DIVERSIFICATION OF CABLE TV OPERATORS INTO BROADBAND—AN INVESTIGATION OF THE U.S. CABLE SYSTEMS

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ABSTRACT

In this paper, we examine the factors that influence the decision of cable TV operators in the U.S. to offer broadband services. Despite efforts at both the federal and the state level to facilitate broadband provision, broadband availability in the U.S. is far from complete, particularly in the rural areas. While there are other broadband technologies in the U.S., such as DSL, fiber, satellite and mobile broadband, cable broadband dominates the broadband market. Using cable firm data, from Warren Publishing's Television and Cable Factbook, for the year 2003–2016, we investigate the role of demographic factors, firm characteristics and entry costs using dynamic choice model techniques. We find that entry costs are significant. We also find that firms that have a higher channel capacity and own multiple local cable TV companies are more likely to diversify into broadband services. The cable TV operators are more likely to deploy broadband in urban, populated, and high-income areas.

Keywords: Cable Industry, Diversification, Broadband
JEL Codes: L22, L25, L38, L96

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"Access to high-speed broadband is no longer a luxury; it is a necessity for American families, businesses, and consumers. Affordable, reliable access to high-speed broadband is critical to U.S. economic growth and competitiveness. High-speed broadband enables Americans to use the Internet in new ways, expands access to health services and education, increases the productivity of businesses, and drives innovation throughout the digital ecosystem." — (Barack Obama, 2015)

1. Introduction

With more than two decades since the digital revolution, though the broadband has assumed a central role in the United States economy and the political system, the broadband coverage in the United States is still far from complete, particularly in the rural areas. In 2016, about 34 million individuals reside in neighborhoods where broadband service is not available, with more than half of those residents living in rural areas. The differences between rural and urban areas is stark in that 39 percent of rural areas but only 4 percent of urban areas do not have fixed broadband access (FCC, 2016).

Given the broadband coverage gap in the U.S., the Obama administration considered comprehensive broadband coverage as one of the top priorities. Through the American Recovery and Reinvestment Act (ARRA) of 2009, the U.S. Congress approved funding of $7.2 billion for broadband planning and deployment initiatives. The Congress specifically assigned $4.7 billion to the Broadband Technology Opportunities Program run by the Department of Commerce's National Telecommunications and Information Administration (NTIA), whereas the remaining $2.5 billion was assigned to the broadband deployment program administered by the Agriculture Department's Rural Utilities Service.

In the U.S., broadband is provided through wireline technology such as cable, DSL and fiber, and wireless technology, such as satellite and cellular data connections. However, the cable broadband provided by cable TV operators dominates the broadband market with a market share of 64 percent in 2017 (Leichtman Research Group, 2017). In addition, Cable TV firms often provide subscribers with better service in terms of upload and download speeds at a lower price (Mahoney & Rafert, 2016). In this paper, we develop and estimate various dynamic choice models of cable firms' decisions to offer broadband services. The models include linear probability models with differences in the treatment of unobserved effects, and probit models with different treatments of unobserved effects as well as the correlation between the unobserved effects and the state dependence variables. Our primary source of data are from Warren Publishing's Television and Cable Factbook for the years 2003–2016, which are combined with county income and population statistics from the Bureau of Economic Analysis, and land area and rural population percentage from the 2010 Census.

These data are the most comprehensive data available on Cable TV operators in the United States. In a dynamic framework, we consider the influence of sunk costs, demographic factors, and firm characteristics. Year dummies are also included to account for any unobserved heterogeneity over time. We test for the presence of entry (sunk) costs by examining the impact of broadband provision in the previous year on providing broadband in the current year, and find that it is statistically and economically important in a wide range of specifications.

There are a few studies that examine the decision of cable firms to offer broadband services. Liu (2007) investigates the determinants of cable firms' diversification into three non-traditional services, i.e., high-speed internet access, pay-per-view television and telephony using cross-sectional data for the year 2004. Seo (2007) assesses the factors that influence cable operators' decision to offer internet, audio and video services using a sample of 500 cable operators in the United States in 2004. Tang (2011) examines cable firms' two-stage entry decision into broadband service, namely, upgrading and subsequent new product introduction, in eight states of the United States, for the years 2001–2006.

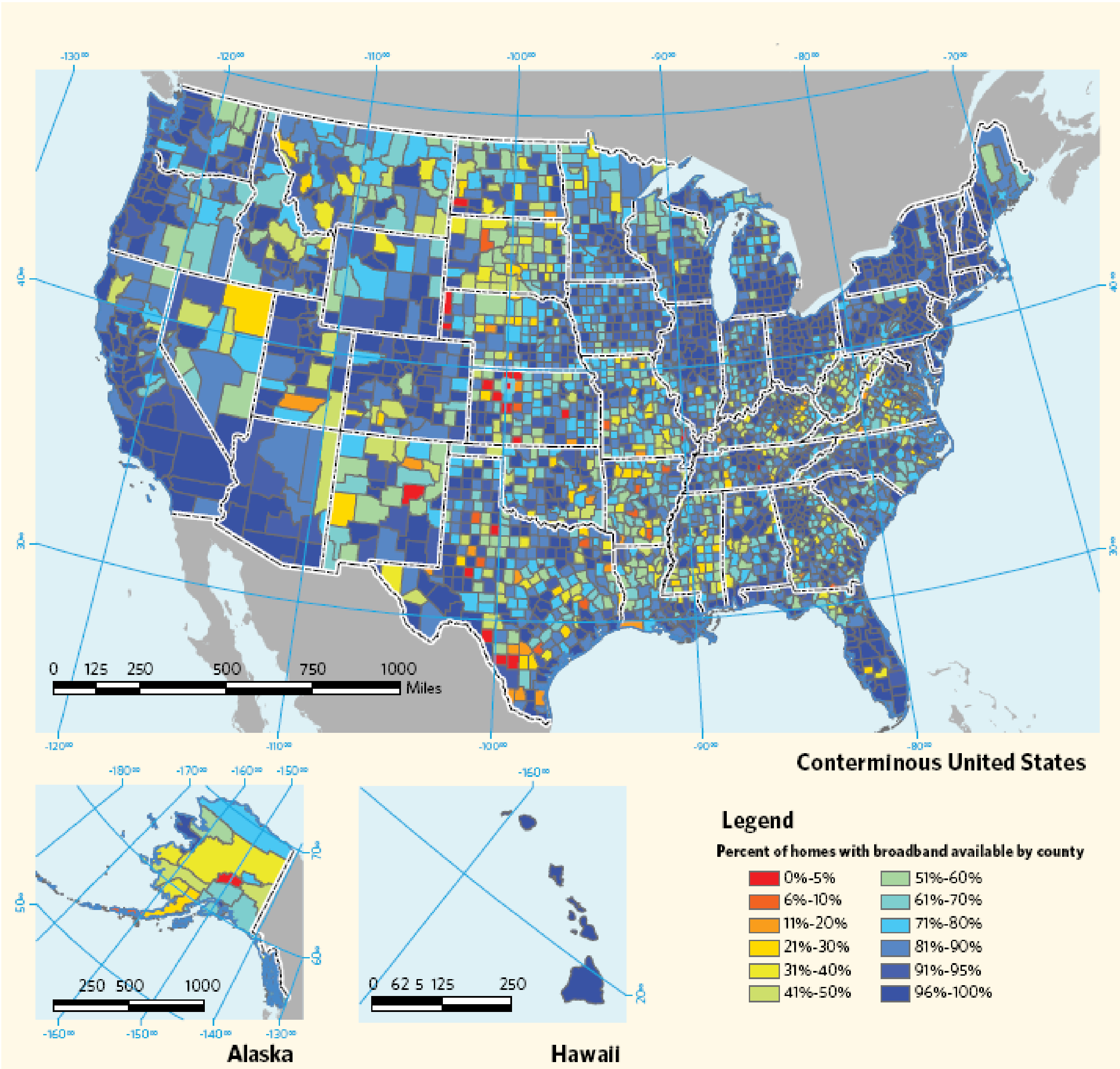
Since, increasing broadband availability is central to national policy through the National Broadband Plan (FCC, 2010), it is important to understand the factors that influence broadband deployment by cable operators, the dominant provider in the broadband market. The usable data is available for all states in the U.S. and runs from 2003 to 2016, which is more recent and substantially longer than prior studies. We find that entry costs are significant for U.S. cable firms. Broadband provision today increases the probability of providing broadband tomorrow by 76%. We also find that firm heterogeneity is substantial. Firm characteristics also influence the decision of cable TV firms to offer broadband. Specifically, firms that have a higher channel capacity are more likely to diversify into broadband services.

The remainder of the paper is organized as follows. Section 2 presents the background and Section 3 details the broadband market. Section 4 reviews existing literature. The data source and variables used in the model are discussed in Section 5. Section 6 presents the model and estimation results, followed by section 7, which concludes.

2. Background

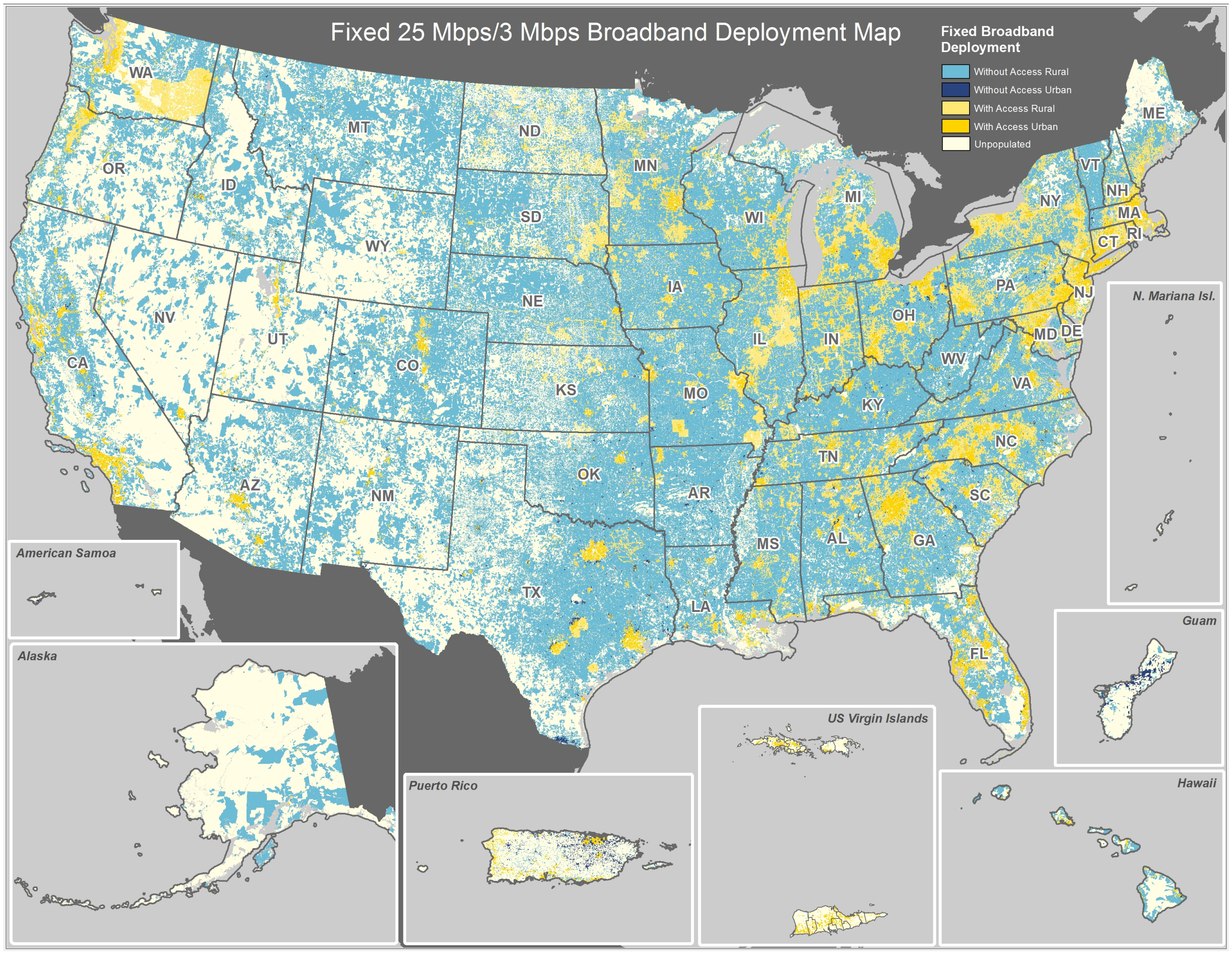
Universal availability and adoption of broadband are central to national policy via the U.S. National Broadband Plan. The plan was mandated by the American Recovery and Reinvestment Act of 2009. Congress required the federal government, under the leadership of Federal Communication Commission (FCC), to develop mechanisms for ensuring universal broadband access in the U.S. The plan, created by FCC in 2010, defines broadband as connection speed of 4 Mbps downstream and 1 Mbps upstream. Figure 1 presents the availability of 4 Mbps capable broadband networks in 2010 by county. In 2015, FCC changed the definition of broadband to connection speeds of at least 25 Mbps downstream and 3 Mbps upstream. The change in broadband definition was based on the premise that the definition adopted in 2010 is not adequate to evaluate broadband deployment that is capable of allowing users to originate and receive high quality voice, video, data and graphics, as mandated by the Telecommunications Act of 1996. Figure 2 presents the map of 25 Mbps/3 Mbps broadband deployment in the U.S in 2015. According to the FCC broadband progress report (FCC, 2015), 17 percent of individuals in the U.S. lack access to 25 Mbps/3 Mbps broadband service,

Figure 1: Availability of 4 Mbps Capable Broadband Networks by County



Source: FCC - National Broadband Plan (2010)

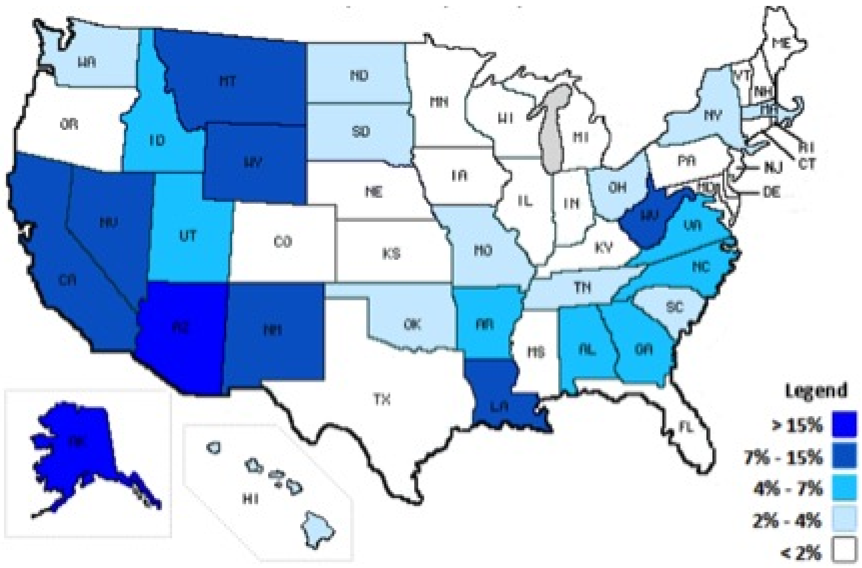
Figure 2: Broadband Deployment Map



Source: FCC - 2015 Broadband Progress Report (2015)

whereas 53 percent individuals residing in rural areas do not have access to 25 Mbps/3 Mbps broadband. In fact, 20 percent of individuals in rural areas lack access to even 4 Mbps/1 Mbps broadband service. Figure 3 illustrates the difference between the percent population that has broadband access in urban areas and those that have access in rural areas in 2014. This difference in broadband availability is based on technology, provider availability, and speed.

Figure 3: Difference in Broadband Availability between Urban and Rural areas



Source: National Broadband Map - 2015

The Department of Agriculture strives to facilitate rural broadband infrastructure through its Broadband Loan and Community Connect programs (Tomer et al., 2017). This program provides funds to assist broadband deployment in rural areas where it is not economically feasible for private providers to offer broadband services. Other than federal government, state and local governments also have policies for comprehensive availability broadband. However, flexibilities in federal law, give states and local municipalities leeway in how they deal with broadband deployment. In some states like Kentucky, public networks construction is underway, whereas in other states like Tennessee, laws reinforced by federal judicial decision prohibit local governments from constructing public networks. Similarly, there is a fragmented landscape that governs how local municipalities deal with cable franchise agreements, right-of-way access and pole attachment policies (Tomer et al., 2017).

There have also been efforts by all the U.S. states to increase broadband availability. They participated in NTIA's state broadband mapping initiatives to find out where broadband is, and more importantly, is not available, in order to facilitate broadband deployment in state economies. The initial funding for this initiative came from the ARRA. The U.S. states continue to make efforts to increase broadband deployment by providing state funding and initiating legislation to identify broadband availability and propose ways to increase coverage. Many states provide grants and funds to give incentive for building infrastructure in order to bring broadband to unserved households. Some states like California provide a model for state broadband initiatives. In 2007, California was one of the first states to create a broadband funding program, the California Advances Services Fund (CASF), with a fund of $315 million in 2016. The majority of the fund is allocated for infrastructure deployment to make broadband available to unserved areas, while the remaining is for expanding broadband access and adoption (California Public Utilities Commission, 2017)[1]. In 2017, the state broadband legislation has increased funding for broadband deployment and has proposed tax incentives for firms that will provide broadband in unserved and underserved areas (Lichtenberg, 2017).

Universal availability of broadband is important because broadband access has economic and social benefits, and the consequences of broadband inequities are sizeable. Individuals with no broadband access or subscription will struggle in being prepared for job opportunities since broadband is now a critical resource for American workers that are looking for jobs and those that are actively employed. In 2015, 79 percent of people who searched for jobs in prior two years used broadband to access information and resources in seeking employment (Smith, 2015). Moreover, broadband enables people to work from home as an alternative to onsite work. In 2016, 22 percent of employed persons did some or all of their work at home on the days they worked, with the percentage increasing to 43 percent for workers with some advanced degree (Bureau of Labor Statistics, 2017).

Beyond the workplace, broadband provides access to many activities. Today, about 69 percent of Americans use social media to connect with others, read news, share information

[1]California's Public Utilities Commission's definition of broadband is different from the FCC definition. It considers an area as served if broadband is available at a speed of at least 6Mbps down and 1.5 Mbps up. This is the case for many other states.

and entertain themselves (Pew Research Center, 2017). Similarly, broadband availability has had a significant impact on individual's commercial behavior. About 79 percent of Americans shop online, with 15 percent of them doing on a weekly basis (Smith & Anderson, 2016). Broadband availability is also an important location factor for knowledge intensive firms, which generate high-paying jobs (Mack & Rey, 2014).

Broadband availability also has a significant impact on education. Schools in areas with either limited broadband service or low broadband adoption face challenge in implementing a digital curriculum, i.e., the use of digital media by teachers and students for educational learning. This is particularly relevant for one-to-one device programs in schools that allow each student to use an electronic device to access the internet, digital course materials, and digital textbooks. The students can use these devices throughout the school day, and often take them home. Though the laptop's broadband capacity might be used in school, many students cannot use the laptop to its full potential when they are home.

In healthcare, broadband has become an important tool in telemedicine, which is an evolving model of care delivery. Telemedicine is the interactive delivery of health service over distance using telecommunication technology. At least 25 U.S. states are using telemedicine networks to provide health services access to medically underserved areas (Alliance for Public Technology and Communications Workers of America, 2008). Telemedicine not only increases patient access to better-equipped and better-staffed health centers, it also reduces cost for patients by reducing patient transports (Oregon Broadband Advisory Council, 2016).

3. Broadband Market

Broadband is available from many different Internet Service Providers and for many different technologies, such as laptops, tablets and mobile phones. Broadband service providers in the U.S. are cable operators, telephone companies, wireless network providers (mobile phone companies) and satellite. Broadband infrastructure comprises of the backbone, the middle mile and the last mile. The backbone consists of high capacity fiber-optic lines that can transmit large amounts of data over long distances. The middle mile connects a telecommunication operator's core network to the local network plant, which provides access to the local loop. The middle mile links the backbone and the last mile. The last mile delivers data from the backbone to homes and businesses.

The cable TV operators deliver broadband services using coaxial cable lines or fiber optic cable or both, whereas the telephone companies provide broadband through digital subscriber line (DSL) systems over traditional phone lines. In addition to the wireline broadband services, satellite and wireless broadband services have gained popularity in the United States. Satellite has the advantage of providing nationwide broadband coverage, which is particularly useful for rural areas, where wireline broadband is either too expensive to install or cannot work due to the long distances between local network plant and end-user. However, satellite broadband is more expensive than DSL or cable broadband, and also requires large investment in equipment by the end-user. Moreover, the speed of satellite broadband depends on end-user's line of sight to the orbiting satellite and the weather. Usually, a customer can expect to get 500 Kbps/80 Kbps broadband services, which is much slower than the speed delivered by DSL and cable broadband[2]. DSL download speeds range from 768 Kps and 25 Mbps whereas cable broadband is capable of download speeds that range between 1 Mbps and 1 Gbps (Mahoney & Rafert, 2016).

The wireless broadband can be fixed or mobile. Wireless technologies use equipment to provide broadband services in remote and sparsely populated areas, where DSL or cable broadband is costly to provide. Wireless broadband services over fixed networks enable consumers to access Internet from a fixed point. The broadband speed is generally comparable to DSL or cable broadband. Wireless local area networks, such as Wi-Fi, provide wireless broadband to extend the reach of last wireline or fixed wireless broadband within a home or building (Kolko, 2007). On the other hand, mobile broadband services, provided by mobile telephone companies, enable smartphone and laptops to access cellular networks. However,

[2] `https://www.fcc.gov/general/types-broadband-connections`

mobile broadband are expensive and usually offer low speeds, in the range of several hundred Kbps, due to low data capacity (Brodkin, 2015). The fastest mobile broadband has download speed between 10 and 20 Mbps (Mahoney & Rafert, 2016). Moreover, many cellular data plans have monthly data limits, due to which mobile broadband cannot be used unlimitedly like wireline broadband.

Wireline broadband, specifically cable broadband, is continuing to increase in the U.S., and not being replaced by mobile broadband (Mercer, 2016). Cable TV operators are currently the primary providers of broadband services in the U.S. In fact, the cable service providers have dominated the U.S. broadband market since the late 1990s. According to a Strategy Analytics Service Provider Strategies service report, cable broadband had 3.3 million new subscribers over the 12-month period from April 2015, with the cable broadband market share being at 62 percent of the total fixed broadband market. The market share of fiber broadband connection was at 23 percent, whereas DSL's market share decreased to 15 percent over the same period (Burger, 2016).

For cable operators, the coaxial cable network, originally constructed for cable TV, is designed to transmit one-way signals. However, it can be used to deliver advanced services such as high speed Internet. In order to provide broadband services, substantial investments are required to make the existing cable TV network capable of two-way traffic required for high speed Internet. The cable operators have to make their infrastructure broadband capable by upgrading analog cable systems to digital systems with 2-way capability. Once the upgrade is complete, the investment cost is sunk. Channel capacity of cable systems is bandwidth used for video services, and is considered a measure of the quality of the cable system. A higher channel capacity suggests a better quality infrastructure for delivering video services, and a higher likelihood of offering broadband services.

The high sunk costs of upgrading cable infrastructure for broadband provision, makes densely populated areas more profitable for broadband deployment than areas where there are fewer households and at a further distance from one another, resulting in gaps in broadband availability.

4. Literature Review

There is a policy debate, at both the federal and the state level, over how to facilitate universal availability of broadband services in the United States. In conjunction with the efforts at the federal and state level to increase broadband coverage, attention has turned increasingly to investigate how broadband access varies in the United States. There is a growing body of literature that has examined broadband deployment from various aspects. These existing studies offer important insights into broadband provision in the United States.

4.1 Demographic Characteristics

Many empirical studies have used broadband data from the Federal Communications Commission (FCC) to investigate the demographic determinants of broadband deployment, including income, race and population density. Due to the large fixed investments requirements to build broadband infrastructure, costs per potential user depend substantially on the population density in the local market. The cost per customer is higher if there is a greater distance among customers, especially for wireline broadband (Telecommunications et al., 2000). Gabel & Florence (2000) examine the influence of cost, demographic and economic variables on the decision of broadband providers to offer residential broadband service, using wire center level data in the U.S. The results provide evidence that the higher the line density and the lower the cost of transporting data traffic to the Internet backbone, the more likely broadband services will be available. They also find that areas where median income is high and adults are between the age 30 and 34 years, there is higher probability of broadband deployment.

Using broadband data from the FCC, Prieger (2003) investigate the causes of incomplete broadband availability. The results reveal that larger markets, greater competition, long commuting distance and education increase broadband deployment. He finds little evidence of unequal availability based on income and black or Hispanic population. Flamm (2005) studies the demographic, economic, geophysical and policy determinants of broadband penetration in the U.S., using broadband deployment data from the FCC. This research is notable for including geographic terrain, which can help to explain the disparity in broadband availability. He finds that geographic terrain, income and population density are most important determinants of broadband penetration. The state fixed effects are also significant, which suggests that state policies matter for broadband deployment.

Clements & Abramowitz (2006) analyze the factors associated with the deployment and adoption of broadband in the U.S., using data from the FCC and a consumer survey in 2005. The results indicate that broadband deployment is higher in geographic areas with large populations, high income and educated residents, whereas, broadband adoption is influenced by demand factors, such as income, age, educational attainment and the presence of children. Another study that considers the influence of demographic and socioeconomic factors on spatially unbalanced landscape of broadband provision in the U.S. is by Grubesic (2008). The results show that large metropolitan areas are the broadband core regions, exhibiting high levels of broadband availability. Using a case study of Ohio, he also finds that median income, household density, average household size and percent black population have a significant impact on the availability of broadband. Li et al. (2011) finds that households in the poorest counties in South Carolina have fewer wireline and wireless providers compared to counties with highest median household income, using broadband data from National Telecommunications and Information Administration (NTIA). They do not find race to be a significant explanatory factor for disparities in broadband availability.

4.2 Rural or Urban

Several studies have explored the differences in broadband deployment in relation to geographical location of an area, particularly, whether an area is urban or rural. The geographical features of an area influence the cost of broadband infrastructure, and hence, the decision to offer broadband service in the area. Whitacre & Mahasuweerachai (2008) examine the location choices of small broadband providers, with less than 250 subscribers, using data from the FCC and the U.S. Census Bureau. The results uncover that small providers tend to locate in urban areas with high levels of income and education, large working age population and a large number of households. Moreover, a small broadband provider is less likely to provide in a rural location compared to an urban area, even after controlling for differences in household and economic characteristics.

Unlike other studies, Wood (2008) examines the propensity of different telecommunications firms, including large and small cable and telephone providers, to offer broadband. Using data collected from interviews with telecommunication firms in Pennsylvania, he finds that rural areas served by small Incumbent local exchange carrier (ILEC) and large cable companies are more likely to have DSL and cable broadband compared to rural areas served by large ILECs and small cable companies. This is because small cable companies, especially those serving low population density areas were least likely to have upgraded their infrastructure, whereas, large ILECs tend to operate under regulation, which rewards efficient investments.

Using data on rural ILECs, Glass & Stefanova (2010) model the decision of rural telephone companies to offer broadband service. The results indicate that areas with longer average loop length and high percent of people without a telephone decrease the likelihood that a rural telephone company will offer DSL in that area. They consider telephone penetration as proxy for the ability of population in the rural areas to pay for DSL. Li et al. (2011) find that that broadband availability differs across urban and rural areas in South Carolina, with similar median household income. For example, many rural areas had no broadband provider whereas urban areas of similar median income had one to three providers. Prieger (2013) uses the FCC data along with U.S. Census Bureau survey to investigate the gap in broadband provision and usage between urban and rural areas in the U.S. in 2010. The empirical analysis shows that broadband availability, number of high-speed fixed broadband and mobile broadband providers are lower in rural areas. Also, the gap in usage rates of fixed broadband between urban and rural areas is sizeable.

4.3 Local Broadband Competition

Local broadband competition also affects the decision of firms to enter the broadband market. There are many empirical studies that estimate the impact of inter-modal and intra-modal competition on broadband diffusion. Few studies have found inter-modal competition to be an important factor in increasing broadband diffusion. Aron & Burnstein (2003) investigate the impact of availability, competition, and demographics on the deployment of broadband in the U.S. states. The results suggest that intermodal broadband competition (cable versus DSL) is an effective catalyst for increased broadband penetration in a state.

Using broadband data from the FCC for the years 1999–2001, Grubesic & Murray (2004) find significant spatial variation in broadband access as a function of provider competition. The results show that major metropolitan areas experienced broadband access relatively early, followed by broadband deployment in smaller metropolitan areas and rural areas. However, some rural areas, specifically in Appalachia and the Upper Great Plains, experienced a loss of broadband providers over time. Denni & Gruber (2006) find that both intra-platform and inter-platform competition are conducive for broadband diffusion in the U.S. Though intra-platform competition has a positive effect on diffusion initially, it fades over time, whereas, in longer-term, inter-platform competition has a stronger influence on the rate of broadband diffusion.

Lee (2006) examine the impact of platform competition, access-based entry and other factors on broadband deployment in the United States. The results suggest that platform (intermodal) competition has been the main driver of broadband deployment in the U.S. They find no evidence of the effect of access-based entry, population density, unbundled network prices and Internet on broadband deployment. Using FCC data on residential broadband subscribership, Wallsten & Mallahan (2010) study the effect of competition on broadband speeds, penetration, and prices. They find that cable, DSL and fiber speeds are all significantly higher when there are multiple providers compared to when there is only one provider.

4.4 Regulatory Factors

There is some empirical work on the impact of regulatory factors on broadband deployment. Wallsten (2005) studies the impact of policies, particularly subsidies, rights-of-way regulations, direct government support for broadband rollout, and unbundling regulations, on broadband penetration, using panel data for the U.S. states over the time period 1999–2004. The analysis suggests that most state-level policies are ineffective and programs targeted at underserved areas do not boost broadband penetration. Whitacre & Mahasuweerachai (2008) examine the effect of federal assistance programs such as United States Department of Agriculture (USDA) broadband grants and loans on the location choice of small providers with less than 250 subscribers. The find no effect of federal policies of grants and loans on the provision of small providers. Using FCC data for the period 1999–2008 and loan data from the Rural Utility Service, Dinterman & Renkow (2017) evaluate the effectiveness of USDA's Broadband Loan Program, which has directed more than $1.8 billion in subsidized loans since 2002, in order to improve broadband access in under-served rural areas. The results indicate that the loans seem to reach the intended target of under-served rural areas with relatively low initial population densities and low levels of broadband service. They also find that the zip codes receiving broadband loans did in fact experience a slight increase in the number of providers.

4.5 Diversification of Cable Operators

As cable firms began offering services other than pay television, they started bundling these services. Liu (2007) examines the determinants of cable firm's diversification into three non-traditional services, namely, high-speed Internet access, pay-per-view television and telephony, using data from the 2005 Television and Cable Factbook, American Community Survey and U.S. Census Bureau. The results suggest that Multiple System Operator (MSO) firms have higher degree of diversification. Moreover, cable operators in areas with large number of basic cable subscribers few number of high-speed Internet providers are more likely to diversify.

Since the broadband capable infrastructure enables firms to offer services including Internet, audio and video, Seo (2007) examines the factors that influence the decision of cable firms to adopt a triple-play strategy. The data includes a sample of 500 cable operators[3] in the U.S. from the 2005 Television and Cable Factbook. He finds that the size of the installed cable subscriber base has the most significant impact on the adoption of triple-play strategies. Using the same sample, in another paper, Seo (2008) investigates the economic determinants that affect cable operator's decision to deploy cable telephony. The results suggest that cable operators are more likely to deploy cable telephony in larger markets, where economies of scale and scope of entry generate long run profits from voice services. Moreover, the age of a cable firm is a significant barrier to entry as a greater age increases the cost of system upgrade for entry into telephony services.

Tang (2011) examines cable firms' two-stage entry decision into broadband service, namely, upgrading and subsequently new product introduction, in eight states of the United States, using data from Television and Cable Factbook for the period 2001–2006. The results indicate that the upgrading decisions are influenced more by the cost determinants whereas the second stage product decisions are affected by demand determinants. Also, anticipated competition from ADSL (asymmetric digital subscriber line) significantly increases the probability of upgrading and offering new digital products.

Chang (2012) studies the DSL entry decision of the telephone company, Qwest Communications International, in the U.S. residential high-speed Internet market in 2002, 2004 and 2006 in 14 states in the western U.S. He finds that the probability of entry into DSL increases where an incumbent offers mixed bundling of cable TV, telephone and high-speed Internet, whereas, the probability of entry decreases with median income or average years of schooling in the markets. A recent paper presents an interesting explanation for the bundling of services by the cable firms. Prince & Greenstein (2013) examine whether bundled ser-

[3]Though there are 8345 cable systems in 2004, only 288 cable systems had a triple-play strategy. The study randomly selects 250 cable systems from the 8057 cable system without a triple-play strategy, and 250 cable systems from the 288 systems that have triple play strategy, to create a sample with equal numbers from both groups of cable systems.

vices reduced churn for cable services in the U.S. between 2007 and 2009, using a consumer marketing dataset from Forrester Research, where churn is defined as the abandonment of a service or service provider by an existing user or household. They find that households that have already purchased a triple-play bundle of pay TV, wired telephone and high-speed Internet, are less likely to switch service providers.

In this paper, we focus on the decision of cable TV operators to provide broadband services. In a dynamic choice model framework, we test the effect of demographic factors, and firm characteristics on the decision to offer broadband. Previous literature suggests that demographic characteristics, such as income and population density, and geographical location, rural or urban, substantially influence the decision of broadband providers to offer broadband service. We also control for unobserved heterogeneity over time by including year dummies. The firm characteristics we include are channel capacity and owning multiple cable systems. We also test for the presence of entry (sunk) costs by examining the impact of broadband provision yesterday on providing broadband today.

5. Data

The empirical analysis uses an unbalanced panel of cable firm data for the years 2003–2016. The data on cable firms comes from Warren Publishing's Television and Cable Factbook, which is the main data source for cable industry in many empirical studies (Goolsbee & Petrin, 2004; Liu, 2007; Seamans, 2012; Seo, 2007, 2008). There are 81599 observations in the data with 9870 independent cable firms. The Television and Cable Factbook details many characteristics of each existing cable firm in operation, including whether they offered broadband services or not. Various cable system characteristics are used in this study because of their potential to influence the decision to offer broadband services. Specifically, the cable characteristics that are included are channel capacity and multiple system ownership (MSO). All cable variables are measured at the system level i for the year t.

In the Television and Cable Factbook, each cable operator is listed under a city, county, and zip code. The county information is used to collect market demographic information for the cable systems. Several demographic variables are included to control for variation across markets that might influence the decision of cable firms to offer broadband services. All demographic variables are measured at the county level. The demographic variables that are included are population, per capita income, land area, and population density. Since, prior literature suggests that broadband provision is usually lower in rural areas than in urban areas, percentage of population living in rural areas in also included in the empirical model. The information on population, land area, population density and personal income come from the Bureau of Economic Analysis. The per capita income is deflated using price deflator from FRED. The information on land area and percentage of population living in rural areas is obtained from the U.S. 2010 Census.

The data on cable firms, from Warren Publishing's Television and Cable Factbook, had many duplicate observations in each year. Those duplicates were dropped, so that each cable firm had only one observation per year. The channel capacity variable had many missing values. For cable firms that did not have missing channel capacity values in all years, the missing values were replaced by either value in preceding year, or following year or by average value. Once duplicates were dropped, and missing values of channel capacity variable were filled, there were 62886 firm year observations, with 7766 cable firms and data from 2003–2016. Moreover, accounts that only offered broadband for one year in between, or did not offer broadband for one year, or were switching back and forth between offering and not offering broadband in different years were dropped from the data. This may have occurred as these are survey data replete with missing data. Then remaining observations were 59057, with 7318 cable firms.

The dependent variable is broadband operating, which is a dummy variable that equals one when a cable firm offers broadband services in addition to cable TV. The independent variables include demographic variables, such as population, per capita income, land area, population density and rural composition, and firm characteristics of channel capacity and whether a cable firm is a multiple system owner (MSO). The prior literature suggests that demographic variables and location (rural/urban) have a strong impact on broadband provision. There is also empirical work that indicates that firm characteristics influence the decision of cable operators to deploy broadband services. Table 1 represents the mean of demographic and firm variables for a cable firm that offers only cable TV compared to a cable operator that offers both cable TV and broadband services.

Table 1: Descriptive Statistics

	TV only	TV & Broadband	Overall
N	44583	32103	76686
Channel capacity	43.87	62.38	51.71***
MSO	0.89	0.92	0.91***
Population (in millions)	0.09	0.25	0.16***
Per capita income	318.85	351.79	332.54***
Rural	60.74	49.33	56.00***
Land area (in 1000 sq miles)	1.13	1.13	1.13
Population Density	0.12	0.39	0.23***

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

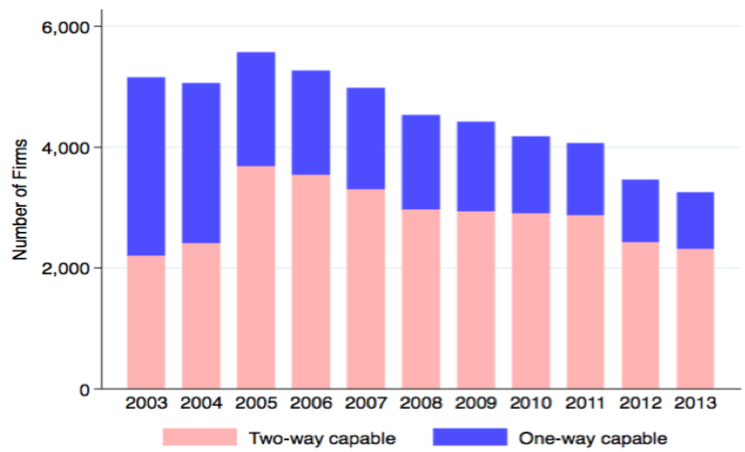
The average population has changed from 0.17 million in 2003 to 0.16 million in 2016. Due to the high fixed costs of upgrading, cable providers are more profitable in areas where costs can be amortized from a larger number of homes (Kolko, 2007). The population is a measure of market size. Cable firms are more likely to offer broadband services in more populated areas. The average real per capita income has increased from 305.73 in 2003 to 369.12 in 2016. Higher per capita income in an area should increase the probability of broadband provision. Land area indicates the geographic spread of the market. A cable firm will have a lower probability of providing broadband services in larger areas.

The average percentage of population living in rural areas as of 2010 Census is about 56 percent. The per customer cost of high-speed cable data deployment is high in rural areas as there are fewer households and at a further distance from one another (Telecommunications et al., 2000). Moreover, the maintenance and repair costs are higher for cable broadband providers in rural areas, especially those providing broadband services in very remote regions (National Telephone Cooperative Association, 2000). The cable broadband providers in rural areas also require more resources per customer, which include duplicate facilities and backup equipment, to warrant a reliable network (Stenberg, 2009). Consequently, the profits generated from broadband provision in rural areas would be lower compared to urban areas; hence, cable firms are less likely to provide broadband in rural areas. Moreover, previous literature suggests that most federal and state level grants and loans targeted at underserved areas have not increased broadband provision (Wallsten, 2005; Whitacre & Mahasuweerachai, 2008).

The average population density increased from 0.23 million per 1000 square miles in 2003 to 0.28 million per 1000 square miles in 2016. Population density is used to control for differences in the cost of serving a market (Goolsbee, 2006). Due to the large sunk investment required to upgrade cable networks to provide broadband services, costs per potential user depend substantially on the population density in the local market. Since, the scale economies in broadband provision makes densely populated areas more profitable to serve, the probability of offering broadband services will be higher in areas that have a higher population density.

Cable television networks were traditionally designed to provide analog television signals via coaxial cable network. These cable systems are capable of transmitting one-way data. In order to provide broadband data services, the cable system has to upgrade analog cable systems to digital systems with two-way capability. Upgrading a cable system for two-way broadband services requires substantial investment costs. The earlier cable system upgraded for data used the telephone for return communication. More recent cable systems are designed for two-way data transmission (Telecommunications et al., 2000). Figure 4 depicts the number of two-way capable and one-way capable firms by year. The variable two-way capable was missing for the years 2014 – 2016. There are 2010 cable firms that offer broadband but are not two-way capable, and there are 8967 cable TV operators that are two-way capable but do not offer broadband services.

Figure 4: Number of two-way and one-way capable cable firms by year



Channel capacity, which is the bandwidth allocated for video services, is a measure of the quality of the cable system. A higher channel capacity suggests a better quality network infrastructure and higher chances of delivering new services including broadband. Therefore, channel capacity should have a positive effect on the likelihood of entry into the broadband market. The average channel capacity changed from 48 channels in 2003 to 55 channels in 2016. MSO is a dummy variable that indicates whether a cable operator owns multiple cable systems. A cable firm that owns multiple cable system is more likely to offer broadband service. In 2003, 92 percent of cable firms owned a multiple system compared to 84 percent firms in 2016.

6. Empirical Application

The empirical application rests on previous work by Roberts & Tybout (1997) and by Bernard & Jensen (2004). Roberts & Tybout (1997) provide a framework that is easily adapted for the present needs. In their model, a firm makes a decision (to export) in a given time period if the current and expected revenues are greater than the current costs and the sunk costs of entry. The result leads to a model of state dependence. Specifically, the dependent variable is a binary variable (δ_{it}) taking a value of 1 if the firm exports and zero otherwise, and it depends on whether the firm exported the time period before. In our application, a firm chooses to enter broadband markets based on profits net of sunk entry costs. The explanatory variables include a set of firm characteristics (X_{it}), demographic characteristics (Z_{it}), and a lagged dependent variable (δ_{it-1}) to capture the sunk costs of entry. The choice model is then framed as $\delta_{it} = 1$ if $\beta X_{it} + \gamma Z_{it} + S(1 - \delta_{it-1}) + \epsilon_{it} > 0$, or 0 otherwise, where X_{it} and Z_{it} are a set of attributes of the firms and the markets in which the firms participate, respectively, and S represents sunk costs of entry.

For the explanatory variables (except for the lagged dependent variable), we follow the literature. In particular, as summarized earlier, there is a rich literature on broadband deployment in terms of demographic characteristics such as income, population and population density (Prieger, 2003; Flamm, 2005). There are also studies that analyze the effects of location, specifically, whether an area is urban or rural, on the decision to offer broadband services (Whitacre & Mahasuweerachai, 2008; Prieger, 2013). Other research has introduced firm determinants of broadband provision such as channel capacity and whether a cable firm owns multiple cable systems (Liu, 2007; Seo, 2007; Tang, 2011). In our specification, we include measures of each of these variables.

The primary issue in estimating the model is whether or not the error term is correlated with the lagged dependent variable. This is the classic issue of state dependence versus heterogeneity (Heckman, 1981). If the unobserved characteristics are permanent or serially correlated, they will cause persistence in broadband provision behavior, which complicates identification of the sunk costs of entry in broadband markets (S).

There are many approaches to estimation[4]. Following Bernard & Jensen (2004), we begin with a linear probability and panel data techniques. A key determination is whether there are individual effects and whether they are best modeled as random or fixed.[5] The results are provided in Table 2 in the first three columns. In column 4, we estimate the model in first differences using the Arellano-Bond GMM estimator using lagged values of the right hand side variables as instrument. The Arellano-Bond estimator is provided to remove a downward bias in the fixed effects estimator. In all cases, we include year dummies to account for any unobserved heterogeneity over time.

The natural log of channel capacity is statistically significant in each of the specifications and positively influences the decision to provide broadband services. Firms that own multiple cable systems (MSO) have a higher probability of offering broadband in the OLS and RE specifications, but are not significant in the FE and GMM specifications. Amongst demographic factors, per capita income is positive and significant in the OLS and RE specifications, but not in the FE and GMM specifications. Finally, in the RE and OLS specifications, firms are less likely to provide broadband in rural areas compared to urban areas, but whether the market is rural or not is not statistically important in the fixed effect specifications (FE and GMM).

The parameter on lagged broadband decision status is positive and significant irrespective of the estimation procedure. However, the magnitudes differ dramatically depending on the treatment of heterogeneity i.e., in the OLS and RE specification, the coefficient is over 0.9. This suggests that broadband provision in previous year increases the probability of offering broadband today by over 90 percent. But, as is well known if there are significant unobserved firm effects, this specification will give inconsistent parameter estimates and typically bias the parameter in an upward direction i.e., the role of sunk costs is overstated.

[4]These include a conditional logit, a probit, and linear probability models with fixed or random effects.

[5]As is well known, the use of random effects requires that the unobserved individual effects are uncorrelated with the regressors, while the fixed effects specification produce biased and inconsistent estimates.

Table 2: Linear Model Coefficient Estimates

VARIABLES	(1) OLS	(2) RE	(3) FE	(4) GMM
Channel capacity	0.041***	0.047***	0.051***	0.096***
	(0.002)	(0.002)	(0.011)	(0.024)
MSO	0.015***	0.015***	0.002	-0.005
	(0.003)	(0.003)	(0.008)	(0.014)
Broadband last year	0.930***	0.916***	0.649***	0.764***
	(0.002)	(0.002)	(0.004)	(0.007)
Population	0.163	0.232*	-0.093	0.300
	(0.115)	(0.122)	(0.366)	(0.725)
Income per capita	0.021**	0.025***	0.013	0.011
	(0.009)	(0.009)	(0.012)	(0.015)
Rural	-0.015***	-0.016***	-0.003	-0.001
	(0.003)	(0.003)	(0.004)	(0.005)
Land area	-0.033	-0.041	-0.045	-0.019
	(0.046)	(0.049)	(0.127)	(0.156)
Population density	-0.001	-0.001***	-0.001	-0.001
	(0.000)	(0.000)	(0.001)	(0.001)
Constant	-0.129***	-0.149***	-0.015	-0.247***
	(0.009)	(0.009)	(0.043)	(0.095)
Observations	59,057	59,057	59,057	51,683
Number of Groups (Firms)		7,318	7,318	6,612

Note: Annual dummies are included in all models. In the OLS regressions SE's are clustered, and in the others robust standard errors, which are in parentheses. A ***, **, * indicate statistical significance at the .01, .05, and .1 percent levels, respectively.

Inclusion of fixed effects does, indeed, reduce the effect considerably. In the FE specification, the parameter is 0.649, suggesting that the probability of offering broadband service is about 65 percent higher if it was offered in the previous time period compared to if it was not. But, as noted in Bernard & Jensen (2004), the fixed-effects specification biases the effects downward, and they use the Arellano-Bond specification, to remove the bias. In our data, the coefficient is larger in magnitude in the Arellano-Bond specification and suggests that the probability of offering broadband service is about 76 percent higher if offered in the previous time period than if not.

From these results, it is clear that the treatment of fixed effects and initial conditions has a very important effect on the empirical examination of the decision of cable TV companies to provide broadband service. The evidence tends to support the notion that there are significant fixed effects. However, it is alarming that the parameters of interest, such as whether market is rural or urban, disappear in such specifications.

Alternative Approaches

The linear probability model has a number of issues. Perhaps, most important for this application is that the predicated probabilities from the linear probability specification can lie outside the 0–1 range. There are alternative strategies to estimate a dynamic discrete choice model, and among these we explore a few alternative approaches. These include a pooled dynamic probit that ignores heterogeneity and state dependence, a random effect probit which controls for heterogeneity, a random effect probit suggested by Wooldridge (2005) and another by Orme (1996). The issue is that the state dependence term and the fixed effects are correlated. The probit without controls suffers from both the lack of controls for heterogeneity as well as that of ignoring the correlation between the unobserved term (which has a fixed effect present) and the lagged state dependence variable. The probit with fixed effect controls ameliorates bias from failure to model fixed effects but ignores the correlation of the fixed effects with the state dependence variable.

Heckman (1981), Wooldridge (2005) and Orme (1996) provide approaches to control for the correlation. Basically, the solution entails modeling the initial conditions. In Heckman (1981), he adds a model of the initial conditions, which is combined with the choice model and estimated simultaneously. Wooldridge (2005) provides a solution wherein you augment the model with the initial condition and mean values of the time varying explanatory variables by the cross-section. Orme (1996) suggests a two-step procedure. In the first stage, the initial condition is estimated as a function of the observed variables. In the second stage, the predicted value from the first stage is included as a variable, along with other explanatory variables.

The results are reported in Table 3. The probit models with and without random effects are quite similar. The state dependence variable, channel capacity, multiple cable system ownership, population, income per capita, and rural are statistically significant with intuitively correct signs. However, the models that control for initial conditions, point to some interesting results. First, the state dependence variable remains statistically important as does channel capacity but none of the other contemporaneous variables have statistical importance. However, the added controls for group means tend to be statistically important, and have the anticipated signs. That is, channel capacity, multiple cable system ownership, per capita income, percent rural are statistically important, but only at the group level. One take on this is that the annual variation is rather small, and the group effect dominates in explaining broadband decisions.

In the Orme specification, column 4 gives the coefficients attached to initial conditions, while column 5 uses those results in the model of interest. In the initial conditions model, channel capacity, multiple system ownership, population, per capita income, percent rural, and land area, each have an important effect on determining whether the cable TV operators offer broadband initially or not and are generally of anticipated sign. In the second stage, the predicted initial condition is used as an explanatory variable, and it has a positive and statistically important effect i.e. firms that initially choose to be in the market are more likely to be in the market in ensuing time periods, which reinforces the state dependent effect. Channel capacity, multiple cable system ownership, and percent rural, each has a statistically important effect in the direction anticipated. Nonetheless, the results do point to accounting for heterogeneity as well as initial conditions. Overall, there is strong evidence that channel capacity, multiple cable system ownership, population, per capita income, and percent rural have strong influences on the decision to provide broadband services.

Table 3: Probit Model – Coefficient Estimates

VARIABLES	(1) Probit	(2) RE	(3) Wooldridge	(4) Orme-Stage 1	(5) Orme-Stage 2
Broadband last year	4.055***	4.596***	4.705***		4.574***
	(0.033)	(0.069)	(0.103)		(0.068)
Channel Capacity	0.656***	1.171***	0.584***	0.974***	0.468***
	(0.035)	(0.060)	(0.155)	(0.049)	(0.106)
MSO	0.265***	0.362***	-0.035	-0.109*	0.453***
	(0.049)	(0.073)	(0.156)	(0.061)	(0.075)
Population	7.104***	12.408***	13.343	6.659***	4.885
	(2.703)	(3.711)	(9.567)	(2.182)	(3.948)
Income per capita	0.480***	0.685***	-0.002	1.125***	0.335
	(0.155)	(0.220)	(0.260)	(0.255)	(0.231)
Rural	-0.225***	-0.294***	0.005	-0.351***	-0.170***
	(0.044)	(0.062)	(0.084)	(0.062)	(0.065)
Land area	-0.692	-0.840	-1.077	-2.804***	0.601
	(0.730)	(1.147)	(2.626)	(1.034)	(1.171)
Population density	0.014	0.024	-0.018	0.024	0.020
Broadband in initial year			-0.229*		2.753***
			(0.122)		(0.346)
Mean channel capacity			0.589***		
			(0.158)		
Mean MSO			0.505***		
			(0.175)		
Mean population			-7.522		
			(12.066)		
Mean income per capita			1.771***		
			(0.446)		
Mean Rural			-0.620***		
			(0.129)		
Mean land area			-0.278		
			(2.957)		
Mean population density			0.141		
			(0.109)		
Observations	59,057	59,057	59,057	7,745	59,053
Number of Firms		7,318	7,318		7,315

Note: A ***, **, * indicate statistical significance at the .01, .05, and .1 percent levels, respectively

7. Conclusion

In this paper, we examine the decision of cable TV operators to offer broadband services. In a dynamic framework, we study the effect of demographic factors and firm characteristics on the probability of providing broadband services. We control for unobserved time heterogeneity by including year dummies. The estimation strategy allows us to identify the role of sunk costs and unobserved firm heterogeneity. Specifically, we test for the presence of sunk costs by examining the impact of broadband provision yesterday on broadband provision today. The data on cable firms are from Warren Publishing's Television and Cable Factbook. It provides the most comprehensive data available on cable TV operators in the United States. The data runs from 2003 to 2016, which is more recent and substantially longer than prior studies. We find that there are significant entry (sunk) costs for U.S. cable firms. Broadband provision today increases the probability of providing broadband tomorrow by 76%. We also find that firm heterogeneity is substantial and important in the decision to provide broadband. Firm characteristics, such as channel capacity, have a significant influence on cable firms' entry decision into broadband services.

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