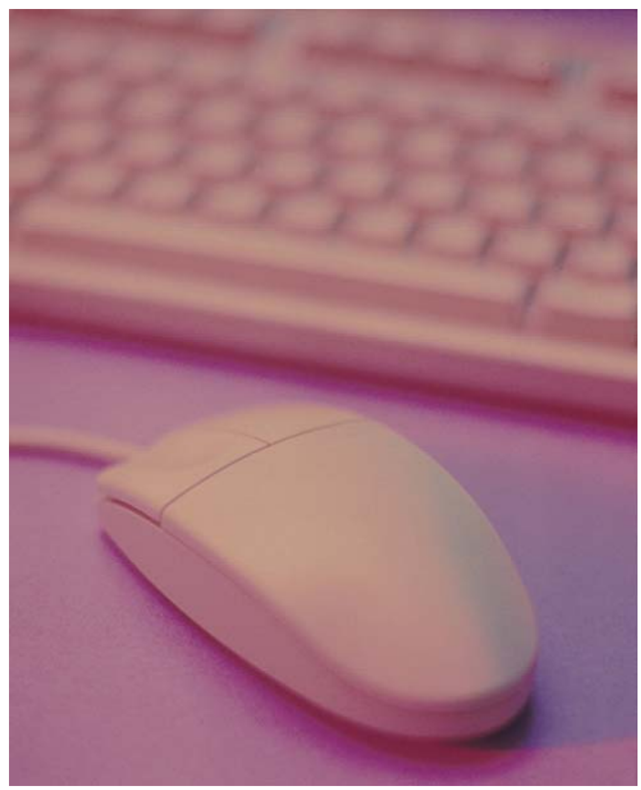
Informing the Debate

Michigan's Communication Infrastructure Needs:

Assessment and Policy Options



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Executive Summary

Broadband is among the most recent in a long series of advancements in electronic information technology that have reshaped economies and transformed societies since the mid-nineteenth century. That the world has benefitted mightily from advances in information technology is beyond dispute. But this does not mean that new information products and services are always on net beneficial or that public moneys to hasten their development and spread are always well spent. Although there is prior experience with broadband and a growing empirical record demonstrating its positive impacts of economic growth, considerable uncertainty remains as to its full implications. This brief report surveys the state of research on the economic effects of broadband and positions the US against peer nations and Michigan within the US and the Great Lakes area. It focuses on the benefits of broadband for productivity, employment, and income but does not attempt a review of the effects of advanced communications on other aspects of wellbeing such as more socially connected citizens.

The effects of telecommunications on the economy have been examined in considerable detail since early studies in the 1970s and 1980s revealed a positive relation between telephone penetration and per capita income. Several studies have since found that telecommunications investment has a positive effect on economic growth. An increasing number of studies reports even higher positive contributions of broadband to economic growth. Similarly, researchers found positive effects of broadband on consumer welfare. Positive employment effects seem to be strongest in industries that heavily rely on information and communication technology. Broadband can be seen as a general-purpose technology with wide repercussions for all sectors and industries. While broadband access increases employment levels, it does not necessarily reduce the unemployment rate in any given location as skilled labor might be attracted from other areas. Furthermore, it is possible that improved broadband access will entail negative effects such as losses of local sales and jobs. Overall, the empirical evidence suggests that the disadvantages of not being connected outweigh these risks. Nonetheless, policymakers need to be sensitive to both positive and potential negative impacts and mitigate the latter if necessary. The potential positive impacts of broadband are particularly important in rural areas. However, it is rural areas in which complementary skills are often lacking and the business case for private sector investment is weakest. Therefore, rural areas pose particularly vexing policy challenges.

In an international comparison, based on widely used metrics such as telephone penetration and prices, the US could boast one of the best telecommunication systems throughout most of the twentieth century. During the 1980s, in response to the lackluster performance of their telecommunication systems, many nations changed their legal and regulatory frameworks and proactively sought to close the gap with the US. Several peer nations succeeded and some even surpassed the US with regard to some important broadband indicators. Although the gap is less

dramatic than many commentators seem to suggest, it is a matter of concern and needs to be taken seriously. Using national averages, the US in 2009 ranked number 15 with regard to broadband penetration per 100 inhabitants; it ranked number six with regard to the price of entry-level broadband service. Although common, the use of single indicators may be misleading given the diversity and heterogeneity of broadband markets. The US does better in broad-based indices that take supply and user-side aspects into account. Within the 50 US states, Michigan, in 2009, ranked 35 with regard to broadband per 100 inhabitants. In the Great Lakes area Michigan occupies third place after Ohio and Illinois and ahead of Indiana and Wisconsin. However, Michigan was behind Indiana with regard to high-speed lines per 100 firms. The available limited data reveals great differences between urban and rural areas in the state.

The vast majority of broadband subscribers in Michigan, as in the rest of the US and the rest of the world, receive service via one of two wireline technologies: the digital subscriber lines (DSL) employed by telephone companies or cable operators' cable modems. Both technologies suffer from high costs for installing common plant and equipment and distribution costs that increase with the distance between customers. As a result, it is often cost prohibitive to provide broadband service with these technologies in rural areas, and even in urban areas economies of scale and density limit the number of financially viable wireline services. Alternative technologies, most of them wireless, for providing broadband service have attracted considerable attention as potential solutions to coverage problems in rural areas and as competitive alternatives to cable and telco-supplied service in urban areas. Most of the wireless implementations have taken one of three forms: satellite, WiFi, and WiMAX. Although each of these approaches has some advantages, none of these technologies have yet proven to be an adequate solution for next-generation broadband access. Another alternative, Broadband over Powerline (BPL), has had only modest success but recent initiatives by players such as IBM might rejuvenate it. With regard to advanced applications, fiber to the home offers the greatest flexibility. As it suffers from even graver cost challenges than DSL and cable modem service, fiber will most likely be expanded gradually to neighborhoods and subsequently to individual subscribers.

Adoption and use of broadband are the outcome of many interacting factors that shape infrastructure supply and demand for services. Key factors driving supply are the cost of rolling-out broadband, the price consumers are willing to pay for broadband services, and the intensity of competition in the market and for the market. Key factors affecting demand are the benefits of broadband use as perceived by consumers, the price of broadband services, and disposable income. All these factors may, in turn, be affected by other variables. For example, the perceived benefits of broadband may be influenced by the level of education of users or the digital literacy of users, i.e. their skills in using advanced information and communication technology. Many (but not all) of the factors driving broadband adoption and use can be influenced by policymakers and hence provide levers to harness the positive impacts from broadband. Measures within the realm of state policy that affect the supply of broadband include subsidies, tax incentives, and provisions that reduce the cost of access to rights of way. Measures that affect the demand side include education programs for potential users (both residential and business), an acceleration of e-government services, a role for the public sector as anchor tenant, and possibly financial support for deserving user groups. Any policy mix will need to be adapted to the changing dynamics of technology and uses. Systematic monitoring of the effects of policy measures is therefore highly recommended.

Introduction

It doesn't seem that long ago that a FCC chairman, referring to the fact that broadband was spreading unevenly within the U.S. population, equated the digital divide to a Mercedes divide—a division where what separated the haves from the have-nots was by no means a necessity.[1] Today the tone of the broadband policy debate is much different. No one seriously questions that broadband is a critical component of the information infrastructures in all economically advanced nations. Now we worry that U.S. competitiveness will suffer if broadband penetration and available bandwidth do not measure up to standards observed in other countries and we ask how the full benefits of broadband can be extended to communities that, due to geographic or economic disadvantages, are currently underserved or simply do not have broadband at all.

Today many states and municipalities have broadband policies, the FCC is working on a plan for bringing broadband to every U.S. home, and the 2009 American Recovery and Reinvestment Act (ARRA) includes $7.2 billion for promoting broadband diffusion in areas still lacking broadband service or identified as underserved due limited choices among providers. These initiatives are important, but it is also generally understood that the moneys provided in the ARRA for broadband promotion are but a down payment on the much larger investment that will be required if advanced broadband service is to become available and affordable everywhere in the United States. Even after the ARRA moneys are spent, realization of its ultimate goals will depend on further initiatives by both federal and state policymakers. For these policies to be effective, they must be founded on a clear understanding of the current state of broadband deployment and what might be done to improve upon it. Unfortunately, as reflected by the allocation of substantial ARRA moneys for broadband mapping initiatives, our knowledge in this regard is not nearly as complete as good policy design demands, and what information is available is neither fully integrated nor as widely disseminated as it should be within the policy community.

This report is designed to assist Michigan policymakers who will be making decisions that will impact the continued development of the state's broadband infrastructure, and especially its diffusion within unserved and underserved areas in the less populated regions. The goal is not to provide new information, but to make what is known about the economic benefits of broadband and the challenges facing Michigan more accessible. The remainder of this report is organized as follows. Section 1 provides a brief overview of the research on broadband's contributions to economic growth and employment. Section 2 presents data and statistical evidence that sheds light on the deployment of broadband infrastructure within the state and how Michigan stacks up when compared to other states and other countries. This assessment of Michigan's situation and challenges to broadband deployment is followed in Section 3 by a

[1] Remark by FCC Chairman Michael Powell at his first news conference in February 2001. See http://www.thegully.com/essays/US/politics_2001/010212powell_fcc.html.

review of options for promoting broadband available to policymakers. As a variety of technologies can be used to provide broadband service and the mix of technologies employed is likely to become increasingly heterogeneous in the future, Section 3 begins with an overview of various technologies that might be used to deliver broadband service, focusing on some of the technologies less familiar than the cable modems and DSL connections offered by cable providers and phone companies currently used to serve the vast majority of Michigan home broadband subscribers.

1. Assessing the Benefits of Broadband Infrastructure

Broadband is among the most recent in a long series of advancements in electronic information technology that have reshaped economies and transformed societies since the first telegraph line commenced operation in 1844. That the world has benefitted mightily from advances in information technology is beyond dispute. But this does not mean that new information products and services are always on net beneficial or that public moneys to hasten their development and spread are always well spent. Policy makers can, and should, demand assurance that public resources bet on policy initiatives have reasonably good odds of paying off.

For such risk and benefits assessments it is natural to turn to research by experts on the technology in question. Most informative are studies that examine prior experience with the technology. However, the newer the technology, the less experience is available to inform current choices. In this case it is necessary to rely on projections based on expert assessments that rely more heavily on theory-based projections or extrapolate from earlier experiences with other technologies that share critical attributes with the technology for which support is sought. In this regard, broadband is something of an intermediate case. We have had the technology long enough to start to accumulate experience with it, but not long enough for its long run impacts to be fully manifest or for a truly rich research literature to have developed.

Mindful of these limitations, this brief overview of the findings of prior research considers work within the larger body of research on investments in information infrastructure that includes earlier generations of technology as well as more recent work focused explicitly on broadband. In considering the findings reported, it is important to keep in mind that the underlying research was focused primarily on measurable economic benefits, such as increases in productivity, national income, or employment that might be attributed to information infrastructure investments. Thus, if information technologies contributed to certain less easily measured aspects of wellbeing, such as more knowledgeable consumers, more socially connected citizens, or more informed voters, these benefits would not directly be reflected in the research assessments described below.

The question of whether telecommunications technology contributes to economic growth is hardly a new one. In one of the earliest studies, Hardy (1980) concluded that increased telephone penetration contributed to economic growth and that it did so by facilitating information transmission and contributing to organizational efficiency. Subsequent research has largely supported Hardy's findings. Working with a sample of 11 European countries in a transitional stage of economic development during 1991-1994, Madden and Savage (1998) found that telecommunications services were important contributors to development and that penetration was a more immediate contributor to growth than infrastructure investments, which is consistent with Hardy's claim that the role of telecommunications in facilitating information transmission is of particular importance. This finding also lends support to the policy decision to allocate a portion of the ARRA broadband funds to promoting adoption and to applications training as well as promoting investment in the physical infrastructure.

In their study of telecommunications and growth in a sample of OECD countries from 1970 through 1990, Röller and Waverman (2001) also found telecommunications infrastructure investments to make positive contributions to economic growth, as did Jacobsen (2003), who used a similar statistical model to examine a much larger mixed sample of developed and developing countries from 1990 through 1999. More recent studies by Jorgenson and Vu (2005) and by Thompson and Garbacz (2007) have reinforced the findings of earlier scholars that investments in information and communications technologies boost the level of economic activity.

The research literature on the economic impacts of broadband is necessarily more limited due to the newness of the technology. However, much of the work that has been done has focused on the impact of variation in broadband diffusion among communities in different parts of the U.S., which makes the findings more relevant to assessments of U.S. and state-level policy options. Perhaps the most consistent finding of this research is a statistically significant positive correlation between increased availability of broadband and employment growth. This is the principal finding of Crandall, Lehr and Litan (2007), who studied differences among U.S. states using broadband penetration as a control variable. Van Gaasbeck et al. (2007) report similar findings from their study of California counties, as do Gillett, et al. (2006), whose study focuses on variation among communities. Gillett et al. also found increases in broadband penetration to be associated with growth in the number of business establishments, a finding replicated by most, though not all, of the other studies in the literature on the economic effects of broadband.

Jed Kolko's (2010) Public Policy Institute of California study is the most recent to look at the productivity and employment consequences of broadband diffusion. Using ZIP-code level data, he, like previous authors, found broadband to have a positive and statistically significant effect on employment. He also employed causality tests to provide empirical confirmation that broadband did contribute to jobs growth, so the observed positive correlation between broadband penetration and employment growth was not simply due to broadband suppliers investing in facilities in areas already experiencing robust growth. Similar to other studies, he also found that broadband's effect on the level of employment varies with the mix of industries providing employment in a given locality. Employment effects seem to be greatest for industries that use information technology more intensively. He found no effect on employment in mining and public administration. Consistent with earlier studies, he also found that while broadband contributes to job growth, it does not seem to be associated with reduced levels of unemployment, which suggests that new jobs may be filled by people who come from elsewhere to take them. Of particular interest to states like Michigan with large sparsely populated regions, and consistent with a recent study sponsored by the U.S. Department of Agriculture (Stenberg, et al., 2009), he found the effect of broadband on job growth to be greatest in low population density ZIP codes.

Most studies of the economic impacts of broadband have focused on jobs, but employment growth is only one of the ways broadband might contribute to economic wellbeing. Greenstein and McDivitt (2009) recently provided an estimate of what might be called the direct benefits of broadband, which is what consumers collectively would be willing to pay to have broadband rather than dialup internet service and the net revenue gains to service providers (over sales of dialup service) minus the incremental cost of offering broadband. For the United States in 2006 they estimate direct benefits of between $12.1 billion and $17.3 billion. The authors are careful to point out that their estimates exclude benefits realized from the provision of other goods and services whose economics might have been favorably impacted by broadband. Perhaps most obvious are the direct consumption benefits of high speed access to the wealth of media content and information services available online, including innovations, such as search engines and social networking services like FaceBook, MySpace and Twitter for which there are no offline antecedents. Furthermore, a host of services and activities involving communication and accessing information can be provided at lower cost and often with greater convenience and quality than was possible before.

Estimates of the magnitude of such benefits are subject to a greater degree of statistical imprecision because they necessarily embed assumptions about how much individuals and organizations benefit from new services and capabilities that cannot be fully captured in economic data. Examples would include advances in telemedicine, e-government, online book sales, streaming video, and the vast numbers of e-business ventures that thrive online. Estimates incorporating benefits of this type are unavoidably more speculative, but are also typically several times to orders of magnitude larger than the Greenstein and McDivitt estimates. Crandall, Jackson and Singer's (2003) well-known projection of benefits between $400 billion and $500 billion under plausible adoption scenarios is near the high end of such forecasts. In a recent update to this study commissioned by Broadband America, Crandall and Singer (2010) update and confirm the earlier these findings. The authors also emphasize the substantial investment in network infrastructure that has taken place since the earlier study. Critics of this and other work have argued that the assumptions driving the empirical analysis are overly optimistic.[2] Examining the effects of broadband on consumers, Dutz, Orszag, & Willig (2009) conclude that the annual net benefits are in the $30 billion range.

The variety of services enabled by broadband just described reflects its status as what Bresnahan and Trajtenberg (1995) call a general purpose technology, by which they mean a technology with pervasive applications. Electricity, the internal combustion engine, and computers are earlier examples of general purpose technologies. A feature of general purpose technologies is that their full economic impacts are typically not realized for many years, often decades, after they are first introduced (David, 1990). While general purpose technologies are initially adopted by organizations and individuals because they make it easier or less expensive to carry out existing tasks and manage already established activities and relationships, discovery of their full potential over time eventually stimulates the development of new products and services and entirely new ways of organizing economic activities that could not have been predicted when the technology was first introduced. In the long run, it is the transformative effects of second stage innovations that exploit unforeseen possibilities inherent in the new technology that produce the biggest benefits for the economy and for consumers. It is important that these longer-term implications of decisions made today be kept firmly in mind in the fashioning of both federal and state broadband policies.

Although the vast majority of studies emphasize the benefits of broadband, there are also risks and possible downsides that need to be addressed where possible. The availability of high-speed Internet access may shift purchasing power from local to online. Furthermore, the ability to outsource tasks and expand the geographic area from which supplies are ordered also has benefits (possibly lower costs) and costs (possible local job losses). Online exposure to other places may increase the incentive of individuals (especially those in rural areas) to move to these places (see, for example, the findings by LaRose at al., 2008). South Korea has become concerned about "virtual ghettos" to which poor segments of the population withdraw. Whereas the evidence overall suggests that the positive effects outweigh the negative ones, this may not hold for every particular community. Regular monitoring that allows changes in the approach to broadband is therefore essential to recognize and mitigate such effects if necessary.

We close this section by emphasizing that small and rural communities are substantially disadvantaged when it comes to adopting this newest linchpin of the information economy. Higher costs due to small scale installations would discourage adoption by individuals and organizations in any case, but for a network technology like broadband this problem is compounded by a tendency for potential adopters to underestimate the benefits of adoption

[2] E.g. D. Burstein, "Unproven Claims about Broadband", available at http://www.dslprime.com/policy/177-p/2622-unproven-claims-about-broadband (last visited 6 March 2010).

because the benefits that arise from linking with other individuals and utilizing internet-resident resources and capabilities cannot be fully appreciated, or even anticipated, prior to use. Finally, the basic knowledge and supporting institutions required to fully realize the benefits of broadband are typically lacking in these communities because such knowledge and institutions typically arise in response to opportunities to utilize a technology. As a result, it is in smaller and rural communities where network technologies promising substantial collective benefits are least likely to be adopted if adoption depends entirely on choices made by local individuals and organizations.

2. The State of Broadband

Broadband deployment is costly. Even if effective demand is present, funds for investment and skilled labor to roll-out networks and services are not unlimited. Therefore, the necessary infrastructure investment will typically have to be distributed over time. However, supply and demand-side conditions can, to a certain degree, be influenced by public policy decisions and private investment may be complemented by public expenditure of resources. How well Michigan does on these counts can be assessed in two principal ways: by examining the State's own historical record of broadband deployment and use and by comparing Michigan to other states, the country as a whole, and possibly even international performance standards. Any interpretation of the empirical facts will have to use judgment, however, as many factors influence the metrics that can be used to assess the state of broadband. For a more complete picture, several indicators should be examined, including the diffusion of broadband service, the price of service, and the available quality of service. Where possible, it is also meaningful to look at changes in these variables over time.

2.1. The US in an international comparison

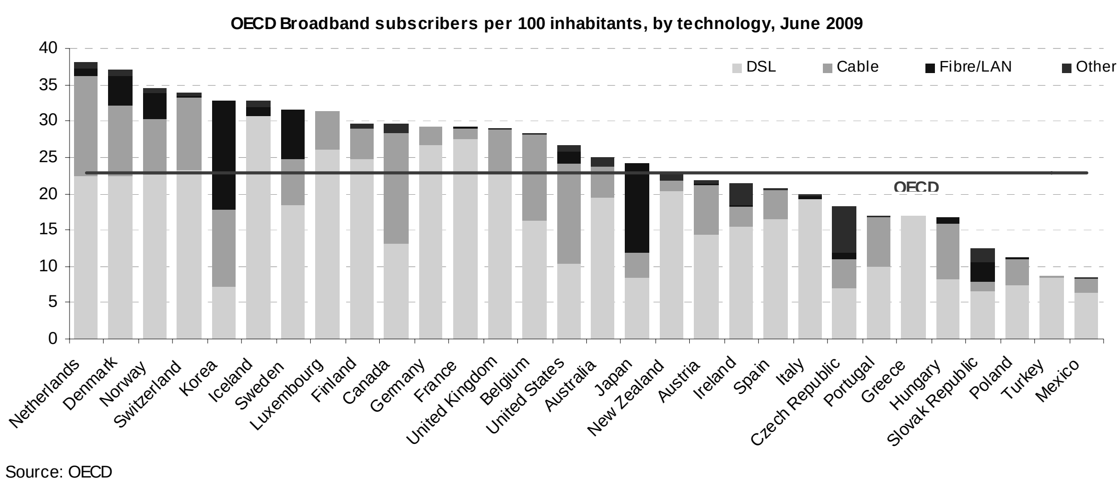
International comparisons of broadband infrastructures have become commonplace. Section 104 of the Broadband Data Improvement Act of 2008 instructs the Comptroller General to systematically collect and compare international data. Such an endeavor has to overcome a number of challenges as simple comparisons often fail to take different economic, technical, political, social, and cultural conditions into account. Nonetheless, international comparisons and rankings have become an important aspect of the benchmarking of national and local policy efforts.

2.1.1. Broadband diffusion

Despite its many weaknesses, the most widely used measure of broadband adoption is the number of broadband subscribers per 100 inhabitants. One main weakness of the metric is that it does not take into account the quality of the broadband infrastructure. The speed and latency of the last-mile connection and the speed of the Internet backbone are not reflected. Furthermore, this metric does not take into account that for fixed broadband a household is the typical broadband subscription unit. However, household size differs across nations; for example Swedish households on average consist of 2.1 persons whereas US households typically average 2.6 people. A nation with a high average household size like the US will reach full adoption at a much lower rate per 100 inhabitants than a nation with smaller households (see Wallsten, 2008, for a detailed discussion). With this caveat in mind, some insights may nevertheless be gained from an international comparison of broadband diffusion.

According to data published by the International Telecommunication Union, the global per country average number of broadband subscribers per 100 inhabitants was 6.06 in 2008, while the US average was 25.59 subscribers per 100 inhabitants.[3] In June 2009 the US ranked above the average of the OECD (Organisation for Economic Co-operation and Development) member countries, a group of 31 industrialized nations: US broadband penetration 26.7 subscribers per 100 inhabitants compared to the OECD average of 22.8. However, the US was trailing peer nations within the OECD, as illustrated by Figure 1. One has to keep in mind that many of these countries are Nordic nations with small household sizes, which biases the data in their favor.

Fig.1. Broadband subscribers per 100 inhabitants by technology (OECD)

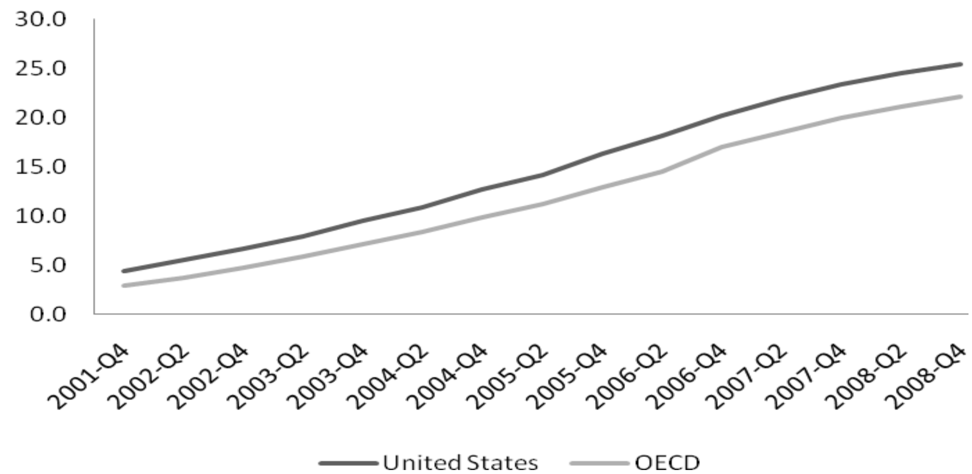


Source: OECD (2010).

[3] See http://www.itu.int/ITU-D/icteye/Reporting/ShowReportFrame.aspx?ReportName=/WTI/InformationTechnologyPublic&RP_intYear=2008&RP_intLanguageID=1. Retrieved July 7, 2009, from ICT statistics database.

Historically, US broadband penetration has been above the OECD average and the absolute gap between the US and the OECD average has widened since 1997. However,-America's rank among the 30 OECD member countries dropped from 3 in 2000 to 12 in 2004 and to 15 by 2008.

Fig.2. US and OECD average broadband penetration

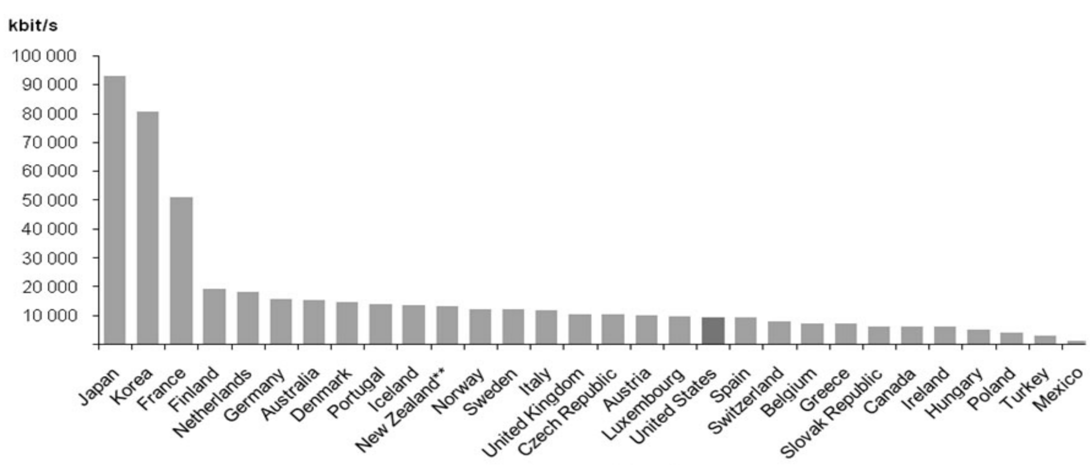


Source: OECD (2009)

2.1.2. Speed and price

In October 2007, according to OECD data, the average broadband download speed advertised in the US was 7.8 megabits per second, ranking the US 14th in the OECD. By September 2008, the US average for advertised download speed had increased to 9.6

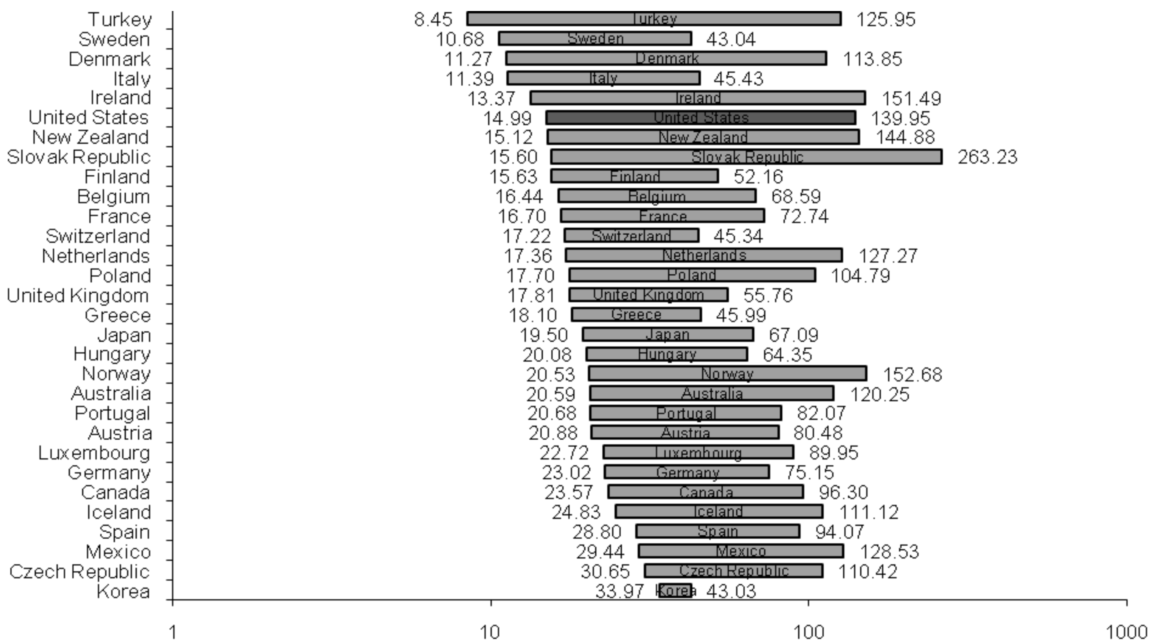
Fig.3. Average advertised broadband download speeds for 2008



Source: OECD (2009).

megabits per second but the country's rank by this measure had deteriorated to 19. The US had the sixth lowest average monthly subscription price, with prices that varied from $14.99 to $139.95. This range of prices is relatively high compared to other countries. This may be due to the diverse geography of the US, which would give rise to wider variation in the cost of providing service, a different market structure, and greater reliance on price differentiation.

Fig.4. Range of broadband monthly subscription prices (September 2008)



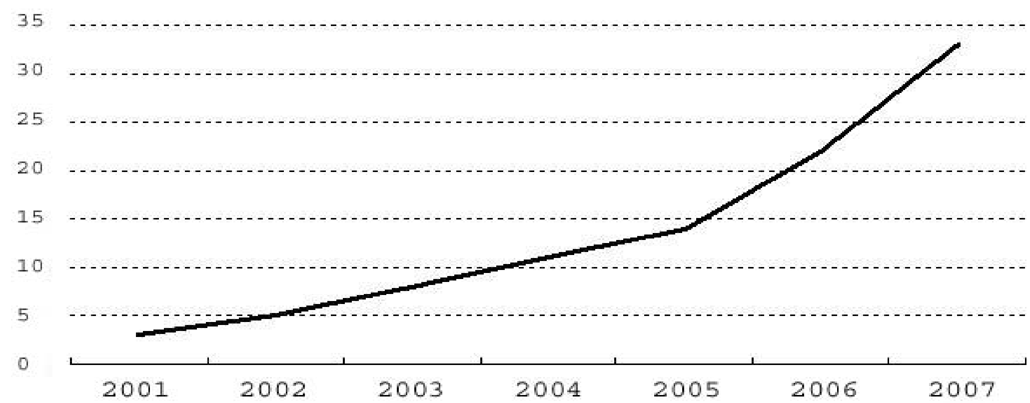
Source: OECD (2009).

2.2. Broadband in the US

2.2.1. High-speed lines per 100 inhabitants

Until 2008, the FCC defined high–speed lines as connections capable of transmitting at least 200 kbps of data in at least one direction. The Commission introduced a new eight–tier classification in 2008. The number of high–speed lines per 100 inhabitants in the US increased from 3 in 2001 to 33 in 2007. Residential high-speed lines per 100 households increased from 31 in 2005, to 40 in 2006 and to 51 in 2007. The number of business high-speed lines per 100 firms increased from 70 in 2005 to 231 in 2006. This dramatic increase is probably due to the remarkable increase in wireless high–speed lines during the past few years.

Fig.5. US high-speed lines per 100 inhabitants

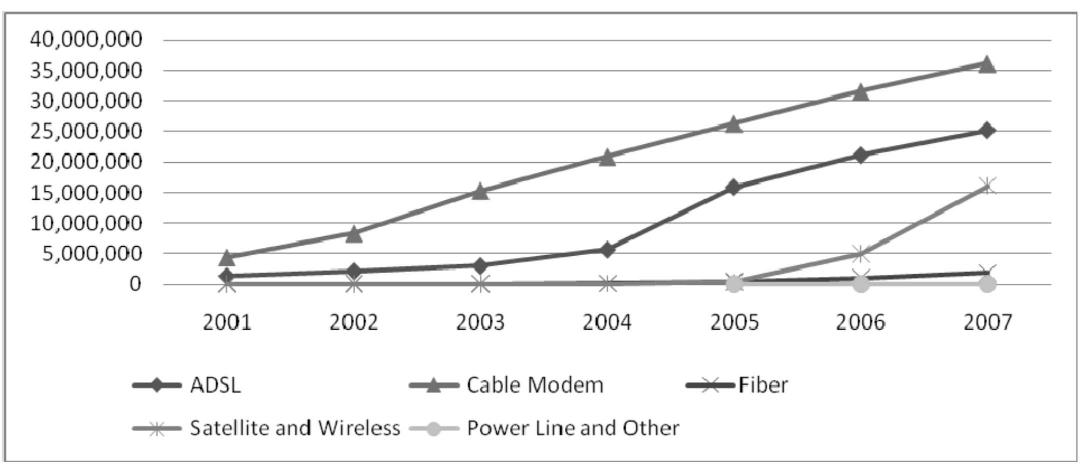


Source: FCC (2003-2009); own calculations.

2.2.2. High-speed lines by technology

Asymmetric Digital Subscriber Line (ADSL) and cable modem service are the most widely used platforms. In recent years, wireless technology has been rapidly deployed, although only a fraction of the users who have a mobile high-speed connection available actually use it for Internet access. Other platforms used in the US include SDLS, fiber, satellites, and a limited number of power line connections.

Fig.6. High speed lines by technology

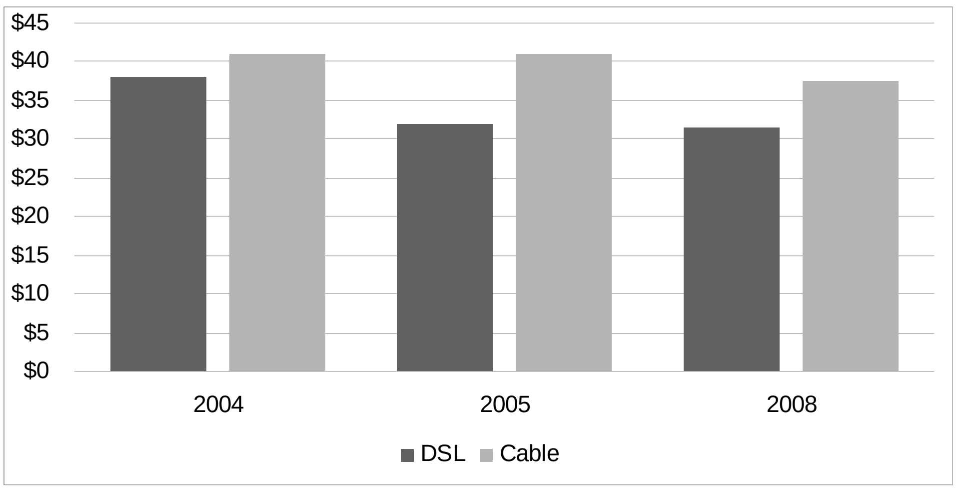


Source: FCC (2009).

2.2.3. Speed and price

According to surveys conducted by the Pew Internet and American Life Project, the average price of broadband service has decreased steadily but rather slowly. In 2004, the average prices for DSL service and cable modem service were $35 and $41, respectively. By 2005, the average price for DSL had fallen to $32, a drop of 8% compared to the previous year. Between 2005 and 2008 DSL prices declined only modestly, but cable modem service prices decreased by 4% on average.

Fig.7. Price of DSL and cable broadband services

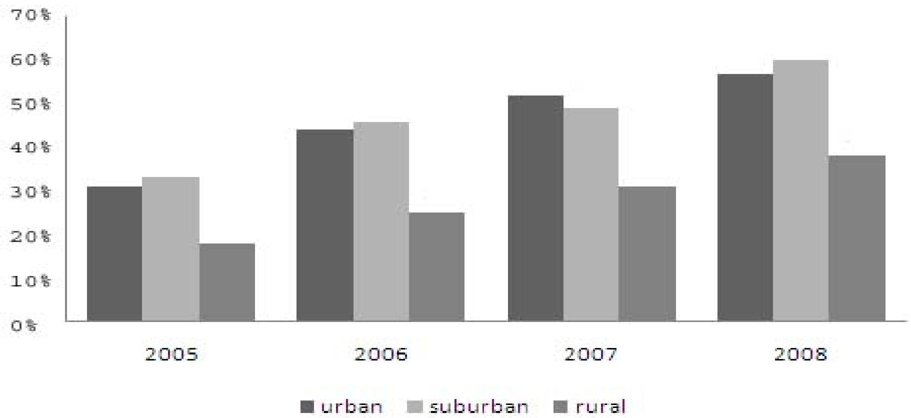


Source: Pew (2008).

2.2.4. Adoption by area

Residential broadband penetration rates have increased in all areas of the United States. Suburban penetration rates slightly exceeded urban penetration rates, except in 2007. Broadband penetration was much lower in rural than in urban and suburban areas. As of 2008, 60% of suburbanites, 57% of urban residents and 38% of rural residents subscribed to broadband. There continues to be a significant gap between urban/suburban areas and rural areas.

Fig.8. Home broadband adoption by area



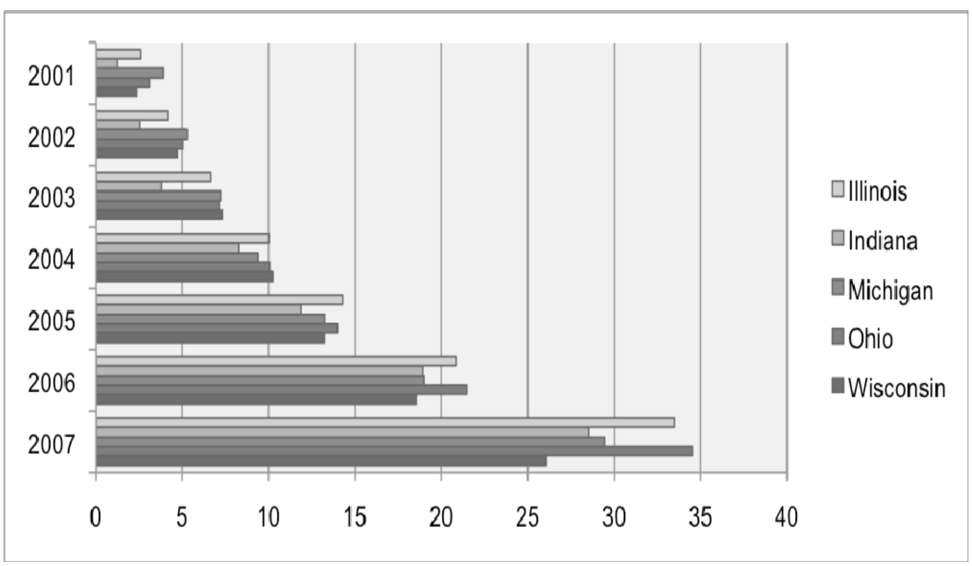
Source: Pew (2008).

2.3. Broadband in the Great Lakes Region and Michigan

2.3.1. High-speed lines per 100 inhabitants

The number of high speed lines per 100 inhabitants for the Great Lakes region states (Michigan, Ohio, Indiana, Illinois, and Wisconsin) was calculated by combining FCC high--speed line data by state with US population data from the census. Until 2003, the number of high-speed lines per 100 inhabitants in Michigan exceeded the average for the Great Lakes region. However, since 2004, Michigan's average was at or below the regional average.

Fig.9. High-speed lines per 100 habitants in the Great Lakes region

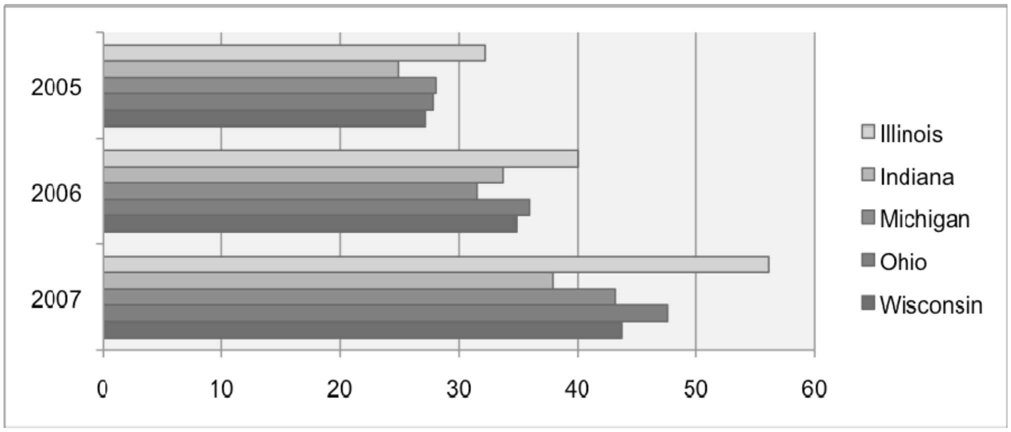


Source: FCC (2003-2009).

2.3.2. Residential high-speed lines per 100 households

Residential high--speed lines per 100 households were also calculated using FCC data regarding high-speed residential lines and US census data. Residential high-speed lines per 100 households have increased from 28 in 2005 to 46 in 2007. Michigan's figure for residential high--speed lines per 100 households was at the Great Lakes States average in 2005 but slightly below the Great Lakes States average in 2006 and 2007. Throughout the period of 2005-2007, Illinois held the top position and Michigan ranked third.

Fig.10. Residential high-speed lines per 100 households from 2005 to 2007

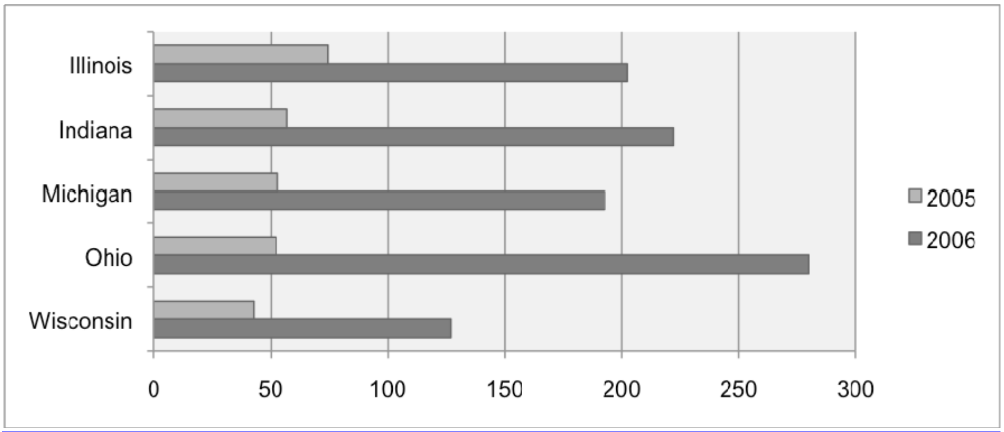


Source: FCC (2007-2009); US Census (2009).

2.3.3. Business high-speed lines per 100 firms

As with residential lines, FCC and US Census Bureau data were used to calculate business high-speed lines per 100 firms. The large increase in business high-speed lines between 2005 and 2006 in all states is probably due to rapid growth in wireless high--speed lines. The number of business broadband lines per 100 firms in Michigan is slightly lower than the Great Lakes regional average.

Fig.11. Business high-speed lines per 100 firms from 2005 to 2006

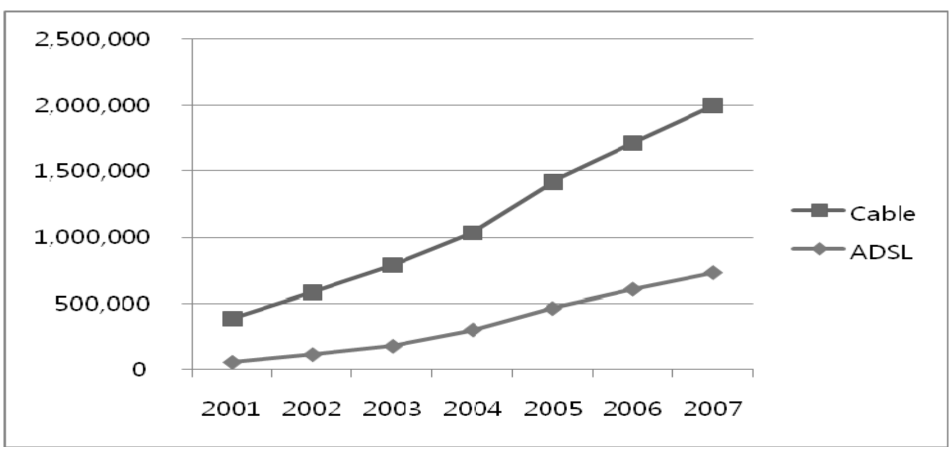


Source: FCC (2007-2008); US Census Bureau (2009).

2.3. 4. ADSL and cable high-speed lines

As of 2007, of the total of 3,557,139 access lines in Michigan, 21% used ADSL, 36% used cable and 43% other platforms. Corresponding US-wide numbers are 31.5% ADSL and 45.1% cable and 23.4% other. In other words, the average nationwide proportion of ADSL and cable lines is significantly greater than that of Michigan. Both types of lines have been growing at steady rates. While starting from a considerably smaller base, the percentage growth in ADSL lines has been considerably higher than for coaxial cable lines in recent years. From 2001 to 2007 the number of ADSL lines increased to 14 times the 2001 figure (from 52,505 to 732,950), while coaxial cable lines increased by a factor of four during the same period (from 329,697 to 1,265,384).

Fig.12. Growth of ADSL and cable high-speed lines in Michigan



Source: FCC (2003-2009).

2.3.5. Number of high-speed service providers

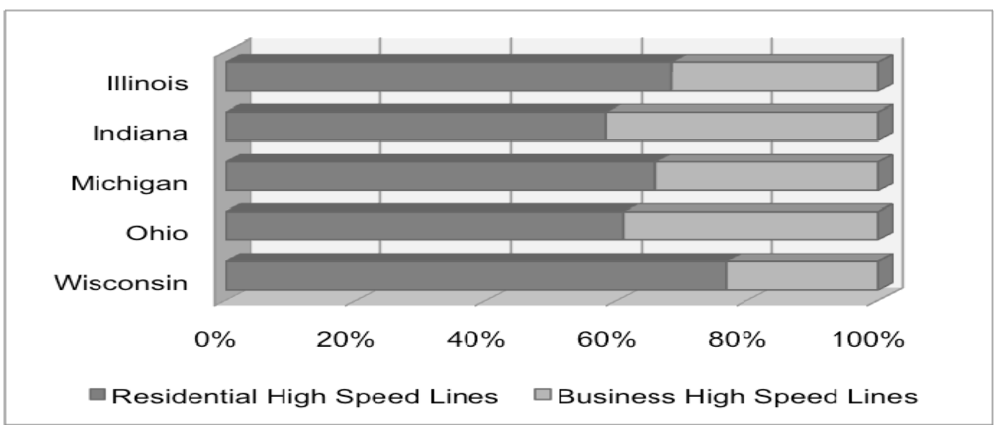
The nationwide number of providers of high speed lines increased from 136 in December 2000 to 1,393 in December 2007, an approximately 10-fold increase. In Michigan, the number of providers increased from 15 in December 2000 to 82 in December 2007, an approximately 5.5 fold increase. The percentage increase in Michigan is less than the national average but it is comparable to the six fold increase in the Great Lakes region overall.

Very limited data is available at a more local level. Due to proprietary data concerns, the FCC only publishes data on the number of providers per ZIP code, which is in many ways insufficient for a detailed assessment of broadband adoption. In 2000, there were 1-3 providers in 61% of Michigan's ZIP codes and no providers in 14% of its ZIP codes. By 2007, there were at least 3 providers in every Michigan ZIP code and 10 or more in 28% of ZIP codes. The number of ADSL providers (43) is 3.3 times the number of cable modem providers (13).

2.3.6. High-speed lines by type of end user

The mix of business and residential high-speed lines varies among the states. In Michigan the shares of residential and business users were 60.8% and 39.3%, respectively, in 2007. These figures are very close to the nationwide averages of 61.1% and 39%. The residential-business composition is quite different for other states in the Great Lakes. The proportion of residential high speed users is higher in Wisconsin and Illinois while the proportion of business customers is higher in Indiana and Ohio (FCC, 2009).

Fig.13. High speed lines by type of end user



Source: FCC (2009).

2.3.7. Broadband speed

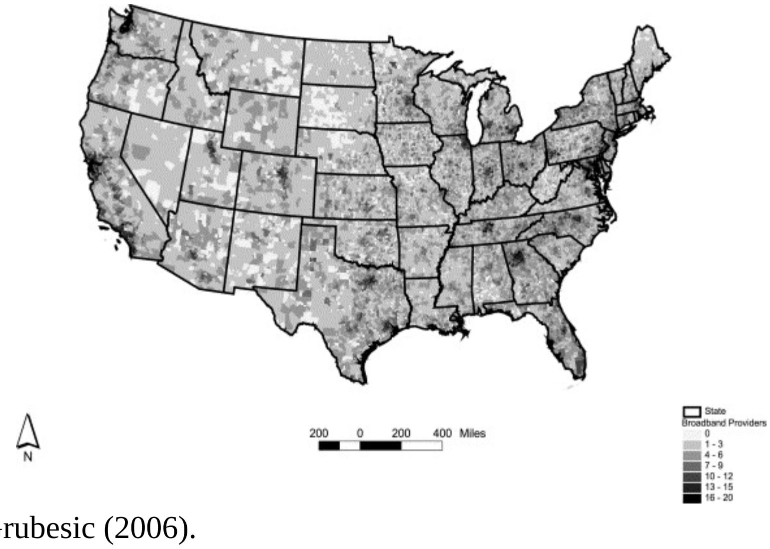
The Communications Workers of America (CWA, 2008) collected data about download and upload speed from nearly 230,000 Internet users who tested their connections using the speed matters website (www.speedmatters.org). Median download speed in Michigan was 2,042 kbps in 2007 and 2,573kbps in 2008. The state's national rank using this metric was 19 in 2007 and 20 in 2008. The median download speeds for Michigan were slightly above the US medians of 1,970 kbps in 2007 and 2,350 kbps in 2008.

2.4. Broadband in Michigan

2.4.1. High speed line providers by ZIP code

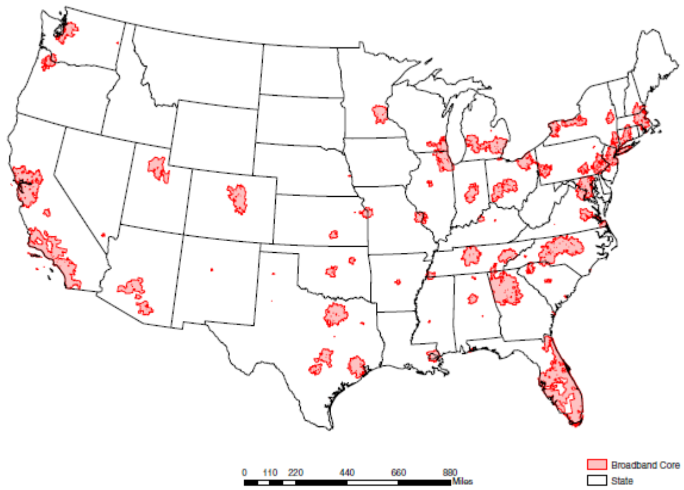
Grubesic (2006) defines the broadband core as a set of regions "where zip codes displaying high levels of broadband availability and competition are surrounded by other zip codes with similar values. These are regions with the highest levels of broadband availability and competition in the United States and are primarily located in urban areas." The following figures show how the number of broadband providers varied by ZIP code for the United States in June 2004 and identifies those regions that are parts of the broadband core and the broadband periphery. Regions in Michigan that are part of the broadband core are all in the southern part of the state.

Fig.14. Broadband providers by ZIP code in 2004



Source: Grubesic (2006).

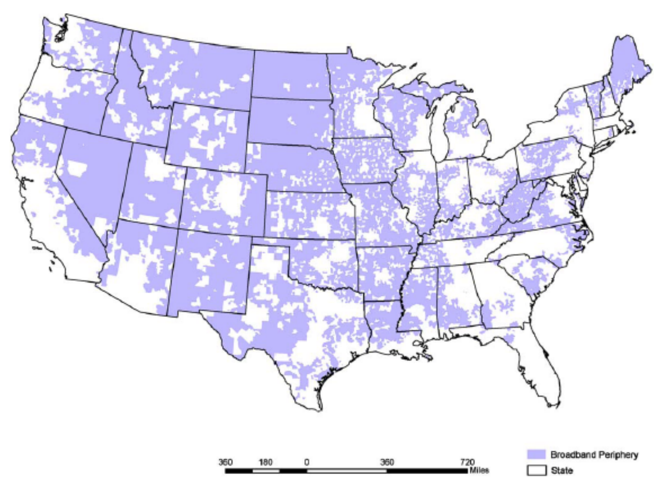
Fig.15. Broadband core areas in 2004



Source: Grubesic (2006).

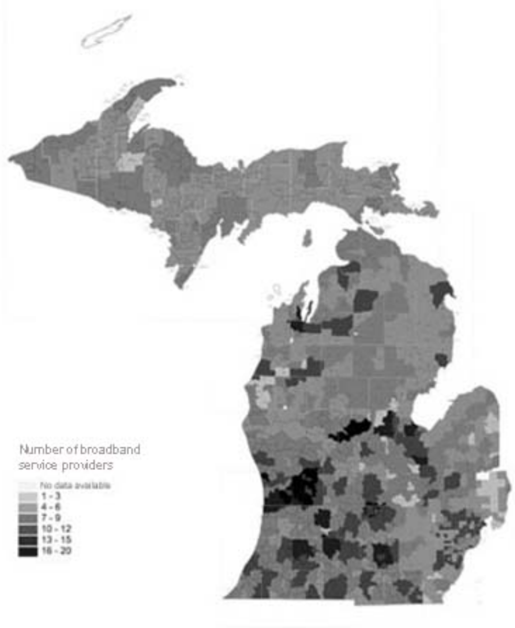
Figure 17 displays numbers of broadband providers by ZIP code for Michigan for December 2007. While the number of broadband providers has grown overall since 2004, the areas designated as "broadband periphery" by Grubesic in 2004, such as the Upper Peninsula, most parts of the northern Lower Peninsula, and the Thumb, are still served by a relatively small numbers of providers compared to other parts of Michigan.

Fig.16. Broadband periphery in 2004



Source: Grubesic (2006).

Fig.17. Number of providers by ZIP code in Michigan, December 2007



Source: FCC & Michigan Information Center.

2.4.2. Broadband speeds in Michigan

The following map reports average download speeds by ZIP code for Michigan in 2008 according to the CWA voluntary test. No tests were launched from white areas. It is difficult to conduct systematic analysis with the data because it is based on voluntary user contributions. Nonetheless, an overall increase in speed seems clear from the comparison of two tests for 2007 and 2008 reported above.

Fig.18. Average download speeds by ZIP code in 2008

Source: CWA (2008)

3. Broadband, Competitiveness, and Economic Growth: Putting Policy in Context

An assessment of measures that might be undertaken to accelerate Broadband infrastructure investment and user adoption in Michigan can tap into a rich research literature that provides a multifaceted picture of the factors facilitating diffusion and those that might impede it. Countries, regions, states, and cities differ widely in the adoption of broadband and the uses of advanced communications. Observable adoption and use patterns are the outcomes of many interacting factors that affect the supply of broadband infrastructure and the demand for services. Key factors driving *supply* are the cost of rolling-out broadband, the price consumers are willing to pay for broadband services, and the intensity of competition in the market and for the market. Key factors affecting *demand* are the benefits of broadband use as perceived by consumers, the price of broadband services, and disposable income. All these factors may, in turn, be affected by other variables. For example, the perceived benefits of broadband may be influenced by the level of education of users or the digital literacy of users, i.e. their skills in using advanced information and communication technology.

Although influenced by different factors, supply and demand for broadband are interdependent and respond to each other. The adoption rate for broadband, whether high or low, will typically be the outcome of this interaction and is rarely constrained by just one component. To design effective policy, it is important to identify and separate supply and demand-side effects as well as the sensitivity of broadband adoption and use to alternative measures. Moreover, it is important to understand possible conflicts and trade-offs between different measures. For example, subsidies provided to new suppliers may under some circumstances elicit new investments by existing suppliers, but there are also plausible scenarios under which public investment displaces private investment. Research has shown that there is no panacea for accelerating broadband adoption. Typically, a mix of carefully orchestrated and coordinated measures will have to be used.

The fixed cost of deploying broadband is of particular interest. It determines the minimal efficient size a company needs to achieve to operate efficiently. It also influences whether a specific market will be sufficiently “thick” to allow competition. If a market is too small or willingness to pay too low to recover the investment and operating costs, commercial service providers will not deploy networks and service unless some additional incentives are offered. This could be subsidies, tax breaks, public-private partnership arrangements in which the public sector assures certain revenue levels, or programs that stimulate private demand.

This section starts with a review of the alternative technologies available to provide broadband. It proceeds with a discussion of the experience with three main sets of public policy measures that are considered by many countries as vehicles to support broadband supply and demand: regulatory policy, taxes and subsidies, and other supportive measures.

3.1 Alternative broadband technologies

The vast majority of broadband subscribers in Michigan, as in the rest of the United States and the rest of the world, receive service via one of two wireline technologies: the digital subscriber lines (DSL) employed by telephone companies or cable operators' cable modems. Both technologies suffer from high costs for installing common plant and equipment and distribution costs that increase with the distance between customers. As a result, it is often cost prohibitive to provide broadband service with these technologies in rural areas, and even in urban areas economies of scale and density limit the number of financially viable wireline services. It is therefore not surprising that alternative technologies, most of them wireless, for providing broadband service have attracted considerable attention as potential solutions to coverage problems in rural areas and as competitive alternatives to cable and telco-supplied service in urban areas. Here we provide a brief overview of major wireless broadband technologies and new developments in wireline delivery of broadband.

3.1.1 Wireless broadband technologies

To date, most of the wireless implementations have taken one of three forms: satellite, WiFi, and WiMAX. Although each of these approaches has some advantages, none of these technologies have yet proven to be an adequate solution for next-generation broadband access.

Satellite

Satellite connections have been used to provide Internet access since the very early days of the network (Takei and Murai, 2003). The ability to reach anywhere in the world has made it the technology of choice for remote regions. However, high cost, high latency, and generally limited capacity, have restricted it to the Internet solution of last resort. Nonetheless, it is still widely used today and some entrepreneurs are developing new business models around this approach.

One of the more promising new uses of satellite is the service provided by O3B (2009). O3B operates a system of Medium Earth Orbit (MEO) satellites with a goal of providing Internet and other communications access in developing countries. By using MEO satellites, which have a lower orbit than their geosynchronous cousins, the latency from beaming a signal up to the satellite is substantially reduced, increasing the overall network performance. In addition, the business model is designed such that the satellite connection is only used for backhaul. Hence, a remote broadband provider can use a technology such as WiMAX to deliver Internet connectivity over the last mile, and O3B can provide the backhaul over their satellite network.

Although MEO systems have received some recent attention, they have a major drawback: they do not have a stationary orbit (Akyildiz, Uzunalio & Bender, 2004). This creates two problems. First, the satellite dish on the ground must constantly adjust itself to track with the satellite as it moves across the horizon, resulting in more complex and expensive equipment. This is in contrast to geostationary satellites in which a fixed antenna is pointed at the satellite and does not require subsequent movement. The second problem is that as the MEO satellite's orbit travels over the horizon and out of signal range, additional satellites are needed to provide coverage to the same region on the earth. In contrast, a single geostationary satellite can continuously cover a region.

Nonetheless, these MEO satellites have generated increased interest in satellites for Internet delivery. Their drawbacks are substantial enough that they are only considered viable solutions in the most distant rural regions. Yet some innovation continues in the satellite Internet sector. In particular, MEO has shown some promise in providing Internet backhaul in remote regions.

WiFi

WiFi, though originally designed as a local networking protocol, has periodically attracted attention as a last mile solution (Bar & Park, 2006). Some early municipal WiFi failures have tempered this interest (Gibbons & Ruth, 2006), but subsequent improvements in the equipment and technology have made this a viable solution in certain limited circumstances. As a result, although municipal WiFi has not fulfilled some of the original hopes, it is seeing a quiet but growing list of successful implementations.

The original value proposition for municipal WiFi was quite compelling. Previous home and office implementations had built the economies of scale necessary to drive down hardware costs and ensure a large potential customer base. The ability to use unlicensed spectrum further reduced the barriers to entry. The relative ease of installing these wireless networks in the home or office led many people to believe that the implementation would be technologically simple. By connecting the access points together in a mesh network, it even appeared that backhaul issues would be irrelevant.

Yet by 2007, municipal WiFi had been declared a failure. Most installations underestimated the number of access points that would be required, overestimated the network throughput, and failed to account for the technical support and user training costs associated with a network technology that is inherently less reliable than a wireline solution. Furthermore, the first generation of municipal WiFi equipment was built with little more than a consumer quality access point in a waterproof housing. These underpowered devices failed to deliver a quality of service that could compete with DSL or cable Internet.

Although the expectations and hype around municipal WiFi have waned, WiFi still plays a role in providing last mile Internet access. This is most apparent in the growing range of higher grade equipment. For example, it is now possible to establish a point-to-point WiFi connection over approximately 2.5 miles, and telco-grade last mile solutions are now available. Furthermore, as equipment quality has improved, business models have also become more realistic, and service providers have learned from past failures (Hamblen, 2008). Many cities are once again attempting to establish networks, particularly in their downtown areas.

Hence, it would be premature to write off WiFi as a potential last mile solution. However, the emphasis on urban centers does not help the larger problem of providing broadband access in unserved regions. These urban areas are already among the best served by other technologies, making WiFi more of a luxury good than a core broadband infrastructure technology.

WiMAX

One of the most promising—and most hyped—technologies for wireless broadband is WiMAX (WiMAX Forun, 2009). It should be noted that it is somewhat difficult to provide an overview of the costs and benefits of WiMAX as the phrase is used to describe a backhaul and a last mile technology, as well as a variety of similar but non-standards-compliant microwave-based broadband technologies. Nonetheless, given the potential to achieve higher speeds and longer ranges than WiFi, it has emerged as one of the key contenders in providing wireless broadband access.

WiMAX comes in two different flavors. The first is the last mile solution, defined under the IEEE 802.16e-2006 standard. It is designed to operate over much longer ranges than WiFi. Furthermore, it has additional quality of service mechanisms designed to help deliver services such as Voice over IP or video services. Recent versions of the WiMAX standards include mobile access. (Not all wireless technologies will work properly when the user is in motion.) The second variant of WiMAX is for backhaul, using the IEEE 802.16-2004 standard. In some cases, WiMAX backhaul is being used for corresponding WiMAX last mile solutions. But WiMAX backhaul has also received some interest for other last mile applications, such as cellular phones, municipal WiFi, or any other case where traditional wireline backhaul is cost-prohibitive.

The WiMAX standard does not specify which spectrum band it must use. It can use unlicensed spectrum, with a particular emphasis on the 5 GHz band, although many broadband providers are hesitant to use open spectrum out of quality of service considerations. The most widely deployed system by Sprint/Clearwire operates in licensed spectrum at 2.5 GHz (WiMAX Broadband Solutions, 2008).

The performance of WiMAX has been a matter of some debate. Although some claims including 50 Mbps at 30 miles have been cited, this is most likely a misinterpretation of the statistics that point-to-point connections can often travel approximately 30 miles and that connection speeds near the antenna can achieve 50 Mbps or greater. Further, most existing metrics do not account for performance when multiple users are accessing the network. Once estimate states that a more likely actual performance for last mile WiMAX is 1-2 Mbps up to a range of 5 miles serving 10 simultaneous connections (Hillestad, Perkis, Genc, Murphy & Murphy, 2006). Such speeds would certainly be superior to dial-up access, but would still be inadequate for next-generation broadband demands.

The lack of standards compliance in existing implementations may threaten the long-term viability of WiMAX. Whereas WiFi is a case study in the cost reducing benefits from the scale economies that come from standards compliance, the lack of WiMAX standards compliance will limit realization of these potential economies of scale. As a result, WiMAX may not see the precipitous drop in component prices that contributed to the popularity of WiFi.

In general, WiMAX is surrounded with a lot of promise, hype, and uncertainty. As companies begin large-scale implementations of the technology, it will be easier to distinguish fact from fiction. It is still too early to fully evaluate the costs and benefits of WiMAX and its closely related technologies.

3.1.2 Wireline connections

Although much of the hype in Internet technologies is currently in the wireless sector, there have also been several recent wireline trends of note. The first is the contest of Fiber to the Home (FTTH) versus pair-bonding, two different approaches deployed by Verizon and AT&T respectively. Although fiber is the gold standard for network access, pair bonding is a more cost effective last mile solution. From the legacy phone infrastructure, most buildings already have two pairs of copper wire that were historically used to provide two phone lines, even if the second line was not used. These two lines can be combined together and treated as a single line, effectively doubling the network capacity. AT&T claims to be able to provide 30 to 60 Mbps over these bonded connections (Gubbins, 2007). These speeds are much higher than the average home consumer currently demands, though such speeds are still only approximately 10% of those possible under Verizon's fiber connections.

The second wireline item of note is the state of broadband over power line (BPL). Although BPL has received some renewed interest with the recent broadband stimulus package, it has yet to see any commercial success. Yet IBM has recently invested in DS2, a supplier of BPL equipment (Gardner, 2009). This has made some pundits speculate that there may yet be some potential in the BPL market.

3.2 Measures affecting broadband investment and demand

Regulation and other public policy measures define the rights and obligations of the different stakeholders in the ICT (information and communication technology) value network. It therefore affects not only the regulated providers of communication services but also their unregulated competitors. During the past two decades, regulation has shifted from retail to wholesale forms of regulation. Therefore, it directly and indirectly affects the supply side of the market but affects the demand side only secondarily. Regulatory provisions affect the horizontal relations between providers (e.g., between ILECs and CLECs) as well as the vertical relations between market players (e.g., between network operators and content and application providers).

The most important factor under the control of policy makers is the degree of openness of a market. One of the most consistent research findings is that competition is the single most important factor boosting broadband supply (e.g., Distaso, et al., 2006; Wallsten, 2008). Given the high technological dynamic and convergence in advanced communication markets, new forms of inter-modal competition are emerging, for example, between wireline and wireless services. Moreover, competitive rivalry may emerge between established and new service providers, often entering from unexpected market segments (e.g., Apple's iPhone). Conventions and methods used by regulators to assess the effectiveness of competition therefore need to be adjusted to reflect these dynamic aspects of competition. For example, rules of thumb requiring the presence of four to five firms for competition to be effective (implicit in regulatory and antitrust doctrine) may not be appropriate any more. It is therefore sensible that regulatory agencies are paying more attention to the role of dynamic entry barriers, the effects of regulatory measures on investment, and their repercussions for innovation. One more appropriate model is to look at competition as a two-stage process: during the first stage, suppliers are in a dynamic technology race to deploy infrastructure (Woroch, 2002) and in a related second stage they compete for consumers by differentiating their prices and service offerings. Whereas price competition is an important form of rivalry during the second stage, it is less important and may even be detrimental during the first stage. Thus, effective competition in broadband may exist under conditions with few suppliers or in situations where competitors operate in close proximity to each other so that they constitute a credible threat of entering an adjacent location.

Recent research has also provided preliminary evidence that regulation influences the balance between short-run and long-run competition in the market for telecommunications. Short-run competition provides immediate consumer benefits via lower prices but it reduces the ability of firms to generate funds to innovate and to invest in risky projects. Long-run competition provides sustained consumer benefits through improvements of the price-quality ratio of products and services. Recognition of this relation dates back to observations made by Schumpeter (1942). This pattern has since been identified in many empirical industry studies (Aghion et al., 2005) including telecommunications (Friederiszick at al., 2006; Waverman, 2007). Regulatory policy therefore faces the challenging task to find a balance between the static and dynamic aspects of efficiency. The design of good regulatory policy therefore requires an explicit recognition of this trade-off.

For this reason, the evidence with regard to wholesale regulatory measures such as unbundling and open access requirements is more heterogeneous. In either case, the regulator can choose from a broad range of options from more to less stringent requirements for unbundling and openness. The specific approach determines rights and obligations between incumbents and new entrants and has effects on the intensity of competition within the industry segment. Empirical research has found that wholesale regulation may have the desired effect of facilitating competition if the market is highly concentrated to begin with (Distaso et al., 2006). However, stringent wholesale regulation may backfire and reduce the incentive to invest and to innovate if the market already shows signs of competition (Hazlett, 2008; Wallsten, 2009). More research is necessary to operationalize the strength of the relation, which may also vary depending on location.

Although research has provided plenty of evidence as to the positive effects of competition on broadband diffusion, there is also substantial understanding that competition and market forces do not work in all conditions. If demand is geographically too dispersed or the level of demand at a specific location too meek to generate an acceptable financial return, decentralized market decisions may not bring forth the desired infrastructure investment or only at a pace that is unacceptable to a community (Bauer et al., 2003). Likewise, if users of broadband services are not fully aware of its actual or potential benefits (e.g., because they do not see the advantages of using broadband for educational or health care purposes), their willingness to pay may be too low, resulting in an investment level that is below a socially optimal level. Lastly, if some of the benefits of broadband access are public goods, that is they accrue to the community at large, private willingness to pay and invest may be insufficient. In all these cases, collective intervention, either by government, cooperation among private stakeholders, or in public-private partnerships, may help overcome the weakness of the market.

Preliminary empirical evidence for the U.S. seems to indicate that investment by municipalities and public utilities in communication access networks is indeed complementary to private sector activity and does not reduce it (Ford, 2007; Hauge et al., 2008). The evidence is much more scattered and hence less conclusive with regard to government investment in wireless networks and backbone infrastructure. During the past decade, many municipalities facilitated deployment of wireless networks. According to Huang (2008), three models have emerged in the U.S.: (1) projects without any public subsidy, (2) projects in which the municipality acts as an anchor tenant to strengthen the investment case; and (3) fully subsidized projects. Engineering cost models and practical experience show that full coverage is only possible with significant subsidies, but this may change with the emergence of WiMAX and other more cost effective platforms. In the wake of the economic crisis of 2008, many countries outside of the U.S., including Australia and the UK, have announced or accelerated existing initiatives to bring broadband closer to remote areas. Such national initiatives are not at all new and their overall success is somewhat uneven. In the 1970s, France initiated an ambitious plan to deploy broadband cable to all households but had to fold it when funding could not be raised; likewise, Germany during the 1980s envisioned deployment of fiber networks but never realized the plan. On the other hand, public investment in the early American Internet and more recently in South Korea and Japan seems to have jump-started private sector investment.

In addition to direct investment or subsidies to private investors, government has several other options to influence communications infrastructure investment. One important vector is to use government to generate a demand-pull effect, for example, by developing e-government services. Another is support for educational programs and measures of knowledge diffusion that enhance digital literacy. Programs supporting research and development, tax credits, and strategic national and regional champion programs (e.g., the European Union's smart car initiative) are all used in attempts to support communication infrastructure development. Relatively little is known about their effectiveness, although they can contribute to an overall policy and economic climate favorable to infrastructure investment. Some measures, such as support for education and business development, if appropriately structured may be complementary to infrastructure investment and strengthen the case for private sector investment (LaRose et al., 2008).

4. Conclusions

As this brief report indicates, broadband creates many potential benefits for the economy. It can contribute to higher quality services in education and health care and may also facilitate civic participation and democracy. Many factors influence the adoption and use of broadband and no panacea exists for state policy makers. Rather, the discussion in this report suggests a mix of measures that affect the supply and demand of broadband, ranging from financial support (where possible) to concerted efforts in education and worker training. Given the dynamic changes that affect high-technology industries, continuous monitoring and adaptation to changing circumstances will be an important component of forward-looking policy.

References

Aghion, P., Bloom, N., Blundell, R., Griffith, R., and Howitt, P. (2005). "Competition and Innovation: An Inverted-U Relationship." *Quarterly Journal of Economics*, 120, 701-728.

Akyildiz, I., Uzunalio, H. and Bender, M. (2004), “Handover management in Low Earth Orbit (LEO) satellite networks,” *Mobile Networks and Applications, 4*, 301-310.

Bar, F. and Park, N. (2006), “Municipal WiFi networks: The goals, practices, and policy implications of the U.S. case,” *Communications & Strategies, 61*, 107-125.

Bauer, J. M., Kim, J. H., and Wildman, S. (2003). “Broadband Deployment: Toward a More Fully Integrated Policy Perspective,” in *Down to the Wire: Studies in the Diffusion and Regulation of Telecommunications Technologies*. A. L. Shampine (ed.). Hauppauge, NY: Nova Science Publishers.

Bresnahan, T. and Trajtenberg, M. (1995), “General Purpose Technologies ‘Engines of Growth’?,” *Journal of Econometrics, 65*, 83-108.

Communications Workers of America (CWA) (2008). A report on Internet speeds in all 50 states. Available at http://www.speedmatters.org/page/-/SPEEDMATTERS/Publications/cwa_report_on_internet_speeds_2008.pdf?nocdn=1

Crandall, R. W., and Singer, H. J. (2010). The Economic Impact of Broadband Investment. Study for Broadband America.

Crandall, R., Jackson, C., and Singer, H. J. (2003), The Effects of Ubiquitous Broadband Adoption on Investment, Jobs, and the U.S. Economy.” Study by Criterion Economics, L.L.C. for the New Millennium Research Council.

Crandall, R. W., Lehr, W., and Litan, R. (2007). The Effects of Broadband Deployment on Output and Employment: A Cross-Sectional Analysis of U.S. Data. *The Brookings Institution Issues in Economic Policy*(6), 1-33.

David, P. (May 1990), “The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox,” *American Economic Review*, 355-361.

Distaso, W., Lupi, P., and Manenti, F. (2006). "Platform Competition and Broadband Uptake: Theory and Empirical Evidence from the European Union." *Information Economics and Policy*, 18(1): 87-106.

Dutz, M., Orszag, J., and Willig, R. (2009). Consumer Benefits of Broadband Connectivity for U.S. Households, Compass Lexecon.

FCC (Federal Communication Commission) (2010). High-speed services for Internet access: status of December 31, 2009.

FCC (Federal Communication Commission) (2009). High-speed services for Internet access: status of December 31, 2007.

FCC (Federal Communication Commission) (2007). High-speed services for Internet access: status of December 31, 2006.

FCC (Federal Communication Commission) (2007). High-speed services for Internet access: status of June 30, 2007.

FCC (Federal Communication Commission) (2006). High-speed services for Internet access: status of December 31, 2005.
FCC (Federal Communication Commission) (2006). High-speed services for Internet access: status of June 30, 2005.
FCC (Federal Communication Commission) (2005). High-speed services for Internet access: status of December 31, 2004.
FCC (Federal Communication Commission) (2004). High-speed services for Internet access: status of June 30, 2004.
FCC (Federal Communication Commission) (2004). High-speed services for Internet access: status of December 31, 2003.
FCC (Federal Communication Commission) (2003b). High-speed services for Internet access: status of December 31, 2002.
FCC (Federal Communication Commission) (2003a). High-speed services for Internet access: status of June 30, 2003.
FCC (Federal Communication Commission) (2002b). High-speed services for Internet access: status of June 30, 2002.
FCC (Federal Communication Commission) (2002a). High-speed services for Internet access: status of December 31, 2001.
FCC (Federal Communication Commission) (2001). High-speed services for Internet access: subscription as of June 30, 2001.
Ford, G. S. (2007). Does a Municipal Electric's Supply of Communications Crowd Out Private Communications Investment? An Empirical Study. *Energy Economics, 29*(3), 467-478.
Friederiszick, H. W., Grajek, M., and Röller, L.-H. (2008). Analysing the Relationship between Regulation and Investment in the Telecom Sector. ESMT White Paper WP-108-01.
Gardner, W. D, (2009, September 9), “IBM financing BPL smart boxes,” *Information Week*.
Gibbons, J. and Ruth, S. (2006), “Municipal WiFi: big wave or wipeout?” *IEEE Internet Computing*, *10*, 66-71.
Gillett, S. E., Lehr, W. H., and Osorio, C. A. (2006). Municipal Electric Utilities' Role in Telecommunications Services. *Telecommunications Policy, 30*(8-9), 464-480.
Greenstein, S. and McDevitt, R., “The Broadband Bonus: Accounting for Broadband Internet’s Impact on U.S. GDP,” Northwestern University (January 2009).
Grubesic, T. H. (2006). "A spatial taxonomy of broadband regions in the United States." *Information Economics and Policy*, 18(4): 423-448.
Gubbins, E. (2007, Jan 22), “AT&T puts its bet on bonded VDSL2,” *Telephony Online*.
Hamblen, M. (2008, June 14), “Wireless ISP steps forward in Portland after failure of free WiFi model,” *Computer World*.
Hardy, A. (December 1980), “The Role of the Telephone in Economic Development,” *Telecommunications Policy*, 278-286.

Hauge, J. A., Jamison, M. A., and Gentry, R. J. (2008). "Bureaucrats as Entrepreneurs: Do Municipal Telecommunications Providers Hinder Private Entrepreneurs?" *Information Economics and Policy*, 20(1): 89-102.

Hazlett, T. W., and Caliskan, A. (2008). Natural Experiments in U.S. Broadband Regulation. *Review of Network Economics, 7*(4), 460-480.

Hillestad, O., Perkis, A., Genc, V., Murphy, S., and Murphy, J. (2006). *Delivery of On-Demand Video Services in Rural Areas via 802.16 Broadband Wireless Access Networks*. Workshop on Wireless Multimedia Networking and Performance Modeling.

Huang, K. C. (2008). *Can City-wide Municipal WiFi be a Feasible Solution for Local Broadband Access in the US? An Empirical Evaluation of a Techno-Economic Model. Ph.D. dissertation.* University of Pittsburgh, Pittsburgh, PA.

Horrigan, J.B. Home Broadband Adoption 2008. Pew Internet and American Life Project; http://www.pewinternet.org/~/media//Files/Reports/2008/PIP_Broadband_2008.pdf

Hughes, A., and Scott Morton, M., "ICT and Productivity Growth—The Paradox Resolved?" Center for Business Research, University of Cambridge, Working Paper # 316. December 2005.

Jacobsen, K. F. L., "Telecommunications - A Means to Economic Growth in Developing Countries?" Report R 2003: 13 (2003), Chr. Michelsen Institute, Bergen, Norway.

Jorgenson, D. and Vu, K. (2005), "Information Technology and the World Economy," *Scandinavian Journal of Economics*, vol. 12, 631-650.

Kolko, J. (2010), "Does Broadband Boost Local Economic Development?" Report from the Public Policy Institute of California.

LaRose, R., Gregg, J., Strover, S., Straubhaar, J., and Inagaki, N. (2008), "Closing the Rural Broadband Gap. Study supported by the US Department of Agriculture." East Lansing, MI, Michigan State University, available at https://www.msu.edu/~larose/ruralbb/.

Madden, G. and Savage, S. (1998), "CEE Telecommunications Investment and jEJcjonomic Growth," *Information Economics and Policy*, 10, 173-195.

Machlup, F., *The Production and Distribution of Knowledge in the United States*, Princeton, New Jersey: Princeton University Press, 1962.

O3B Networks, (2009), "O3B Networks Home." Retrieved from http://www.o3bnetworks.com/ on October 4, 2009.

OECD (Organization for Economic Co-operation and Development) (2010), Broadband Portal, online resource available at http://www.oecd.org/sti/ict/broadband, data retrieved March 10, 2010.

OECD (Organization for Economic Co-operation and Development) (2009), Broadband Portal, online resource available at http://www.oecd.org/sti/ict/broadband, data retrieved June 14, 2009.

PEW (2008). Internet & American Life Survey 2008, retrieved from http://www.pewinternet.org/Reports/2008/Home-Broadband-2008.aspx.

Röller, L. and Waverman, L. (2001), "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach," *American Economic Review*, 74, 909-923.

Schumpeter, J. A. (1942). *Capitalism, Socialism, and Democracy*. New York: Harper.

Stenberg, P., Morehart, M., Vogel, S., Cromartie, J., Breneman, V., and Brown, D. (2009), "Broadband Internet's Value for Rural America," USDA Economic Research Service.

Takei, J. and Murai, J. (2003), "Satellite Communication in the Internet: Its history and the Technology." Symposium on Applications and the Internet Workshops (SAINT 2003 Workshops).

Thompson, H. G. and Garbacz, C. (2007), "Mobile, Fixed Line and Internet Service Effects on Global Productive Efficiency," *Information Economics and Policy*, 19, 189-214.

US Bureau of the Census (2009a), County Business Patterns, Retrieved January 9, 2009, from http://www.census.gov/econ/cbp/index.html

US Bureau of the Census (2009b), Population Estimates Program. Retrieved January 9, 2009, from http://factfinder.census.gov/home/en/official_estimates_2007.html.

Van Gaasbeck, K. A., Perez, S., Sharp, R., Schaubmayer, H., Owens, A., and Cox, L. (2007). Economic Effects of Increased Broadband Usage in California: Sacramento Research Institute.

Wallsten, S. (2008). Understanding International Broadband Comparisons. Washington, DC: Technology Policy Institute, available at SSRN: http://ssrn.com/abstract=1136831. Hazlett, T. W., & Caliskan, A. (2008). Natural Experiments in U.S. Broadband Regulation. *Review of Network Economics*, *7*(4), 460-480.

Wallsten, S., and S. Hausladen, S. (2009), Net Neutrality, Unbundling, and Their Effects on International Investment in Next-Generation Networks. *Review of Network Economics,* 8(1), 90-112.

Waverman, L., M. Meschi, B. Reillier, and K. Dasgupta (2007), Access Regulation and Infrastructure Investment in the Telecommunications Sector: An Empirical Investigation. London, Law and Economics Consulting Group with the Support of ETNO.

WiMAX Broadband Solutions, Inc. (2008), "Sprint Nextel in Clearwire spectrum swap, stepping up RBOC challenge." Retrieved from http://www.wimaxforum.org/resources/frequently-asked-questions on October 4, 2009.

WiMAX Forum (2009), "Frequently Asked Questions: WiMAX Forum. http://www.wimaxforum.org/resources/frequently-asked-questions. Retrieved October 4, 2009.

Woroch, G. A. (Fall 2002). "Open Access Rules and the Broadband Race." *The Law Review of Michigan State University Detroit College of Law*, 719-742.