advantage of internet use. In these cases, the perceived cost or risks associated with adoption outweigh the perceived benefits.

Research has shown that the life cycle of a household (stages that reflect marital status, age, and presence of children) can influence internet adoption. In a study of 750 households, Brown and Venkatesh (2005) found that attitudinal beliefs had the highest influence on broadband adoption intent for single parents and full nesters, specifically the broadband's utility for children. Control beliefs had the highest influence on broadband adoption intent among childless couples and the elderly, specifically requisite knowledge and ease of use.[25] This study pre-dated the availability of widespread mobile broadband and smartphones and focused strictly on fixed internet adoption.

Government (federal, state and local) programs have been infusing technology into the education system for nearly a decade, so children are becoming more exposed to the internet and have built confidence in their computer and internet skills. As a result, it is expected that households with K-12 children are more likely to adopt broadband, but adoption is still low among rural and low-income households (see Note [26]). Many internet adoption programs (including those interviewed for this research) work closely to ensure schools allow student ample exposure, help build digital literacy and confidence,

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[25] Brown, Susan A., and Viswanath Venkatesh. 2005. "Model of Adoption of Technology in Households: A Baseline Model Test and Extension Incorporating Household Life Cycle1." *MIS Quarterly* 29 (3): p.402.

[26] While more schools utilize technology in the classroom, some schools in rural or economically depressed areas are reticent to assign research or homework that requires access at home – which may diminish demand for service at home.

and offer after-school or in-school time to use computing and internet resources to conduct homework assignments. These programs see children as "ambassadors" to more widespread broadband adoption at home. They are more likely to be exposed to technologies through school (observational and enabled learning), and can master the complexity outside the home while helping others master the complexity at home. While households with children have been the target of digital literacy programs in the schools and subsidized cost programs at home, the influence of households with children on the adoption of mobile broadband is not known.

However, many adoption programs do not see mobile broadband as the functional equivalent to fixed, so these programs typically do not address mobile broadband. However, while mobile broadband has limitations for scholastic use, it never-the-less offers some differentiated value and could be used as a substitution for fixed broadband.

> *H3: Households with children are more likely to adopt mobile broadband than households without children.*

Recently, research has focused on multiple theories behind technology adoption and attempted to apply them to broadband adoption (Kim and Garrison, 2009;[27] Grzybowski,

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[27] Kim, Sanghyun, and Gary Garrison. 2009. "Investigating Mobile Wireless Technology Adoption: An Extension of the Technology Acceptance Model." *Information Systems Frontiers; New York* 11 (3): 323–33.

2014[28], Zarmpou, 2012[29]). Theories in technology adoption and the diffusion of innovation point to skills and social factors that could play a part in adoption. Current research on social cognitive theory has focused on technology adoption, identifying factors that foster (or inhibit) the motivation to adopt. While demography is recognized as an influencing factor, consumer understanding of the relative advantage of services differs based on potential utility or benefit they may assign. It recognizes that different consumer groups place different premiums on the value of fixed broadband, and that other means of access (e.g., mobile) may have greater (or at least differentiated) utility for the functions they need or value.

Outside the home internet access points give consumers an opportunity to "try before they buy," to learn the perceived usefulness or relative advantage and build digital skills and confidence in their ability to master the technology (reducing complexity). Research has shown that the ability to observe and try technologies at work or school fosters a greater adoption in the home.[30] Through these outside venues, they can learn and experience the advantages of the technology, build confidence in technical skills, and lower the anxiety of adoption.[31]

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28 Grzybowski, Lukasz. 2014. "Fixed-to-Mobile Substitution in the European Union." *Telecommunications Policy* 38 (7): p.601

29 Zarmpou, Theodora, Vaggelis Saprikis, Angelos Markos, and Maro Vlachopoulou. 2012. "Modeling Users' Acceptance of Mobile Services." *Electronic Commerce Research* 12 (2): 225–48.

30 Kyriakidou, Vagia, Christos Michalakelis, and Thomas Sphicopoulos. 2013. "Driving Factors during the Different Stages of Broadband Diffusion: A Non-Parametric Approach." *Technological Forecasting and Social Change* 80 (1): 132–47.

31 LaRose, Robert, Kurt DeMaagd, Han Ei Chew, Hsin-yi Sandy Tsai, Charles Steinfield, Steven S. Wildman, and Johannes M. Bauer. 2012. "Broadband Adoption| Measuring Sustainable Broadband

Consumer preferences may also reflect differences in the compatibility of the technology to their lifestyle, their perception of the complexity of the technology (and their ability to master it) and other innate consumer characteristics. The adoption of mobile devices for access to the internet can be driven by compatibility with lifestyle as well as a reduction in complexity (mobile devices are considered simpler to connect and operate than computers).

> *H4: Households with access to internet outside the home are more likely to adopt mobile broadband service.*

Consumer risk tolerance and comfort level with uncertainty is a likely factor in adoption decisions. For many consumers, the uncertainty regarding volatility of installation and recurring costs are deterrents to adoption.[32] Many services are usage sensitive and pay as you go, while still others lock consumers into a plan, and will escalate charges for usage above the minimum.[33]

Other forms of risk include those associated with technological obsolescence, credit and banking fraud, identity theft, online harassment, cyber-bullying, and privacy/security. In

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Adoption: An Innovative Approach to Understanding Broadband Adoption and Use." *International Journal of Communication* 6 (0): 25. p.2584

[32] Gideon and Gabel. p.743

[33] Although this is rapidly changing as providers now bundle services for a discounted fixed monthly price and offer unlimited data services.

recent years, online security breaches of retailers (e.g., Target), online search engines/email providers (e.g. Yahoo), government agencies (OPM), and insurers (Anthem), privacy of online transactions and disclosures have been headline news. These events make consumers keenly aware of privacy and security concerns. In a study by Chong et al. (2010) in Malaysia, they found that privacy and security had a strong impact on a consumer's decision to adopt mobile broadband.[34]

> *H5: Households that perceive (or have experienced) high privacy and security risks related to internet use are more likely to adopt mobile over fixed broadband or disconnect completely.*

There is scant literature applying technology adoption theory for mobile broadband adoption and it's relationship with fixed broadband adoption. The household environment (life cycle stage based on young and old, children or no children) is expected to provide a context for perspectives that will influence decisions to adopt. Children themselves may introduce technology in the home. Opportunities to observe and experience new technologies outside the home and the risks associated with adoption are also expected to be contributing factors to both consumers' decisions to adopt and their choice between fixed and mobile broadband.

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[34] Chong, Alain Yee-Loong, Keng-Boon Ooi, Nathan Darmawan, and Voon-Hsien Lee. 2010. "Determinants of 3g Adoption in Malaysia: A Structural Analysis." *The Journal of Computer Information Systems; Stillwater* 51 (2): 71–80.

This research is intended to add to the literature regarding fixed and mobile technology broadband adoption. Much of the literature internationally has studied the impact of mobile broadband on developed and undeveloped countries, while in the U.S. much of the research to date has focused on fixed and mobile *voice* telephony. Most government metrics tracking broadband have been collected from industry disclosures, focusing largely on fixed deployment and mobile coverage. Few government programs follow adoption of broadband or specifically the choices between access technologies. Only recently with the emergence of high-speed 3G technologies has the literature begun to focus on the trade-offs for internet access. The convergence of these technologies can create a more ubiquitous internet infrastructure but also can force consumer trade-off decisions to balance cost and lifestyle factors.

CHAPTER 3: A BRIEF HISTORY

Introduction of the telephone in the late 19th century ushered in a new paradigm for communication and business. It provided instantaneous communications between subscribers, improved public safety, connected suppliers with consumers, and broadened the reach of business.

With the emergence of the internet in the late 20th century, businesses were transformed once again. Few question that the internet has created new businesses and extended the reach of many more. Governments have invested vast resources into their country's infrastructure to ensure access for more citizens and businesses.

The United States has been among the world leaders in universal telephone service with a highly structured, regulated telecommunications industry over the past century. It was considered a first amendment right to have access to telephone service for public safety, emergency services, and communications.

In the U.S., telecommunications is provided through private industry. Service providers have typically favored provision of services to high-density, higher socio-economic groups to maximize revenues and profits. Since the Communications Act of 1934, federal and state government policies and programs have shifted billions of dollars to subsidize physical connections primarily in areas less attractive to industry: rural and low-income areas.[35,36]

Competition and subsequent deregulation allowed the industry to restructure its services and chase more profitable pursuits. Rapid advances in technology and the growth of the internet has provided great impetus for the growth of the underlying infrastructure, particularly in easy access, highly populated areas. The result has been an uneven deployment of high speed internet services with rural, low-income areas having limited services at an affordable cost.

Fixed to Mobile Substitution

Much of the literature until 2010 has focused on cellphone adoption, specifically Fixed to Mobile Substitution (FMS). FMS primarily addressed voice telephony service – i.e. replacing a home phone with a mobile phone. While the term FMS was used in a broad set of studies, it generally did not mean the classic economic definition of substitution as cross-price elasticity of demand."[37]

The dynamics of voice communication are different from that of mobile broadband.

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[35] Blackman, Colin R. 1995. "Universal Service: Obligation or Opportunity?" *Telecommunications Policy* 19 (3): p.172

[36] Mueller, Milton. 1997. "Universal Service and the Telecommunications Act: Myth Made Law." *Communications of the ACM* 40 (3): p.41, 43

[37] Vogelsang. p. 5

Voice telephony is essentially one-to-one communication, or person-to-person, while mobile internet can be one-to-one, one-to-many, or person-to-machine (or information resource). FMS studies typically researched two-sided networks, calling plans, rate structures, the "mobility premium," and network effects.[38] Regulators focused on the impact on access charges as fixed networks declined in favor of mobile.[39] In other studies, the excess capacity of unused fixed networks with high sunk costs presented issues with average incremental costs over the long-run.[40] These disruptions of long-standing cost models created policy implications for termination and origination costs, and impacted regulations for fixed providers that could inhibit competition.

In addition to a largely voice telephony oriented body of research, much of the literature also focused on supply–side issues. U.S. telecommunications regulation over the past 100 years set the table for today's environment. U.S. telecommunications policies have centered on the conviction that only a natural monopoly could achieve economies of scale to deliver affordable, ubiquitous telephone service. This view led to a regulatory environment that protected that monopoly from new market entrants, allowed network providers relief from antitrust regulation to acquire other competitors, and created a more integrated network. Internal subsidies were permitted to maintain artificially high prices in some market segments (long distance) to help offset the costs in other segments (local telephone service). Local regulation provided few incentives for monopolies to upgrade

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38 Ibid. p. 5
39 Grzybowski. p.601
40 Vogelsang. p. 15

their infrastructure and granted these monopolies broad leeway to capitalize and utilize local rights of way.

This focus on monopoly management and price controls created a path dependency for most regulators, and likewise much of the literature has focused on these issues. However, technology disruption from mobile broadband creates a new opportunity to rethink supply-side regulation and research the implication of this new means of alternative access.

There is relatively little literature on the impact of fixed and mobile broadband in the U.S., largely due to recency of available data. Much of the literature prior to 2005 was on substitution and complementary effects of mobile cellular and fixed voice communications. In 2005, the first mobile broadband technology, 3G, was introduced, but took several years to upgrade infrastructure and penetrate the subscriber base.[41] In 2010, it reached 50 percent penetration, and by the 3rd quarter of 2014, reached over 100 percent penetration.[42] However, these numbers can be deceiving, because mobile broadband is measured by subscriptions per 1000 residents, and some households may have multiple subscriptions, while others have none.

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[41] Mishra, Ajay R. 2010. "Cellular Technologies for Emerging Markets: 2G, 3G and Beyond." Willey - Nokia Siemens Networks

[42] "Broadband Access - Wireless Mobile Broadband Subscriptions - OECD Data." 2017. *theOECD*. Accessed February 5

One conclusion drawn from FMS is that as mobile networks mature they become substitutes for the fixed networks and "ultimately can lead to their demise."[43] While FMS is focused on voice telephony, mobile broadband offers a somewhat differentiated service. Mobile broadband developments could change the market dynamics of FMS. Literature that addresses mobile broadband as an alternative to fixed broadband in the U.S. is very limited, but is now emerging in the past few years.

Since 2008, the Federal Communications Commission (FCC) tracks broadband deployment relying on data from the providers, but does not track adoption and use.[44] Since 2009, the National Telecommunications and Information Administration (NTIA) monitors coverage of broadband through its mapping programs, and has funded state level initiatives to help foster access and adoption.[45] The U.S. Census Bureau has tracked internet adoption by household through the Community Population Survey since 2006, but has only surveyed mobile internet since 2011.[46] This dataset is the most promising, since it can be used to count the number of households that have at least one mobile subscription.

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43 Vogelsang. p. 5

44 Federal Communications Commission (FCC). 2016a. "Form 477 County Data on Internet Access Services." December.

45 National Telecommunications and Information Administration (NTIA). 2016a. "Broadband Map - Technology." National Broadband Map. December.

46 National Telecommunications and Information Administration (NTIA). 2015. "Current Population Survey (CPS) Computer and Internet Use Supplement." July.

Building a Mobile World

Digital cellular networks (2G) were first introduced in 1991, and have steadily grown and developed since. While initial digital cellphones were not feature rich and fell well short of today's capabilities, they created two important elements critical to modern mobile broadband. First, they created the digital infrastructure of cell towers and backbone networks that created a largely ubiquitous network nationwide. Second, they created a cultural shift in communications – the ability to communicate virtually anywhere at anytime.

By definition, *mobile broadband* requires a device such as smartphones, tablets, USB cards or PC cards to communicate with the digital cellular networks. It is not WiFi or satellite communications, often referred to as *wireless* broadband.[47] True "broadband" digital cellular communications was not achieved until the specification of 3G standards in 1998, capable of 384 kbps to as much as 4 Mbps. 3G network implementation took from 2002 (first implementation) until 2009 to comprise 50 percent of the infrastructure in the U.S. However, these tend to be in more populated areas, where there is potential for greater revenues for the providers. Wireless providers are reticent to provide more mobile wireless cell towers and/or upgrade existing towers to digital and higher speeds (3G and 4G) in rural areas because it is not economically worthwhile. In fact, cell tower construction has slowed since 2013 in favor of Distributed Antenna Systems (DAS) that

[47] Thompson Jr., Herbert G., and Christopher Garbacz. 2011. "Economic Impacts of Mobile versus Fixed Broadband." *Telecommunications Policy* 35 (11): p. 1001.

allow subdividing mobile coverage areas in more densely populated regions.[48]

In 2008, LTE (or 4G) standards were introduced, which allows still greater speeds (downlink rates of 300 Mbps and uplink rates up to 75 Mbps). In 2014, LTE smartphones made up over 50 percent of the subscriber population in the U.S. Despite leading globally in LTE subscriber adoption, the U.S. is falling behind most countries in the download speed of its LTE networks, coming in 14th slowest behind North American neighbors Canada and Mexico, and behind Russia.[49]

The Smartphone: Handheld Internet

Even with 3G and 4G LTE networks supporting relatively high-speeds and ample capacity, it wasn't until 2007 with the introduction of the first "smartphone," the Apple iPhone, that the merits of high-speed network access become evident.[50] The iPhone was a catalyst for many other providers such as Samsung to enter the market. In 2011, smartphone mobile devices outsold PCs for the first time.[51] In 2017, the U.S. is expected to have the world's highest penetration rate at 63.5 percent.[52]

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[48] Wireless Telecommunications Bureau. 2015. "Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services." DA 15-1487. Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993. Washington, D.C.: Federal Communications Commission. p.46

[49] "US High-Speed Wireless Is Actually among the World's Slowest." 2017. *CNET*. Accessed February 26.

[50] Kim, Dongil, JeeEun Karin Nam, JungSu Oh, and Min Chul Kang. 2016. "A Latent Profile Analysis of the Interplay between PC and Smartphone in Problematic Internet Use." *Computers in Human Behavior* 56 (March): p. 360

[51] Leber, Jessica. 2012. "Questions for Mobile Computing." *MIT Technology Review*. May 1.

[52] "US Smartphone Market." 2017. *www.statista.com*. Accessed February 27.

Since the widespread availability of mobile broadband devices and networks, smartphone and network providers have diminished the clear-cut differentiation and more seamless interaction across applications, multiple devices, and access methods, referred to as *service convergence*.[53] This convergence can take the form of device integration (e.g., across Apple or Android operating systems), in the cloud (for storage or shared applications across multiple platforms), or in the network (e.g., WiFi hotspots or personal cellphone hotspots that bridge network services). In the latter case, it is referred to as *network convergence*.[54]

Coupled with the availability of smartphone is the emergence of mobile applications (or "apps"). These apps enable mobile broadband devices to communicate, collect and share information in the forms of voice, text, and video. Mobile apps are now growing faster than desktop internet applications.[55] As of 2017, there are over 2 million mobile apps available for mobile devices - a $77 billion market.[56] These applications often come with their own "ecosystem" for messaging, sharing social content, navigating, playing games, etc. It is estimated that individuals spend 52 percent of their digital media time on these mobile applications.[57] These apps are often easier to learn and operate than their desktop

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53 Studer. p.135.
54 Ibid.
55 Nour. p. 54.
56 "The 2017 Mobile App Market: Statistics, Trends, and Analysis." 2017. *Business 2 Community*. Accessed February 27.
57 Ibid.

counterpart, permitting users to build confidence and reduce anxiety associated with technical skill acquisition.

CHAPTER 4: LITERATURE REVIEW

This section describes the technology adoption theories and their relationship to each other and mobile broadband adoption. It also includes research to date on fixed and mobile broadband adoption and current literature regarding mobile broadband substitution, both globally and domestically.

Technology Adoption Theory Literature

While government programs and analysis have focused on the demographics of the divide, there is emerging empirical evidence that "demography is not a destiny" – that technology adoption is more a result of relative value, norms, and attitudes.[58] Theory suggests there may be different value systems in place for distinctive subscriber communities that affect their market choices (to connect or not, fixed or mobile). These may be the result of different mechanisms for learning (observational or enabled) that come from exposure in schools or the workplace.

Theories in technology adoption and the diffusion of innovation point to skills and social factors that could play a part in adoption. While many components of each theory overlap, each offers new aspects and perspectives that comprise a more comprehensive

[58] LaRose et al. 2012. p.2588

ontology. Notably, government sponsored programs to date have focused on very narrow aspects of technology adoption theory, primarily digital literacy.

Barriers to Broadband Adoption. There are some more obvious barriers to broadband adoption. The high cost of purchasing a computer (and software) can be a deterrent to broadband adoption. The U.S. Census Bureau 2013 American Community Survey (ACS) found that 84 percent of Americans have a computing device at home (including PCs, tablets and smartphones), and 74 percent have at least low-speed (dial-up) internet access.[59] These figures vary widely by geography and demographics. For example, in a 2011 NTIA study, 45 percent of seniors indicated they did not have a home computer, compared to only 20 percent of those under age 65.[60] (See Note 61.) NTIA also found that low-income households who do not own a computer indicated they "don't need it" or are "not interested."[62] There was no clear value proposition. Owning a personal computer increases the probability of adopting broadband services by 18.3 percent.[63]

While the U.S. has competitive pricing for data services at lower speeds, the higher tier broadband is relatively costly at $76.64 for speeds up to 50 Mbps and 199.99 for speeds

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59 US Census Bureau. 2016. "ACS New State & Local Income, Poverty, Health Insurance Statistics." Accessed May 5.

60 Davidson, Charles M., Michael J. Santorelli, and Thomas Kamber. "Toward an inclusive measure of broadband adoption." *International Journal of Communication* 6, no. 0 (2012): p.2556

61 Author analysis of 2015 CPS data did not show much improvement since 2011. In 2015, 49 percent of the CPS primary respondents 65 and over did not have a computer compared to nearly 31 percent of those under 65. Nearly 44 percent of the younger respondents without computers had smartphones, while only 17 of seniors without computers had smartphones.

62 Davidson et al. p.2564

63 Roycroft, Trevor R. 2013. "Empirical Study of Broadband Adoption Using Data from the 2009 Residential Energy Consumption Survey." *Journal of Regulatory Economics* 43 (2): p.225.

up to 100 Mbps. This ranks the U.S. at 41st in terms of subscriber cost among developed countries (in cost per megabit in purchase power parity (PPP) dollars).[64] However, prices for broadband are difficult to discern due to bundling and variations in speed. The NTIA and the FCC only periodically study pricing and the data is subject to considerable variation across the country.

In 2013, thirty-six percent of non-adopters cite the cost of broadband as the reason they do not have service at home.[65] The federal government has several programs that help subscribers to limit installation and recurring costs. The Link-up program offers a $100 discount on installation fees, while Lifeline offers discounts up to $9.25 per month for fixed or mobile services.[66] The "Internet Essentials" program by Comcast (mandated as a conditions of their merger agreement with Universal) seeks to lower the cost of broadband service ($9.95/month), offer low cost computers (149.99 including Microsoft Office), and provide free classes (locally or online) to build digital literacy.[67] While affordability is often cited in surveys as a primary reason for not adopting, other studies show little impact of monthly subscriber costs on adoption.[68] In fact, only one-third of those eligible for federal assistance programs for installation and recurring costs (Link-

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[64] "Point Topic - Residential Broadband Tariff Scorecard by Country – Q2 2016." 2017. Point Topic. Accessed April 26.

[65] Gilroy, Angele A., and Lennard G. Kruger. 2013. "Rural Broadband: The Roles of the Rural Utilities Service and the Universal Service Fund." CRS Report for Congress CRS-2013-RSI-0317. Congressional Research Service, Resources, Science, and Industry Division (CRS). p.12

[66] Federal Communications Commission. 2014. "Universal Service Support Mechanisms." *FCC Guides*. April 12.

[67] Davidson et al. p.2563

[68] Tomer and Kane. 2015. p.2

Up and Lifeline) actually enroll for the subsidy.[69] These assistance programs can lower costs to subscribers, but it is clear that for many, if it is not "relevant" or they are "not interested," then no price is attractive.

Other technologies serve as indicators of propensity for broadband adoption, including television sets and television service. Roycroft (2013) studied the relationship of broadband access with television services, considered to be complementary services. Network providers often offer these as part of a "bundle" of services. He found that owning a television set increases probability of broadband adoption by 3.3 percent. He also found that those that use cable television (pay services) are more likely to adopt broadband, while rural and elderly communities that often utilize over-the-air television are less likely to adopt. Subscribing to cable television increases the likelihood of broadband adoption by about 21 percent over broadcast (over-the-air) television.[70] This may be due to lower incremental monthly costs of adding broadband service as part of a bundle as well as the ready presence of a physical connection that lowers installation costs. Notably, research by Roycroft also found that the length of time a television is turned on lowers the probability of a broadband connection, indicating potential substitution effects.[71]

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69 Gideon and Gabel. p.740

70 Roycroft. pp.214, 225-226

71 Ibid. pp.222-24

Technology Adoption Models/Theories

Recently, research has focused on multiple theories behind technology adoption and attempted to apply them to broadband adoption. Theories in technology adoption and the diffusion of innovation point to skills and social factors that could play a part in adoption. The following section explores the different theories, the components considered for each theory and its appropriateness and challenges toward broadband adoption measurement. It concludes with potential components that are not included or only partially addressed by current technology adoption models. These models could yield insight into additional causal/contributing factors for broadband adoption.

Diffusion of Innovation Theory. Everett M. Rogers first introduced diffusion of Innovation Theory in 1962, authoring a book by the same name (the 2nd most cited book in social sciences).[72] In it, he describes how communications channels spread ideas over time. He focused on the social components of sharing information to help move through the stages of adoption. His theory on the diffusion of innovation (often characterized as a paradigm) has five distinct characteristics. The first is *relative advantage* – is it better than current alternatives? Adopters must examine current process or product to determine if the new innovation has perceived advantages over their current environment. The second is *compatibility* – is it consistent or a good fit with current lifestyle, beliefs, and values, as well as other adopted technologies? The closer and more consistent the fit, the more likely they will be to adopt. The third characteristic is *complexity* – can I master

[72] Rogers, Everett M. 2003. *Diffusion of Innovations, 5th Edition*. 5th edition. New York: Free Press.

the skills necessary to utilize this technology? In this case, it is the belief or confidence in their ability to be proficient at operating the new technology. The fourth is *trialability* – can I see if it will work for my skills and my needs? An ability to experiment is crucial to building confidence and determining fit. Finally the fifth characteristic is *observability* – can I readily see through others how they use and benefit from the technology? This exposure is essential in meeting the thresholds of the previous characteristics. It also adds a social component that allows potential users to see how it is utilized in their social circles.[73]

Rogers also illustrated five stages of adoption. The stages were initial exposure, developing a positive/negative impression of the innovation, decision to accept or reject, actual usage, and confirmation of if its value and continued use.[74] He plotted adopters on the familiar S-curve, and categorized them as ‘‘innovators, early adopters, early majority, late majority and laggards.’’[75]

Hilbert (2011) built on Rogers' theory and stressed the importance of the communications, or ties between nodes, not simply the nodes. By observing the attributes (frequency, direction and strength) as well as the content of the ties, patterns can be discerned that can shed light on influences in adoption.[76]

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[73] LaRose et al. 2007. p.361
[74] Rogers. 2003.
[75] Hilbert. pp.716
[76] Ibid. pp.724

The DoI theory is independent of geography and demographics that define the digital divide. The theory focuses first on the benefits and value that could be gained through adoption. These will be different for different groups as their social dynamics and needs may be unique. The theory then focuses on social networks and learning, the ability to communicate and share benefits, lessons learned, and confidence building through observation and trial. While some government and industry programs offer training, they fail to potentially exploit some of the communal ties and values that might increase demand. (See Note 77).

Social Cognitive Theory (SCT). Social cognitive theory also focuses on communications and learned behaviors, particularly observational and enabled learning.[78] SCT includes expected outcomes (anticipated benefit), self-efficacy (confidence that they can master performance even if they haven't experienced it yet), habit strength (prior use of the internet), observational learning (evaluating what others are doing with an innovation), and enactive learning (through their own experience). [79] Habit strength has a time element embedded in it, since the more time or exposure to an activity, the greater the habit strength. This may make access outside the home at work or school, where there is sustained exposure, superior to intermittent access characteristic of libraries and community centers.

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[77] As noted in Chapter 6, this became integrated into the approach by some of the organizations to foster broadband adoption. The "trusted agent" approach is used to strengthen and increase the frequency of communications among the key players in the community, lowering apprehension or fear of the technology and engendering a willingness to try.

[78] LaRose at al. 2012. p.2583

[79] Tsai, Hsin-yi Sandy, and Robert LaRose. 2015. "Broadband Internet Adoption and Utilization in the Inner City: A Comparison of Competing Theories." *Computers in Human Behavior* 51, Part A (October): 345.

SCT theory is closely related to DoI theory and shares some of the same characteristics, with the possible exception of habit strength (although it could be argued that it is closely related to complexity). This theory also focuses on learning and its impact on human behavior, factors that are worthwhile exploring in understanding broadband adoption.

Larose et. al. (2012) used the SCT model to predict broadband adoption intentions. They found significant positive relationships with expected outcomes, self-efficacy, habit strength, observational learning, and enactive learning. Notably, the influence of these SCT variables was twice that of the demographic variables. [80]

Ongena et al. (2012) researched adoption through its functional use. They classified these functions "as an information, communication, entertainment, or transaction service."[81] Ontega et al. also further classified services as hedonic (for pleasure such as entertainment) or utilitarian (for productivity or efficiency). [82] These categories are consistent with some aspects of the social cognitive theory.

Model of Adoption of Technology in Households (MATH). MATH borrows heavily from the Theory of Planned Behavior (TPB) and focuses primarily on inherent consumer norms, attitudes, and control beliefs. Normative beliefs are external to the potential adopter, represented by friends and family, social and media influences, and the

[80] LaRose et al. 2012. p.2588
[81] Ongena et al. p. 294
[82] Ibid. p. 283

workplace. Attitudinal beliefs are more internal, stemming from personal utility such as productivity, entertainment, or status gains. Finally, control beliefs stem from fear of uncertainties, such as privacy, security and safety concerns.[83]

The MATH model encompasses many of SCT's concepts, such as attitudinal beliefs that are similar to expected outcomes, and control beliefs such as ability are similar to compatibility attitudes. The external factors that influence normative beliefs that are included in MATH are not explicitly addressed (other than through observational learning) in both DoI and SCT.

In a study of 750 households without a personal computer, Brown and Venkatesh (2005) used the MATH model to predict intentions to adopt a PC. Results showed that the MATH model accounted for 50 percent of the variance, with the expected attitudes and norms showing a significant positive influence (with the exception of status gains for attitudinal beliefs and workplace influences on normative beliefs), while controls showed the expected negative influence on adoption (fear of technological advances and cost). However, when the MATH was run with household life cycle (12 stages arrayed across marital status, age, children, etc.) and income, the model accounted for 74 percent of the variance. It reduced the impact of most of the belief variables, with the exception of the utility for children. Stratifying the MATH variables by household life cycle was the most compelling finding. For example, attitudinal beliefs had the highest influence on

[83] Tsai and LaRose. p. 346.

broadband adoption intent for single parents and full nesters, specifically the broadband's utility for children. Control beliefs had the highest influence on broadband adoption intent among childless couples and the elderly, specifically requisite knowledge and ease of use.[84] These findings are directly comparable to broadband adoption challenges for specific household groups.

Technology Acceptance Model (TAM). TAM builds on the Theory of Reasoned Action (TRA), a model used in social psychology. Similar to MATH, TAM includes norms and attitudes combined together to create better predictors of adoption.[85] However, TAM also includes perceived usefulness (defined as productivity improvement) and perceived ease of use, similar to the relative advantage and complexity components of DoI.[86]

TAM does not include past experiences (trialability) so is often used when there is limited or no data on past exposure to the technology (e.g., through dial up, schools, libraries, or the workplace).[87]

In a study of students in South Korea, Kim and Garrison (2009) developed the Mobile Wireless Technology Acceptance Model (MWTAM), which extends TAM to include perceived ubiquity (ability to conduct uninterrupted communications between the user

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84 Brown and Venkatesh. p.402.
85 Davis, Fred D., Richard P. Bagozzi, and Paul R. Warshaw. 1989. "User Acceptance Of Computer Technology: A Comparison Of Two." *Management Science* 35 (8): p.983
86 Ibid. p.985
87 LaRose at al. 2012. p.2584

and other users on other networks), perceived reachability (ability to reach anyone at anytime), and job relevance (the extent to which users find mobile wireless applicable to their job). The results of their study showed that these factors helped to account for most of the variance for the individual's intention to adopt mobile wireless.[88]

Unified Theory of the Acceptance and Use of Technology (UTAUT). The UTUAT model originated via TAM from the TRA. The UTUAT model includes many familiar elements, including performance expectancy (similar to perceived usefulness in TAM and relative advantage in the DoI model), effort expectancy (similar to complexity in the DoI model and self-efficacy in the SCT model), social influence (similar to normative beliefs in MATH), and one more appropriate for the workplace adoption, referred to as facilitating conditions. Facilitating conditions is the trustworthiness of organizational support and infrastructure, and the organizational commitment to the technology or innovation long-term. UTUAT also includes interactions with control variables representing gender, age, and prior experience.[89] UTUAT is primarily tailored to the organizational (workplace) environment and does not include factors that may be more suitable for technology adoption in the home.[90] In an empirical study of workplace intentions to adopt, Venkatesh (2003) used the UTUAT model and found that the highest significant correlation to broadband adoption intent was with performance expectancy.[91]

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88 Kim and Garrison. 2009. pp. 323–33.

89 Venkatesh, Viswanath, Michael G. Morris, Gordon B. Davis, and Fred D. Davis. 2003. "User Acceptance of Information Technology: Toward a Unified view1." *MIS Quarterly* 27 (3): p.447

90 Tsai and LaRose. p.347.

91 Venkatesh at al. 2003. p.462

UTUAT2. Building on UTUAT, UTUAT2 was extended to include a consumer adoption context. UTUAT2 includes additional components of hedonic motivation (the "fun" or pleasure gained, similar to attitudinal beliefs of MATH) and habit strength (similar to habit strength in the SCT model).[92] UTUAT2 also includes the component price value to capture the perceived benefit over monetary cost preferences of consumers. This is notable because cost is cited as one of the gating factors for broadband adoption. In this case, it must be weighed against the perceived value to be gained, and could be considered similar to the relative advantage component of the DoI model. In the model, when age and gender are added they may have an influence on price value. Experience is also added as it is expected to influence habit strength.[93]

The components of UTUAT and UTUAT2, initially developed for workplace technology adoption, are useful additions in understanding household adoption. In a cross-country study of mobile health services, Dwivedi et al. (2016) found that price value was a consistent determinant of adoption, while hedonic motivation was not a significant factor in the U.S. and Canada.[94] This is consistent with previous NTIA studies, where affordability was consistently cited as an inhibitor to adoption by nearly a third of

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[92] Tsai and LaRose. p.347.

[93] Venkatesh, V., J. Thong, and X. Xu. 2012. "Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology." *MIS Quarterly* 36 (1): 157–78.

[94] Dwivedi, Yogesh K., Mahmud Akhter Shareef, Antonis C. Simintiras, Banita Lal, and Vishanth Weerakkody. 2016. "A Generalised Adoption Model for Services: A Cross-Country Comparison of Mobile Health (m-Health)." *Government Information Quarterly*. p.9

potential adopters.

Model Comparison. Understanding technology adoption theories can help to identify the causalities and potential barriers to broadband adoption. Table 1 shows the various theories employed to better understand technology adoption. Only UTAUT2 includes the price value trade-off of technology adoption, although TAM and DoI do consider relative advantage of adoption over current methods, which could include an inherent cost consideration. While there is significant overlap among key components in each of the theories, the underlying definitions differ somewhat, and empirical studies often use a set of subcomponents that further define and quantify the component.

Components	**Diffusion of Innovations** (DoI)	**Social Cognitive Theory** (SCT)	**Model of Adoption of Technology in Households** (MATH)	**Technology Adoption Model (TAM)**	**Unified Theory of Adoption and Utilization of Technology (UTAUT)**	**UTAUT2**
Relative Advantage	X	"expected outcomes"		"perceived usefulness"	"performance expectancy"	"performance expectancy"
Compatibility	X		"control beliefs"			
Complexity	X	"self efficacy"		"perceived ease of use"	"effort expectancy"	"effort expectancy"
Trialability	X	"enactive learning"				
Observability	X	"observational learning"				
Normative Beliefs			X	X		
Attitudinal Beliefs			X	X		**
Habit Strength		X				X
Hedonic Motivation						X
Price Value Perceptions						X
Facilitating Conditions					X	X

** Some elements of attitudinal beliefs fall under compatibility*

*** Some elements for facilitating conditions and hedonic motivation fall under attitudinal beliefs*

Table 1: Component Comparison of Technology Adoption Theories

Some research has been conducted to test the fit of different models and each of the associated components. Expected outcomes are consistently the greatest indicator of broadband intentions, with learning (observational and enabled), and self-efficacy and habit strength also having a positive influence.[95] Given that so many theories rely on a measure of "relative advantage" in its various permutations, analysis should stratify the benefits associated with different classes of users. The Brown and Venkatesh (2005) categorization of households differentiated the different needs based on household life cycle stages, a potentially useful construct for analysis of future adoption programs.

Trialability, observability and habit strength are key components to many digital literacy programs, and can have a direct impact on complexity. Programs such as Older Adults Technology Services (OATS) digital literacy training to seniors claim strong results, with 93 percent of seniors receiving training still using computers after 6 months.[96] However, articulating a compelling relative advantage unique to target communities is critical to gaining interest from those that do not see it as relevant to their lives. Those communities are not likely to invest the time in digital literacy training in the first place if broadband is not relevant to them.

While the UTUAT models both speak to workplace experience, a broader component may be the trialability or observability of potential subscribers in the workplace. Time spent on computers and the internet in the workplace can both build awareness of the

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95 LaRose et al. 2012. p.2588
96 Davidson et al. p.2560

benefits and generate confidence in technical skills to master the technology.

Figure 3 below shows the relationships among each of the theories. While each has their own unique definitions, they generally fall under or are consistent with other elements of the Diffusion of Innovation and Social Cognitive theories. For this research, the elements of DOI and SCT will be the descriptive elements going forward.

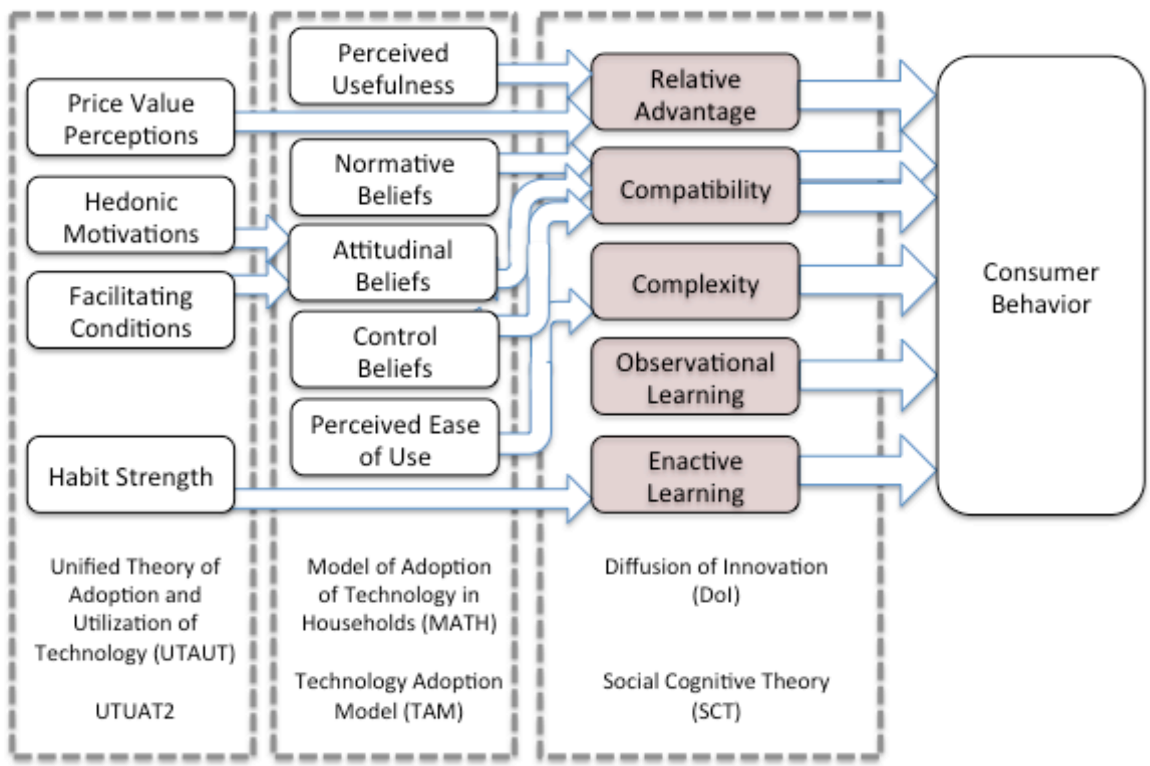

Figure 3: Relationship of Technology Adoption Theories

International Research on Fixed and Mobile Broadband

Globally, internet penetration is over 50 percent in emerging economies (China, Brazil, Malaysia) and 87 percent in the 11 most advanced economies.[97] Mobile broadband has surpassed fixed service in developing and developed countries, while in other regions fixed and mobile service have reached parity.

The Organization for Economic Cooperation and Development (OECD) through the International Telecommunication Union (ITU) collects telecommunications information and statistics across 222 different countries. Given the variety of development embodied by these countries, it presents a data-rich opportunity to analyze the trade-off within and among countries. The datasets include both fixed and mobile voice, internet, and broadband internet per 1000 inhabitants.[98]

Since 2010, a significant amount of research has been conducted in OECD countries, specifically Europe and Korea, where mobile broadband has made significant inroads and data could be gathered efficiently.[99] Most of these studies suggest a strong relationship between broadband and its impact on growth and efficiency, but each has unanswered issues with the direction of causality. [100] In addition, while these approaches and methods

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[97] Poushter, Jacob. 2016. "Smartphone Ownership and Internet Usage Continues to Climb in Emerging Economies." *Pew Research Center's Global Attitudes Project*. February 22.
[98] Lin, Chiun-Sin. 2013. "Forecasting and Analyzing the Competitive Diffusion of Mobile Cellular Broadband and Fixed Broadband in Taiwan with Limited Historical Data." *Economic Modelling* 35 (September): p. 210
[99] Kyriakidou et al. p. 133.
[100] Thompson and Garbacz. p. 999.

offer value, the results are not very generalizable for use in the United States due to different demographics, topology, network diversity, and cultures.

Lee et al. (2011), in a study of 30 OECD countries, found that fixed broadband diffusion is impacted by unbundling the local loop, income, education, price and population density. For mobile broadband diffusion, multiple standards and population density (more urban) are the most significant positive factors.[101] Many of the demographic and geographic factors track closely with the U.S. digital divide.

Thompson and Garbacz (2011) studied 215 OECD countries' broadband penetration rates and found that mobile broadband has a positive impact on country GDP per household. They also found that mobile and fixed broadband have a positive impact on low-income countries, although mobile broadband's impact is lower than that of higher-income countries.[102] While the U.S. has often stressed the economic impact of fixed broadband to GDP, it has not addressed the potential economic impact of mobile broadband.

Grzybowski (2014) research of EU countries from 2005 to 2010 showed that the 3G reduced the number of households with both fixed and mobile (voice only) service in favor of mobile broadband only service.[103] Kyriakidou et al. (2013), in a study of 26 European countries from 2001 to 2009, found that E-government initiatives as well as

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[101] Lee, Sangwon, Mircea Marcu, and Seonmi Lee. 2011. "An Empirical Analysis of Fixed and Mobile Broadband Diffusion." *Information Economics and Policy* 23 (3–4): p. 231

[102] Thompson and Garbacz.. p. 999

[103] Grzybowski. p.601

people that use the internet at work have a positive effect on fixed broadband adoption. They also found that population density had a positive impact on fixed broadband adoption, suggesting people in urban centers are more likely to adopt.[104] Kyriakidou's findings are consistent with U.S. studies on fixed broadband adoption access through work.[105]

Afridi et al. (2010), conducted a longitudinal study in the UK from 1999 to 2006, analyzing the price elasticity of fixed and mobile voice communications. They found a negative relationship between price for fixed and mobile and a positive relationship between GDP and mobile phone usage, concluding the importance of both competition and price to industry development.[106] Ongena at al. (2012) conducted a survey of 628 households in the Netherlands and found that mobile devices are a complement to fixed service. They also found that mobile devices have a "reinforcement" effect for women, who are more likely to conduct transactions on a mobile device that they can already perform on a PC (fixed service). [107]

Lee et. al (2015), in a study of Korea in 2011, found that access and skill gaps create

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104 Kyriakidou et al. 132–47.

105 Kolko, Jed. 2012. "Broadband and Local Growth." *Journal of Urban Economics* 71 (1) (January): 100–113.

106 Afridi, Sajjad Ahmad, Syed Umar Farooq, Muhammad Imran Ullah, and Roeen Rahmani. 2010. "The Analysis of Cellular Services and Estimating Fixed to Mobile Price Elasticities-A Case Study of United Kingdom." *European Journal of Scientific Research* 40 (3): pp. 438-439.

107 Ongena, Guido, Harry Bouwman, and Hugo Gillebaard. 2012. "Displacement and Supplemental Effects of the Mobile Internet on Fixed Internet Use." *JMM: The International Journal on Media Management* 14 (4): p. 294

greater barriers to online activity adoption.[108] A recent study conducted by Kim et al. (2016) on 653 middle and high school students in Korea analyzed "problematic internet use (PIU)" and determined that gender was a significant variable, with males preferring gaming on mobile devices as a complement to PCs, while females preferred social network services on smartphones as a substitute for PCs. Through their research they also found evidence that that all participants were more likely to use the PC less once they used a smartphone, with adolescents reducing PC use more than adults.[109]

Chiun-Sin Lin (2013) studied mobile adoption in Taiwan from 2005 to 2011 and concluded that fixed broadband is not influenced by mobile, but that mobile adoption is influenced by the adoption of fixed broadband.[110] Low-income and rural households were not factored into the analysis, so it is difficult to determine at if this form of commensalism held true across diverse demographics.

In a study of Bangkok's residential internet consumers, Madden et al. (2015) found that mobile and fixed services were considered substitutes with positive cross-price effects, but that the two were not mutually exclusive. They recognized that due to geographic and service availability differences across Thailand those substitution characteristics

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[108] Lee, HyunJoo et al. p. 45
[109] Kim et al. 2016. p. 367
[110] Lin, Chiun-Sin. p. 211

between fixed and mobile might be different.[111]

Mohamed Abdalla Nour (2014) conducted a survey of 220 undergraduate students in the Middle East to determine preferences regarding mobile internet adoption. He found no significant difference between male and female mobile access preference, but did find that electronic communications, transactions, and entertainment affects the choice of mobile internet.[112] Gwangjae Jung (2013), in a study of consumers in Singapore from 2006 to 2012, determined that smartphone users did not substitute their broadband or cable TV services, but could not conclude that there was a complementary effect.[113]

From this body of international research, a significant amount of energy is expended to understand the nature and relationship of fixed and mobile broadband. Most conclude that is both a function of demographics and consumer choice.

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111 Madden, Gary, Suphat Suphachalasai, and Thanet Makjamroen. 2015. "Residential Demand Estimation for Bundled Fixed-Line and Wireless Mobile Broadband Services." *Applied Economics* 47 (47): p. 5046.

112 Nour. p. 54.

113 Jung, G. The impact of smartphone adoption on consumers switching behavior in broadband and cable TV services. In *Proceedings of the 35th Annual Pacific Telecommunications Conference 2013.* Red Hook, NY: Curran Associates, 2013, pp. 205-218.

US Studies of Fixed and Mobile Broadband

Since 2010, mobile broadband has nearly doubled the amount of fixed connections.[114] As mobile broadband has increased penetration, fixed broadband has also continued to increase, but at a decreasing rate (reaching the peak of the S-curve). In his seminal book, "Diffusion of Innovation" (2005), Everett Rogers plotted adopters on the familiar S-curve, and categorized them as ''innovators, early adopters, early majority, late majority and laggards.''[115] Figure 4 below shows these S-curves for household adoption through 2005, with cellphone and internet of most interest to this discussion. (See Note 116).

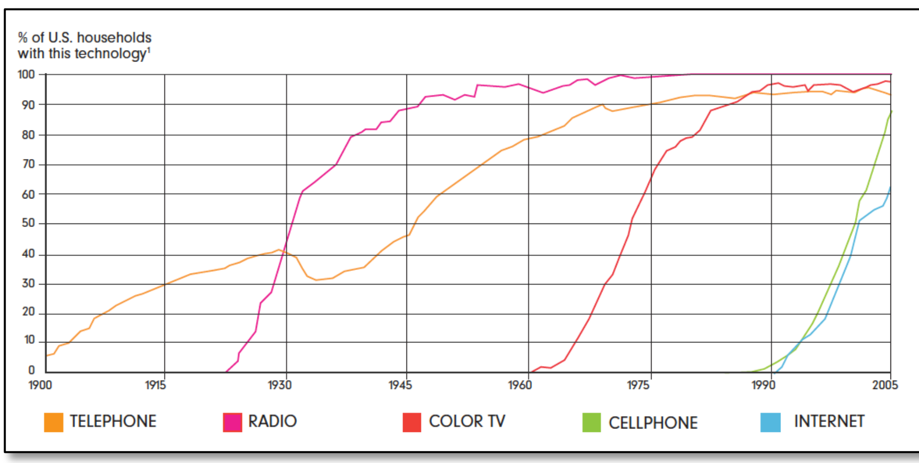

Figure 4 – Percent of U.S. Households with this Technology[117]

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114 Whitacre, Brian. 2017. "Fixed Broadband or Mobile: What Makes Us More Civically Engaged?" *Telematics and Informatics*. Accessed February 25.

115 Hilbert, Martin. 2011. "The End Justifies the Definition: The Manifold Outlooks on the Digital Divide and Their Practical Usefulness for Policy-Making." *Telecommunications Policy* 35 (8): pp.716

116 Note that the cellphone referenced here refers primarily to voice telephone service – smartphones and the infrastructure capable of mobile broadband was not really mature until the late 2000s. That said, the advantages of cellphones to communicate anytime, anywhere competed with fixed voice service, and set the stage for more advanced broadband services.

117 Dailey, Dharma, Amelia Byrne, Alison Powell, Joe Karaganis, and Jaewon Chung. 2010. "Broadband Adoption in Low-Income Communities: A Social Science Research Council Report for the FCC." Social Science Research Council. London School of Economics and Political Science.

The public internet was introduced in the early 90s and paced cellular technology. For the next two decades, it was largely limited to the existing fixed infrastructure – copper wire (dial-up), coax cable, fiber and satellite. The NTIA defines broadband as a minimum 768 kbps download speed and 200 kbps upload speed, while the FCC established a future minimum download speed of 4 mbps.[118] The National Broadband Map currently shows that 88.8 percent of the U.S. population has speeds of at least 3 Mbps, including satellite service.[119] However, satellite service is not considered optimal, due to its high latency and slow upload speeds. In 2015, the FCC defined broadband as 25 Mbps download/3 Mbps upload for fixed services (including satellite).[120] In 2016, no satellite service met that standard.[121]

Literature on mobile broadband, particularly in the US has been challenged by the more recent emergence of mobile broadband and the relative lack of data. The timeframe for user adoption and subsequent data generation for research is compressed into the past decade, beginning with the introduction of the smartphone in 2007 and 3G rollout.

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118 Grimes, Arthur, Cleo Ren, and Philip Stevens. 2012. "The Need for Speed: Impacts of Internet Connectivity on Firm Productivity." *Journal of Productivity Analysis* 37 (2): 187–201.

119 Wireline Competition Bureau, Industry Analysis and Technology Division. "Internet Access Services: Status as of December 31, 2015." *Federal Communications Commission*. November.

120 The FCC and NTIA have received criticism for varied guidance regarding the amount of uplink/downlink speeds constitute "broadband", at times acquiescing to market pressures to allow slower speeds to more rural areas. In a dissenting statement, FCC Commissioner Pai criticized the majority that it was relegating "certain Americans to a slow lane for broadband." Source: "Section 706 Inquiry Eyes Mobile Broadband." 2015. *Telecommunications Reports; Washington* 81 (16): p. 16

121 "2016 Broadband Progress Report." 2016. *Federal Communications Commission*. January 27.

The FCC began tracking fixed broadband penetration in earnest in 2008, collecting information from fixed and mobile network providers regarding broadband deployment.[122] To protect proprietary information regarding providers' customer base, estimates are limited to the number of fixed and mobile providers and the number of fixed connections per 1000 households by county.

The Census Bureau (sponsored by the Bureau of Labor Statistics) has been tracking internet adoption in some form since the early 1990s. In 2009 and 2010, the Community Population Survey (CPS) conducted the "School and Enrollment and Internet Use" supplement survey to determine the type (e.g., dial-up, cable, fiber, satellite) and extent of fixed internet adoption.[123]

In 2011, the CPS introduced the "Computer & Internet Use" (CIU) supplement, a biannual survey more focused on technology adoption, including the use of smartphones.[124] The Supplement data on mobile broadband captured households that used smartphones for internet functions (requiring greater bandwidth than voice and text). The CPS CIU supplement survey has been conducted twice since – once in 2013 and again in 2015, each offering a rich set of new data and inquiries (e.g., 2015 survey included a series of internet privacy, security and safety questions).

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[122] Federal Communications Commission (FCC). 2016. "Form 477 County Data on Internet Access Services." December.

[123] National Telecommunications and Information Administration (NTIA). 2015. "Current Population Survey (CPS) Computer and Internet Use Supplement." July.

[124] US Census Bureau. 2017. "Complete Technical Documentation." Accessed February 28.

At least one study combines the FCC broadband availability data with the 2010 CPS "School Enrollment and Internet Use" Supplement data regarding consumer broadband demand for fixed services and some limited smartphone use. James Prieger (2013) used these datasets to conduct research to understand the demographics of broadband adoption. He recognized that without pricing data, it was not possible to perform a true economic analysis of fixed and mobile substitution. He did find that adoption was very different depending on metropolitan status – with those in metro areas more likely to adopt mobile broadband than non-metro areas, but both (as of 2010) did not use them as complements. He did find that mobile broadband was more likely to be used as a substitute in rural areas.[125]

Mobile Broadband Substitution Research

With networks continuing to advance in capacity, "smart" mobile devices are catching up with fixed broadband's functionality and ubiquity. New smartphones, tablets, wearable devices (glasses, watches, fitness trackers), and emerging artificial intelligence-enabled devices are all making significant inroads in the internet world once dominated by PCs. [126] Trade journals and industry reports have forecasted the rise of the smartphone and ultimate surpassing of the PC and fixed internet services. [127] User time on mobile devices

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[125] Prieger, James E. 2013. "The Broadband Digital Divide and the Economic Benefits of Mobile Broadband for Rural Areas." *Telecommunications Policy* 37 (6–7): p. 499
[126] Nour. p. 68.
[127] Ibid. p. 54.

appears to have surpassed that of fixed internet time for adolescents.[128] Increased functionality through new social forums and functions, GPS-enabled applications, and new productivity tools (banking, shopping, and communications) have bolstered the use of smartphones among the younger consumers.[129]

A significant amount of research has studied the substitution characteristics of fixed households access (trades between dial-up, DSL and cable modem), demonstrating that dial-up "is not considered a substitute for broadband," but depended on the intensity of use.[130] Other studies have shown that mobile voice and fixed voice are price sensitive, that drop in price will increase usage for both mobile and fixed, and concluded that the regulatory environment should focus on price and quality improvement to foster greater adoption.[131] It is not clear whether similar elasticities and substitution effects exist with fixed and mobile broadband.

Service bundling can also have an impact on adoption and substitution/ complementary effects. In his research of European Union fixed and mobile substitution, Grzybowski (2014) studied the impact of *bundling* services – where providers offer discounts to consumers for each additional service added to their bundle. This reduced the number of

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[128] Kim et al. 2016. p. 361

[129] Pearce, Katy E., and Ronald E. Rice. 2013. "Digital Divides From Access to Activities: Comparing Mobile and Personal Computer Internet Users." *Journal of Communication* 63 (4): pp. 722-723

[130] Crandall, Robert W., J. Gregory Sidak, and Hal J. Singer. 2002. "The Empirical Case Against Asymmetric Regulation of Broadband Internet Access." *Berkeley Technology Law Journal* 17 (3): 953–87.

[131] Afridi et al. p. 438.

mobile only households, allowing households to reduce the cost of mobile by combining it with fixed internet, cable television, and home voice service. Using lagged effects, Grzybowski also found that the number of mobile subscribers also impacts subsequent mobile adoption, potentially indicating a greater utility through network effects. [132]

Fixed broadband service will continue to grow (although at a diminishing rate) due to high bandwidth internet needs. In the moment, limitations on speed and data pricing for mobile broadband have limited its ability to replace fixed broadband. However, with 5G standards expected for 2020, mobile broadband may ultimately be an effective substitute for fixed service. [133]

U.S. Digital Demographic Divide Research

Pearce and Rice (2013) describe the digital divide as "the gap between advantaged and disadvantaged computer users and nonusers in the United States and often focuses on socio-economic differences."[134] With all the advances in devices and networks, they are not uniformly deployed or adopted. The broadband divide persists despite technology proliferation and government incentive programs to connect households across the U.S. In a recent survey of 2000 households, the Pew Research Center showed the diversity of Americans representing whites and minorities and all income and education levels

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132 Grzybowski. p.610

133 "Section 706 Inquiry Eyes Mobile Broadband." 2015. *Telecommunications Reports; Washington* 81 (16): p. 16

134 Pearce and Rice. p. 722

choosing to disconnect from fixed broadband in favor of smartphones.[135]

Despite the success in physically connecting households, an estimated 27 percent still do not have fixed or mobile internet access at home.[136] However, this percentage does not count those that may have access through the workplace, schools, or community centers (e.g., libraries). Gideon and Gabel (2011) attribute this decline of fixed connections to increases in certain demographics (i.e. increases in the Black population and the elderly), inconsistencies and unpredictability in consumer pricing, and increases in mobile telephony.[137]

Even with access, those with greater resources or access (e.g., through both fixed and mobile, or outside the home at work or school) will gain more skills and leverage the full potential of the internet over those with limited access and skills. Those with robust access can be more efficient, network and build social and intellectual capital, and take full advantage of online resources. They also develop superior digital literacy, fostering "the ability to access, analyze, evaluate and communicate messages in a wide variety of forms."[138] Lee at al. (2015) studied uses of the internet and found that while there was an access gap there was also a skills gap, represented by a lack of digital literacy and different levels of competence in a variety of networked applications. Those who have

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[135] Horrigan, John B., and Maeve Duggan. 2015. "Home Broadband 2015." *Pew Research Center: Internet, Science & Tech*. December 21.

[136] NTIA. 2015. "Current Population Survey Internet and Computer Use." June.

[137] Gideon and Gabel. 2011. p.740

[138] Aufderheide, P. 1993. Media Literacy. A Report of the National Leadership Conference on Media Literacy Conference Report, Aspen Institute, Washington, DC.

been on longer and have more ubiquitous access have more creative and productive network skills than those with more limited access, creating a secondary divide.[139] Given these stark differences, over time the gap will continue to increase in terms of knowledge gap and enhanced well-being between those with more robust internet access and those without.[140]

Certain demographic communities, particularly Hispanic, non-Asian nonwhite households and the elderly, are over-represented in rural and low-income areas. The more educated the consumer, the more likely to adopt, possibly due to high income and greater exposure. [141] As a result, rural and low-income population segments will not share in the immediate and future benefits of broadband, particularly as it becomes an integral part of other public infrastructures. (See Note 142)

Age plays a significant role in broadband adoption. Young adults are the largest demographic for smartphone adoption, regardless of education or income. Lee et al. (2015) found that older adults (over 65) are more reticent to adopt, often due to a lack of understanding of the benefits and a perceived lack of technical skills to master the technology. Of those older adults that did adopt, the older they were, the more they

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[139] Lee et al. p. 45

[140] Pearce and Rice. 2013. p. 722

[141] Tomer, Adie, and Jose Kane. 2015. "Broadband Adoption Rates and Gaps in U.S. Metropolitan Areas." Brookings Metropolitan Policy Program. p.4

[142] There is also what is referred to as a *rural-rural divide* (Gilroy and Kruger, 2013) Many universities are located in rural areas, and often receive rural grant monies to improve the local infrastructure. The areas adjacent to the universities receive a disproportionate share of the money, and those improved infrastructures often skew or bias the reporting numbers (Malecki, 2003). Adoption may be much worse than measured in areas without a university.

utilized the internet for information online.[143]

Mossberger et al. (2012) studied the impact of online access as an enabler of "digital citizenship." They used survey data over a 5-year span in Chicago to study the relationships between access (fixed or mobile) and activities online. They found that civic engagement was strong with fixed and did not diminish with mobile access (although mobile was not as strong as fixed). However, they also found that Blacks and Latinos online were more likely to engage in civic discourse than those without online access. Mobile engagement is stronger for both of these groups than Whites.[144] In this case, access can be an enabler for some communities to exercise their right to free speech.

The Rural Gap

Rural, economically depressed areas are still unserved or underserved.[145] Among the challenges are high cost, low perceived value, technical proficiency, and consistency with norms.[146] Rural areas are often more difficult and costly to connect, leading to fewer competitive options for service. Rural consumers are also more likely to be less technically proficient and lack the compelling social and network effects to connect (e.g.,

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143 Lee et al. p. 46

144 Mossberger, Karen, Caroline J. Tolbert, and Allison Hamilton. 2012. "Measuring Digital Citizenship: Mobile Access and Broadband." *International Journal of Communication (19328036)* 6 (January): p. 2503

145 Seifert, Mark G. 2009. *Hearing on Oversight of the American Recovery and Reinvestment Act of 2009: Broadband*. Washington, D.C.

146 LaRose, Robert, Jennifer L. Gregg, Sharon Strover, Joseph Straubhaar, and Serena Carpenter. 2007. "Closing the Rural Broadband Gap: Promoting Adoption of the Internet in Rural America." *Telecommunications Policy* 31 (6–7): p.360-61

no one else in their social circles is online).

Rural network providers are less likely to invest in infrastructure (both in the switching centers and local loop) without subsidies, so services are more likely to be limited to older (lower speed) connections. Since network providers rely on economies of scale (and queuing theory of shared resources), a smaller subscriber base may make them unwilling to promote high-demand broadband services (e.g. video) because they may overload their networks.[147,148]

In his 2010 study of U.S. household broadband supply and adoption, Prieger (2013) found that the availability of rural fixed and mobile broadband is much lower than urban areas, and operates at lower speeds than fixed and mobile networks in urban areas. However, mobile coverage is often different than fixed and can serve to close the gaps where fixed broadband is unavailable. Availability was cited as the reason for non-adoption 10 percent of the time for rural households, while only one percent of the time for the general population. He also points out some of the responses were "suspect," since satellite was included in the definition of access and its availability was nearly ubiquitous.[149]

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[147] Ibid. p.360-61, 371

[148] Malecki, Edward J. 2003. "Digital Development in Rural Areas: Potentials and Pitfalls." *Journal of Rural Studies* 19 (2): p. 209

[149] Prieger, James E. 2013. "The Broadband Digital Divide and the Economic Benefits of Mobile Broadband for Rural Areas." *Telecommunications Policy* 37 (6–7): p. 489

Not surprisingly, Prieger also found that rural and low-income areas also had fewer network providers. He also found that despite fewer network service providers, once income was factored, adoption of mobile broadband was no longer statistically different between rural or metropolitan areas.[150] (See Note 151)

Prieger also studied usage characteristics of rural and urban households, and also found that rural households internet usage rates were remarkably lower.[152] This could be due to several factors, including limited work or school computers and internet access, so that the need to be connected at home is reduced.

Means of Access Outside the Home.

Understanding how much exposure in the work environment takes place may be a strong indicator of broadband adoption in the household. Time spent using computers and broadband services at work can raise awareness of benefits, and build confidence in technical skills necessary to operate the technology. Information technology centric businesses are more likely to provide opportunities for hands-on experience.

Some studies have also shown a reverse effect, in which households with internet contribute to the presence of small businesses in information intensive industries

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150 Ibid. p. 493

151 This is consistent with the preliminary analysis performed for this study using FCC Form 477 data on the number of provider by county. While there was some significance ($p < 0.10$) for number of providers, the coefficient was very small. Income and education were much better indicators of adoption.

152 Prieger. p. 500

(information, finance and insurance, real estate, and professional and scientific services.[153,154]).

Kolko's analysis did not show a direct impact on local eligible employment or local wages (with the zip code unit of measurement), leading to Kolko's conclusion that broadband-enabled firms could be drawing labor from outside the zip codes.[155] This has some implications for this research in that even though households may be rural, respondents may have access to the internet through work because they travel to areas where internet may be more available.

Access through the workplace in unserved or underserved communities may be limited. Among the key considerations for businesses to relocate to areas is the adequacy of telecommunication infrastructure available to them.[156,] Businesses will not locate to areas without robust infrastructure, so the community does not get exposed and is less likely to adopt, lowering demand, and ultimately lowering investment in infrastructure. Without a digitally literate workforce, higher income jobs will not come to rural areas and the cycle begins again, with the workforce not expanding its digital skills. It also forces rural communities to subsist on lower incomes, making broadband relatively less affordable, and adoption goes down, as does investment in infrastructure. Out-migration of children

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153 Shideler, David, and Narine Badasyan. 2012. "Broadband Impact on Small Business Growth in Kentucky." *Journal of Small Business and Enterprise Development* 19 (4) (October 26): 589–606.
154 Kolko. p. 106
155 Ibid.
156 Malecki. pp. 204, 212

is also a factor – broadband can improve education and reduce exodus of the young, but without the more educated and young in these communities today, there is less demand for broadband services, and fewer businesses that create demand (See Note 157)

Technology enabled schools require significant bandwidth to be able to service the faculty and students and the education process. When aggregating the demands of dozens of faculty and staff and hundreds of students, the need for broadband access becomes quickly evident.[158] For younger children and those challenged with language skills, broadband technology and applications can also provide a material difference in improving literacy outcomes.[159] Much instruction is now technology-enabled, and many homework assignments and research are conducted through the internet.

Households with K-12 children are more likely to adopt broadband, but there is still a disparity among rural and poor households. Nearly one-third of U.S. schools lack sufficient access to the bandwidth required for students, teachers, and instruction within the schools, estimated at 100 Mbps for 1000 users (The FCC has stated that the goal for schools is to achieve 1 Gbps per 1000 users.)[160] This is particularly evident in rural and low-income areas. While more schools utilize technology in the classroom, some schools

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157 "Brain drain" was an explicit concern for some of the organizations interviewed. This will be discussed directly in Chapter 6.
158 Tolfes, Tom, and Tammy Stephens. 2009. "21st Century Networks for 21st Century Schools". Consortium for School Networks.
159 Biancarosa, Gina, and Gina G. Griffiths. 2012. "Technology Tools to Support Reading in the Digital Age." *The Future of Children* 22 (2) (October 1): 139–160.
160 "Section 706 Inquiry Eyes Mobile Broadband." pp. 15-16

in rural or economically depressed areas are reticent to assign research or homework that requires access at home.[161]

Libraries have similar needs as schools – they serve as the only access to the internet for millions of Americans, filling the gap for those where access is not available or affordable. Dailey et al. (2010) found that in many communities, libraries remain the focal point for education and job searches, which are increasingly performed online.[162] However, the bandwidth required for multimedia applications and the aggregate impact of tens to hundreds of computers require more bandwidth than is typically available, particularly in rural communities. In addition to insufficient capacity, Libraries also need computing resources and technical skills support to take full advantage of broadband services. It is estimated that 50 percent of the terminals in libraries are more than 3 years old.[163] However, LaRose et al. (2007) found that community access through libraries and computing centers offers some relief, but it has a weak correlation with broadband adoption in the home.[164] So while it may be a key resource in the community, it may not advance home adoption.

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161 LaRose, Robert, Jennifer L. Gregg, Sharon Strover, Joseph Straubhaar, and Serena Carpenter. 2007. "Closing the Rural Broadband Gap: Promoting Adoption of the Internet in Rural America." *Telecommunications Policy* 31 (6–7): p.360-61

162 Dailey et al. 2010.

163 Mandel, Lauren H., Bradley Wade Bishop, Charles R. McClure, John Carlo Bertot, and Paul T. Jaeger. 2010. "Broadband for Public Libraries: Importance, Issues, and Research Needs." *Government Information Quarterly* 27 (3) (July): 280–291.

164 LaRose et al. 2007. p. 371

CHAPTER 5: RESEARCH STRATEGY

The research approach involved two separate, overlapping efforts. The first stage was to conduct interviews with leaders and representatives of programs whose mission was broadband adoption. The second stage was a quantitative investigation into the relationship of mobile broadband in the adoption of household broadband. Legacy research has focused primarily on fixed broadband in the U.S., so particular analysis was focused on a comparison of mobile broadband with patterns of traditional determinants of fixed broadband to the home.

Interviews with Broadband Adoption Organizations

Telephone interviews were conducted to provide context to the analysis. Interviews were sought from organizations that had worked in communities to help foster access and adoption of internet/broadband services. The targeted organizations were selected through the NTIA State Broadband Initiative website, each representing NGOs or consortiums that received grant money to "support the efficient and creative use of broadband technology to better compete in the digital economy."[165] These efforts are often non-profit organizations working through community institutions and small

[165] National Telecommunications and Information Administration (NTIA). 2016. "State Broadband Initiative." *BroadbandUSA: Connecting America's Communities*.

businesses to encourage access, adoption, and use. Interviews also included an internet provider that created an internet adoption program that provides low-cost computers and discounted installation and recurring fees to qualified households. The targeted organizations and coverage information are listed in Table 2 below. These organizations lead programs focused on the creating demand and fostering adoption of broadband.

Program	Organization	Coverage
21st Century Information and Support Ecosystem: Make it Easy Where You Are	One Economy Corporation	31 States + DC
Internet Essentials	Comcast	50 states and Territories
DC-Broadband Education, Training and Adoption (DC-BETA)	DC Government	DC
Freedom Rings: Sustainable Broadband Adoption	The Urban Affairs Coalition	Pennsylvania
Public Adoption Through Libraries (OPAL II): Every Community Online	Connected Nation, Inc.	Ohio
e-Vermont: The Vermont Community Broadband Project	Vermont Council on Rural Development	Vermont
Project Endeavor	Communication Service for the Deaf, Inc.	50 states and Territories

Table 2: Contact Organizations (Source: BTOP)

Initial outreach was done via email, with follow-up emails as reminders and to establish a time and date for each interview. Each organization was asked to set aside a short amount of time to discuss and learn from their perspectives regarding primary drivers for internet adoption. Each interview included an introduction to the research and line of inquiry regarding their organization's efforts. The structure of the interview was the same: introduction, overview of their organization, its origins (and impact of federal funding as appropriate) geographic scope, process, challenges and impediments, progress, and plans going forward. Questions also included any observations or insights into the research questions and hypotheses related to this research. Specifically, they were asked about the role of mobile broadband (smartphones) in bridging the digital divide, adoption of households with children, access outside the home (e.g., workplace), and any known issues with privacy and security. Appendix A contains the interview protocol. Because the interview stage overlapped with the quantitative analysis, more informed questions (based on the data analyzed to date) could be integrated into the interviews. The interviews resulted in a better understanding or technology adoption factors, and the conditions and environment in which these unserved or underserved communities exist. They confirmed tenets of adoption theory and helped to define specific inquiries for quantitative analysis. The perspectives, approaches, challenges and successes helped to inform policy implications and recommendations resulting from this research.

Quantitative Analysis

The intent of the research is to better understand some of the drivers for broadband adoption, specifically where there is data associated with fixed and mobile adoption that includes key demographics, urban and rural areas, and decision factors that are influenced by intrinsic consumer factors such as observational and enabled learning, complexity and compatibility with control beliefs. Consistent with current program metrics and statistics, households are the unit of measurement. Even though mobile adoption is most often a personal connection to the internet, fixed adoption is most often shared. For this analysis, the primary respondent represents the household, and answers to survey questions address whether the household has fixed broadband, and whether anyone in the household uses mobile broadband.

Figure 5 below shows the influences on mobile service adoption. Those factors identified as extrinsic factors are beyond the scope of this current research, but play a definitive role in consumer decision to adopt. The highlighted areas in red in the graphic show the focus of this research, and are consistent with the five tenets of DoI and SCT adoption theories. Household demographics are used to determine if mobile has the same patterns of adoption as fixed broadband. While considered a demographic characteristic, households with children can play a large role in the intrinsic factors influencing adoption.

The competitive environment was at one point considered for integration into the analysis. The FCC uses a county designation to provide the number of fixed and mobile providers and the penetration of fixed broadband per 1000 households. By linking the datasets by county, it would provide an indicator of competition as well as fixed availability for each household within a county. County designations could also allow a spatial analysis to be performed so that adjacencies and spillover effects could be studied.

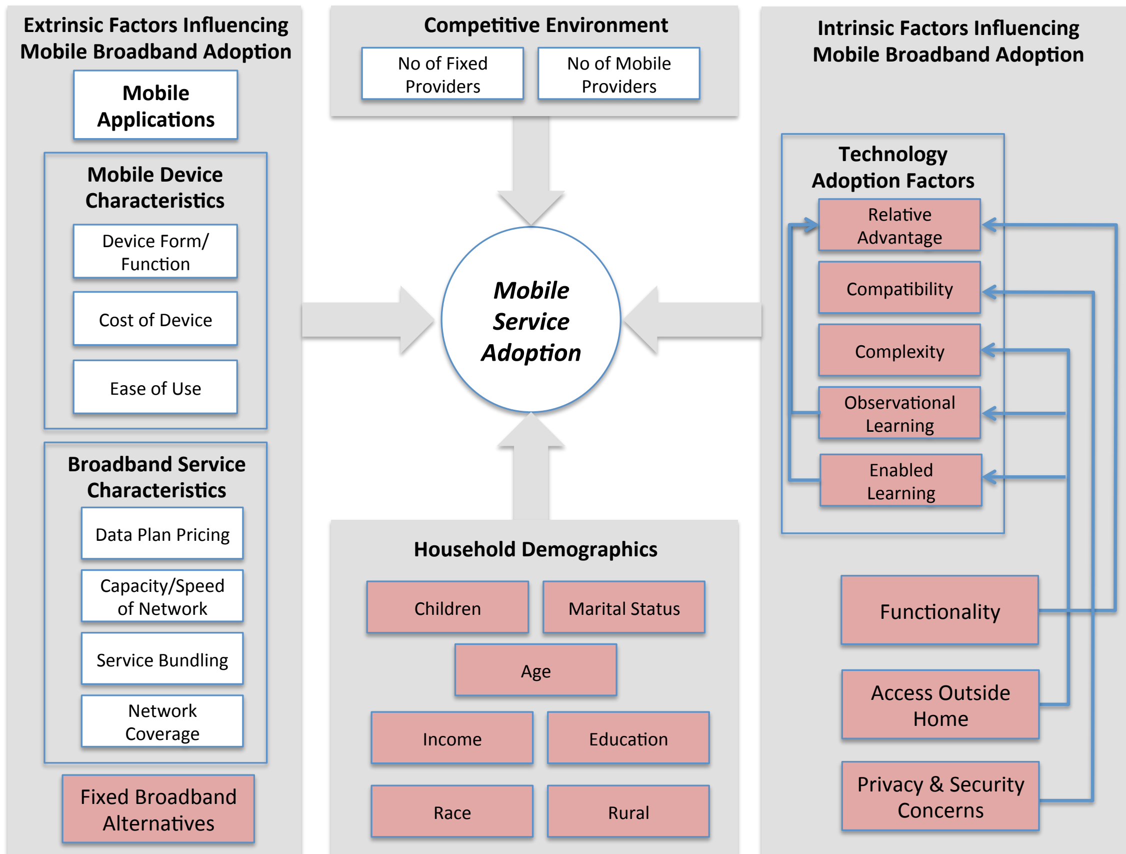

Figure 5: Overview of Influencing Factors for Mobile Broadband Adoption

However, the CPS dataset only identified 217 counties, so matching with the FCC dataset reduced the effective dataset by 60 percent. Eliminating households not associated with a county could create bias in the results. It is uncertain why many households did not have a county designation, but it could be to help protect the anonymity of the respondent household (since a significant amount of demographic detail was included, identifying a household in a sparsely populated county the county could risk disclosure). Instead, the designation (without geographic location) of metropolitan and non-metropolitan that was used in the CPS dataset was used for rural and urban designation.

Intrinsic Factors that Influence Mobile Broadband Adoption

Consistent with technology adoption theory (and fundamental consumer behavior), households must perceive benefits of internet adoption that outweigh the cost and risks associated with it. Households with fixed broadband service are considered households without internet service, even if they have mobile broadband access. For the purpose of this research, "No Internet" households will have *no fixed or mobile broadband service* and those households that are "Mobile Only" *have only mobile broadband*, with no fixed broadband services

The intrinsic factors included in this research are functionality of the mode of access (what functions are performed), access outside the home, and perceived risks, specifically privacy and security. The amount of exposure to internet services – in the past or currently through access outside the home (e.g., work, school, libraries) – will determine households' ability to try and observe the benefits of internet access, as well as build confidence in their technical skills (reducing the complexity factor). Finally, perceived risks regarding privacy and security address control factors that are part of consumer's compatibility with lifestyle.

Consumers cite multiple reasons for not connecting to a fixed internet at home. Some have had fixed internet before and disconnected, while others have never been connected. The reasons for not connecting will be measured for both "No Internet" and "mobile only" against whether the household has never-adopted or un-adopted fixed internet to the home. It is expected that those who have had access will be more aware of the benefits as well as the costs and perceived risks.

Data Sources

The anchor dataset for this study is the Computer and Internet Use Supplement (2015) of the Current Population Survey (CPS), jointly sponsored by the Bureau of the Census and the National Telecommunication Information Administration (NTIA). The CPS polls nearly 56,000 households each month, and tries to keep recipients for four years in a rolling fashion.[166] It is large enough and representative enough to use for statistical analysis and can be utilized for longitudinal research to characterize changes over time. It is comprised of samples from 217 counties and 76 cities. The dataset includes those that do not have internet available in their area – "not available" is among the responses to why they do not connect.

The CPS contains key data elements on household demographics, including race and ethnicity, children in the home, employment, education, gender and age. Most will be used as fixed effects or controls to test the impact of a select demographic or variable. These demographic details are also sufficient to characterize households by the MATH household life cycle types to help understand the impact of different household life cycle changes, independent of race, education/income and rural/urban areas. The CPS contains

[166] National Telecommunications and Information Administration (NTIA). 2015. "Current Population Survey (CPS) Computer and Internet Use Supplement." July.

data fields for internet adoption and reasons for adoption (and non-adoption). The 2015 CPS also contains answers to questions regarding privacy and security that could assist in the analysis of control beliefs.

The CPS Computer and Internet Use (CIU) supplement in its current form has been conducted every two years since 2011, allowing a longitudinal analysis of adoption over time. A different version that collected internet adoption was administered in 2010 that was combined with school enrollment, and still other earlier versions have been collected since 2006.

Since the CPS household sample is refreshed every four years, the sample households decay by 50 percent every two years, so the 2015 survey has no sample households from the 2011 survey. Grouping by household life cycle stages (younger households, households with children, households without children, and elderly households), race and ethnicity, income, and rural status across time, general trends for adoption can be identified with some reliability. However, for other issues regarding broadband adoption (e.g., privacy and security), questions within the CIU supplement change over time and analysis is unable to establish a longitudinal trail of changing household attitudes and decision factors.

The changes to the CPS Computer and Internet Use supplement over time are evident. While the circumstances are unknown, the 2013 CPS supplement response rate was far less than the response rates for those supplements conducted in 2011 and 2015. The 2013 survey includes separate population frequency weights specifically for use with the supplement data (not necessary for 2011 and 2015) that corrected for the anomaly and put the weighted populations on par with one another.

In the process of research and continued refinement, other datasets were identified that offered independent insights, but linking them to the CPS reduced the sample size and caused increased variance and instability in the results. The other datasets also failed to differentiate between cellphones and smartphones (between voice only and broadband). As a result, the CPS was exclusively used in testing these hypotheses, providing greater internal consistency and (within a sample year) isolating specific household responses to internet adoption choices.

Segmentation

Schejter et al. (2010), in a paper on market segmentation for FMS, laid out several potential segmentation schemes to help isolate policy strategies for different consumer preferences. They summarized four ways to segment the market: geographic, demographic, psychographic, and behavioral characteristics.[167] This research will segment using some geographic characteristics (rural and urban), select demographics (age, race, children), limited psychographics (social class and lifestyle inferred through income and education), and behavioral characteristics (responses to reasons for adoption,

[167] Schejter, Amit M., Alexander Serenko, Ofir Turel, and Mehdi Zahaf. 2010. "Policy Implications of Market Segmentation as a Determinant of Fixed-Mobile Service Substitution: What It Means for Carriers and Policy Makers." *Telematics and Informatics* 27 (1): p. 94

access away from home, concerns regarding privacy and security). The segmentation for geography, demographics and selected psychographics is consistent with research to date regarding the digital divide for fixed broadband access, and will be extended here to include mobile broadband adoption. The behavioral characteristics are more exploratory to understand the consumer intrinsic values regarding benefits and risks that influence adoption behavior of both fixed and mobile broadband.

The first segmentation conducted as part of this research was by "family life cycle" or household life cycle (since the unit of measurement is typically household, which represents one family). Exposure to potential adoption benefits will be influenced by the age and stage of family households (12 stages arrayed across marital status, age, children, etc.).[168] The family life cycle first proposed by Gilly and Enis (1982) was utilized to maximize the significance of the results.[169] Table 3 shows the stages of the Gilly-Enis family life cycle.

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[168] Brown and Venkatesh. p.402.

[169] Gilly, M.O., and B.M. Enis. 1982. "Recycling the Family Life Cycle: A Proposal for Redefinition." *Advances in Consumer Research* 9: 271–76.

No	Stage	Characteristics		
		Marital Status	Age	Children @ Home
1	Bachelor I	Single person living alone	Under 35	None
2	Bachelor II	Single person living alone	Age 35-64	None
3	Newlywed	Two adults living together	Primary Respondent under age 35	None
4	Single Parent	One adult	Any age	Any number of children, any age
5	Full nest I	Two adults living together	Primary Respondent under age 35	Youngest child under age 6
6	Delayed full nest	Two adults living together	Primary Respondent age 35 or older	Youngest child under age 6
7	Full nest II	Two adults living together	Primary Respondent under age 35	Youngest child age 6 or above
8	Full nest III	Two adults living together	Primary Respondent between age 35 and 65	Youngest child age 6 or above
9	Childless couple	Two adults living together	Primary Respondent between age 35 and 65	None
10	Older couple	Two adults living together	Primary Respondent age 65 or older	None
11	Bachelor III	Single person living alone	Primary Respondent age 65 or older	None

Table 3: Stages in the Gilly-Enis (1982) Family Life Cycle

The family life cycle was applied to CPS data to stratify households by type and to increase the fidelity of the regression models. Table 4 shows the frequency count of households by each category.

Household Type	Frequency	Percent	Cumulative
Bachellor I	4,872	9.25	9.25
Bachellor II	10,578	20.08	29.32
Newlywed	1,257	2.39	31.71
Single Parent	4,364	8.28	39.99
Full Nest I	2,053	3.90	43.89
Delayed Full Nest	2,050	3.89	47.78
Full Nest II	516	0.98	48.76
Full Nest III	4,981	9.45	58.21
Childless Couple	8,652	16.42	74.63
Older Couple	5,681	10.78	85.41
Bachellor III	7,686	14.59	100.00
Total	52,690	100.00	

Table 4: 2015 CPS Households by Household Life Cycle Categories

In nearly every regression, this household life cycle was used as a control variable. In some cases where the fixed effects further subdivided the household categories, a modified model aggregated the categories to maintain a higher number of observations and increase significance. Since there was considerable variance among the household life cycle categories in the three datasets used in the longitudinal analysis, the aggregated dataset minimized the impact. As described above, segmentation by age (older and younger) and children (with and without) helped to reduce variance and were useful in testing specific hypotheses. Young households was defined as under 35 years of age without children, households without children between 35 and 64 years of age, households with children were also between 35 and 64 and had children under 18 years of age, and elderly households were 65 years of age and older. Table 5 shows the aggregated household types.

Household Type	Frequency	Percent	Cumulative
Young Household	6,129	11.63	11.63
Household w/o Children	19,230	36.50	48.13
Household w/ Children	13,964	26.50	74.63
Elderly Household	13,367	25.37	100.00
Total	52,690	100.00	

Table 5: CPS Households by Aggregated Household Categories (Used in Longitudinal Analysis)

In addition, the dependent variables were also segmented to isolate adoption behavior. The CPS contains attributes for each household surveyed. In his study of EU FMS, Grzybowski structured households into four types: "(i) fixed-line only; (ii) mobile only;

(iii) both fixed-line and mobile; and (iv) without access to any telecommunications services."[170] For the longitudinal and many regression analyses, the same categories are utilized for fixed and mobile broadband adoption. The fixed only and mobile only households are utilized in the analysis where a clear distinction must be determined to ascertain the service being referred to in response to a particular survey question. Caution must be exercised regarding the coefficients, since the signs change contingent on the dependent variable. The "No Internet" households will have coefficients that *contribute to non-adoption* of broadband, while the other categories will have coefficients that *contribute to adoption* of a specific broadband access technology.

In addition, two other dependent variables were used in the research – one for fixed broadband service (whether or not the household had mobile service as well), and mobile broadband service (whether or not the household had fixed service as well). These designations allowed for a larger set of observations and increased significance of the results. They were most often used when controlling for the presence of the alternate access method.

Longitudinal Analysis

Since the CPS collects internet use data through its supplement every other year, a longitudinal view was possible to identify long term trends. While the CPS collects adoption and demographics each time, it changes the supporting questions regarding the

[170] Grzybowski. p.603

reasons for adoption (or non-adoption). While these questions gain new insights each time, they do not allow long-term trend analysis of attitude, behavioral, and decision factors. For example, in 2013 they inquired regarding all the elements of cost, including bundled services. In 2015, they dropped this line of questioning in favor of privacy and security.

Linking specific households across datasets to understand causal behavior and concerns regarding adoption behavior was not possible due to household abstraction (to protect privacy) and designed household turnover (refreshing the sample households progressively over the course of four years). However, grouping household types (young and elderly, with and without children) and by key demographic factors (race and ethnicity, low-income, and rural), allowed an analysis to be conducted over time. Some variation was encountered within these categories, so variance percentages were calculated and listed with the results as a proxy for sample variance.

Adoption by demographic characteristics was possible, so panel data was generated for households by age and children, general population adoption by type, and Black and Hispanic, low-income, and rural low-income households. This allows a comparison over time for each demographic for each broadband access type.

Fixed Effects: Controlling for Select Demographics

Since the regressions were performed strictly on the 2015 dataset, time-invariant effects were not a factor. However, since several characteristics showed a strong influence on broadband adoption, they became candidates to be controlled under a fixed effects regression. Characteristics unique to the household were most often used as fixed effects so that the net effect of the independent variables can be assessed. Since education, rural and race had the highest coefficients with significance across all connection types, these were combined to create fixed effects groups to keep these effects constant as other behavioral factors were analyzed. Income and education were determined to be highly correlated at 0.4524, so eliminating income as a factor was not considered an issue. In some cases the fixed effects were reduced if one was used as an independent variable or as a condition in the model (e.g., testing separately for rural and urban areas).

Regression Model

The CPS was constructed as a survey tool and not necessarily intended for regression analysis. A significant amount of data cleansing occurred to ready the data for consumption in the statistical analysis tools. This included converting non-response values from -1 to missing (null), binary Yes (1) and No (2) responses to Yes (1) and No (0), in order to maintain the integrity and consistency of the regression.

Since the intent is to measure broadband adoption, both fixed and mobile, new variables were created that truly represent both. For the CPS, “internet in the home” included a host of different means to connect to the internet, but also included dial-up and mobile data service. Dial-up service is not considered broadband, and mobile data service is more appropriately categorized as mobile broadband.

For mobile broadband service, the CPS inquired whether anyone in the household had a cellphone or smartphone (one inquiry). A cellphone may or may not have data service. A positive response to this question still did not provide sufficient information to determine if anyone in the household uses mobile broadband. A new variable was created based on the response to "internet in the home" question above (a positive response to mobile data service), as well as uses of a mobile device (e.g., browsing the web, access to social networks, GPS, etc.).

Once the dataset was cleansed and conditioned, variables for family type categories were established along with connection types (fixed service, mobile service, fixed only, mobile only, both mobile and fixed, and No Internet households). Age categories were created to capture age groups large enough to create significance in the analysis. A rural indicator was created for those households designated as "non-metropolitan." To reduce the number of fixed effects but still be effective, race and ethnicity, household income were categorized to simplify the group variable (binary for race and ethnicity, and quartiles for household income). Finally, index variables were created for privacy and security concerns by adding the number of independent concerns for each household raised through the survey.

Regression analyses are performed for different dependent variables for adoption, including fixed broadband adoption, mobile broadband adoption, fixed only adoption, mobile only adoption, both fixed and mobile adoption, and No Internet. Independent variables will include those for age, race, education, income and metropolitan status to test Hypothesis 1, whether fixed and mobile adoption follow similar patterns among selected communities that represent the digital divide. Those variables with the highest significant coefficients were held constant through fixed effects to isolate the impact of other explanatory variables that may support each subsequent hypothesis.

For Hypothesis 2, using mobile broadband as the dependent variable, households with and without fixed broadband to the home are tested across various income levels to determine the relationship. The signs of the coefficients indicate whether the relationship is choosing among alternatives (substitution) or complementary. Since price of the services is not available (and can differ widely based on location, competition, service selection and bundling), it is not factored into the analysis. The results therefore do not indicate true substitution in the traditional economic definition. A similar regression is performed using fixed broadband as the dependent variable (with and without the presence of mobile broadband) to test the effects of possible substitution in the other direction.

In addition, an analysis of the functions performed over each access type is conducted to determine if households treated the access types as functional equivalents. Functions are grouped using the categories developed by Ongena et al. (2012) in their study of fixed and mobile adoption in the Netherlands.[171] They grouped functions into Information (information gathering through web browsing and searches, maps and travel planning), Communication (email, teleconferences, twitter and social networking), Entertainment (video clips, on demand broadcasting, and downloading music), and Transaction (buying goods or service, online banking). For this research, social networking was very well represented in the dataset, so it was split from the Communications category as a standalone variable. In addition, job searches, online training, and telecommuting were not included in Ongena' categories but were distinctive enough that they were grouped under a new category called Productivity. The analysis compares the fixed only, mobile only, and households with both fixed and mobile to determine if these functions contributed to adoption and if they contributed differently among access types.

To test H_3, the presence of children in the home is regressed against access type to determine if children increase adoption of mobile broadband. Conditional regression is specified to determine the impact of rural and urban geographies and the presence of the alternate access technology in the household.

The remaining regressions test factors of adoption consistent with Diffusion of Innovation, and Social Cognitive theories. Specifically, opportunities for observational and enabled learning are presented by access outside the home. Each location (work

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171 Ongena et al. p. 283.

school, travel, community center, other's home) is regressed against each of the dependent variables to determine the contribution to adoption of each. UTUAT theory suggests that access at work will likely heighten utilitarian awareness of internet functions which could convey greater "performance expectancy" at home.[172] This will indicate whether No Internet households that lack access outside the home influences adoption at home.

Accessing the internet outside the home can lead to improved technical proficiencies and expose consumers to the benefits of broadband as well as the risks. They can be exposed through numerous means, but some are inherently different. In work or school, and in some cases on travel (depending on the nature of travel), consumers interface with internet as part of their routine or job/school responsibilities. In these environments, they may have coworkers or peers as well as IT service resources to assist them in both learning and operating the technology. Coffee shops, libraries, community centers, and someone else's home are typically more *voluntary* access points, and may not be accompanied by the environment and resources like that of work or school.

The reasons for not adopting at home or away are also regressed using causal factors, including interest, affordability, equipment issues, and privacy and security concerns. The CPS inquired directly to determine the reasons households did not choose to adopt fixed broadband at home. Notably, these households may have mobile access, so the

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172 Venkatesh at al. 2003. p.462

analysis includea reasons for not connecting adopting fixed broadband both from those without any broadband as well as those with mobile broadband.

Finally, a series of privacy and security concerns and experiences are regressed for each broadband access type. These reflect the types of concerns that might challenge a control belief as defined by the MATH Theory.[173] The CPS inquires specifically regarding these privacy and security concerns:

- Conducting financial transactions such as banking, investing, or paying bills online
- Buying goods or services online
- Posting photos, status updates, or other information on social networks
- Expressing an opinion on a controversial issue on a blog or social network, forum, or email
- Identity theft
- Credit card or banking fraud
- Data collection or tracking by online services
- Data collection or tracking by government
- Loss of control over personal data such as email or social network profiles
- Threats to personal safety, such as online harassment, stalking, or cyber-bullying

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173 Tsai and LaRose. p. 346.

Experiences include:

- Experienced an online security breach, identity theft, or a similar crime
- Experienced online harassment, stalking, or cyber-bullying

Finally, scores were created to aggregate the number of security and privacy concerns and experiences for each household. These scores are independent variables to determine the impact on each method of broadband adoption.

Since research shows that childless couples and elderly are more susceptible to these concerns in the fixed broadband adoption, privacy and security concerns are also tested for its impact on mobile broadband adoption.

Threats to Validity

Because of the simultaneity of using a fixed year dataset, the regressions could not determine causality. Since the CPS did not use consistent questions on the supplements, lagged effects to answers to inquiries could also not be determined. For the analyses, we can only determine the static characteristics (demographic profile, presence of fixed or mobile, children or no children) and behavioral responses (access outside the home, privacy and security concerns) of households.

For longitudinal panel studies of common datasets, maturation of the subjects, exogenous factors/events that could affect results, and experimental mortality (loss of subjects over time) must be considered to ensure research integrity. A thorough review of CPS documentation and comparative and descriptive analyses of the data helped to identify and mitigate potential issues.

External validly is critical if the research is to be generalizable to the broader populations to ensure consistent policy recommendations. Threats to external validity include measurement errors and selection bias of the datasets that could bias the generalizability of the results. A thorough review of the context of the data collection, the survey instruments, and collection methodology was conducted to identify and mitigate potential issues and reduce threats to validity. As mentioned earlier, the CPS dataset for 2013 appears to have unique weights for the supplement that corrects for a non-response rate. It is unclear if other factors contributed to the lower number of households in the supplement and if that could create unwanted bias.

The analysis can also demonstrate endogeneity resulting from omitted variables.[174] However, in most cases we are only analyzing the contribution to household decisions to adopt, not creating a model to predict adoption, which would involve many other factors. In these cases, omitted variables were not a concern.

[174] Wooldridge, J. M. 2009. Introductory Econometrics: A Modern Approach, 4th Edition. Mason, OH: South-Western Cengage Learning.

CHAPTER 6: ANALYSIS AND RESULTS

The approach of this study to explore mobile broadband adoption utilizes three different analyses. The first is a set of interviews from broadband adoption organizations that help to set the stage and develop a deeper context from which subsequent analysis could be performed. While they specifically addressed fixed broadband adoption, the insights, lessons learned, and challenges may be similar to those encountered for mobile broadband. The second analysis examines fixed and mobile adoption longitudinally using a series of CPS datasets to test the first three demographic hypotheses regarding patterns of adoption, potential fixed and mobile substitution, and patterns of adoption by households with children. A panel analysis permits investigation of long-term trends within target demographic communities beyond the digital divide. The third analysis utilizes regression techniques on the latest CPS dataset (2015) to explore all the hypotheses, including those hypotheses that relate to individual household consumer behavior, specifically access outside the home and privacy and security concerns. This statistical analysis explores consumer tendencies and isolates drivers and barriers to mobile broadband adoption.

Interview Results

Interviews were conducted with organizations focused on fostering fixed broadband adoption in communities on the other side of the digital divide. Organizations included a corporate philanthropy organization, a state government program, and a non-profit (the latter two sponsored by federal grant programs). Each was generous with their time, described the mission and momentum of their programs, and shared thoughts regarding access, adoption, barriers to adoption, productive use, and technology challenges and opportunities.

Genesis. Each of the programs was initially created from different circumstances. Corporate philanthropy originated as a condition of an agreement with the government to allow a large corporate merger to take place. The government program was a state initiative to foster rural development. Federal funds allowed it to accelerate and deepen its support for developing online social networks and marketplaces to accelerate broadband adoption. Finally, the non-profit entity started with a localized mission and expanded to thirteen neighboring states. Despite differing origins, each organization saw it as an opportunity for goodwill and broader community service and was deeply committed to its mission. All were focused on *fixed* broadband adoption.

Process and Progress. Each organization took different approaches, largely based on their mission objectives and target communities. One focused on small businesses (both at home and stand-alone workplaces, profit and non-profit) to help expand adoption of broadband in local communities to grow business and offer opportunities for greater exposure to workers. Market segmentation was used to help identify how different industry sectors (e.g., agriculture) use and benefit from broadband technology.

Another approach focused on integrating with social network structures in the community. These structures dramatically expanded as residents see the benefits of social forums that strengthen community, provide an opportunity for bartering, and foster enjoyment. This required working through trusted agents or community organizations to try, adopt, and spread the word within their social circles. The goal was to lower the barriers of anxiety due to complexity, foster awareness, encourage trial, and learn/experience the benefits of broadband adoption.

Another organization initially focused primarily on households with children, working one-on-one with schools and local organizations (Boys and Girls Clubs, YMCA, non-profits, libraries) to integrate, build awareness and generate trust. School-age children would become advocates within the home on the benefits of broadband. They also served as educators within the home to lower the anxiety and complexity barriers. Since the challenges to adoption in the home were the cost associated with connecting, this program offered low-cost computers ($150) and subsidized broadband access (9.95/month) to qualified households.

Within the communities, there was initial apprehension and resistance to change, particularly among the elderly. Broadband adoption organizations worked through trusted community members and fostered familiarity through a local presence, to ease and eventually overcome concerns regarding technology adoption.

Finally, another initiative focused largely on supply in rural areas. Because of difficult terrain and remote households, a concerted effort was made in small towns to connect downtown districts with WiFi, allowing remote residents to come to the town to conduct online commerce or other functions. They also worked with small mobile providers to erect cell towers in local communities.

Challenges and Impediments. Nearly all of the participants reflected challenges associated with broadband adoption. They described some of the rural, low-income communities as not a "culture of internet," meaning they don't feel they need it or do not understand it. Throughout all communities there was a lack of education and understanding of the social and economic benefits and a lack of relevance to their everyday lives. Most did not have the necessary digital literacy and affordable access to the technology.

All interviewees shared their experiences in dealing with the communities they serve, expressing some of their concerns. Some saw communities "on the decline" where the traditional jobs through manufacturing had long gone, creating broad poverty. They saw challenges with limited opportunity and limited momentum in these areas, ultimately leading to a "brain drain," where younger generations left to seek opportunities elsewhere. Some cited that low-income households with children were their primary targets because large providers who tend to seek more high-income households left them out of the "marketing" and outreach. One stated their mission would never be complete, because technology is a moving target, and these communities will always need help to keep pace.

Some Downsides. While most cited great promise and upside to helping these communities, at least one expressed some concerns that school-age children are "over-invested" in screen time, that could distract from studies or other engagement. Some communities remain suspicious of how internet-based technology intersects or interferes with the growing minds of children. They see those that are online often "hashing around" and are too quick and react without stepping back and thinking.

Going Forward. While federal grant money has expired under the larger Broadband Technology Opportunities Program (BTOP), many will continue their efforts. The state program and non-profit will be more limited in scope but will continue digital literacy and community-based programs. For the corporate-sponsored program, they are expanding their reach beyond their initial targeted communities and opening up digital literacy to any interested persons (on-line and in-person).

All programs were deeply committed to making a difference in these communities and see the tangible benefits their programs have seeded. They understand that access through alternate technologies will continue to reinvent itself, whether through mobile or through new fixed infrastructure access. Fixed internet access has already evolved from copper wire (twisted pair), coaxial cable, fiber optics, and now may soon be available through power lines. Mobile has gone from analog to digital, from broadcast radius to cellular, and though multiple generations of access standards that progressively boost speed and versatility. As these technologies evolve, they plan to continue to modify programs to help meet the challenge of adoption within these communities.

Longitudinal Analysis Results

The adoption of internet services is not static over time as technology and infrastructure improve and programs for a more inclusive internet are launched (supply-side programs as well as cost reduction and technical skill programs). Using the CPS CIU supplement data from 2011 to 2015 (three datasets), a series of panel data comparisons can be analyzed. The CPS refreshes households over the course of four years, so households in the 2011 sample are no longer in the 2015 sample. Due to large variations between household types between each year's datasets, the household types were generalized into four groups, allowing more meaningful analysis: young households (under 35 years of age), households with no children (bachelors and couples between 35 and 64), households with children, and elderly (households over 65 years of age). The first is a comparison by generalized household types from 2011 to 2015.

Table 6 shows the longitudinal analysis of key demographics for No Internet households, fixed broadband households, and mobile broadband households. There is some variance among surveys regarding the size of the underlying population sizes, which could impact some of the year-over-year comparisons (see Note 175).

Table 6A shows the households that are "No internet" households (they do not have fixed or mobile broadband access). The three key demographics (Black and Hispanic, low-income, and rural low-income) shown are consistent with current literature regarding the challenges in today's digital divide. Rural low-income areas are often cited as an area to target internet connectivity programs.[176] They have historically been difficult and expensive to connect physically, and often do not have the updated wireless infrastructure (if they have infrastructure at all).[177]

The data from the CPS also reflects these disparities. Black and Hispanic households remain 7.3 percent behind the general population in the 2015 CPS. Low income and low-income households in rural (non-metropolitan) areas lag the furthest behind the general population by 22.3 and 26.3 percent respectively (2015 numbers).

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[175] For example, Blacks and Hispanics made up 26.0 percent of the weighted survey population in 2015, while representing 24.4 percent of the survey population in 2011. Household income under $25K made up 28.5 percent of the weighted population in 2015 and represented 24.7 percent of the population in 2011. Household characteristics also fluctuated between surveys as well, ranging by as much as 6.7 percent (among the elderly households). These margins established thresholds to determine significance of results.

[176] LaRose et al. 2007. p. 371

[177] Mueller. p.44

A: Households with No Internet	**2011**	**2013**	**2015**	**2011-2015**	**Survey Variance**
Young Households	12.7%	9.3%	13.6%	0.9%	0.7%
Households w/o Children	24.0%	20.3%	22.3%	-1.7%	1.5%
Households w/ Children	14.7%	10.1%	14.2%	-0.4%	1.8%
Elderly	47.5%	42.8%	39.9%	-7.6%	2.5%
General Population Total	24.9%	21.2%	23.1%	-1.7%	2.1%
Black & Hispanic	36.1%	29.3%	30.4%	-5.7%	1.6%
Low Inc: <$25K	48.1%	43.3%	45.4%	-2.7%	3.8%
Rural Low Income	54.2%	53.2%	49.4%	-4.7%	1.3%

B: Households with Fixed Broadband	**2011**	**2013**	**2015**	**2011-2015**	**Survey Variance**
Young Households	79.7%	83.1%	81.9%	2.2%	0.7%
Households w/o Children	73.4%	75.7%	73.7%	0.3%	1.5%
Households with Children	80.8%	83.1%	82.0%	1.2%	1.8%
Elderly	51.6%	55.5%	58.2%	6.6%	2.5%
General Population Total	71.7%	74.1%	73.4%	1.7%	2.1%
Black & Hispanic	57.5%	61.8%	63.9%	6.3%	1.6%
Low Inc: <$25K	45.7%	47.6%	49.2%	3.5%	3.8%
Rural Low Income	40.1%	39.7%	44.8%	4.7%	1.3%

C: Households with Mobile Broadband	**2011**	**2013**	**2015**	**2011-2015**	**Survey Variance**
Young Households	54.2%	80.3%	80.7%	26.5%	0.7%
Households w/o Children	26.2%	57.4%	65.2%	39.0%	1.5%
Households with Children	37.6%	76.8%	77.7%	40.1%	1.8%
Elderly	8.2%	26.3%	38.9%	30.7%	2.5%
General Population Total	29.1%	58.6%	64.4%	35.3%	2.1%
Black & Hispanic	28.9%	57.2%	60.8%	31.9%	1.6%
Low Inc: <$25K	20.6%	38.1%	42.7%	22.0%	3.8%
Rural Low Income	16.6%	28.4%	38.0%	21.4%	1.3%

Table 6: Longitudinal Analysis for Key Demographics (2011-2015)

From this panel, the gap appears to be closing for those on the other side of the digital divide. Key demographic communities have all increased internet adoption between 2011 and 2015, with the elderly making the largest leap at 7.6 percent (well outside the survey variance of 2.5 percent), and Blacks and Hispanics show significant progress at 5.7 percent reduction (with survey variance of 1.6 percent), compared to 1.7 percent for the general population.

Table 6B shows household adoption of fixed broadband service. These statistics coincide with the federal government's BTOP program that focused on low-income and rural fixed broadband penetration (largely supply-side, with some adoption initiatives). The patterns of adoption are similar to the inverse of the No Internet households in that the elderly have among the lowest fixed broadband adoption and those households with children and have among the highest fixed broadband adoption.

The table also shows strong gains from 2011 to 2015 in key targeted demographics: elderly, Black and Hispanics, low-income and rural low-income households. Black and Hispanic households have been shown in previous studies to have a lower adoption rate for fixed connections.[178] Note that by this traditional metric that Black and Hispanics, low-income and rural low-income households are still far below the general population by 9.5, 24.2 and 28.4 percent respectively (2015 numbers).

[178] Gideon and Gabel. p.740

Table 6C shows a double digit increase across the board for mobile broadband services. The largest increases were in households with and without children (ages 35 to 65). While young households gained the least, they started at a higher adoption rate in 2011 and have the highest mobile broadband adoption rates among households in 2015. The elderly also gained significantly, but given their low adoption rate in 2011 they remain at the lowest adoption rate among households in 2015. Black and Hispanics, low-income, and rural low-income all showed significant gains, but still lagged behind the general population.

Table 6C also shows that households with children are more likely to adopt mobile broadband than those without children, supporting H_3. While households with children only marginally exceed the adoption rate of those without children within the same age bracket (ages 35 to 65) (and within the survey variance), they far exceed young and elderly households (outside the survey variance).

These panels reflect a rapidly growing mobile adoption segment among all key demographics. The following figures put the adoption rates in context for each of the target populations. For each, fixed broadband shows it is increasing but at a diminishing rate (with the exception of rural, low-income households). No internet households, while declining overall, show a bounce in 2015, reflecting an uptick in houses that are not adopting, consistent with the findings of Pew Research.[179] Mobile adoption has the steepest slope, demonstrating the velocity by which it is being adopted by all communities. While penetration has not reached that of fixed, it is clearly showing a means of alternative access for all communities. Figures 6 through 9 show a graphic depiction of the rates of broadband growth for key demographics.

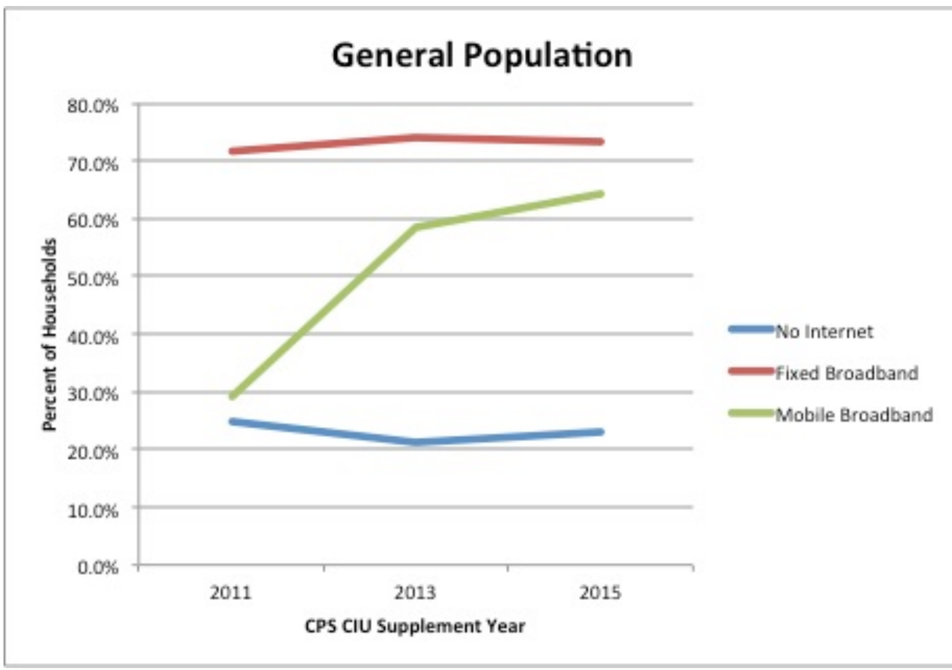

Figure 6: 2011-15 Broadband Adoption for the General Population

179 Horrigan and Duggan. 2015. "Home Broadband 2015." *Pew Research Center: Internet, Science & Tech*. December 21.

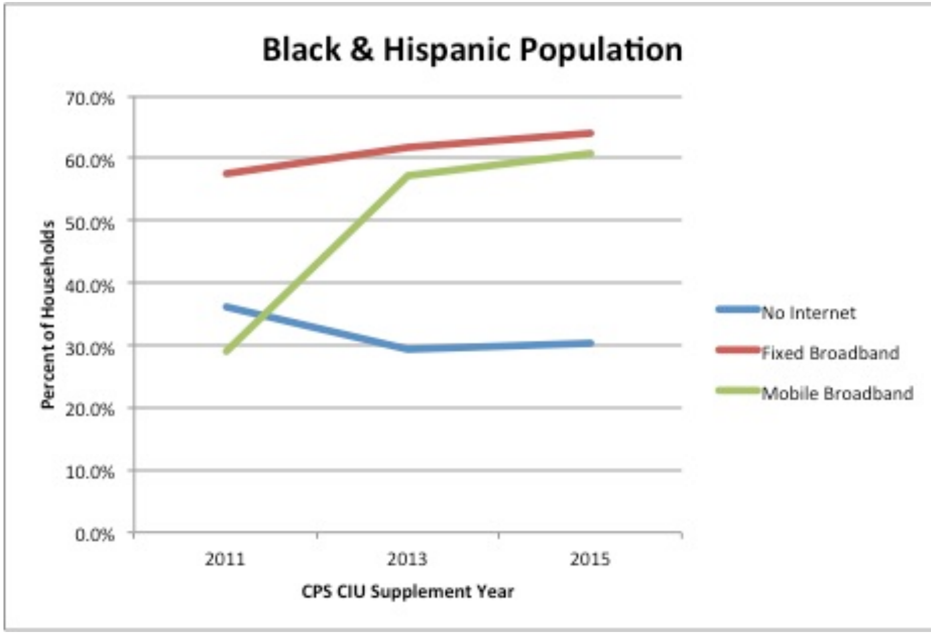

Figure 7: 2011-15 Broadband Adoption for the Black & Hispanic Households

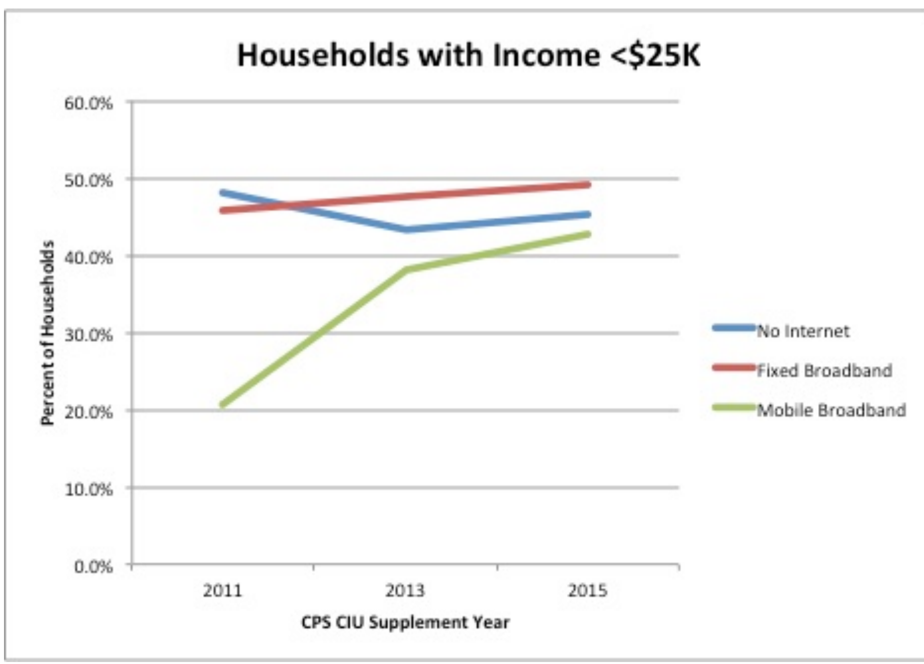

Figure 8: 2011-15 Broadband Adoption for Households with Household income < $25K

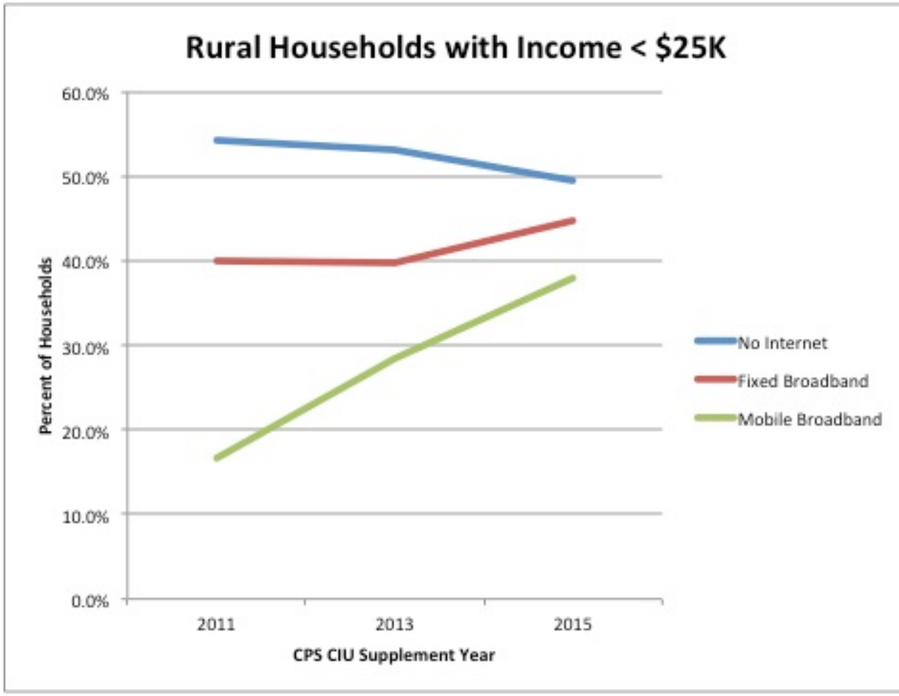

Figure 9: 2011-15 Broadband Adoption for Rural Households with Household income < $25K

While fixed continues to grow, its slope is greatly diminished. Mobile broadband clearly is undergoing a more rapid ascent. Fixed broadband has been introduced and deployed over a longer period of time (20+ years), so it may be reaching saturation. Mobile has not reached the penetration rate per household as fixed, but the two are converging. This analysis would support H_1, in which the patterns of adoption of mobile are similar to fixed, with the timing and acceleration of mobile being more compressed.

The question then turns to H_2: Are rural low-income households turning to mobile broadband as an alternative to fixed? An analysis of the nature of the connection – fixed only, mobile only, fixed & mobile and No Internet provides a summary of the method of access that can offer insight. Table 7 shows the type of connections to the home over time.

Households	Fixed Only 2011-2015	Mobile Only 2011-2015	Fixed & Mobile 2011-2015	No Internet 2011-2015	Survey Variance
Young Households	-27.4%	-3.1%	29.6%	0.9%	0.7%
Households w/o Children	-37.3%	1.4%	37.6%	-1.7%	1.5%
Households with Children	-39.7%	-0.8%	40.9%	-0.4%	1.8%
Elderly	-23.1%	1.0%	29.7%	-7.6%	2.5%
General Population	-33.5%	0.1%	35.2%	-1.7%	2.1%
Black & Hispanic	-26.3%	-0.7%	32.6%	-5.7%	1.6%
Low Inc: <$25K	5.7%	-9.1%	-8.4%	-2.7%	3.8%
Rural Low Income	6.9%	-5.1%	-7.9%	-4.7%	1.3%

Table 7: Household with Single and Multi-Modal Connections (2011-2015)

Even with the double-digit growth in mobile broadband, it appears it is most often adopted as a complement to fixed service, not a substitute. Only households without children and the elderly show a positive increase in mobile only access from 2011 to 2015, but the increase is within the survey variance. Low-income and rural low-income households increased for fixed only, while the percentage of mobile only households reduced over time. Blacks and Hispanics kept pace (but still lagged) with the general population that adopted both fixed and mobile broadband. The number of fixed and mobile households could also be impacted by those providers that bundle fixed and wireless broadband into one service contract (AT&T, Verizon).

Regression Analysis Results

The U.S. digital divide is most commonly described as a function of demography and geography. This section will analyze and compare fixed and mobile broadband access for demographic and geographic factors that have been attributed to the U.S. digital divide. It will use fixed effect regression analysis mitigating the effects of key demographics to isolate the impact of variables of interest.

Patterns of Adoption

The results of the analysis should provide evidence whether the patterns of adoption for mobile broadband are the same as fixed broadband (H_1). Five regressions were performed for each of the key demographic categories: Households with mobile broadband only access (no fixed broadband), households with mobile broadband with or without fixed access, households with fixed only access (no mobile broadband), households with fixed broadband (with or without mobile), and households with No Internet access (no fixed or mobile broadband). For each of the dependent variables, five regressions were performed: for age (using race and ethnicity as a fixed effect), race and ethnicity (using income as a fixed effect and household type as a control), education and income (using race and ethnicity as a fixed effect and household type as a control.) Household type is defined by marital status, age, and presence of children using the Gilly-Enis family life cycle.[180] The results for households within a metropolitan and non-metropolitan areas are shown in Table 8 and 9 on the following pages. For each unit

[180] Gilly and Enis. p. 271–76.

increase in educational attainment (based on the scale shown), adoption of the broadband access (by fixed or mobile) increases by the coefficient shown.

Mobile Broadband Adoption Impact by Age. Age is one of the defining factors used to characterize the digital divide. In this analysis, age is a significant factor across the board. The older the age of the primary respondents for the household, the less likely they are to adopt fixed or mobile broadband. This is consistent with current research that older households are more likely to disconnect or never adopt at all.[181] Notably, older households are even less likely to adopt mobile broadband (stronger negative coefficients). For those who have only one service, the sign is positive for fixed only households (significant over 55 years old), while negative for mobile only households, indicating that if they are choosing only one means of access, older households are more likely to select fixed over mobile broadband. Older households in non-metro areas are more likely to not adopt fixed or mobile broadband than older households.

[181] Lee et al. 2015. p. 46

Age (Ref Group: <25 Yrs Old)	Mobile Only	Sig	Mobile Service	Sig	Fixed Only	Sig	Fixed Service	Sig	No Internet	Sig
25-34	-0.0058700		-0.0527232	***	-0.0015488		-0.0481264	***	0.0539963	***
35-44	-0.0070971		-0.1010669	***	0.0168443	*	-0.0746298	***	0.0817269	***
45-54	-0.0141380	**	-0.0900311	***	0.0138215		-0.0667495	***	0.0808875	***
55-64	-0.0110470	**	-0.2079455	***	0.0669131	***	-0.1322943	***	0.1433413	***
65-74	-0.0246880	***	-0.3489368	***	0.1500299	***	-0.1843253	***	0.2090133	***
75-84	-0.0361448	***	-0.4958980	***	0.1756619	***	-0.2971431	***	0.3332878	***
85+	-0.0355452	***	-0.5919259	***	0.0737571	***	-0.4855813	***	0.5211265	***
Race (Ref Group: White)										
Black Only	0.0211635	***	-0.0321082	***	-0.0409538	***	-0.0930264	***	0.0718629	***
American Indian, Alaskan Native Only	0.0338191	***	0.0068797		-0.0556633	***	-0.0880184	***	0.0541994	**
Asian Only	-0.0024905		-0.0062116		0.0010072		-0.0004442		0.0029346	
Hawaiian/Pacific Islander Only	0.0245642	*	-0.0297754		0.0135692		-0.0450651		0.0205010	
Ethnicity (Ref Group: Non-Hispanic)										
Hispanic	0.0162150	***	-0.0326496	***	-0.0318306	***	-0.0813374	***	0.0651224	***
Education (Ref Group: < 1st Grade)										
1st, 2nd, 3rd, or 4th Grade	0.0201067		0.0133179		-0.0175468		-0.0266017		0.0064950	
5th or 6th Grade	0.0491557	**	0.0003483		0.0205165		-0.0302108		-0.0189449	
7th or 8th Grade	0.0238867		0.0015568		0.0244510		0.0006378		-0.0245245	
9th Grade	0.0473034	**	0.0318295		0.0264077		0.0040987		-0.0514022	
10th Grade	0.0335528	*	0.0408210		0.0338857		0.0395986		-0.0731513	**
11th Grade	0.0360191	*	0.0996619	**	0.0306674		0.0909696	**	-0.1269887	***
12th Grade or No Diploma	0.0468225	**	0.0925284	*	0.0538767		0.0949627	**	-0.1417853	***
High School Grad - Diploma or Equiv (GED)	0.0431375	**	0.1711072	***	0.0591320	*	0.1792492	***	-0.2223867	***
Some College but no degree	0.0339603	*	0.2985652	***	0.0575280	*	0.3160641	***	-0.3500244	***
Assoicate Degree - Occupational/ Vocational	0.0288898		0.3190572	***	0.0578493		0.3453759	***	-0.3742657	***
Assoicate Degree - Academic Program	0.0291281		0.3236561	***	0.0457331		0.3373039	***	-0.3664320	***
Bachelor's Degree	0.0197302		0.3551200	***	0.0372862		0.3691372	***	-0.3888674	***
Master's Degree	0.0197590		0.3892308	***	0.0232193		0.3935191	***	-0.4132780	***
Professional School Degree	0.0190389		0.4304903	***	-0.0211586		0.3879497	***	-0.4069886	***
Doctorate Degree	0.0247861		0.3852449	***	0.0385590		0.4045344	***	-0.4293205	***
Household Income (Ref Group: < $5000)										
5,000 TO 7,499	-0.0098869		0.0040008		-0.0087386		0.0037864		0.0061005	
7,500 TO 9,999	-0.0239001	***	-0.0501677	***	0.0053273		-0.0220740		0.0459740	***
10,000 TO 12,499	-0.0234264	***	-0.0340659	*	0.0233391	*	0.0049427		0.0184837	
12,500 TO 14,999	-0.0040223		0.0231407		0.0032998		0.0243577	***	-0.0203354	
15,000 TO 19,999	-0.0106810		0.0229067		0.0321403	**	0.0644993	***	-0.0538183	***
20,000 TO 24,999	-0.0098794		0.0552145	***	0.0453953	***	0.1050470	***	-0.0951675	***
25,000 TO 29,999	-0.0091630		0.0970556	***	0.0396219	***	0.1427889	***	-0.1336258	***
30,000 TO 34,999	-0.0205883	***	0.1120602	***	0.0419872	***	0.1677494	***	-0.1471611	***
35,000 TO 39,999	-0.0173211	***	0.1528010	***	0.0411993	***	0.2030175	***	-0.1856964	***
40,000 TO 49,999	-0.0235870	***	0.2010391	***	0.0429810	***	0.2568926	***	-0.2333056	***
50,000 TO 59,999	-0.0301323	***	0.2408677	***	0.0261899	**	0.2920038	***	-0.2618715	***
60,000 TO 74,999	-0.0302817	***	0.2748872	***	0.0176917		0.3189755	***	-0.2886938	***
75,000 TO 99,999	-0.0362117	***	0.2864975	***	0.0011817		0.3248455	***	-0.2886339	***
100,000 TO 149,999	-0.0396045	***	0.3240985	***	-0.0225166	**	0.3418291	***	-0.3022246	***
150,000 OR MORE	-0.0404786	***	0.3483416	***	-0.0494915	***	0.3432941	***	-0.3028155	***

Table 8: Broadband Adoption by Key Demographics: Detail (Metropolitan)

Age (Ref Group: <25 Yrs Old)	Mobile Only	Sig	Mobile Service	Sig	Fixed Only	Sig	Fixed Service	Sig	No Internet	Sig
25-34	-0.0104604		-0.0693414	***	-0.0092750		-0.0708217	***	0.0812821	***
35-44	-0.0086878		-0.1163476	***	-0.0002977		-0.1055228	***	0.1142106	***
45-54	-0.0088538		-0.1278982	***	0.0105400		-0.1155281	***	0.1243820	***
55-64	-0.0315763	***	-0.2778434	***	0.0839402	***	-0.1706862	***	0.2022626	***
65-74	-0.0579829	***	-0.4290914	***	0.1681592	***	-0.2104982	***	0.2684812	***
75-84	-0.0561408	***	-0.5764549	***	0.1507907	***	-0.3811615	***	0.4373023	***
85+	-0.0581360	***	-0.6426760	***	0.0800132	***	-0.5098062	***	0.5679423	***
Race (Ref Group: White)										
Black Only	0.0206093	***	-0.0177935		-0.0751149	***	-0.1032533	***	0.0826440	***
American Indian,	0.0299356	***	-0.0187430		-0.0320659		-0.0739934	***	0.0440578	*
Asian Only	-0.0167707		-0.0071928		0.0093483		0.0153918		0.0013789	
Hawaiian/Pacific Islander Only	0.0577619	**	0.0038781		-0.0646237		-0.1056527	*	0.0478908	
Ethnicity (Ref Group: Non-Hispanic)										
Hispanic	-0.0013350		-0.0866758	***	-0.0106658		-0.0980986	***	0.0994336	***
Education (Ref Group: < 1st Grade)										
1st, 2nd, 3rd, or 4th Grade	0.0001951		-0.0406448		-0.0531274		0.0314767		-0.0316718	
5th or 6th Grade	0.0293208		-0.0169996		-0.0027832		0.0560454		-0.0853662	
7th or 8th Grade	0.0609477		0.0136635		-0.0803772		-0.0111210		-0.0498267	
9th Grade	0.0724286		0.0320369		-0.0344844		0.0456682		-0.1180968	
10th Grade	0.0671726		0.0396308		0.0127812		0.1028750		-0.1700475	
11th Grade	0.0508282		0.0763640		0.0121496		0.1529356		-0.2037638	**
12th Grade or No Diploma	0.0482710		0.1371472		-0.0041209		0.1913410	*	-0.2396121	**
High School Grad -	0.0530107		0.1615323		0.0376688		0.2611874	**	-0.3141981	***
Some College but no degree	0.0443070		0.2848882	**	0.0435045		0.3992324	***	-0.4435394	***
Assoicate Degree -	0.0446202		0.2924149	***	0.0332774		0.3936990	***	-0.4383192	***
Assoicate Degree -	0.0355826		0.3202778	***	0.0224499		0.4259873	***	-0.4615699	***
Bachelor's Degree	0.0321287		0.3630002	***	0.0282423		0.4738408	***	-0.5059695	***
Master's Degree	0.0275784		0.4001983	***	0.0218781		0.5149808	***	-0.5425592	***
Professional School Degree	0.0307530		0.4049381	***	0.0336396		0.5217604	***	-0.5525134	***
Doctorate Degree	0.0488271		0.4114266	***	0.0171182		0.4911172	***	-0.5399443	***
Household Income (Ref Group: < $5000)										
5,000 TO 7,499	-0.0006086		-0.0516569		0.0204631		-0.0250084		0.0256170	
7,500 TO 9,999	0.0088434		-0.0167531		-0.0044411		-0.0266640		0.0178206	
10,000 TO 12,499	0.0251450		0.0022827		0.0163840		-0.0093255		-0.0158195	
12,500 TO 14,999	0.0167099		0.0333591		0.0254463		0.0446468	*	-0.0613567	**
15,000 TO 19,999	0.0181821		0.0402212		0.0143074		0.0385367		-0.0567188	**
20,000 TO 24,999	0.0077596		0.0599684	**	0.0471605	**	0.1019454	***	-0.1097050	***
25,000 TO 29,999	0.0068832		0.0710823	***	0.0671924	***	0.1239878	***	-0.1308710	***
30,000 TO 34,999	0.0195256	*	0.1264652	***	0.0766450	***	0.1845116	***	-0.2040372	***
35,000 TO 39,999	0.0095886		0.1566117	***	0.0659198	***	0.2146276	***	-0.2242163	***
40,000 TO 49,999	-0.0036505		0.2258000	***	0.0533279	***	0.2749891	***	-0.2713385	***
50,000 TO 59,999	0.0022650		0.2334201	***	0.0537585	***	0.2821947	***	-0.2844597	***
60,000 TO 74,999	-0.0023714		0.2884802	***	0.0242211		0.3158275	***	-0.3134561	***
75,000 TO 99,999	-0.0064761		0.3059940	***	0.0132468		0.3271131	***	-0.3206370	***
100,000 TO 149,999	-0.0064425		0.3313468	***	-0.0193662		0.3269947	***	-0.3205522	***
150,000 OR MORE	-0.0011312		0.3385406	***	-0.0058357		0.3353426	***	-0.3342113	***

Table 9: Broadband Adoption by Key Demographics: Detail (Non-Metropolitan)

Mobile Broadband Adoption Impact by Race and Ethnicity. Research has identified certain demographic communities, particularly African Americans and Hispanic, non-Asian nonwhite households and the elderly as over-represented in the digital divide.[182] From these regressions, only African Americans ("Black Only") and Hispanic households were consistently significant across the board. With the exception of mobile only households, the Black only households' coefficients are negative (compared to White households), meaning they are less likely than White households (the reference group) to adopt any form of broadband. In metro areas, for each one percent increase in white household adoption of fixed broadband, Black households were 0.093 percent less likely to adopt. However, for each one percent increase in White household adoption, Black households were only 0.032 percent less likely to adopt mobile broadband. This indicates that Black households are closer to white households in adoption of mobile than fixed broadband. In fact, they are more likely than White households to have a mobile only household. Hispanic households show similar trends, with each one percent increase in non-Hispanic households, Hispanic households were 0.081 percent less likely to adopt fixed broadband, but only 0.032 percent less likely to adopt mobile broadband. Blacks and Hispanics in non-metro areas are even less likely to adopt fixed or mobile broadband than those in metro (urban) areas.

The only demographics that are consistently significant are the Black only and Hispanic households. Their high, negative coefficients are both squarely on the other side of the

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[182] Davidson et al. p.2556

digital divide (the exception being mobile only households). Regression analyses will utilize Black only and Hispanic households as part of the fixed effect to mitigate its impact on other independent variables of interest.

Education and Mobile Broadband Adoption. Low-income and less educated populations are also less likely to adopt fixed broadband services.[183,184] The more educated the consumer, the more likely to adopt, possibly due to higher income and greater exposure to broadband technologies. Since education is highly correlated with income, they are analyzed independently to determine which is a more significant factor in mobile broadband adoption.

Educational attainment clearly has an impact on broadband adoption as a whole, with fixed broadband more likely than mobile. For households with only one form of access, higher incomes are correlated positively with fixed broadband and negatively with mobile broadband. The coefficient gap between fixed and mobile is much wider in non-metro areas (0.10 to 0.11 gap), while the coefficients are lower and the gap between fixed and mobile coefficients is much narrower for those with some college or higher in metro areas.

Income and Mobile Broadband Adoption. Income is highly correlated with educational achievement. The results show that as income grows, households are more

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[183] US Census. Bureau, 2016. "ACS New State & Local Income, Poverty, Health Insurance Statistics."
[184] Tomer and Kane. 2015. p.4

likely to adopt broadband services. However, the analysis also shows relatively uniform adoption coefficients for fixed or mobile, metro or non-metro.

Rural Impact on Mobile Broadband Adoption. The rural and urban divide compounds the digital divide. Many low-income and less educated households are in more rural areas, which can be more difficult to physically connect due to terrain and distance. Mobile broadband offers a low cost of entry alternative that often does not have the challenges faced by fixed broadband.

To test the potential relationship between fixed and mobile broadband service adoption and the possible differences in more urban and rural areas, a more direct regression analysis was conducted. In this case, two regressions were performed with mobile broadband and fixed broadband as the respective dependent variables. For each, metropolitan status (binary) and the alternate access technology were used as the independent variable. Fixed effects were both education (quartiles) and race and ethnicity (binary), creating eight groups for the analysis, and household life cycle was used as a control variable. Table 10 shows the results of this analysis.

The results show that metropolitan areas are more likely to foster mobile broadband adoption over fixed broadband, although both coefficients are positive and relatively small. The existence of fixed broadband in the home is a stronger indicator of mobile broadband adoption than mobile broadband is as an indicator of fixed broadband adoption.

Dependent Variable: Mobile Broadband	Coefficient	Sig
Metropolitan	0.0198866	***
Household Fixed Internet	0.6184776	***
R2:	0.4478	

Dependent Variable: Fixed Broadband	Coefficient	Sig
Metropolitan	0.0231276	***
Uses Smartphone	0.5363983	***
R2:	0.4173	

Table 10: Likelihood of Adoption in Rural Areas

To understand the relative impact that metropolitan size could have on the adoption of the alternate access technologies, a regression was performed on each, using the metro area size as the independent variable. Once again, education and race were used as fixed effects, and household life cycle is the control. The regressions show a positive relationship between metro population size and adoption of broadband.

The results are show in Table 11 below.

Metro Population Size (Ref Group: Non-Metro)	Mobile Only	Sig	Mobile Service	Sig	Fixed Only	Sig	Fixed Service	Sig	No Internet	Sig
100,000 - 249,999	-0.0106112	***	0.0366026	***	-0.0060925		0.0416655	***	-0.0310544	***
250,000 - 499,999	-0.0065184	**	0.0437876	***	-0.0008259		0.0479353	***	-0.0414169	***
500,000 - 999,999	-0.0106574	***	0.0437921	***	-0.0065274		0.0463519	***	-0.0356945	***
1,000,000 - 2,499,999	-0.0103857	***	0.0406827	***	0.0053919		0.0545123	***	-0.0441266	***
2,500,000 - 4,999,999	-0.0096775	***	0.0590692	***	-0.0103159	*	0.0564552	***	-0.0467776	***
5,000,000+	-0.0142797	***	0.0553625	***	-0.0093758	**	0.0554959	***	-0.0412162	***
R2:	0.0088		0.1201		0.0317		0.0717		0.0814	

Table 11: Impact of Metropolitan Area Size on Fixed and Mobile Adoption

Although they marginally differ, the direction of signage and magnitude of coefficients remain largely the same for fixed and mobile broadband, lending support to H_1.

Potential Fixed and Mobile Broadband Substitution

This section examines the relationship between fixed and mobile broadband, specifically in low-income and rural households with lower incomes (H_2). Low-income households may opt for mobile broadband over fixed due to the lower cost of entry (computer vs. smartphone), and lower subscription rates (albeit speed and usage limitations). Due to geographic limitations for fixed service, mobile services may also be a more likely alternative for access in rural communities.

Table 12 shows that without fixed broadband access, households are more likely to use mobile broadband as income increases. Among the findings with significance, for those households without fixed broadband they are all positive coefficients. The relative few negative coefficients were not statistically significant. For those households with fixed broadband service already in the home, they are less likely to adopt mobile broadband if household income is below $35K, and more likely to adopt mobile broadband as a complement to fixed service at high incomes (above $35K). While the significances differ among the lower and higher income households, the coefficients change from negative to positive in the $35-40K income range.

For those non-metro households without fixed broadband access, low-income households are more likely to adopt mobile broadband as an alternative as income grows above $10K. While more limited in terms of significance, metro households show a similar pattern above $35K. However, the coefficients are much smaller for those in metro areas, which could be a consequence of limited fixed broadband options in the non-metro areas. These results indicate that non-metro households may see mobile broadband adoption as an alternative or substitute to fixed broadband, so long as it is affordable for low-income households. Given the challenges for providers in providing fixed broadband access (due to terrain or distance), mobile may be a more efficient way to provide access.

A: Dependent Variable:	Nonmetropolitan				Metropolitan			
Mobile Broadband	w/o Fixed		With fixed		w/o Fixed		With fixed	
Household Income	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**
5,000 TO 7,499	-0.0024557		-0.0750056	*	-0.0101130		0.0142000	
7,500 TO 9,999	0.0380255		-0.0522051		-0.0297886		-0.0498722	**
10,000 TO 12,499	0.0562548	**	-0.0589072	*	-0.0243570		-0.0554164	***
12,500 TO 14,999	0.0595065	**	-0.0568838		0.0199999		-0.0105322	
15,000 TO 19,999	0.0611772	**	-0.0370846		0.0131511		-0.0464779	**
20,000 TO 24,999	0.0525514	**	-0.0521870	*	0.0218758		-0.0332605	*
25,000 TO 29,999	0.0567808	**	-0.0573041	*	0.0437894	**	-0.0150352	
30,000 TO 34,999	0.1101331	***	-0.0449507		0.0183060		-0.0003810	
35,000 TO 39,999	0.0954326	***	-0.0186104		0.0467929	**	0.0150111	
40,000 TO 49,999	0.0807660	***	0.0347488		0.0529564	***	0.0337641	**
50,000 TO 59,999	0.1048058	***	0.0336645		0.0468132	**	0.0572878	***
60,000 TO 74,999	0.1135452	***	0.0729647	***	0.0791773	***	0.0700914	***
75,000 TO 99,999	0.1197844	***	0.0825499	***	0.0453055	**	0.0838294	***
100,000 TO 149,999	0.1118433	***	0.1147819	***	0.0353643	*	0.1126995	***
150,000 OR MORE	0.1389046	***	0.1133179	***	0.0187216		0.1397081	***
R2:	0.0935		0.1109		0.0572		0.0896	

B: Dependent Variable:	Nonmetropolitan				Metropolitan			
Fixed Broadband	w/o mobile		With mobile		w/o mobile		With mobile	
Household Income	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**
5,000 TO 7,499	0.0309076		-0.0121448		-0.0108044		0.0188880	
7,500 TO 9,999	0.0181226		-0.0288622		0.0130203		0.0321741	**
10,000 TO 12,499	0.0479757		-0.0671913	***	0.0349355		0.0362287	***
12,500 TO 14,999	0.0794329	**	-0.0309219		0.0167269		0.0095966	
15,000 TO 19,999	0.0606430	*	-0.0303179		0.0728378	***	0.0265331	**
20,000 TO 24,999	0.1242320	***	0.0038683		0.1050551	***	0.0330911	***
25,000 TO 29,999	0.1445242	***	0.0084374		0.1176441	***	0.0425889	***
30,000 TO 34,999	0.2192398	***	-0.0060201		0.1272042	***	0.0650644	***
35,000 TO 39,999	0.2240354	***	0.0179284		0.1521280	***	0.0655447	***
40,000 TO 49,999	0.2479806	***	0.0465754	**	0.2066919	***	0.0798512	***
50,000 TO 59,999	0.2744034	***	0.0380495	**	0.2355465	***	0.0908227	***
60,000 TO 74,999	0.2863959	***	0.0482357	**	0.2792592	***	0.0924965	***
75,000 TO 99,999	0.2890740	***	0.0534094	***	0.2655222	***	0.1001192	***
100,000 TO 149,999	0.2408550	***	0.0539961	***	0.2532427	***	0.1047590	***
150,000 OR MORE	0.2786170	***	0.0483342	**	0.1948100	***	0.1058617	***
R2:	0.0729		0.0290		0.0738		0.0322	

Table 12: Impact of Income on Mobile and Fixed Broadband Adoption

Although marginally significant, the coefficients for those households with fixed broadband in the home are largely consistent between nonmetropolitan and metropolitan areas, perhaps reflecting that once you have fixed broadband service, adopting mobile broadband is a function of more discretionary income. For those with higher incomes (above $60K in non-metro areas and $40K in metro areas), all coefficients are positive, allowing that households above that threshold may consider mobile broadband as a complementary service. Even with lower significance, this provides partial support for H_2, that mobile broadband may be a substitute for fixed broadband at lower income levels for both metro and non-metro (rural) areas.

Table 12B shows the analysis with fixed broadband as the dependent variable. They show similar results in non-metro areas in terms of significance and signage, but coefficients are nearly double that of mobile adoption. Fixed broadband appears to be the "first choice" as income increases. For those already with smartphones, there is only coefficient with significance in non-metro areas (in the $10K to 12.5K range), so there is little to support substitution. In metro areas, all significant coefficients are positive, providing little evidence of a substitution effect and giving support to more complementary relationship between fixed and mobile broadband.

Functional Roles of Fixed and Mobile Broadband

An analysis was conducted to identify the functional roles for fixed and mobile broadband to determine the common and complementary relationships of both. Table 13 below shows the results of the analysis. Of the results that were significant, most of the signage for mobile only and fixed only households are alike, demonstrating they are largely functional similar. Coefficients do differ, demonstrating a potential preference of one over another. Fixed and mobile households were uniformly significant and positive, demonstrating perhaps that households with multiple means of access are more technically savvy and take full advantage of the medium. Those households with only one means of access show lower, and often negative coefficients, suggesting these functions to do not lead to adoption.

Internet Use Description	Mobile Only	Sig	Fixed Only	Sig	Fixed & Mobile	Sig
Information (Web browsing, searches, lookup)	0.0005772		0.0205566	**	0.0614927	***
Communication (Email, texts, social networks, conference calls, medical monitoring	0.0183776	***	0.0023477		0.0947073	***
Social Networking	-0.0051990	*	-0.0417717	***	0.0584216	***
Entertainment (Video, audio)	-0.0101264	***	-0.0671001	***	0.0913330	***
Transaction (Online banking, shopping, IoT communications)	-0.0418139	***	-0.0303118	***	0.1061148	***
Productivity (Telework, Job training, Job searches)	0.0055646	**	-0.0574675	***	0.0331193	***
R2:	0.0216		0.1088		0.1261	

Table 13: Functional Use of Mobile and Fixed Broadband

Household Life Cycle and Broadband Adoption

In recognition that households may undergo various life cycle changes regardless of race, education, income and geography, an analysis was conducted on life cycle stages, as defined in Chapter 4. Age, marital status, and children under eighteen define each of twelve, mutually exclusive household stages. Brown and Venkatesh (2005) first introduced this method to increase the fidelity of their model.[185] These stages were regressed against fixed and mobile broadband adoption. Race and education and metro status were used as fixed effects. Table 14 on the following page shows the impact of household type on broadband access.

Age is a factor in the most significant, positive household coefficients. Both "Older Couple" and Bachelor III (over 65 years of age) and Bachelor II (between 35 and 64) households are among the most likely not to have broadband. If they do, they are more likely to be fixed only access households. This is consistent with the regression analysis on age groups, which concluded that the older you are, the less likely you are to adopt, and for those that do adopt, it's more likely to be fixed broadband only. However, in both sets of regressions, households with children were largely insignificant, necessitating a more direct approach to the impact of children.

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185 Brown and Venkatesh. 2005. p.402.

Household Type	Mobile Only	Sig	Fixed Only	Sig	Fixed & Mobile	Sig	No Internet	Sig
Bachelor I	0.0202899	***	-0.0031475		0.0190746		-0.0345056	***
Bachelor II	0.0201350	***	0.0655155	***	-0.1861592	***	0.1055997	***
Newlywed	< omitted >		< omitted >		< omitted >		< omitted >	
Single Parent	0.0291020	***	0.0249060	**	-0.0228938		-0.0301487	**
Full Nest I	0.0078707		0.0049621		-0.0033978		-0.0097919	
Delayed Full Nest	-0.0063862		0.0303561	**	-0.0470062	***	0.0259370	*
Full Nest II	0.0219815	**	0.0276959		-0.0485291	**	-0.0047016	
Full Nest III	-0.0002561		0.0339013	***	-0.0588233	***	0.0226060	*
Childless Couple	0.0028352		0.0849129	***	-0.1367939	***	0.0536472	***
Older Couple	-0.0142071	**	0.1918675	***	-0.3144476	***	0.1487043	***
Bachelor III	-0.0117069	***	0.1285264	***	-0.4011564	***	0.2924344	***
R2:	0.0311		0.0082		0.1037		0.0787	

Household Type	Mobile Only	Sig	Fixed Only	Sig	Fixed & Mobile	Sig	No Internet	Sig
Young Household	-0.0064702		-0.0289214	*	0.0655604	***	-0.0252337	
Household w/o Children	-0.0095454		0.0469260	***	-0.1146129	***	0.0856849	***
Household w/ Children	-0.0120895		-0.0017365		0.0119576		0.0051920	
Elderly Household	-0.0357180	***	0.1296959	***	-0.3132136	***	0.2325436	***
R2:	0.0031		0.0293		0.0942		0.0603	

Table 14: Impact of Household Type on Fixed and Mobile Internet Adoption

Children and Broadband Adoption

Using education and race as a fixed effect, a direct regression was performed for those households with children. The previous model split children household life cycle stages by age and marital status in the first set of regressions, and split households with children from those without by age in the second regression. The disaggregation likely inhibited the significance of our findings. In this regression children are represented by a single binary metric – households with (1) and without (0) children. Table 15 shows the results of the analysis.

	Nonmetropolitan				Metropolitan			
	w/o Fixed		With fixed		w/o Fixed		With fixed	
Dep Var: Mobile Broadband	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**
Presence of Children < 18	0.1312695	***	0.1263061	***	0.0742049	***	0.0646478	***
	w/o Mobile		With Mobile		w/o Mobile		With Mobile	
Dep Var: Fixed Broadband	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**
Presence of Children < 18	-0.0048274		0.0010525		0.0286404	**	0.0103964	***

Table 15: Impact of Children on Fixed and Mobile Internet Adoption

There is evidence that having children in the household has a significant positive effect on broadband adoption in general, and a greater impact in mobile broadband adoption than fixed. The analysis also shows that metro and non-metro households are more likely to adopt mobile broadband *with or without* fixed broadband service adoption. Households in non-metro areas are nearly twice as likely to adopt mobile broadband than metro households with children.

In metro areas, households with children are 4 to 6 times more likely to adopt mobile broadband than fixed, regardless of whether they already have the alternate access method. This may reflect that mobile service use may supplant some functionalities of fixed broadband, lessening the need for fixed service.

Intrinsic Factors Results

While much of the digital divide has been defined and scrutinized by its demographics, "demography is not a destiny."[186] As evidenced by the interview results, some factors

[186] LaRose et al. 2012. p.2588

remain up to the consumer, whose decisions may follow rational economic behavior – balancing benefits with costs and risks. The CPS survey inquired of respondents their reasons for adoption and not to adopt, as well as concerns regarding privacy and security. This section will analyze the responses by households to provide insights into the determinants for fixed and mobile broadband adoption.

Reasons for No Internet Adoption

The CPS Computer and Internet Use supplement inquired directly asking why households did not have access to the internet at home. For the CPS, this was interpreted as no *fixed* broadband service. Since households without fixed service could still have mobile broadband service (i.e., mobile only households), these households were included in the analysis. The universe of responses are captured between "No internet" and "Mobile Only" households. Therefore, the coefficients are mirror images of one another – they are the same except for their direction, positive or negative, accounting for all the variance within the response. They remain informative to contrast the differences among those who disconnect completely and those that adopt mobile broadband only.

For each of the analyses, a fixed effect model was used, holding constant household income, race and ethnicity (Black and Hispanic), and metropolitan status of household. Household life cycle was the control variable, allowing age, marital status and children to be factored into the model. As shown in the Table 16 below, households with no Internet are more likely not to adopt because of lack of need or interest (significant positive coefficients).

Reasons for No Fixed Broadband at Home	No Internet Coefficient	No Internet Sig	Mobile Only Coefficient	Mobile Only Sig
Don't need it	0.0382723	***	-0.0382723	***
Not interested	0.0644290	***	-0.0644290	***
Can't afford it	0.0001856		-0.0001856	
Not worth the cost	-0.0442431	***	0.0442431	***
Can use it elsewhere	-0.1179288	***	0.1179288	***
Not available in area	-0.0606820	***	0.0606820	***
No computer, or computer inadequate or broken	-0.0009337		0.0009337	
Online privacy or cybersecurity concerns	0.0336215	*	-0.0336215	*
Personal safety concerns	0.0070959		-0.0070959	
Household moved or is in the process of moving	-0.1274710	***	0.1274710	***
Other	0.0283816	***	-0.0283816	***
R2:	0.0770		0.0770	

Table 16: Reasons for No Fixed Broadband At Home

Although many have never had fixed internet at home or have disconnected, many adopted mobile broadband as their primary means of internet access. The results shed light on the trade-offs between fixed and mobile. Among the responses for mobile only households, "don't need it" and "not interested" were negative, indicating that these households see the value in adoption of fixed broadband in the home (and reduced the likelihood of mobile broadband adoption). However, the positive coefficients regarding "not worth the cost," "can use it elsewhere", and "not available in the area" were reasons that fixed was not adopted but contributed to mobile broadband adoption. While only marginally significant ($p < 0.10$), "online privacy or cybersecurity concerns was a stated reason for households to adopt fixed broadband, and also reduced the likelihood of mobile broadband adoption.

A regression was also performed for those that have never adopted fixed broadband and those that had adopted before but have since disconnected. Table 17 shows the results for the analysis. For Mobile only households, the largest differential in significant, positive coefficients is for inadequate or no computer, can use it elsewhere, household is moving. Mobile only households that are unadopters have outdated or broken computers that led them to disconnect from fixed broadband and are not a mobile only household. The ability to use fixed broadband elsewhere also led to decisions to un-adopt fixed and be a mobile only household. Transitional households that are in the process of moving are mobile only, which allows them to remain connected until the process is complete. The largest significant, negative differential for coefficients between mobile only household never-adopters and un-adopters is "Not interested," conveying that these households are not interested in fixed broadband and it diminished mobile broadband adoption as well.

Reasons for No Fixed Broadband at Home	Never-Adopters No Internet	Sig	Never-Adopters Mobile Only	Sig	Un-Adopters No Internet	Sig	Un-Adopters Mobile Only	Sig
Don't need it	0.0276043	***	-0.0276043	***	0.0182505		-0.0182505	
Not interested	0.0475014	***	-0.0475014	***	0.0721002	***	-0.0721002	***
Can't afford it	-0.0016035		0.0016035		0.0108859		-0.0108859	
Not worth the cost	-0.0238273	*	0.0238273	*	-0.0261433		0.0261433	
Can use it elsewhere	-0.1011611	***	0.1011611	***	-0.1299553	***	0.1299553	***
Not available in area	-0.0679239	***	0.0679239	***	-0.0893076	*	0.0893076	*
No computer, or computer inadequate or broken	0.0114937		-0.0114937		-0.0664043	***	0.0664043	***
Online privacy or cybersecurity concerns	0.0308753		-0.0308753		0.0295566		-0.0295566	
Personal safety concerns	0.0116624		-0.0116624		0.0085905		-0.0085905	
Household moved or is in the process of moving	-0.0875461	**	0.0875461	**	-0.1409235	*	0.1409235	*
Other	0.0299952	***	-0.0299952	***	0.0321856		-0.0321856	
R2:	0.0619		0.0619		0.08270		0.08270	

Table 17: A Comparison of Reasons for No Fixed Broadband for Never-Adopters and Un-Adopters

Accessing Broadband Outside the Home

The following Table shows where households with different connection types are likely to use broadband outside the home. Households with mobile service (whether or not they have fixed) and households with fixed service (whether or not they have mobile) have strong positive coefficients associated with work, school, and travel. Consistent with previous research the contribution of access through libraries and community centers is small.[187] Notably, all "No internet" households show negative coefficients, which could mean they are less likely to have access outside the home. The larger negative coefficient for work may mean they likely do not have employment that requires access to a computer or the internet.

187 LaRose et al. 2007. p. 371

Location Internet is accessed:	Mobile Service	Sig	Fixed Service	Sig	No Internet	Sig
Work	0.2764321	***	0.2653117	***	-0.2818342	***
School	0.1022953	***	0.1226980	***	-0.1099165	***
Café or Coffee Shop	0.0221906	***	0.0112651	**	-0.0085698	**
On Travel	0.2616785	***	0.1679801	***	-0.1449131	***
Library/Community Center	0.0335019	***	0.0047579		-0.0240019	***
Someone else's home	0.0788617	***	0.0466450	***	-0.0443649	***
Other	0.0123417		0.0031675		-0.0108747	
R2:	0.3621		0.2964		0.3254	

Table 18: Households that Access Internet Outside the Home

While most R2 coefficients have been small as we examine each small factor contributing to adoption, the coefficients for access outside the home are notably large. Having access outside the home accounts for a significant amount of variation in the model and is a significant contributor to fixed and mobile broadband adoption. These regression results demonstrate similarities in traditional determinants of fixed and mobile adoption (H_1) and also support the H_4 regarding the influence of access outside the home on mobile broadband adoption.

Table 19 shows the relationship of industry with households who access the internet through work (in this case, using households with access through work as the dependent variable). The coefficients are largely negative with those industries not typically associated with high computer skills or information processing. The sign changes from negative to significantly positive with the educational and health services industry, and gets progressively larger through the information services, financial and public administration.   While the armed forces shows a significant and positive coefficient, the sample size is relatively small compared to other industries represented.

Dependent Variable: Access Internet at Work

Industry	Coefficient	Sig
Agriculture, forestry, fishing, ..	-0.1333778	***
Construction	-0.1041717	***
Mining	-0.0692101	***
Transportation and utilities	-0.0591921	***
Leisure and hospitality	-0.0565187	***
Manufacturing	-0.0416992	***
Wholesale and retail trade	-0.0185730	
Professional and business services	0.0518713	***
Educational and health services	0.0780701	***
Financial activities	0.0886070	***
Information	0.0886311	***
Public administration	0.1078369	***
Armed Forces	0.5793468	***
R2:	0.0389	

Table 19: Internet Access at Work by Industry

Reasons for Not Accessing the Internet Outside the Home

Table 20 below shows the relationship between households with varying internet connections and the rationale for not connecting outside the home. For fixed broadband households, it is less that they are “not interested” or “can’t afford it”(significant negative coefficients), but more that is not worth it. They cite “no mobile device” as a contributing factor and privacy, security and safety concerns (which could also related to “not worth the cost”) as primary reasons not to access outside the home.

Reason for No Internet Use Outside Home	Mobile Only	Sig	Mobile Service	Sig	Fixed Only	Sig	Fixed Service	Sig	No Internet	Sig
Don't Need it	-0.0007415		0.0105756		0.0245558	***	0.0397747	***	-0.0390332	***
Not interested	0.0010241		-0.0429198	***	-0.0667450	***	-0.0948177	***	0.0937936	***
Can't afford it	-0.0005940		-0.0371245	***	-0.1043208	***	-0.1213214	***	0.1219154	***
Not worth the cost	-0.0011082		0.0299607		0.1023276	***	0.1102235	***	-0.1091153	***
Nowhere to go that has an Internet connection	-0.0014120		0.0075500		0.0937080	***	0.1063467	***	-0.1049347	***
No computer, or computer inadequate or broken	-0.0018213		-0.0721574	***	-0.1593331	***	-0.2034491	***	0.2052703	***
No mobile device, mobile device inadequate or broken	0.0020710		-0.0399960	**	0.1555419	***	0.1322398	***	-0.1343108	***
Online privacy or cybersecurity concerns	0.0009346		0.0583910	***	0.0795915	***	0.1188482	***	-0.1197829	***
Personal safety concerns	-0.0015681		0.0586246	***	0.0887068	***	0.1042882	***	-0.1027201	***
Household moved to location with no internet	-0.0006445		0.0547662		-0.0987207		-0.0079369		0.0085814	
Other	-0.0005583		-0.0487318	***	-0.0382998		-0.0662712	***	0.0668295	***
R2:	0.0023		0.0196		0.0537		0.0660		0.0653	

Table 20: Reasons for Not Accessing Internet Outside the Home

For households with mobile broadband (there were no significant results for mobile only households), the largest positive coefficients are related to privacy, security and safety concerns. Notably, their coefficients are nearly half of the coefficients for households with fixed broadband, reflecting a lower concern (but still a contributor limiting access outside the home for mobile broadband users).

Finally, the primary reasons for No Internet households not to access the internet outside home is an inadequate or lack of a computer, followed by “Can’t afford it” and “Not interested.” Perhaps surprisingly, privacy, security and safety concerns are not contributing reasons for lack of internet access outside the home for No Internet households. Inadequate or lack of a computer was a significant and positive reason for no access outside the home. However, inadequate or lack of a mobile device was significant and *negative* for accessing internet outside the home for No Internet households. That could be interpreted that No Internet households have access to a mobile device to reach the internet outside the home.

Security and Privacy

This analysis tests the type and veracity of concerns for privacy and security against access technologies. Using the fixed effects model and controlling for household type, a series of regressions were performed for each access type. The results are shown in Table 21 below.

Risk perceptions of those adopting fixed and mobile are largely consistent, with some notable differences. All of the coefficients were small, indicating that privacy and security risks play only a small role in broadband adoption decisions. Those with positive coefficients contribute to the selection of the particular access technology, perhaps as a result of the belief that access technology is more resilient from threats or that they have processes/programs in place to mitigate these threats. Those concerns with negative coefficients are likely to diminish the likelihood of adoption.

Privacy and Security	Mobile Only	Sig	Fixed Only	Sig	Fixed and Mobile	Sig	No Internet	Sig
Concern:								
Conducting financial transactions such as banking, investing, or paying bills online	-0.0042529		0.0399200	***	-0.0320816	***	0.0006228	
Buying goods or services online	0.0016696		0.0193652	***	-0.0140387	**	-0.0033271	
Posting photos, status updates, or other information on social networks	0.0070537	**	-0.0166511	***	0.0191697	***	-0.0106656	***
Expressing an opinion on a controversial issue on a blog or social network, forum,or email	-0.0064622	**	-0.0161393	***	0.0183755	***	0.0027533	
Identity theft	-0.0068725	***	0.0079508	**	0.0116225	***	-0.0102412	***
Credit card or banking fraud	-0.0028275		-0.0172084	***	0.0291166	***	-0.0123945	***
Data collection or tracking by online services	-0.0027764		-0.0188707	***	0.0244053	***	-0.0030961	
Data collection or tracking by government	0.0061939	*	0.0145149	**	-0.0222344	***	0.0030370	
Loss of control over personal data such as email or social network profiles	0.0001163		-0.0145319	***	0.0132019	**	-0.0012818	
Threats to personal safety, such as online harassment, stalking, or cyberbullying	0.0042177		-0.0142054	**	0.0083982		0.0019666	
Other concerns	-0.0054640		-0.0118257		-0.0141562		0.0247362	***
Experienced an online security breach, identity theft, or a similar crime	-0.0119208	***	-0.0599106	***	0.0776099	***	-0.0102247	***
Experienced online harassment, stalking, or cyber-bullying	0.0136697	**	-0.0321081	***	0.0280878	**	-0.0111389	**
R2:	0.0120		0.0848		0.0701		0.0138	

Table 21: Security/Privacy Concerns and Experiences by Connection Type

Of those that are significant, single access households (mobile only or fixed only) have mostly negative coefficients, meaning these households' concerns/experiences diminish adoption of the respective access technology. Single access households also show a negative correlation with experiences as a result of online security breach, identity theft, or a similar crime online.

With the exception of banking and buying goods online, fixed and mobile households have many significant, positive coefficients for concerns which foster the adoption of these technologies. However, these households may choose which access technology they use to mitigate the concern or threat – it is indistinguishable in the survey response.

Fixed households had concerns regarding banking and buying goods online, but these concerns supported their adoption of fixed broadband in the home, perhaps due to better control and protections in place. Remarkably, concerns regarding banking and buying goods online had a negative impact on adoption for those households with more robust access (mobile and fixed service), who might be considered more aware and tech savvy to deal with such threats.

For No Internet households, only threats to personal safety (online harassment or stalking) and loss of control of personal data contributed positively to being a No Internet household. These households also had negative coefficients for concerns about identity theft and banking fraud, possibly a reflection that these are not concerns because they have no internet access (i.e., a simultaneity issue).

The concerns and experiences were tallied to generate a score for those households with more than one concern or experience. Table 22 below shows the regressions for each connection type based on their scores. No internet households show negative coefficients, but that may be a result of limited exposure to privacy or security threats. For fixed only households, they show a positive relationship with number of concerns in the past year, but a negative relationship with current security concerns. Notably, mobile broadband household has an order of magnitude lower coefficients for all concerns/experiences, with only one of significance, which is both small and negative –

experience with security events. It is possible that mobile only households likely perceive they have less exposure to security threats. Fixed and mobile households have the highest positive coefficients that contribute to adoption, perhaps under the belief that experience has helped them to better prepare and mitigate threats.

Description	Mobile Only	Sig	Fixed Only	Sig	Fixed and Mobile	Sig	No Internet	Sig
Number of security concerns in past year	-0.0002408		0.0088425	***	-0.0038505	**	-0.0031334	***
Experience with security events	-0.0075040	***	-0.0557939	***	0.0688091	***	-0.0097103	***
Number of current security concerns	-0.0005997		-0.0075979	***	0.0117035	***	-0.0039937	***
R2:	0.0103		0.0811		0.0659		0.0110	

Table 22: No of Security Incidents/Concerns by Connection Type

CHAPTER 7: FINDINGS AND CONCLUSIONS

This study explores how the emergence of mobile broadband changes household broadband adoption in the United States, particularly among those that are on the other side of the digital divide. It identifies key areas of impact for mobile broadband, and describes how it could fulfill a role in U.S. broadband policy. Previous chapters outlined the history of telecommunications policy and broadband, culminating in the recent emergence of a mobile broadband infrastructure and devices. The current state of research literature demonstrates the need for more current research on the role and relationship of mobile to fixed broadband.

A set of interviews helped to establish context and direction, and in-depth quantitative analysis established new insights on the role of mobile broadband in closing the digital divide. This research utilizes the latest CPS CIU Supplement datasets (2011- 2015) that permit a comparative analysis of the role of fixed and mobile broadband in bridging the digital divide, particularly for Blacks and Hispanics, low-income, and low-income rural communities. The findings create a direction for future research and suggest new policies for inclusion of mobile broadband in federal and state initiatives. The purpose of this chapter is to summarize key findings and draw conclusions on how this study impacts current research and broadband programs.

Interview Findings

Each of the interviews represented a different intersection point with broadband adoption – a statewide agency, a non-profit covering 13 states, and a corporate foundation extension of an internet provider. While the approaches differed, they converged on the challenges associated with broadband adoption. They described some of the rural, low-income communities as not a "culture of internet" – they don't feel they need it or do not understand it. Apprehension and resistance to change persisted in the communities they serve, particularly among the elderly. While some were suspicious of the technology initially, working through trusted community members and building familiarity through a local presence, these suspicions were eased.

Throughout all communities there is a lack of education and understanding of the social and economic benefits, and a lack of relevance to their everyday lives. Most did not have the digital literacy and affordable technology to access fixed broadband technology. None of the initiatives addressed mobile broadband adoption, although most were aware of some substitution in rural areas.

These interviews set the stage and provided needed context for the research, facilitating empirical analysis of factors that appeared to be material to broadband adoption in targeted communities.

Quantitative Analysis Findings

The intent of the analysis was not to create a predictive model of consumer adoption behavior, but to identify and compare factors that influence mobile and fixed broadband adoption. The following figures 10 and 11 show the selected factors consistent with the stated hypotheses that influence mobile and fixed broadband adoption. Where there are no numbers assigned, the findings were insignificant. The red numbers or arrows indicate a negative coefficient; the factor is associated with lower adoption.

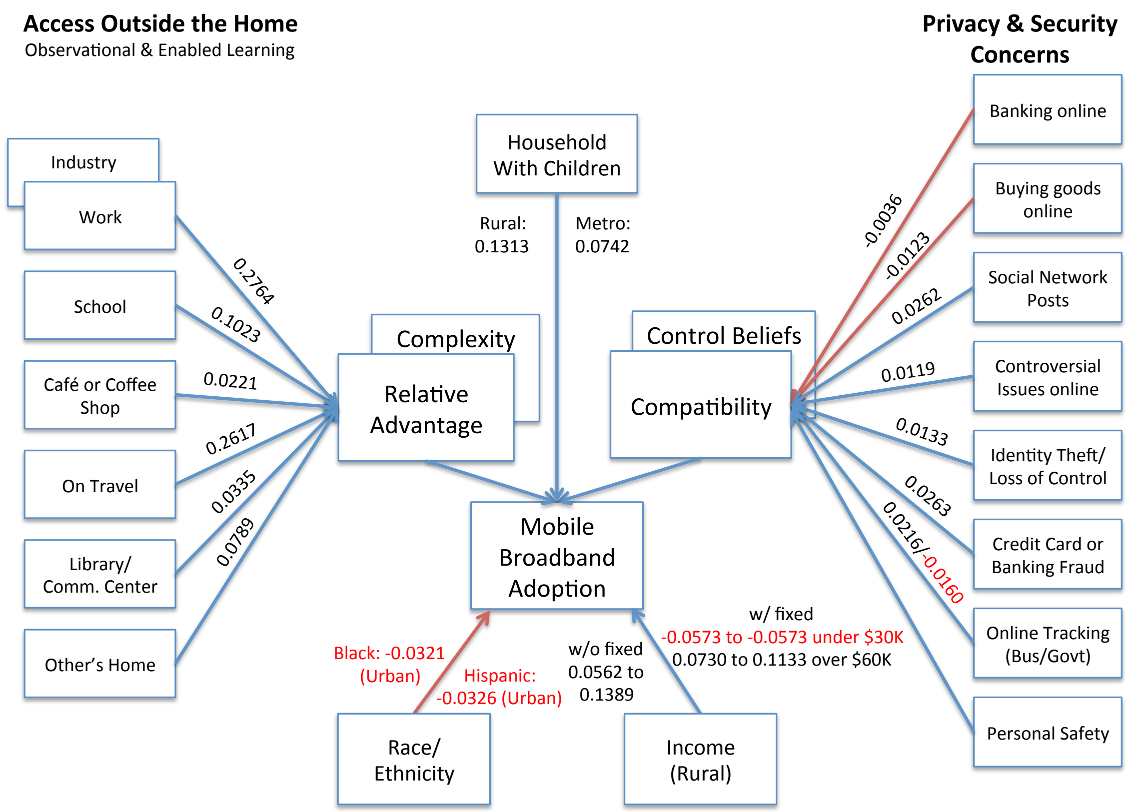

Figure 10: Mobile Broadband Adoption Factors

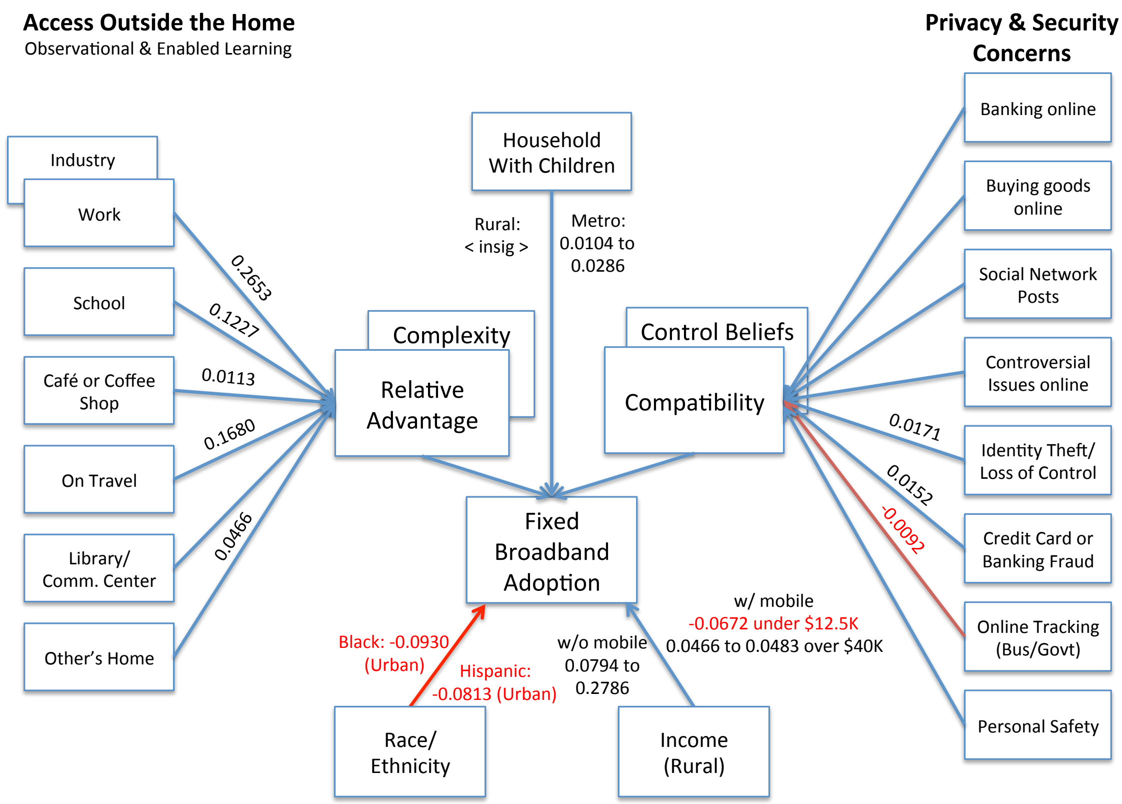

Figure 11: Fixed Broadband Adoption Factors

The following section will discuss each of the hypotheses in succession.

H_1: The patterns of adoption for mobile broadband are the same as fixed broadband.

The longitudinal analysis showed that while fixed broadband continue to have the highest penetration per household; mobile broadband has made remarkable progress in the past 5 years. Fixed and broadband have similar adoption patterns – both are more readily adopted in metro areas and are challenged in rural (non-metro) areas. Both fixed and broadband have common target communities that remain challenged in adoption, although the extent of challenges differs for each. Elderly favor fixed broadband but remain well behind the general population, while Blacks and Hispanics have embraced the new mobile broadband technologies and are (almost) keeping pace with the general population.

The regression analysis showed that at a macro level, fixed and mobile broadband adoption follow similar patterns, with mobile offering an alternative to fixed in rural, lower-income areas where fixed is either unavailable or unaffordable. At higher income levels, mobile complements fixed, with many households now employing both, performing common functions on both platforms, a potential example of service convergence.

The patterns for adoption are similar – adoption declines with age and population density, and increases with education and income. While the direction of the coefficients (positive or negative) was largely the same, the coefficients were often different. The older the household, the less likely they were to adopt. However, if they had only one means to connect, they were more likely to connect with fixed broadband than mobile. This may reflect the current emphasis on fixed broadband services. Elderly programs specifically designed to build digital literacy have centered around building digital literacy on fixed computers, and shared housing facilities for the elderly (retirement communities, assisted living, and senior citizen centers) typically have shared fixed broadband connections.

Regression analysis also showed that Black and Hispanic households were less likely to connect than the general population, but when they connected, they were much more likely to adopt mobile broadband over fixed broadband. In the longitudinal analysis, Black and Hispanic households were 7.3 percent behind the general population in 2015 (closing the gap from 11.2 percent behind in 2011). However, Black and Hispanic households were more aggressive in mobile broadband adoption, trailing the general population by only 3.6 percent in 2015.

Although not as strong a contributor as fixed, mobile broadband follows the same pattern as fixed for educational attainment – the higher the education, the higher the adoption rate. The coefficients were consistently higher for fixed and mobile broadband in non-metro areas for those with some college or higher than those in metro areas. This may reflect the increased exposure through both education (more school, more opportunities) and the more information-intensive industries that employ households with these educational achievements.

Closely associated with higher education attainment, households with progressively higher income also increased adoption relatively consistently for fixed and mobile broadband. There is little distinction among the coefficients for fixed and mobile, non-metro and metro. They are significant and get progressively higher with household incomes above $20K.

Finally, the results of the analysis also show a positive relationship between metropolitan households in both fixed and mobile broadband adoption. Although the coefficients are significant and small, it shows a slight edge to fixed adoption over mobile (0.023 vs. 0.020). Adoption of mobile or fixed shows a high correlation whether the alternate technology has been adopted, with mobile adoption being more likely for households with fixed broadband than fixed adoption for those households with mobile broadband. This may be due to rural (non-metro) households that have access to fixed are more likely in a mobile broadband coverage area, while those with mobile broadband may be in a coverage area, but don't necessarily have access to fixed.

In addition, the greater the population size of the metro area, the more likely they are to adopt both fixed and mobile broadband, with a higher coefficient for mobile. This may be due to higher number of providers, ubiquitous coverage, and potentially network effects from an increasing number of adopters.

Based on these findings, the results of the analyses support H_1. The patterns of adoption for mobile broadband are generally the same as fixed broadband, with the same demographic profile on the same side of the digital divide: Older, Black and Hispanic, lower-income and rural. However, there are distinctly different coefficients for adoption of mobile and fixed broadband which show promise in closing the gap in some communities (primarily Black, Hispanic and rural low-income households).

The CPS C&IU supplement asked directly why households did not adopt fixed broadband at home. The analysis of answers could be divided into those with no fixed and mobile (i.e. "No Internet"), and those with mobile only. Mobile only households indicated that fixed broadband was not worth the cost, that it could be accessed elsewhere, or that fixed broadband simply wasn't available in their area. However, they also stated that privacy and security concerns were among the reasons they do not adopt both fixed and mobile broadband, although the significance was not as robust as the other results ($p < 0.10$).

H_2: Low-income and rural households with lower incomes are more likely to adopt mobile technologies as an alternative or substitute to fixed broadband services.

Rural, low-income households are more likely to adopt mobile broadband if they have no fixed service and are less likely to adopt mobile if they have fixed broadband service, regardless of rural or urban status. Without fixed broadband, rural and metro low-income households (under $30K) without fixed service are more likely to purchase mobile broadband as an alternative to fixed service. High-income households (over $60K in rural and 40K in metro areas) with fixed broadband are more likely to adopt mobile broadband as a complementary service.

Longitudinal analyses showed the general population adopting mobile broadband as a complementary service overall, with households choosing to have both fixed and mobile over one access method. As fiber has become available in rural and low-income communities and programs focus on fixed adoption, these communities have increased fixed broadband adoption, but mobile has also grown dramatically.

Although the significance among income levels is scattered, the results generally support H_2 that low-income and rural households without fixed broadband will adopt mobile technologies as a substitute for fixed. If fixed and available, regression shows a stronger correlation with fixed over mobile at various income levels. At higher incomes (above $40K), it appears the fixed and mobile broadband services are more complementary. Household disposable income, fixed broadband availability and mobile coverage may be factors for low-income households, particularly in rural areas.

H_3: Households with children are more likely to adopt mobile broadband than those households without children.

The results of the analysis support H_3: All households with children show a significant and positive effect on fixed and mobile broadband adoption (with the exception of rural households with mobile, which was not significant). Rural households with children areas are the most likely to adopt mobile service whether or not the household has fixed broadband already. The adoption of fixed broadband by rural and urban households was significantly lower than that of mobile adoption, regardless of whether they already had mobile broadband or not. This may be due to the convenience and improved logistics associated with smartphones in coordinating children's activities.

H_4: Households with access to internet outside the home are more likely to adopt mobile broadband service.

The results of the analysis support H_4. Households that use internet services at work, school, or on travel are significantly more likely to adopt fixed and mobile broadband. Accessing the internet at work had the highest contribution to fixed and mobile broadband adoption at home, while those that did not have access through work had the highest rate of non-adoption. School internet use also showed a similar relationship with fixed and mobile, but the contribution to adoption was less than half that of access at work. Access while on travel also had a high correlation, with the highest correlation to those households that have adopted mobile broadband. This may be demonstrating the need of these households to be connected anytime, anywhere, including while on travel. Finally, the results of this analysis show a small, significant coefficient for access outside the home through libraries and community centers. This is consistent with previous research that these venues have been shown to have marginal impact on household fixed broadband adoption.[188]

[188] LaRose et al. 2007. p. 371

The findings are consistent with adoption theory regarding observation and enabled learning that is available through opportunities outside the home. The analysis of industry regarding internet access at work shows that industries that are more information technology intensive yield greater accessibility to learn, experience and build confidence in technical skills.

The CPS CI&U also inquired directly to understand the reasons respondents did not access the internet outside the home. Among the highest coefficients were online privacy and security concerns and personal safety concerns (which were not a concern for No Internet households to not access the internet outside the home). This could be attributed to heightened awareness of all broadband households (fixed and mobile) about using public computers and unfamiliar "open" or unprotected networks.

H_5: Households that perceive (or have experienced) high risk factors related to internet use are more likely to adopt mobile over fixed broadband or disconnect completely.

The analysis is mixed and weak regarding H_5 and is at best, inconclusive. Most of the coefficients were small. Among the significant findings for households with No Internet service, most of the stated privacy concerns or experiences contributed positively to the decision not to adopt broadband (with the lone exception of "other concerns"). Simultaneity may be an issue here, in that households with no internet will also likely have fewer concerns and experiences with privacy and security issues. It may be less a cause for non-adoption but more a reflection of the current condition.

For mobile only households, the results were mixed. Privacy concerns regarding social network posts, expressing opinions online, loss of control of personal data, and tracking by business actually *contributed* to mobile service adoption. Banking and buying good online as tracking by the government were concerns cited that *diminished* the likelihood of mobile broadband adoption. Privacy concerns regarding credit card and banking fraud contributed to fixed broadband adoption, while tracking by the government diminished adoption (although for government tracking the coefficient was exceptionally small and marginally significant ($p < 0.10$)).

Finally, those households with both fixed and mobile are seemingly resilient to most security concerns, with many leading to positive adoption of both fixed and mobile in the home. This may be due to more robust security measures and protocols established in a fully connected, technology savvy, home. Of the negative contributors, doing banking or shopping online, data collection by the government, and online harassment and stalking were the only detractors to household fixed and mobile adoption. Even with strong security measures in the home, performing banking and shopping online requires some loss of control as the consumer must furnish personal information to conduct business.

Summary Conclusion

Recent campaigns to close the digital divide have focused on fixed adoption, and there is evidence of progress in fixed broadband adoption in targeted communities on the other side of the divide. However, even without government programs and stimulus, mobile broadband has seen substantially greater growth than fixed. While functionality and speed are limited, mobile broadband has become a viable alternate for some low-income and rural households. Exposure remains critical to adoption of both technologies, including opportunities for internet access at both work and school.

Households with children have been the initial target for federal programs for fixed adoption, but for rural areas, mobile may be a more viable alternative. The elderly have adopted more fixed broadband in recent years, but are well short of the general population. Mobile broadband's ease of use and low cost of entry could help to bridge the gap. For seniors who have anxiety over the complexity and benefit, interfaces are now becoming more user-friendly and interactive which could help to advance both fixed and mobile broadband adoption (e.g., Apple's Siri, Microsoft's Cortana, Google's Home, Amazon's Alexa).

While demographics play a role, technology adoption theories such as DoI and SCT which look to consumer intrinsic attitudes and behaviors play a significant role in broadband adoption. Adoption programs that address all five key factors: relative advantage, observational and enabled learning, complexity, and compatibility are likely to be much more successful than strictly digital literacy programs. The interviews highlighted the importance of building trust and becoming a part of the community, giving communities an opportunity to learn and create their own unique platforms that meet their needs. The quantitative evidence suggest there are many factors beyond demography that are in play, and these contribute to a complex and nuanced decision making process regarding adoption.

Chapter 8: Policy Implications & Future Directions

With mobile networks increasing in capacity and throughput, more "unlimited" data plans that mitigate some of the cost volatility risk, and an expanding number of mobile devices, mobile broadband service adoption will continue to grow. Even without the subsidies provided to foster the implementation and adoption of fixed broadband, mobile broadband adoption has grown double digits over the past decade. With 4G being rolled out nationwide and 5G around the corner, mobile broadband may soon become the functional equivalent of fixed broadband. When it does, there may be competition between the two that could yield more affordable pricing plans and enhanced services.

In many areas, the dominant providers offer both fixed and mobile services (e.g., Verizon and AT&T). This allows the opportunity for more service convergence enabled through bundling services and sharing storage (i.e., through the cloud), shared access to entertainment, and common message platforms. Application providers, particularly social media, are optimizing their services specific to the platform (smartphone or computer) and providing seamless transparency to move between devices. This transparency can offer significant advantages, but security to protect data and ensure privacy is necessary and prudent. Regulators must also be wary to ensure that these large providers do not exhibit anti-competitive behaviors.

The Divide Persists

Analysis shows that demographics continue to play a significant role in adoption. Policy-makers should continue to focus on the same demographic communities as fixed broadband – rural, low-income, Blacks and Hispanics, and the elderly. Some communities, most notably Blacks and Hispanics, have already shown a predilection for mobile broadband, nearly pacing the general population in adoption (although still behind). Designing and leveraging government programs that utilize this technology can ensure equal opportunities for those that still lack fixed broadband connectivity.

Utilizing alternate access technologies such as mobile broadband can help to close the gap more quickly than fixed broadband alone. Even with eventual adoption, a "capability gap" will persist among those early adopters who can leverage the full capability of digital opportunities and those that are only now coming online. Realizing the full benefit of utilization will require continuous awareness and education programs.

Mobile broadband coverage in very rural areas remains a challenge with limited coverage and slower speeds. However, emerging standards (4G and 5G), expanded coverage, and greater functionality in mobile devices are allowing mobile broadband to quickly catch up to fixed broadband. Government programs focused on fixed broadband supply should expand to include increased coverage and upgrades to mobile infrastructure, particularly in rural areas.

Spectrum sales by the federal government generate significant revenues. Some of these are used to reengineer the systems of those who have vacated the frequencies. A portion of these resources should be routinely directed at building out or upgrading mobile infrastructure in rural areas (much like universal service subsidies for fixed services). In addition, subsidies to lower costs and digital awareness and literacy programs within these communities are essential in bridging the divide.

Policy Recommendations

Continue to Encourage Fixed Broadband Adoption. Outreach programs such as those interviewed found that providing fixed broadband access through the schools and small businesses increased household adoption. Analysis showed a strong correlation among those that access the internet outside the home and household adoption of both fixed and mobile broadband. Repeated exposure through observation and trial over time at work, school or travel helps potential adopters to realize the relative advantage and be comfortable in mastering the technology. Regression analysis shows that libraries and community centers do not contribute to household adoption, but still may be the means of alternate access for some communities where access to the home is unavailable.

Foster Increased Mobile Broadband Coverage. While mobile may be easier to access than fixed broadband, mobile coverage can still be an issue in very rural areas. If there is coverage, the carrier has not invested in providing the latest technology, so these rural areas are still operating at 1G (analog) or 2G (limited digital) speeds. Interviews with representatives from adoption programs mentioned that some household members would travel to more urban areas to get signal. One program petitioned a local wireless provider to erect a cell tower in the downtown area of a small town to increase access to residents who frequent the town. Providing enticements or relief to mobile providers (tax incentives, rights of way, building rooftop or pole access) can help to entice private investment. Fostering competition when possible can help to lower costs and increase service quality. If private providers don't play, some municipalities have built their own networks (generally WiFi) to help foster connection in some population centers.[189]

Generate Greater Demand. Since the patterns of adoption for fixed and mobile are similar, current fixed infrastructure and adoption programs should be extended to include mobile broadband. Awareness, digital literacy, and discounted access device programs can foster increased demand to attract further investment. Schools, libraries and community centers should include mobile as well as fixed broadband as part of their outreach. Ruggedized and secure mobile devices can be "checked out" and used at home where households do not have broadband. Analysis indicated that low-income households may make trade-offs between fixed and mobile, so specific programs can be designed to help families make sound decisions and ensure adequate training to ensure proficiency and realize the full benefits.

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[189] City of Wilson, NC. "Greenlight Community Broadband." 2015.

Interviews suggested that household children could be a virtual "Trojan horse." They could bring the technology home and expose others to the technology, and help to build the technical competence and confidence to operate the technology. Regression analyses showed a high correlation for households with children and mobile broadband adoption, particularly for rural households. Increased demand for services could lead to increased supply and coverage by providers. One interview stated that providers do not direct-market rural or low-income communities, instead focusing on more populous areas with higher incomes. Tailored messaging to those communities could increase awareness and demand for services, making it more relevant to their unique needs.

Outreach to Older Households. The largest community that remains largely disconnected is the elderly, who lag far behind the general population in broadband adoption. Analysis showed that of those seniors that do adopt, they are more inclined to adopt fixed broadband over mobile. The elder population will continue to grow within the U.S., and their needs may be best accommodated by broadband services, including mobile. The elder population will need more access to health care, including wellness programs, and will likely have less mobility. They could benefit particularly from remote access to services (banking, commerce), telemedicine applications, and social networks available through broadband. With advancements in interactive access and artificial intelligence (e.g., Amazon's Alexa, Google's Home, Apple's Siri, and Microsoft's Cortana), broadband could be both a lifeline and an interactive "companion" to elderly shut-ins. Since mobile devices are generally lower cost, easier to use, and will interface with a variety of health and medical monitoring devices, a concerted effort to build awareness and enable the adoption of mobile broadband among the elderly is appropriate. The elderly do not get the exposure at work or school as younger households or households with children. Exposure and learning for seniors must occur at locations more common to the elderly, such as senior centers, retirement communities, doctor offices, and health clinics.

Build Trust. A common component of the success of those programs interviewed was building trust with communities where there was no "culture of internet" and where it was perceived as irrelevant. Technology adoption policies and programs should work with local, trusted organizations that are part of the targeted community to encourage greater digital literacy (fixed and mobile), and foster workplace exposure in industries that are not typically information processing intensive. Programs should continue to target schools and students who can be "ambassadors" for adoption at home. Broadband adoption programs have demonstrated that building community support centers, working through trusted agents in the community, and assisting them in building their own unique social networks have been highly effective.

Reduce Risk. While the results of the regression analysis were inconclusive regarding its impact on broadband adoption, privacy and security must be addressed for each of the new populations that come online. The elderly can be a particularly vulnerable community that may be victims of scams and other threats posing as legitimate enterprises. Education programs and security software should be integrated into all outreach and digital literacy programs.

Ensure Competitiveness. In some rural areas, one carrier may provide both fixed and mobile services. Given the high sunk cost of fixed infrastructure, there is often little incentive to build out the mobile infrastructure or lower costs. In these cases, regulators should monitor closely those providers that control all means of access in some areas, so that anti-competitive behavior is checked and consumer welfare is protected. Anti-trust review of wireless corporate mergers should be scrutinized for their impact on rural areas. Where possible, competition and market forces are preferred over regulation. Policy-makers can create incentives for new market entrants by allowing for diverse standards and architectures that foster innovation and increased competition will encourage competition.

Academic Implications

The research conducted contributes to technology adoption theory, specifically regarding mobile and fixed broadband adoption. While the form factors, technology, and versatility differ between the two access methods, they follow similar patterns of adoption. The intrinsic factors of observational and enabled learning (specifically exposure outside the home) are among the greatest influencing factors for adoption in the home. Challenges to control beliefs (specifically privacy and security) had only marginal impact, were inconsistent, and suffered from simultaneity, making causality a challenge. Privacy and security warrant further, more focused research.

Directions for Further Research

This research only touched the surface of mobile broadband adoption. While mobile broadband has made inroads in bridging the digital divide, its future is still more promising. Further research in this area will build on more complete and robust datasets and mobile broadband services and systems that are more capable than in the past.

Extrinsic factors such as mobile applications, device form/function, device costs, data plan pricing, capacity/speed of the network, service bundling and network coverage can be captured and analyzed. Performing such an analysis on a nationwide scale is problematic, so may be more appropriately performed on a regional, state or other confined geographic area. Competition, represented by the number of fixed and mobile providers serving target communities, would also factor into the analysis.

Intrinsic factors can be assessed through surveys, but they would necessarily be more specific than the current CPS CIU supplement. For example, when referring to privacy and security, the survey would need to inquire for fixed and mobile independently. The access method they were referring to in this research had to be deduced from other responses (in this case, to get pure responses, it required that fixed only and mobile only households could be used for some questions).

Understanding the extrinsic and intrinsic factors that drive consumer broadband adoption can help to tailor programs to ensure maximum effectiveness. Since technology will continue to evolve to challenge and potentially replace existing technologies, adoption programs should embrace continuous change management processes to assist communities that will likely fall behind. It will likely require government, industry and NGOs to work in a concerted fashion to create embedded programs that foster continuous communication and trust to ensure exposure and relevance to the affected communities.

APPENDIX A: INTERVIEW PROTOCOL

Open-ended Interview Guide

The interviews were largely unstructured, allowing the respondent to take the discussion to their areas of interest or concern. Questions were open-ended and invited discussion, depending on the individual. The intent was to be conversational, and allow their passions to dictate direction. I expressed that I did not want my research interests to confine the discussion too narrowly. The protocol followed the inductive case study approach and changed slightly as the interview progressed. Not all topics generated discussion, as it became apparent that some of the areas of inquiry were not within the domain of their mission.

Introduction

Beyond the initial introduction in my email, I shared with the respondent the scope of my doctoral dissertation, including my background and passion for understanding broadband adoption. I shared with them how I came to know the work they do in their organization. I expressed my appreciation and interest in knowing how they operated and thought about challenges they faced. I thanked them for the time they took from their schedule to address this important issue.

Some inquired about whether they would be on the record, and I told each that their responses would be generalized and combined with others. This was acceptable to each.

Script

Opening dialogue:

- Thank you for taking the time today to discuss broadband / internet adoption
- As I mentioned in my email, I am working on my dissertation for a PhD in Science & technology policy
- I am calling a few key players who have been involved in helping communities connect to the internet.
- My research is looking to understand potential substitution – mobile broadband – and other factors that could influence adoption.
- My goal today is to learn from your experience and get your perspective on what you've seen and what you think are factors influencing adoption.
- Having *access* to the internet is necessary but not sufficient.
- The federal government has spent billions to ensure connectivity – but recent numbers show that adoption is down for fixed internet

Specific inquiries:

- Tell me about your program.
- How well has it been accepted?
- What are the challenges you encountered?

- Were there particular demographic that presented a challenge? Why?
- How did you attract people to your program if they are not interested?
- Did your program address mobile broadband?
- Were there concerns regarding privacy and security when accessing the internet?
- What do you see as the path forward?
- Thank you for your time today. Do you have any questions for me?

Each session concluded with an open invitation to follow up one another.

APPENDIX B: DATA DICTIONARY

CALCULATED VARIABLES

<table>
<tr><th>Field</th><th>Name</th><th>Question:</th><th>Source</th></tr>
<tr><td>MATHID</td><td>Household Life Cycle Type</td><td>gen mathid = 1 if (pemaritl > 1) & (prtage < 35) & (prchld == 0)
replace mathid = 2 if (pemaritl > 1) & (prtage > 34 & prtage < 65) & prchld == 0
replace mathid = 3 if (pemaritl == 1) & (prtage < 35) & (prchld == 0)
replace mathid = 4 if (pemaritl > 1) & (prchld > 0)
replace mathid = 5 if (pemaritl == 1) & (prtage < 35) & (prchld == 1 | prchld == 2 | (prchld >= 5 & prchld <= 9) | prchld >= 11)
replace mathid = 6 if (pemaritl == 1) & (prtage > 34) & (prchld == 1 | prchld == 2 | (prchld >= 5 & prchld <= 9) | prchld >= 11)
replace mathid = 7 if (pemaritl == 1) & (prtage < 35) & (prchld == 3 | prchld == 4 | prchld == 10)
replace mathid = 8 if (pemaritl == 1) & (prtage > 34) & (prchld == 3 | prchld == 4 | prchld == 10)
replace mathid = 9 if (pemaritl == 1) & (prtage > 34 & prtage < 65) & (prchld == 0)
replace mathid = 10 if (pemaritl == 1) & (prtage > 64) & (prchld == 0)
replace mathid = 11 if (pemaritl > 1) & (prtage > 64) & (prchld == 0)
replace mathid = 12 if mathid == .
label define mathid 1 "Bachellor I" 2 "Bachellor II" 3 "Newlywed" 4 "Single Parent" 5 "Full Nest I" 6 "Delayed Full Nest" 7 "Full Nest II" 8 "Full Nest III" 9 "Childless Couple" 10 "Older Couple" 11 "Bachellor III" 12 "Other"
label values mathid mathid</td><td>Calculated</td></tr>
<tr><td>AGEBRACKET</td><td>Age in years by ranges</td><td>gen agebracket = 1 if prtage < 25
replace agebracket = 2 if prtage > 24 & prtage < 35
replace agebracket = 3 if prtage > 34 & prtage < 45
replace agebracket = 4 if prtage > 44 & prtage < 55
replace agebracket = 5 if prtage > 45 & prtage < 65
replace agebracket = 6 if prtage > 64 & prtage < 75
replace agebracket = 7 if prtage > 75 & prtage < 81
replace agebracket = 8 if prtage == 85</td><td>Calculated</td></tr>
</table>

<table>
<tr><th>Field</th><th>Name</th><th>Question:</th><th>Source</th></tr>
<tr><td>QUADINC</td><td>Income by groups (quadrants)</td><td>gen quadinc = 1 if hefaminc < 8
replace quadinc = 2 if hefaminc > 7 & hefaminc < 12
replace quadinc = 3 if hefaminc > 11 & hefaminc < 15
replace quadinc = 4 if hefaminc > 14
label define quadinc 1 "<$25K" 2 "$25K-50K" 3 "$50K-100K" 4 ">$100K"
label values quadinc quadinc</td><td>Calculated</td></tr>
<tr><td>EDLEVEL</td><td>Highest Education attained by groups</td><td>gen edlevel = 1 if peeduca < 39
replace edlevel = 2 if peeduca == 39
replace edlevel = 3 if peeduca > 39 & peeduca < 43
replace edlevel = 4 if peeduca > 42

label define edlevel 1 "No High School" 2 "High School" 3 "Some College" 4 "B.S. or Higher"
label var edlevel "Education Group"
label values edlevel edlevel</td><td>Calculated</td></tr>
<tr><td>FIXEDSERVICE</td><td>Households with fixed service</td><td>gen fixedservice = 1 if hehomsu2 == 1 | hehomsu4 == 1 | hehomsu5 == 1 | hehomfac == 1 | hehomte2 == 1 | hehomte3 == 1 | hehomte5 == 1 | hebundle == 1 | heoutck == 1
replace fixedservice = 0 if fixedservice == . & (henohm1 == 1 | henohm2 == 1 | henohm3 == 1 | henohm4 == 1 | henohm5 == 1 | henohm6 == 1 | henohm7 == 1 | henohm8 == 1 | henohm9 == 1 | henohm10 == 1 | henohm11 == 1 | heprinoh >= 1)</td><td>Calculated</td></tr>
<tr><td>SMARTPHONE</td><td>Households with mobile service</td><td>gen smartphone = 1 if hewearab == 1 | heoutmob == 1 | heoutck == 2
replace smartphone = 0 if smartphone ==. & (heoutck == 1 | hemphone == 0)</td><td>Calculated</td></tr>
<tr><td>MOBILEONLY</td><td>Households with mobile service only</td><td>gen mobileonly = 1 if fixedservice != 1 & smartphone == 1
replace mobileonly = 0 if mobileonly ==.</td><td>Calculated</td></tr>
<tr><td>FIXEDONLY</td><td>Households with fixed service only</td><td>gen fixedonly = 1 if fixedservice == 1 & smartphone != 1
replace fixedonly = 0 if fixedonly == .</td><td>Calculated</td></tr>
<tr><td>FIXEDAND MOBILE</td><td>Households with both fixed and mobile service</td><td>gen fixedandmobile = 1 if fixedservice == 1 & smartphone == 1
replace fixedandmobile = 0 if fixedandmobile ==.</td><td>Calculated</td></tr>
<tr><td>NOINTERNET</td><td>Households without any internet</td><td>gen nointernet = 1 if fixedservice == 0 & smartphone == 0
replace nointernet = 0 if nointernet == .</td><td>Calculated</td></tr>
<tr><td>BLACKHISP</td><td>Black or Hispanic Variable</td><td>Gen blackhisp = 1 if ptdtrace == 2 | pehspnon == 1</td><td>Calculated</td></tr>
</table>

Field	Name	Question:	Source
CURRSECSCORE	Current security concerns	gen currsecscore = hepscon1 + hepscon2 + hepscon3 + hepscon4 + hepscon5 + hepscon6 + hepscon8 replace currsecscore = 0 if hepscon7 == 1 | currsecscore == 0 label var currsecscore "No of current security concerns"	Calculated
PASTSECSCORE	Security concerns in past year	gen pastsecscore = hepspre1 + hepspre2 + hepspre3 + hepspre4 label var pastsecscore "No of security concerns in the past year"	Calculated
EXPSECSCORE	Experience with security breaches	gen expsecscore = hecyba + hecbully label var expsecscore "Security Experience"	Calculated
INFOSCORE	Internet Use Score: Information Services	gen infoscore = pewebbro + peontheg + pemedinf + pemedcom replace infoscore = 0 if infoscore ==.	Calculated
COMMSCORE	Internet Use Score: Commun-ications	gen commscore = peemail + petextim + pesocial + peconfer + pemedmon replace commscore = 0 if commscore == .	Calculated
ENTAINSCORE	Internet Use Score: Entertainment	gen entainscore = pevideo + peaudio replace entainscore = 0 if entainscore ==.	Calculated
TRANSCORE	Internet Use Score: Transactions	gen transcore = pefinanc + peecomme + pehomiot replace transcore = 0 if transcore ==.	Calculated
PRODSCORE	Internet Use Score: Productivity	gen prodscore = petelewk + pejobsch + peedtrai replace prodscore = 0 if prodscore == .	Calculated
INFOBIN	Internet Use Score: Information Services (Binary)	gen infobin = 1 if pewebbro == 1 | peontheg == 1 | pemedinf == 1 | pemedcom == 1 replace infobin = 0 if infobin ==.	Calculated
COMMBIN	Internet Use Score: Commun-ications (Binary)	gen commbin = 1 if peemail == 1 | petextim == 1 | pesocial == 1 | peconfer == 1 | pemedmon == 1 replace commbin = 0 if commbin == .	Calculated
ENTAINBIN	Internet Use Score: Entertainment (Binary)	gen entainbin = 1 if pevideo == 1 | peaudio == 1 replace entainbin = 0 if entainbin ==.	Calculated
TRANSBIN	Internet Use Score: Transactions (Binary)	gen transbin = 1 if pefinanc == 1 | peecomme == 1 | pehomiot == 1 replace transbin = 0 if transbin ==.	Calculated

<table>
<tr><th>Field</th><th>Name</th><th>Question:</th><th>Source</th></tr>
<tr><td>PRODBIN</td><td>Internet Use Score: Productivity (Binary)</td><td>gen prodbin = 1 if petelewk == 1 | pejobsch == 1 | peedtrai == 1
replace prodbin = 0 if prodbin == .</td><td>Calculated</td></tr>
<tr><td>BHMETRO</td><td>Fixed Effects Variable: Black/ Hispanic & Metro</td><td>gen bhmetro = (blackhisp * 10) + metro</td><td>Calculated</td></tr>
<tr><td>INCMETRO</td><td>Fixed Effects Variable: Income & Metro</td><td>gen incmetro = (quadinc * 10) + metro</td><td>Calculated</td></tr>
<tr><td>BHINC</td><td>Fixed Effects Variable: Income & Black/ Hispanic</td><td>gen bhinc = (quadinc * 10) + blackhisp</td><td>Calculated</td></tr>
<tr><td>BHINCMETRO</td><td>Fixed Effects Variable: Income & Black/ Hispanic & Metro</td><td>gen bhinc = (blackhisp *100) + (quadinc * 10) + metro</td><td>Calculated</td></tr>
</table>

KEY DEMOGRAPHICS

Field	Name	Question:	Source
PERRP	Household Reference Person	Relationship to Reference Person Response: 01 Reference person w/rels. 02 Reference person w/o rels. 03 Spouse 04 Child 05 Grandchild 06 Parent 07 Brother/sister 08 Other rel. Or ref. Person 09 Foster child 10 Nonrel. Of ref. Person w/rels. 11 Not used 12 Nonrel. Of ref. Person w/o rels. 13 Unmarried partner w/rels. 14 Unmarried partner w/out rels. 15 Housemate/roommate w/rels. 16 Housemate/roommate w/out rels. 17 Roomer/boarder w/rels. 18 Roomer/boarder w/out rels.	2015 CPS CIU Supplement
PRTAGE	Demographic Information	Person's Age Response: 00-79 Age in Years 80 80-84 Years Old 85 85+ Years Old	2015 CPS CIU Supplement
PEMARITL	Demographic Information	Marital Status Response: 1 Married - spouse present 2 Married - spouse absent 3 Widowed 4 Divorced 5 Separated 6 Never married	2015 CPS CIU Supplement
PESEX	Demographic Information	Sex Response: 0 Female; 1 Male	2015 CPS CIU Supplement
PRNMCHLD	Demographic Information	Number of own children <18 years of age Response: 0:99 Number of own children under 18 years of age	

Field	Name	Question:	Source
PRCHLD		Presence of own children <18 years of age by selected age group Response: 0 No own children under 18 years of age 1 All own children 0- 2 years of age 2 All own children 3- 5 years of age 3 All own children 6-13 years of age 4 All own children 14-17 years of age 5 Own children 0- 2 and 3- 5 years of age (none 6-17) 6 Own children 0- 2 and 6-13 years of age (none 3- 5 or 14-17) 7 Own children 0- 2 and 14-17 years of age (none 3-13) 8 Own children 3- 5 and 6-13 years of age (none 0- 2 or 14-17) 9 Own children 3- 5 and 14-17 years of age (none 0- 2 or 6-13) 10 Own children 6-13 and 14-17 years of age (none 0- 5) 11 Own children 0- 2, 3- 5, and 6-13 years of age (none 14-17) 12 Own children 0- 2, 3- 5, and 14-17 years of age (none 6-13) 13 Own children 0- 2, 6-13, and 14-17 years of age (none 3- 5) 14 Own children 3- 5, 6-13, and 14-17 years of age (none 0- 2) 15 Own children from all age groups	
GTMETSTA	Demographic Information	Metropolitan Status Response: 1 Metropolitan 2 Nonmetropolitan 3 Not Identified	2015 CPS CIU Supplement
GTCBSASZ	Demographic Information	Metropolitan Area (CBSA) Size Response: 0 Not Identified or Nonmetropolitan 2 100,000 - 249,999 3 250,000 - 499,999 4 500,000 - 999,999 5 1,000,000 - 2,499,999 6 2,500,000 - 4,999,999 7 5,000,000+	

Field	Name	Question:	Source
PTDTRACE	Demographic Information	Race Response: 01 White Only 02 Black Only 03 American Indian, Alaskan Native Only 04 Asian Only 05 Hawaiian/Pacific Islander Only 06 White-Black 07 White-AI 08 White-Asian 09 White-HP 10 Black-AI 11 Black-Asian 12 Black-HP 13 AI-Asian 14 AI-HP 15 Asian-HP 16 W-B-AI 17 W-B-A 18 W-B-HP 19 W-AI-A 20 W-AI-HP 21 W-A-HP 22 B-AI-A 23 W-B-AI-A 24 W-AI-A-HP 25 Other 3 Race Combinations 26 Other 4 and 5 Race Combinations	2015 CPS CIU Supplement
PEHSPNON	Demographic Information	Response: 0 Non-Hispanic 1 Hispanic	

Field	Name	Question:	Source
PEEDUCA	Demographic Information	Highest level of school completed or degree received Response: 31 Less than 1st Grade 32 1st, 2nd, 3rd or 4th Grade 33 5th or 6th Grade 34 7th or 8th Grade 35 9th Grade 36 10th Grade 37 11th Grade 38 12th Grade No Diploma 39 High School Grad-Diploma Or Equiv (GED) 40 Some College but No Degree 41 Associate Degree-Occupational/Vocational 42 Associate Degree-Academic Program 43 Bachelor's Degree (Ex: BA, AB, BS) 44 Master's Degree (Ex: MA, MS, MENG, Med, MSW) 45 Professional School Deg (Ex: MD, DDS, DVM) 46 Doctorate Degree (Ex: PhD, EdD)	2015 CPS CIU Supplement
HEFAMINC	Demographic Information	Family income - Combined income of all family members during the last 12 months. Includes money from jobs, net income from business, farm or rent, pensions, dividends, interest, social security payments and any other money income received by family members who are 15 years of age or older.) Response: 1 Less than $5,000 2 5,000 to 7,499 3 7,500 to 9,999 4 10,000 to 12,499 5 12,500 to 14,999 6 15,000 to 19,999 7 20,000 to 24,999 8 25,000 to 29,999 9 30,000 to 34,999 10 35,000 to 39,999 11 40,000 to 49,999 12 50,000 to 59,999 13 60,000 to 74,999 14 75,000 to 99,999 15 100,000 to 149,999 16 150,000 or more	2015 CPS CIU Supplement

TECHNOLOGY IN THE HOME

Field	Name	Question:	Source
HEMPHONE	Technology in the Home	(Do you/Does anyone in this household) use a cellular phone or smartphone? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEWEARAB	Technology in the Home	(Do you/Does anyone in this household) use a wearable Internet-connected device such as a smart watch or glasses? Examples include an Apple Watch, Microsoft Band, or Google Glass Response: No 0; Yes 1	2015 CPS CIU Supplement
HEOUTMOB	Technology in the Home	This question is about how (you/members of this household) use the Internet outside the home. While away from home, (do you/does anyone in this household) access the Internet using a mobile Internet service or a data plan for a cellular phone, smartphone, tablet, laptop, or other device? This type of Internet service is provided by a wireless carrier, and may be part of a package that also includes voice calls from a cellular phone or smartphone. Response: No 0; Yes 1	2015 CPS CIU Supplement
HEINHOME	Technology in the Home	(Do you/Does anyone in this household, including you, use the Internet at home? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEOUTCK	Technology in the Home	Earlier you mentioned that you only use the Internet at home, but you've also indicated that you use mobile Internet service or a data plan to go online outside the home. Which is correct? 1 (You/members of this household) only use the Internet at home 2 (You/members of this household) use a mobile Internet service or a data plan to go online outside the home, in addition to using the Internet at home	2015 CPS CIU Supplement
Field	**Name**	**Question:**	**Source**
I am going to read a list of ways that people access the Internet from their homes. Keep in mind that some people connect from home in more than one way. At home, (do you/ does anyone in this household) access the Internet using:			
HEHOMTE1	Technology in the Home	Mobile Internet service or a data plan for a cellular phone, smartphone, tablet, laptop, or other device? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEHOMTE2	Technology in the Home	High-speed Internet service installed at home, such as cable, DSL, or fiber-optic service? Response: No 0; Yes 1	2015 CPS CIU Supplement

Field	Name	Question:	Source
HEHOMTE3	Technology in the Home	Satellite Internet service? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEHOMTE4	Technology in the Home	Dial-up service? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEHOMTE5	Technology in the Home	Some other service? Response: No 0; Yes 1	2015 CPS CIU Supplement
Field	**Name**	**Question:**	**Source**
HEBUNDLE	Technology in the Home	(Do you/Does your household) have Internet as part of a "bundle" through your Internet service provider? Response: No 0; Yes 1	2015 CPS CIU Supplement

FUNCTIONS PERFORMED ONLINE

Field	Name	Question:	Source
PEEMAIL	Functions Performed Online	(Do you/Does NAME) use email? Response: No 0; Yes 1	2015 CPS CIU Supplement
PETEXTIM	Functions Performed Online	What about texting or instant messaging? (Do you/Does NAME) use a texting or instant messaging service? Response: No 0; Yes 1	2015 CPS CIU Supplement
PESOCIAL	Functions Performed Online	What about social networking? (Do you/Does NAME) use social networks such as Facebook or Twitter? Response: No 0; Yes 1	2015 CPS CIU Supplement
PECONFER	Functions Performed Online	What about participating in video or voice calls, or video conferencing over the Internet? (Do you/Does NAME) participate in video or voice calls, or video conferencing? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEWEBBRO	Functions Performed Online	What about browsing the Web? (Do you/Does NAME) browse the Web? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEVIDEO	Functions Performed Online	What about watching videos? (Do you/Does NAME) watch videos over the Internet? Examples include YouTube and Netflix. Response: No 0; Yes 1	2015 CPS CIU Supplement
PEAUDIO	Functions Performed Online	What about streaming or downloading music, radio programs, or podcasts online? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEONTHEG	Functions Performed Online	What about on-the-go services such as maps, GPS, or reviews of nearby businesses? (Do you/Does NAME) use on-the-go services? Examples include Google Maps, Yelp, and Fandango. Response: No 0; Yes 1	2015 CPS CIU Supplement
PETELEWK	Functions Performed Online	What about telecommuting, or working while away from (you/his/her) usual workplace? (Do you/Does NAME) use the Internet to telecommute or work while away from (your/ his/her) usual workplace? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEJOBSCH	Functions Performed Online	What about searching for a job? (Do you/ Does NAME) use the Internet to search for a job? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEEDTRAI	Functions Performed Online	What about online classes or job training? (Do you/Does NAME) use the Internet for educational classes or job training? Response: No 0; Yes 1	2015 CPS CIU Supplement

Field	Name	Question:	Source
PEFINANC	Functions Performed Online	What about financial services such as banking, investing, or paying bills online? (Do you/Does NAME) use the Internet for financial services such as banking, investing, or paying bills online? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEECOMME	Functions Performed Online	What about online shopping, travel reservations, or other consumer services? (Do you/Does NAME) use online shopping, travel reservations, or other consumer services? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEHOMIOT	Functions Performed Online	What about interacting with household equipment such as a connected thermostat, light bulb, or security system? (Do you/ Does NAME) use the Internet to interact with household equipment? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEMEDINF	Functions Performed Online	(Do you/Does NAME) research health information online, such as WebMD or similar services? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEMEDCOM	Functions Performed Online	What about communicating with a doctor or accessing health records or health insurance records online? (Do you/Does NAME) communicate with a doctor or access health records or health insurance records online? Response: No 0; Yes 1	2015 CPS CIU Supplement
PEMEDMON	Functions Performed Online	(Do you/Does NAME) use a health monitoring service that connects to the Internet? Response: No 0; Yes 1	2015 CPS CIU Supplement

USING INTERNET OUTSIDE THE HOME

Field	Name	Question:	Source
HEINWORK	Internet Use Outside the Home	What about at work? (Do you/Does anyone in this household) use the Internet at work? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEINSCHL	Internet Use Outside the Home	What about at school? (Do you/Does anyone in this household) use the Internet at school? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEINCAFE	Internet Use Outside the Home	What about at a coffee shop or other business that offers Internet access? (Do you/Does anyone in this household use the Internet while at a coffee shop or other business that offers Internet access? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEINTRAV	Internet Use Outside the Home	What about while traveling between places? (Do you/Does anyone in this household) use the Internet while traveling between places? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEINLICO	Internet Use Outside the Home	What about at a library, community center, park, or other public place? (Do you/Does anyone in this household use the Internet at a library, community center, park, or other public place? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEINELHO	Internet Use Outside the Home	What about at someone else's home? (Do you/Does anyone in this household) use the Internet at someone else's home? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEINOTHR	Internet Use Outside the Home	(Do you/Does anyone in this household) use the Internet at some other location we haven't covered yet? Response: No 0; Yes 1	2015 CPS CIU Supplement

REASONS FOR NOT USING THE [FIXED BROADBAND] AT HOME

Field	Name	Question:	Source
What are the reasons why (you/members of your household) do not use the Internet at home?			
HENOHM1	Reasons for No [Fixed Broadband] at Home 1	Don't need It Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM2	Reasons for No [Fixed Broadband] at Home 2	Not Interested Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM3	Reasons for No [Fixed Broadband] at Home 3	Can't afford it Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM4	Reasons for No [Fixed Broadband] at Home 4	Not worth the cost Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM5	Reasons for No [Fixed Broadband] at Home 5	Can use it elsewhere Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM6	Reasons for No [Fixed Broadband] at Home 6	Not available in area Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM7	Reasons for No [Fixed Broadband] at Home 7	No computer, or computer is adequate or broken Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM8	Reasons for No [Fixed Broadband] at Home 8	Online privacy or cybersecurity concerns Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM9	Reasons for No [Fixed Broadband] at Home	Personal Safety Concerns Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM10	Reasons for No [Fixed Broadband] at Home 10	Household moved or is in the process of Moving Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM11	Reasons for No [Fixed Broadband] at Home 11	Other Response: No 0; Yes 1	2015 CPS CIU Supplement

Field	Name	Question	Source
HEPRINOH	Reasons for No [Fixed Broadband] at Home	Of the reasons you just listed for not going online at home, which (do you/does your household) consider to be the most important? 1 Don't need it 2 Not interested 3 Can't afford it 4 Not worth the cost 5 Can use it elsewhere 6 Not available in area 7 No computer, or computer inadequate or broken 8 Online privacy or cybersecurity concerns 9 Personal safety concerns 10 Household moved or is in the process of moving 11 Other	2015 CPS CIU Supplement

Reasons for Not Using the Internet Outside the Home

Field	Name	Question:	Source
HEEVROUT	Reasons for Not Using the Internet Outside the Home	(You previously mentioned that (you/ members of your household) use the Internet at home, but not at other locations/blank) (Have you/Has anyone in this household) ever used the Internet from a location other than home? Response: No 0; Yes 1	
Field	**Name**	**Question:**	**Source**
What are the reasons why (you/members of your household) do not use the Internet outside the home?			
HENOOU1	Reasons for Not Using the Internet Outside the Home 1	Don't need It Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOOU2	Reasons for Not Using the Internet Outside the Home 2	Not Interested Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOOU3	Reasons for Not Using the Internet Outside the Home	Can't afford it Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOOU4	Reasons for Not Using the Internet Outside the Home 4	Not worth the cost Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOOU5	Reasons for Not Using the Internet Outside the Home 5	Can use it elsewhere Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM6	Reasons for Not Using the Internet Outside the Home 6	No computer, or computer is adequate or broken Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOHM7	Reasons for Not Using the Internet Outside the Home 7	No mobile device, or mobile device inadequate or broken Response: No 0; Yes 1	2015 CPS CIU Supplement

Field	Name	Question:	Source
HENOOU8	Reasons for Not Using the Internet Outside the Home 8	Online privacy or cybersecurity concerns Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOOU9	Reasons for Not Using the Internet Outside the Home 9	Personal Safety Concerns Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOOU10	Reasons for Not Using the Internet Outside the Home 10	Household moved and is no longer near previous Internet use location Response: No 0; Yes 1	2015 CPS CIU Supplement
HENOOU11	Reasons for Not Using the Internet Outside the Home 11	Other Response: No 0; Yes 1	2015 CPS CIU Supplement

Field	Name	Question:	Source
HEPRINOO	Reasons for Not Using the Internet Outside the Home	Of the reasons you just listed for not going online outside the home, which (do you/does your household) consider to be the most important? Response: 1 Don't need it 2 Not interested 3 Can't afford it 4 Not worth the cost 5 Nowhere to go that has it 6 No computer, or computer inadequate or broken 7 No mobile device, or mobile device inadequate or broken 8 Online privacy or cybersecurity concerns 9 Persona safety concerns 10 Household moved and is no longer near previous Internet use location 11 Other	2015 CPS CIU Supplement

PRIVACY AND SECURITY SURVEY QUESTIONS

Field	Name	Question:	Source
During the past year, have concerns about privacy or security stopped (you/anyone in this household) from doing any of these activities online:			
HEPSPRE1	Past Year: Privacy and Security Concerns 1	Conducting financial transactions such as banking, investing, or paying bills online? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEPSPRE2	Past Year: Privacy and Security Concerns 2	Buying goods or services online? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEPSPRE3	Past Year: Privacy and Security Concerns 3	Posting photos, status updates, or other information on social networks? Response: No 0; Yes 1	2015 CPS CIU Supplement
HEPSPRE4	Past Year: Privacy and Security Concerns 4	Expressing an opinion on a controversial or political issue on a blog or social network, or in a forum, email or any other venue? Response: No 0; Yes 1	2015 CPS CIU Supplement

Field	Name	Question:	Source
Overall, what concerns (you/members of your household) the most when it comes to online privacy and security risks?			
HEPSCON1	Overall: Privacy and Security Concerns 1	Identity theft Response: No 0; Yes 1	2015 CPS CIU Supplement
HEPSCON2	Overall: Privacy and Security Concerns 2	Credit card or banking fraud Response: No 0; Yes 1	2015 CPS CIU Supplement
HEPSCON3	Overall: Privacy and Security Concerns 3	Data collection or tracking by online services Response: No 0; Yes 1	2015 CPS CIU Supplement
HEPSCON4	Overall: Privacy and Security Concerns 4	Data collection or tracking by government Response: No 0; Yes 1	2015 CPS CIU Supplement
HEPSCON5	Overall: Privacy and Security Concerns 5	Loss of control over personal data such as email or social network profiles Response: No 0; Yes 1	2015 CPS CIU Supplement
HEPSCON6	Overall: Privacy and Security Concerns 6	Threats to personal safety, such as online harassment, stalking, or cyberbullying Response: No 0; Yes 1	2015 CPS CIU Supplement
HEPSCON7	Overall: Privacy and	No concerns	2015 CPS CIU Supplement

Field	Name	Question:	Source
	Security Concerns 7	Response: No 0; Yes 1	
HEPSCON8	Overall: Privacy and Security Concerns 7	Other concerns Response: No 0; Yes 1	2015 CPS CIU Supplement

Field	Name	Question	Source
HECYBA	Past Year: Privacy and Security Concerns	During the past year, (have you/has any member of your household) been affected by an online security breach, identity theft, or a similar crime? Response: No 0; Yes 1	2015 CPS CIU Supplement
HECBULLY	Past Year: Privacy and Security Concerns	During the past year (have you/has any member of your household) experienced online harassment, stalking, or cyber-bullying? Response: No 0; Yes 1	2015 CPS CIU Supplement

APPENDIX C: REGRESSION ANALYSIS MODELS (STATA)

Table 8: Key Demographic Variables for Broadband Adoption (Metropolitan)

```
xtset bhinc
xtreg mobileonly i.agebracket if metro == 1, fe
xtreg smartphone i.agebracket if metro == 1, fe
xtreg fixedonly i.agebracket if metro == 1, fe
xtreg fixedservice i.agebracket if metro == 1, fe
xtreg nointernet i.agebracket if metro == 1, fe

xtset hefaminc
xtreg mobileonly i.ptdtrace i.mathid if metro == 1, fe
xtreg smartphone i.ptdtrace i.mathid if metro == 1, fe
xtreg fixedonly i.ptdtrace i.mathid if metro == 1, fe
xtreg fixedservice i.ptdtrace i.mathid if metro == 1, fe
xtreg nointernet i.ptdtrace i.mathid if metro == 1, fe

xtreg mobileonly pehspnon i.mathid if metro == 1, fe
xtreg smartphone pehspnon i.mathid if metro == 1, fe
xtreg fixedonly pehspnon i.mathid if metro == 1, fe
xtreg fixedservice pehspnon i.mathid if metro == 1, fe
xtreg nointernet pehspnon i.mathid if metro == 1, fe

xtset blackhisp
xtreg mobileonly i.peeduca i.mathid if metro == 1, fe
xtreg smartphone i.peeduca i.mathid if metro == 1, fe
xtreg fixedonly i.peeduca i.mathid if metro == 1, fe
xtreg fixedservice i.peeduca i.mathid if metro == 1, fe
xtreg nointernet i.peeduca i.mathid if metro == 1, fe

xtreg mobileonly i.hefaminc i.mathid if metro == 1, fe
xtreg smartphone i.hefaminc i.mathid if metro == 1, fe
xtreg fixedonly i.hefaminc i.mathid if metro == 1, fe
xtreg fixedservice i.hefaminc i.mathid if metro == 1, fe
xtreg nointernet i.hefaminc i.mathid if metro == 1, fe
```

Table 9: Broadband Adoption by Key Demographics: Detail (Non-Metropolitan)

```
xtset bhinc
xtreg mobileonly i.agebracket if metro == 0, fe
xtreg smartphone i.agebracket if metro == 0, fe
xtreg fixedonly i.agebracket if metro == 0, fe
xtreg fixedservice i.agebracket if metro == 0, fe
xtreg nointernet i.agebracket if metro == 0, fe

xtset hefaminc
xtreg mobileonly i.ptdtrace i.mathid if metro == 0, fe
xtreg smartphone i.ptdtrace i.mathid if metro == 0, fe
xtreg fixedonly i.ptdtrace i.mathid if metro == 0, fe
xtreg fixedservice i.ptdtrace i.mathid if metro == 0, fe
xtreg nointernet i.ptdtrace i.mathid if metro == 0, fe

xtreg mobileonly pehspnon i.mathid if metro == 0, fe
xtreg smartphone pehspnon i.mathid if metro == 0, fe
xtreg fixedonly pehspnon i.mathid if metro == 0, fe
xtreg fixedservice pehspnon i.mathid if metro == 0, fe
xtreg nointernet pehspnon i.mathid if metro == 0, fe

xtset blackhisp
xtreg mobileonly i.peeduca i.mathid if metro == 0, fe
xtreg smartphone i.peeduca i.mathid if metro == 0, fe
xtreg fixedonly i.peeduca i.mathid if metro == 0, fe
xtreg fixedservice i.peeduca i.mathid if metro == 0, fe
xtreg nointernet i.peeduca i.mathid if metro == 0, fe

xtreg mobileonly i.hefaminc i.mathid if metro == 0, fe
xtreg smartphone i.hefaminc i.mathid if metro == 0, fe
xtreg fixedonly i.hefaminc i.mathid if metro == 0, fe
xtreg fixedservice i.hefaminc i.mathid if metro == 0, fe
xtreg nointernet i.hefaminc i.mathid if metro == 0, fe
```

Table 10: Likelihood of Adoption in Rural Areas

```
xtset bhinc
xtreg smartphone metro fixedservice i.mathid, fe
xtreg fixedservice metro smartphone i.mathid, fe
```

Table 11: Impact of Metropolitan Area Size on Fixed and Mobile Adoption

```
xtset bhinc
xtreg mobileonly i.gtcbsasz i.mathid, fe
xtreg smartphone i.gtcbsasz i.mathid, fe
xtreg fixedonly i.gtcbsasz i.mathid, fe
xtreg fixedservice i.gtcbsasz i.mathid, fe
xtreg nointernet i.gtcbsasz i.mathid, fe
```

Table 12: Impact of Income on Mobile and Fixed Broadband Adoption

```
xtset blackhisp
xtreg smartphone i.hefaminc i.mathid if fixedservice == 0 & metro == 0, fe
xtreg smartphone i.hefaminc i.mathid if fixedservice == 1 & metro == 0, fe
xtreg smartphone i.hefaminc i.mathid if fixedservice == 0 & metro == 1, fe
xtreg smartphone i.hefaminc i.mathid if fixedservice == 1 & metro == 1, fe

xtreg fixedservice i.hefaminc i.mathid if smartphone == 0 & metro == 0, fe
xtreg fixedservice i.hefaminc i.mathid if smartphone == 1 & metro == 0, fe
xtreg fixedservice i.hefaminc i.mathid if smartphone == 0 & metro == 1, fe
xtreg fixedservice i.hefaminc i.mathid if smartphone == 1 & metro == 1, fe
```

Table 13: Impact of Household Type on Fixed and Mobile Internet Adoption

```
xtset bhincmetro
xtreg mobileonly bach1 bach2 newlywed singleparent fullnest1 delayfullnest
    fullnest2 fullnest3 childlesscouple oldercouple bach3, fe
xtreg fixedonly bach1 bach2 newlywed singleparent fullnest1 delayfullnest
    fullnest2 fullnest3 childlesscouple oldercouple bach3, fe
xtreg fixedandmobile bach1 bach2 newlywed singleparent fullnest1 delayfullnest
    fullnest2 fullnest3 childlesscouple oldercouple bach3, fe
xtreg nointernet bach1 bach2 newlywed singleparent fullnest1 delayfullnest
    fullnest2 fullnest3 childlesscouple oldercouple bach3, fe

xtreg mobileonly hhyoung hhwochild hhwchild hhold, fe
xtreg fixedonly hhyoung hhwochild hhwchild hhold, fe
xtreg fixedandmobile hhyoung hhwochild hhwchild hhold, fe
xtreg nointernet hhyoung hhwochild hhwchild hhold, fe
```

Table 14: Functional Use of Mobile and Fixed Broadband

```
xtset bhincmetro
xtreg mobileonly infobin commbin pesocial entainbin transbin prodbin i.mathid,
    fe
xtreg smartphone infobin commbin pesocial entainbin transbin prodbin i.mathid,
    fe
xtreg fixedonly infobin commbin pesocial entainbin transbin prodbin i.mathid, fe
xtreg fixedservice infobin commbin pesocial entainbin transbin prodbin i.mathid,
    fe
xtreg nointernet infobin commbin pesocial entainbin transbin prodbin i.mathid, fe
```

Table 15: Impact of Children on Fixed and Mobile Internet Adoption

```
xtset bhinc
xtreg smartphone hhchild if fixedservice == 0 & metro == 0, fe
xtreg smartphone hhchild if fixedservice == 1 & metro == 0, fe
xtreg smartphone hhchild if fixedservice == 0 & metro == 1, fe
xtreg smartphone hhchild if fixedservice == 1 & metro == 1, fe

xtreg fixedservice hhchild if smartphone == 0 & metro == 0, fe
xtreg fixedservice hhchild if smartphone == 1 & metro == 0, fe
xtreg fixedservice hhchild if smartphone == 0 & metro == 1, fe
xtreg fixedservice hhchild if smartphone == 1 & metro == 1, fe
```

Table 16: Reasons for no Fixed Broadband At Home

```
xtset bhincmetro
xtreg nointernet henohm1 henohm2 henohm3 henohm4 henohm5 henohm6
    henohm7 henohm8 henohm9 henohm10 henohm11 i.mathid, fe
xtreg mobileonly henohm1 henohm2 henohm3 henohm4 henohm5 henohm6
    henohm7 henohm8 henohm9 henohm10 henohm11 i.mathid, fe
```

Table 17: A Comparison of Reasons for No Fixed Broadband for Never-Adopters and Un-Adopters

```
xtset bhincmetro
xtreg nointernet henohm1 henohm2 henohm3 henohm4 henohm5 henohm6
      henohm7 henohm8 henohm9 henohm10 henohm11 i.mathid if heevrhom
      == 0, fe
xtreg mobileonly henohm1 henohm2 henohm3 henohm4 henohm5 henohm6
      henohm7 henohm8 henohm9 henohm10 henohm11 i.mathid if heevrhom
      == 0, fe
xtreg nointernet henohm1 henohm2 henohm3 henohm4 henohm5 henohm6
      henohm7 henohm8 henohm9 henohm10 henohm11 i.mathid if heevrhom
      == 1, fe
xtreg mobileonly henohm1 henohm2 henohm3 henohm4 henohm5 henohm6
      henohm7 henohm8 henohm9 henohm10 henohm11 i.mathid if heevrhom
      == 1, fe
```

Table 18: Households that Access Internet Outside the Home

```
xtset bhincmetro
xtreg smaprtphone heinwork heinschl heincafe heintrav heinlico heinelho heinothr
      i.mathid, fe
xtreg fixedservice heinwork heinschl heincafe heintrav heinlico heinelho heinothr
      i.mathid, fe
xtreg nointernet heinwork heinschl heincafe heintrav heinlico heinelho heinothr
      i.mathid, fe
```

Table 19: Internet Access at Work by Industry

```
xtset bhincmetro
xtreg heinwork ib12.prmjind1 i.mathid, fe
```

Table 20: Importance of Reasons for Not Accessing Internet Outside the Home

```
xtset bhincmetro
xtreg mobileonly henoou1 henoou2 henoou3 henoou4 henoou5 henoou6 henoou7
      henoou8 henoou9 henoou10 henoou11 i.mathid, fe
xtreg smartphone henoou1 henoou2 henoou3 henoou4 henoou5 henoou6 henoou7
      henoou8 henoou9 henoou10 henoou11 i.mathid, fe
xtreg fixedonly henoou1 henoou2 henoou3 henoou4 henoou5 henoou6 henoou7
      henoou8 henoou9 henoou10 henoou11 i.mathid, fe
xtreg fixedservice henoou1 henoou2 henoou3 henoou4 henoou5 henoou6
      henoou7 henoou8 henoou9 henoou10 henoou11 i.mathid, fe
```

```
xtreg nointernet henoou1 henoou2 henoou3 henoou4 henoou5 henoou6 henoou7
      henoou8 henoou9 henoou10 henoou11 i.mathid, fe
```

Table 21: Security/Privacy Concerns and Experiences by Connection Type

```
xtset  bhincmetro
xtreg mobileonly hepspre1 hepspre2 hepspre3 hepspre4 hepscon1 hepscon2
      hepscon3 hepscon4 hepscon5 hepscon6 hepscon8 hecyba hecbully i.mathid,
      fe
xtreg fixedonly hepspre1 hepspre2 hepspre3 hepspre4 hepscon1 hepscon2
      hepscon3 hepscon4 hepscon5 hepscon6 hepscon8 hecyba hecbully i.mathid,
      fe
xtreg fixedandmobile hepspre1 hepspre2 hepspre3 hepspre4 hepscon1 hepscon2
      hepscon3 hepscon4 hepscon5 hepscon6 hepscon8 hecyba hecbully i.mathid,
      fe
xtreg nointernet hepspre1 hepspre2 hepspre3 hepspre4 hepscon1 hepscon2
      hepscon3 hepscon4 hepscon5 hepscon6 hepscon8 hecyba hecbully i.mathid,
      fe
```

Table 22: No of Security Incidents/Concerns by Connection Type

```
xtset  bhincmetro
xtreg mobileonly pastsecscore expsecscore currsecscore i.mathid, fe
xtreg fixedonly pastsecscore expsecscore currsecscore i.mathid, fe
xtreg fixedandmobile pastsecscore expsecscore currsecscore i.mathid, fe
xtreg nointernet pastsecscore expsecscore currsecscore i.mathid, fe
```

APPENDIX D: GENDER ANALYSIS

Gender was a key demographic cited in some literature affecting broadband adoption. [190,191] More recent research (Nour, 2014) found that the gender gap had diminished significantly in recent years. [192] An analysis was performed to understand the makeup of the CPS sample in terms of primary respondent and any notable differences in adoption patterns. The adoption overall were largely consistent (within the survey variance). The only notable difference was among female and male elderly households – elderly female households were behind their male counterparts by 7.1 percent.

[190] Ongena at al. p. 286
[191] Lee et al. (2015) p. 46
[192] Nour. p. 68.

Household Type (Prim. Resp: Female)	Fixed Only	Mobile Only	Fixed and Mobile	No Internet	Total
Young Household	5.9%	4.3%	76.8%	13.1%	100.0%
Household w/o Children	12.7%	4.1%	61.1%	22.1%	100.0%
Household w/ Children	7.8%	4.4%	72.5%	15.3%	100.0%
Elderly Household	21.3%	2.2%	33.2%	43.2%	100.0%
Percent	12.7%	3.7%	59.0%	24.5%	100.0%

Household Type (Prim. Resp: Male)	Fixed Only	Mobile Only	Fixed and Mobile	No Internet	Total
Young Household	5.6%	4.8%	75.7%	13.9%	100.0%
Household w/o Children	12.4%	3.9%	61.3%	22.4%	100.0%
Household w/ Children	8.5%	3.0%	75.5%	13.0%	100.0%
Elderly Household	21.1%	1.6%	41.3%	36.1%	100.0%
Percent	12.3%	3.3%	62.7%	21.7%	100.0%

Connection Types by Gender

A similar analysis was performed on functional use for male and female respondents representing each household. For households with fixed service, the notable differences were between Text/IM and web browsing for male households (larger negative coefficients) and female households (small positive coefficients). Females were more likely to use text/IM on mobile devices. Male households with fixed service also more likely to use "on-the-go" services than their female households counterpart.

For the male no internet households, communications services such as email and text/IM made them more likely to adopt internet services, while female no internet households it contributed to their likelihood not to adopt, although the coefficients were very small.

Primary Respondent: Male	Fixed Only		Mobile Only		No Internet	
Internet Functions Performed	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**
Email	0.0314125	**	0.0000271		-0.0370858	***
Text/IM	-0.1295615	***	0.0327685	***	-0.0456474	***
Social networking	-0.0147659	*	-0.0058727		0.0017089	
Video or voice conference calls	-0.0039229		-0.0027709		-0.0006653	
Web browsing	-0.0637773	***	0.0136068		0.0563532	***
Watching videos	0.0138037		0.0129023	**	0.0086383	**
Streaming/Downloading Music	0.0172494	**	0.0112830	**	0.0035335	
On-the-Go Services (e.g., maps, yelp,	0.1009014	***	-0.0122405	**	0.0136433	***
Telecommuting	0.0399618	***	-0.0017667		-0.0000069	
Job Search	-0.0066122		-0.0065210		-0.0088642	**
Online classes or job training	0.0093431		0.0071695		-0.0081439	**
Online banking	0.0200922	**	0.0172792	***	0.0143721	***
Online shopping	0.0014900		0.0384427	***	0.0111396	**
Interact with household devices	0.0118843		0.0057624		0.0053367	
Research health information	0.0033689		0.0017892		0.0021363	
Communicate w/doctor; Access Healt	0.0132030		0.0053129		0.0007751	
Health monitoring service	0.0079281		-0.0137238		0.0013443	
R2:	0.0826		0.0315		0.0623	

Functional Use by Male Primary Respondents

Primary Respondent: Female	Fixed Only		Mobile Only		No Internet	
Internet Functions Performed	**Coefficient**	**Sig**	**Coefficient**	**Sig**	**Coefficient**	**Sig**
Email	0.0169942	***	0.0119018	***	0.0093630	***
Text/IM	0.0134377	***	0.0094110	***	0.0074035	***
Social networking	0.0092356		0.0064681		0.0050884	**
Video or voice conference calls	0.0082097		0.0057496		0.0045231	
Web browsing	0.0145888	**	0.0102172		0.0080377	***
Watching videos	0.0091731		0.0064243		0.0050539	
Streaming/Downloading Music	0.0084833	**	0.0059412		0.0046739	
On-the-Go Services (e.g., maps, yelp,	0.0097230	***	0.0068094		0.0053569	***
Telecommuting	0.0085621	***	0.0059964		0.0047173	
Job Search	0.0081263		0.0056912		0.0044772	
Online classes or job training	0.0086799		0.0060789		0.0047822	
Online banking	0.0099364	*	0.0069589	***	0.0054745	
Online shopping	0.0104390		0.0073109	***	0.0057514	***
Interact with household devices	0.0140388		0.0098319		0.0077347	
Research health information	0.0081266		0.0056914	**	0.0044774	
Communicate w/doctor; Access Healt	0.0085482		0.0059866		0.0047096	
Health monitoring service	0.0137376		0.0096210		0.0075687	
R2:	0.0937		0.0301		0.0969	

Functional Use by Female Primary Respondents

Appendix E: Impact of Supply Side Characteristics

FCC datasets were utilized to match county household penetration (per 1000 housholds) for fixed internet and the number of providers in each county (fixed and mobile).[193] While some have significance, most the coefficients in the regression are very small. The analysis shows a positive effect on fixed internet connections (although the significant is $p < 0.10$ and the coefficient small). It has a negative effect on Mobile Only households (they have more choices). The number of fixed providers has a positive impact on those with no internet, although significance is $p < 0.05$ and the coefficient very small. Finally, the number of mobile providers has a negative effect on fixed only, a positive effect on fixed and mobile, and reduces households with no internet. It is notable that availability and the number of providers has little effect on adoption, giving support to greater focus to the consumer side of broadband adoption.

These factors were dropped from the analysis due to small coefficients, relatively few coefficients with significance, and its impact on the available CPS dataset. Only 20,000 of the 52,000+ CPS observations has assigned FIPS codes, and so by matching with the

[193] "Form 477 County Data on Internet Access Services." 2014. *Federal Communications Commission*. February 24.

FCC database, a large number of observations would be dropped, potentially creating unwanted bias in the analysis.

Description	Fixed Only	Sig	Mobile Only	Sig	Fixed & Mobile	Sig	No Internet	Sig
Residential Fixed High-Speed Connections per 1000 Households	0.0080963	*	-0.0186417	***	0.0679186	***	-0.0164788	***
Providers of Residential Fixed High-Speed Connections	-0.0009263		0.0006496		0.0003329		0.0014398	**
Providers of Mobile High-Speed Connections	-0.0099661	***	0.0001708		0.0173436	***	-0.0066186	**

FCC Supply-side Characteristics by Connection Type (2015)

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BIOGRAPHY

Ron Hodge is a business leader with over 30 years of professional experience in the consulting industry. As a Senior Vice President/Partner at Booz Allen Hamilton, he was a champion of "intrapreneurship," successfully leading start-up businesses and driving rapid growth and diversification of new lines of business, service offerings and key market segments within the $1B Technology Practice. He also served on the firm's governing finance and operations group, overseeing the performance and policies for the firm, representing 25,000+ employees and over $5B in annual revenue.

Among the businesses he started was the firm's Wireless Practice, which initially focused on mobile systems for first responders at the Federal, state and local governments. He led an interdisciplinary team comprised of wireless engineers, spectrum specialists, security experts, public safety practitioners (police, fire and EMTs), and financial analysts. His business portfolio grew to include support for smart infrastructures (i.e., intelligent transportation systems), tactical radio, radio frequency identification (RFID), and medical supply tracking, and conducted commercial assignments in number portability. His Network Design and Analysis Center (NDAC) team also performed resiliency and survivability modeling on the U.S. telecommunication system, identifying vulnerabilities for providers to remedy.

He serves on the board for businesses and educational institutions, and is the Chairman for Virginia Tech's Management Advisory Board. He is a featured speaker at various forums on topics such as Innovation, Information Sharing, Critical Thinking, and Management Consulting.

He is currently on sabbatical from industry and pursuing a Ph.D. in Public Policy from George Mason University, focusing on advanced communications. He earned his MBA (Information Systems Management) from George Washington University and a B.S. in Management and Marketing from Virginia Tech.