Economic Benefits of Expanding Broadband in Select Missouri Counties

June 2021

Extension
University of Missouri

Exceed

Table of Contents

Executive summary ..... **iii**

Economic Benefits of Broadband Expansion **1**

Economic Benefits by Category 1

Methodology **5**

Key Assumptions 5

Broadband Benefit Assumptions 8

Economic Model 10

Economic Benefits of Broadband Expansion in Select Missouri Counties **11**

County Selection Process 11

Selected County Characteristics and Direct Model Inputs 12

Economic Benefits Summary for the Select Missouri Counties 13

Individual County Summaries **15**

Bollinger County, Missouri, Broadband Expansion Economic Benefit Analysis 16

Henry County, Missouri, Broadband Expansion Economic Benefit Analysis 18

Nodaway County, Missouri, Broadband Expansion Economic Benefit Analysis 20

Conclusion **22**

Executive Summary

Gauging precisely how broadband impacts the economy — in terms of jobs, gross domestic product and other economic measures — is difficult as benefits are intertwined with advances in computing and improved digital literacy. Other gains, such as quality-of-life improvements, are easy to recognize but harder to quantify. Finally, broadband installation and household adoption occurring over a long period means broadband's economic benefits take time to unfold.

Despite these measurement challenges, recent research provides a practical approach to understanding how broadband expansion benefits local economies over many years. Economic gains tied to broadband include the following:

- **Broadband investment:** Installing broadband infrastructure to previously unserved households will generate construction-related economic gains over several years.
- **Telemedicine:** Virtual health care saves households money by reducing visits to the emergency room and doctor's office. It also reduces lost income associated with travel and missed work.
- **Education productivity:** Access to online resources increases teacher productivity.
- **Income:** Broadband technology enables more effective job matching, online training, access to goods and services, and it improves productivity that can raise household and farm incomes.
- **Employment:** Community job growth, especially in knowledge-intensive services, leads to entrepreneurial, investment and productivity gains.

Although necessary, broadband access is not sufficient for economic growth. To realize economic benefits, community residents and businesses must increasingly adopt broadband service and gain skills in using broadband-related technologies. **Increased broadband adoption drives long-term economic gains.**

About this study

This study estimated the 10-year economic benefits that would result from expanding fixed broadband adoption in three Missouri counties that vary in their existing adoption levels and population size: Bollinger, Henry and Nodaway. Fixed broadband includes fiberoptic, cable, or DSL (digital subscriber line) technologies considered more reliable that other broadband connections. The study considered minimum and maximum broadband adoption growth scenarios to capture the range of potential economic outcomes in a 10-year period. The minimum scenario assumes a 10 percentage point increase in household fixed broadband adoption for Bollinger and Henry counties, and a 7.5 percentage point increase for Nodaway County. In the maximum scenario, household fixed broadband adoption increases by 20 percentage points for Bollinger and Henry counties, and 15 percentage points for Nodaway County. Nodaway County had a higher household fixed broadband adoption level already, so gains are assumed to be less than the other two counties.

Key study findings

The following discussion describes how job, labor income and gross domestic product indicators would change under the minimum and maximum broadband adoption gains.

Job and labor income growth are the most tangible economic benefits expected from expanded broadband adoption:

- In both scenarios, all counties see substantial employment growth in the 10-year period. Exhibit 1 shows employment gains by year 10 for Bollinger (79), Henry (261) and Nodaway (143) counties under the minimum scenario. Job gains double in the maximum scenario.
- For context, Exhibit 1 shows the average annual job growth rates as a percent of 2019 employment along with county job trends from 2014 to 2019. The minimum scenario shows annual job growth of 0.8% for Nodaway County and 1.6% for Bollinger County. Those counties had slower growth rates — 0.2% and 0.6%, respectively — from 2014 to 2019. Henry County had average annual job declines of 3.4% from 2014 to 2019. Annual gains of 3.2% in the maximum scenario, all else equal, would largely wipe out those declines.
- Labor income would also grow further as broadband use expands; see Exhibit 1. From $16 million in total labor gains for Bollinger County in the minimum scenario to $148 million for Henry County in the maximum scenario, these income gains would increase spending in local communities and benefit businesses and residents alike. Labor income would largely mirror job gains in average annual growth rates.

Gross Domestic Product (GDP) communicates the value of all final goods and services produced in a county. It represents the largest measure of economic benefits from broadband expansion.

- The study projected that GDP would increase significantly under both minimum and maximum scenarios; see Exhibit 1. For example, Bollinger County gains $23 million in total GDP over 10 years in the minimum scenario and nearly $39 million in the maximum scenario. The more populated Nodaway and Henry counties have greater GDP increases ranging from $56 million to $206 million, depending on the scenario.
- With modest 10 percentage point broadband adoption gains, Bollinger and Henry counties would **increase their annual GDP by an estimated 1.4% and 1.7%**, respectively, relative to their 2019 GDP levels. Annual GDP growth would total an estimated 2.4% and 3.2%, respectively, assuming 20 percentage point broadband adoption gains in these counties.
- In Nodaway County, with 7.5 percentage point broadband adoption gains, **annual GDP would**

How Significant is GDP Growth?

GDP measures total economic growth that results in new income and profits circulating within a community.

For the three counties, the minimum growth scenario shows annual, inflation-adjusted GDP increases of less than 2%.

Even those gains, which may seem modest, are significant. For example, Bollinger County had a 2.2% annual GDP growth rate from 2014 to 2019. Adding 1.4% to the county's economy each year would, all else equal, **boost GDP annual gains to 3.6%.**

This represents a 64% increase in annual GDP gains

For context, the annual GDP growth rate from 2014 to 2019 for Missouri and the U.S. averaged 1.1% and 2.5%, respectively.

grow by 0.8% compared with 2019 levels. Annual GDP would grow by 1.5% assuming the maximum broadband adoption gain of 15 percentage points.

Exhibit 1 shows how the three counties' economies benefit from fixed broadband expansion in terms of county employment, labor income and GDP under the two scenarios.

Exhibit 1. Minimum and Maximum Fixed Broadband Adoption Scenario Summaries of the Employment, Labor Income and GDP Benefits by County

	Bollinger	Henry	Nodaway
Minimum Scenario - 10 Percentage Point Increase in Household Fixed Broadband Adoption*			
10-Year Total Economic Benefits of Broadband Expansion			
Employment Gain in Year 10	79	261	143
Total Labor Income *(in Millions)*	$16.4	$78.8	$37.3
Total Gross Domestic Product *(in Millions)*	$23.3	$109.4	$55.7
Average Annual Gains of Broadband Expansion Compared to 2019 Figures and Prior 5-Year Trends			
Annual Avg. Employment as % of 2019 Emp.	1.6%	1.5%	0.8%
*For Reference: Annual Employment % Change, 2014-19***	*0.2%*	*-0.7%*	*0.6%*
Annual Avg. GDP as % of 2019 GDP	1.4%	1.7%	0.8%
*For Reference: Annual GDP % Change, 2014-19***	*2.2%*	*-3.4%*	*-1.2%*
Maximum Scenario - 20 Percentage Point Increase in Household Fixed Broadband Adoption*			
10-Year Total Economic Benefits of Broadband Expansion			
Employment Gain in Year 10	159	524	287
Total Labor Income *(in Millions)*	$26.7	$148.4	$68.8
Total Gross Domestic Product *(in Millions)*	$38.7	$205.9	$102.8
Average Annual Gains of Broadband Expansion Compared to 2019 Figures and Prior 5-Year Trends			
Annual Avg. Employment as % of 2019 Emp.	2.7%	2.9%	1.5%
*For Reference: Annual Employment % Change, 2014-19***	*0.2%*	*-0.7%*	*0.6%*
Annual Avg. GDP as % of 2019 GDP	2.4%	3.2%	1.4%
*For Reference: Annual GDP % Change, 2014-19***	*2.2%*	*-3.4%*	*-1.2%*

*Notes: *Nodaway County gains are assumed to be 7.5 and 15 percentage points for minimum and maximum scenarios, respectively, due to higher initial broadband adoption levels. ** Reference source is U.S. Bureau of Economic Analysis, 2014-19. Employment is average annual growth rate. GDP is compound annual growth rate in real dollars.*

This study intended to test whether the methodology and scenarios used in the analysis reasonably estimate broadband adoption benefits. The findings are specific to the three counties analyzed, but comparable Missouri counties would likely see similar gains. Given the COVID-19 pandemic and the country's resolve to better connect its economy, this study creates a timely foundation for understanding how broadband expansion economically benefits Missouri communities — a foundation on which further research can build.

Economic Benefits of Broadband Expansion

This analysis will document the economic benefits arising from expanded broadband availability and the ensuing adoption. We begin by defining important terms in the context of this study.

The term "broadband" or "fixed broadband," is used interchangeably in this analysis, and it refers to moderate-to-high speed broadband services delivered by fiberoptic, cable, or DSL (digital subscriber line) technologies. This "fixed broadband" definition excludes satellite, wireless or cellular technologies currently considered less reliable.

Moderate-to-high speed "broadband services" is defined by the Federal Communications Commission (FCC) as broadband speed of at least 25 Mbps (transfer of "megabits per second") of download speed and at least 3 Mbps of upload speed, which is often referred to as 25/3. The 25/3 speed is currently assumed to be sufficient for communities to benefit economically. However, what counts as "sufficient" will change as applications and technologies used by households demand more information and faster broadband service, so this assumption must be revisited periodically.

"Broadband availability" refers the presence of broadband infrastructure so that a household or business can request and receive that service. The FCC provides information on broadband availability, but the quality of those data has been criticized for overstating coverage and speed.[1] Due to FCC data issues, we use U.S. Census data to estimate households in a county needing broadband infrastructure.

"Broadband adoption" refers to the number of households in a county that subscribe to fixed broadband services. This figure comes from the U.S. Census Bureau's American Community Survey (ACS) 5-Year estimates.[2] The household fixed broadband adoption level is an important driver of economic benefits. If consumers perceive that broadband service is too costly, they will not adopt the service even if it is available. Other reasons for non-adoption include digital illiteracy or simply not wanting broadband services.

For more information on defining broadband, availability, and access, see the University of Missouri Extension guide DM601, Broadband Technologies: A Primer on Access and Solutions.

Economic Benefits by Category

This section reviews the different economic benefits researchers have found after the introduction of broadband services. Several studies document the relationships, or correlation, between broadband adoption and economic gains. Causal research findings, however, statistically isolate those relationships, to suggest cause-and-effect. These studies are particularly useful in an economic benefit analysis.

Telemedicine

Telemedicine creates a range of benefits to health care providers and the patients they serve. Health care providers benefit from rural hospital cost savings due to outsourcing services and increased lab and pharmacy work that can be performed locally.[3] Telemedicine allows patients to reduce travel

time and the associated lost work income. Virtual health care consultations can also save patients money as these services cost less and can reduce the number of emergency room visits.[4,5]

Telemedicine gains to patients, enabled by broadband adoption, are easy to understand from a cost perspective. However, the benefits to health care providers and communities are more complex as local spending can be transferred in different directions. For example, a rural hospital can reduce costs by contracting with a larger city hospital to provide specialized services. That spending would in turn benefit the urban community, while reducing the need for doctors at the rural location. This can lower the overall cost for a rural hospital and keep it financially viable, but it does mean less high-income employment in the community. Moreover, a rural community can benefit from spending at local labs or pharmacies because the telemedicine patient is less likely to travel to a larger city hospital for diagnosis. In these instances, urban labs and pharmacies lose income.

Education Productivity

The COVID-19 pandemic brought urgent attention to the need for remote learning. It highlighted how learning losses resulting from school closures has disadvantaged students, especially those from lower-income families, perhaps diminishing their lifetime of earnings.[6] While broadband service is a basic requirement for remote learning, many rural school districts in 2020 struggled to help students that lacked home broadband access.[7] COVID-19 has created a large experiment on the benefits and costs of remote learning that is still in progress. Prior to the pandemic, research on causal educational benefits from broadband expansion largely focused on cost savings to schools to provide education or in teacher's time to find information.[8]

Research has also demonstrated that having broadband access to the learning resources positively correlates with better school outcomes for students.[9] But quantifying the benefits in a causal manner can prove difficult. However, new information surrounding student learning during the COVID-19 pandemic, and increased interest in broadband access, may result in new causal research into educational benefits in the years ahead.

Household Income

The potential to raise incomes with broadband adoption makes intuitive sense as people can bolster their pay with greater access to online educational resources, productivity tools, and the ability to find more job opportunities. Given that it is so strongly linked with other factors such as educational and skill attainment and job selection, isolating income gains from broadband adoption can prove challenging.

One often-cited study estimated household income gains from increased broadband adoption that can be interpreted as causal.[10] The research shows that as nonmetro counties move from moderate-to-higher levels of broadband adoption, the median household income rises by 1.3% over ten years.

The reasons for income increases are complex and related to other benefits used to measure economic gains from broadband. Educational attainment, employment opportunities, productivity and other factors are intertwined with income so that estimating separate gains from these factors can risk overestimating economic benefits. Conversely, including modest income gains with other

related measures can serve as a proxy for benefits, such as quality-of-life or the ability to remote work, that are harder to quantify.

Farm Income

Broadband access is becoming increasingly important for agricultural producers. An early study of farming-related broadband benefits suggested that economic gains came from the real-time information on weather, pricing, and management practices. [11] This 2011 study found that U.S. Department of Agriculture broadband loans administered in the early 2000s had a positive impact on farm profits of 3%, driven mainly by increased crop sales. Livestock or animal production operations were less sensitive to broadband access. Many agricultural producers now have access to real-time market and weather data using smart phones, so many of these benefits are already integrated into the farm economy.

However, a more recent study of farming gains confirmed the on-going benefit of broadband to crop production. [12] The 2020 study found that broadband availability had a small, but statistically significant, impact—a 1% increase in broadband access caused a 0.1% increase in crop yields. Explanations for these gains include the use of precision farming techniques and machinery.

Employment

Installing broadband infrastructure in a community spurs immediate, but temporary, employment gains in construction and supply-chain industries. While important, these short-term job gains can be minimal as much of the spending for specialized workers and materials goes to firms outside the county. Increased broadband adoption, however, creates lasting employment gains to the local economy.

Employment gains from broadband expansion encompass the positive impacts that this technology has on business growth, investment, entrepreneurship, and productivity gains. Whether broadband facilitates a new business location or enables the expansion of current commercial activities, employment increases are tangible economic benefits that can be seen, and by extension, can lower unemployment levels. While research shows a correlation between broadband and economic development, a handful of studies attempt to isolate the cause-and-effect, or causal, relationship between greater access and specific business and workforce gains.

Business formation is an important benefit arising from broadband expansion. Several studies have found that broadband expansion has positive impacts on new firm creation in rural counties.[13] Another study found that the number of knowledge-intensive professional and business service firms grew as the number of broadband providers increased.[14] Similar findings from 2012 research confirmed that benefits of broadband expansion can be seen in service industries that rely most heavily on information technology.[15] The research indicated that even though broadband expansion is associated with employment growth, it does not increase average pay. One possible explanation is that the draw of employment opportunity increased the population, and therefore the labor supply, which suppressed wage increases.

New and expanding firms increase employment, but growth from broadband expansion can be harder to detect in urban areas. A 2014 study found that employment gains from broadband adoption are seen in nonmetro counties, with no meaningful relationship uncovered in metropolitan counties.[16] One reason may be that the gains in urban areas are already incorporated into the economy or that other factors contribute to job growth. Lower unemployment levels, expected when employment increases, were also found in this research and, more recently, from a 2020 study of high-speed broadband benefits.[17]

Broadband productivity benefits in knowledge-intensive industries have also been documented, along with a dilemma for rural areas with less educated or skilled workers.[18] A 2013 study found that broadband produces positive productivity impacts when used by a highly-educated or skilled workforce. Rises in productivity also impacts income as more productive employees can be paid more. The research suggests that rural areas with broadband availability, but with lower workforce education/skill levels, may see employment losses as businesses outsource work to other areas or use technology to substitute for workers. That is the other impact of productivity; while it benefits businesses and worker income, it can mean less employment in the local area.

A 2020 study also found productivity benefits from broadband that was influenced by factors such as distance to metropolitan areas and educational attainment.[19] The research supported similar findings from other studies that a more educated workforce, in closer proximity to a metropolitan area, is related to higher productivity gains.

Other Benefits

Expanded broadband adoption spurs additional gains that are harder to quantify. They are not explicitly captured in this economic benefit analysis, but are nevertheless important to recognize as attempts to measure their influences will likely be the work of future research.

A 2020 study of high-speed broadband in Chattanooga, TN highlights a number of important benefits found in the metro community over ten years.[20] Many of these gains are difficult to measure, but the study discusses potential benefits that include improvements to:

- **Civic services:** The city utility implemented "smart grid" technologies to reduce outages from major weather events, lower long-term operating costs, and lower rates to customers. Other potential benefits included more efficient transportation services and increased public safety.
- **Quality-of-life:** The ability to shop online and the learn skills remotely, such as fixing a broken faucet, can provide cost savings and convenience to consumers.
- **Remote work/learning:** Telecommuting gives some workers the ability to earn income during events like the COVID-19 pandemic. Over the long-term, it can also reduce traffic congestion and lower costs for both workers and businesses. Similarly, the ability of students to learn from home enabled the continuation of learning during the pandemic.

There is certainly no way to capture all the positive and, sometimes disruptive, effects of broadband expansion. The challenges of the COVID-19 pandemic illustrate how quickly technologies, like

broadband, can shift benefits to different populations, businesses, and places. Over the long-term the impact of broadband, just like highways and other connecting technologies, will benefit and shape the economy to create new jobs, industries, and institutions. But the pandemic has shown that those unable to access broadband, either by their location, type of work, or financial situation, are quickly at a comparative disadvantage as the economy evolves.

Methodology

A recent Purdue University study informs the methodological approach used in this analysis, while several causal research papers underpin the assumptions for economic benefit inputs.[21] Given rapid changes in our economy and broadband service provision during the COVID-19 pandemic, estimating future broadband benefits is not straightforward. Recognizing that broadband adoption will accelerate in the coming years, however, this analysis lays the groundwork for continued research as the new, more connected, economy emerges.

Key Assumptions

Economic benefits are divided into general assumptions that underpin the basics of investment timing and household broadband adoption gains, and assumptions that cover the specific benefit areas of telemedicine, education productivity, income and employment.

Broadband investment and timing

The build out of broadband services represents an initial cost to the Internet Service Provider (ISP) to pay for materials and labor. The ISP investment activities create community-level economic benefits as workers are paid, supplies purchased, etc. for the duration of the project. These temporary activities directly add new income to the county through local spending which in turn spurs indirect benefits as some part of that spending circulates throughout the local economy. However, specialized labor or supplies are needed from outside the county and that spending does not influence local income or jobs.

The investment to bring fixed broadband to households over ten years is assumed to be $3,500 per household. The November 2020 FCC Connect America Fund Phase II Missouri broadband applications informed this figure. The auction had 12 winning Missouri bidders that, on average, indicated a cost per location of nearly $2,700 to provide a minimum 25/3 Mbps service level. However, further analysis to remove the influence of outliers, raised the cost per location to $3,200. The FCC cost data, though, still has issues because the bidders are not just fixed broadband providers. Criteria include the preference to select bidders who cover the largest area for the lowest cost, often with wireless technologies. Given this, a higher value of $3,500 was used in developing a uniform cost assumption, as some estimates topped $4,500 per location. This may still underestimate the cost to install fixed broadband, but it is balanced by an overestimate of households that need broadband service.

To estimate total broadband investment spending needed over a ten-year period, the $3,500 cost per location is multiplied by the number of households in a county that had not yet adopted fixed broadband services in 2019. This is a simplifying assumption given that costs will vary by location, geography, and technology. Furthermore, a household may not have adopted broadband even though a local ISP serves the area. Therefore, using households that have not adopted broadband does overestimate the need for service. FCC data would provide an alternative measure of broadband availability but it has also faced criticisms, as noted earlier, of overestimating coverage and speed.

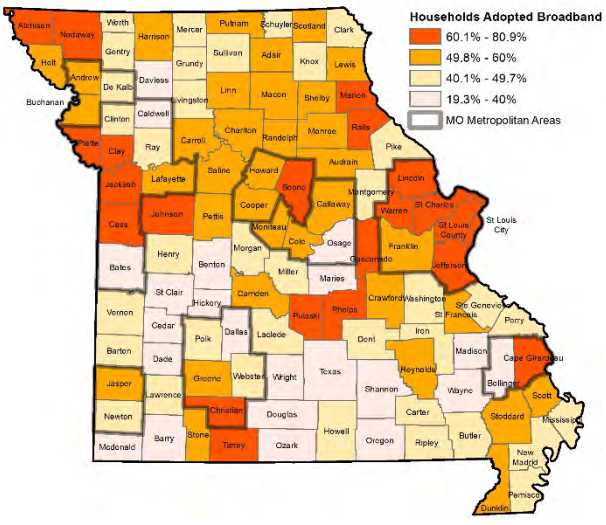
This analysis estimates construction impacts to the local economy with a recognition that investment assumptions rely on flawed datasets. While efforts are made to balance the data biases, these figures should be used with caution. For these reasons the investment estimate will not be suitable for return-on-investment calculations as more detailed ISP figures would need to include operations cost, timing, and new subscriber revenue. Nevertheless, this assumption does provide a uniform approach to estimating the initial economic spending benefits to a community for broadband installation.

The timing of broadband investments is assumed to occur over a 6-year period, based on the FCC's Connect America Fund requirements. Winning bidders must have 40% of locations served by the end of year three, 20% each subsequent year, with 100% of locations served by the end of year six. Given that the first year in a long-term investment project usually involves upfront planning, often in a centralized headquarters, it is assumed that local construction activity will begin in year two. Exhibit 3 on the following page provides the investment year timing assumptions.

Household broadband adoption rate increases and timing

Household broadband adoption is the key causal factor in realizing the economic benefits of broadband investments. While this must follow the availability of broadband services, if households do not purchase those services, then the community will see limited economic benefits. Furthermore, the ISP provider will not be able to recover the cost of making broadband services available.

Exhibit 2. Missouri County Household Fixed Broadband Adoption, 2015-2019



The U.S. Census Bureau ACS 2019 five-year summary is used to determine county-level fixed broadband adoption levels – see Exhibit 2. Counties in Missouri range from 19% (Bollinger County) to 81% (St. Charles County) in adoption levels. For context, the lowest U.S. county adoption level was 10% and the highest level 90% during the same time period. The median county adoption level was 49.7%.

Discussions with subject-matter experts and a Pew Research Center survey that tracks U.S. broadband adoption growth trends informed the scenarios for assumed gains in broadband adoption rates.[22] The Pew survey broke down responses by urban, suburban, and rural communities. Over a five-year period ending in February 2021, urban areas adoption levels increased by 5%, suburban by 8%, and rural by 11%. These increases reflect the reality that urban and suburban areas, typically with higher adoption levels than rural communities, are slowing in relative gains as more remote populations catch up with broadband infrastructure. The COVID-19 pandemic has accelerated broadband demand, especially in underserved rural areas, so that these adoption increases are likely on the lower end of future growth trends. For example, the Pew data show that 9% of the 11% jump in rural areas came from adults adopting broadband in the last two years.

This analysis assumes two broadband household adoption level increases:

- **Minimum scenario:** A gain of 10 percentage points in household adoption over a ten-year period for counties with a household adoption base rate of less than 60% in 2019. Counties with 60% or higher base rate will gain 7.5 percentage points over ten years to reflect slower growth when the community starts at a higher base rate.
- **Maximum scenario:** A gain of 20 percentage points in household adoption over a ten-year period for counties with a household adoption base rate of less than 60% in 2019. Counties with 60% or higher base rate will gain 15 percentage points over ten years to reflect slower growth when the community starts at a higher base rate. Gains are capped at an 85% adoption level.

The 60% adoption base rate distinction for gains assumes counties with lower base rates will see a greater economic boost as they begin catching up with counties already at higher levels of adoption. This assumption was informed by research from Whitacre et al. (2014).[10]

Exhibit 3 indicates the assumed timing of broadband investments and broadband adoption gains. As broadband investments occur, households are expected to rapidly increase adoption during the first five years to equal 90% of total gains. The remaining 10% of gains are realized in years 6 to 10.

Exhibit 3. Broadband Investment and Household Broadband Adoption Levels and Timing

Characteristic	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cumulative broadband investment	0%	20%	40%	60%	80%	100%	100%	100%	100%	100%
Minimum Scenario - Household Broadband Adoption Increases above Base Adoption Rate										
Household adoption gains *if county base rate < 60%*	0%	2.0%	4.0%	8.0%	9.0%	9.2%	9.4%	9.6%	9.8%	10.0%
Household adoption gains *if county base rate => 60%*	0%	1.5%	3.0%	6.0%	6.8%	6.9%	7.1%	7.2%	7.4%	7.5%
Maximum Scenario - Household Broadband Adoption Increases above Base Adoption Rate										
Household adoption gains *if county base rate < 60%*	0%	4.0%	8.0%	16.0%	18.0%	18.4%	18.8%	19.2%	19.6%	20.0%
Household adoption gains *if county base rate => 60%*	0%	3.0%	6.0%	12.0%	13.5%	13.8%	14.1%	14.4%	14.7%	15.0%

Broadband Benefit Assumptions

Broadband investment and household adoption timing inform the speed at which these technologies benefit communities economically. However, the economic gains come from different components that, when combined, form the basis for describing the potential benefits over time to a community.

Telemedicine

Telemedicine benefits were informed primarily by research from Whitacre (2011)[3], Gordon et al. (2017)[4], and Nord et al. (2019).[5] While health care providers benefit, Whitacre's research notes there are questions about where the gains would accrue. This study focuses on the telemedicine benefits to patients, which alone are significant. Telemedicine gains represent the largest direct benefit in two of the counties studied, while in the third they are second only to farm income gains.

This analysis used four subcategories of telemedicine benefits:

- *Patient savings from reduced use of emergency departments*
  Patients with broadband access to telemedicine are assumed to have fewer emergency room (ER) visits per year. Nord et al. show that the average ER visit cost $928 while a telehealth consultation averages $45, so the net savings to a patient is $883. The Center for Disease Control (CDC) 2017 data indicates that were 43 visits to the ER per 100 people in that year.[23] Missouri Department of Health and Senior Services 2015 data indicated 39 ER visits per 100 people.[24] This analysis uses the 2017 CDC figures and assumes that, of the 43% of the population in new households with broadband service, half receive savings due to avoiding one ER visit during the year.
- *Patient savings from initial health consultation via internet*
  Similar to ER savings, patients with access to telemedicine are assumed to make fewer in-person doctor visits. Estimated net savings are also based on Nord et al. that show average costs of urgent care ($131) and physician office ($108) visits, compared to the $45 for telehealth consultations. It is assumed that one urgent care and two physician office visits are replaced with initial telehealth consultations, saving $211 a year, per new households with broadband service.
- *Patient transportation savings due to telemedicine*
  The reduction in ER visits also saves transportation costs for patients who would to travel to the nearest hospital for treatment. There is likely travel savings from urgent care and physician office visits that are avoided but these services are more numerous and distance data is a limiting factor. Transportation savings is derived from the reduced ER visits per new household with broadband services that is multiplied by the 2021 IRS rate of 56 cents per mile and average roundtrip miles to a hospital for rural (21) and urban (9) travelers based on a Pew study.[25]
- *Missed work income savings to patient*
  The income from missed work, due to the travel and time spent at a hospital visit, is calculated as an additional patient benefit. Lost time is estimated as the average roundtrip time to a hospital for rural (0.57 hours) and urban (0.35 hours) patients, from the Pew study, plus an hour visit for

health care services. This figure is multiplied by the county's median hourly earnings for the ER visits saved by new households with broadband service.

Education Productivity

We estimated Kindergarten to 12th grade (K-12) teacher productivity gains using research from Smith et al. (2008).[8] This research included a teacher survey where 20% of respondents indicated that online resources saved them up to one hour a week with an additional 20% indicated they saved up to two hours a week. This time savings works out to an average of 0.6 hours saved a week due to online resources. That time savings scales up with broadband investment timing as it is assumed that public schools would have these services as soon as available. The scaled-up time savings are then multiplied by the total costs of K-12 teacher's salaries in the county based on data from the Missouri Department of Elementary and Secondary Education.[26] These productivity benefits will modestly accrue to the school district that can, over time, save money by reducing labor needs through increased productivity.

Income

Household incomes are expected to rise in homes that adopt broadband. Research from Whitacre et al. (2014)[10] estimates that, for nonmetro counties, the increase in household income is 1.3% over 10 years for counties with higher levels of adoption (=> 60%) compared to counties at moderate levels (40%-60%). These findings underpin the income growth assumption in this analysis with the consideration, from this and other research, that economic benefits do not scale up uniformly across all geographies, as influences like the proximity to metros and labor supply can impact income gains (Kim & Orazem (2016),[13] Kolko (2012)[15]). Whitacre et al. notes that any number of factors can drive income gains, but could include increased worker productivity.

The median household income (MHHI) rate of increase is adjusted by the final level of broadband adoption at the end of ten years:

- MHHI is assumed to increase by 1.3% over ten years if a county significantly gains in broadband adoption levels by 20 percentage points or more.
- MHHI is assumed to increase by 0.65%, or half of 1.3%, over ten years if broadband adoption increases are less than 20 percentage points over ten years.

We applied median household income growth to the number of new households with broadband service each year. This income growth is cumulative, so that a household adopting broadband in year two will accumulate more income over the ten years than a household gaining broadband service in year four.

In certain situations, **Farm income** can also be expected to increase, and as a result we analyzed that separately from household income. Two studies point to gains in crop farming from expanded broadband access, but gains to livestock production are less clear (Kandilov et al. (2011),[11] LoPiccalo (2020)[12]). LoPiccalo's 2020 research into crop yield gains are used as the basis for assuming farm income growth.

This analysis assumes that for every 1% increase in new households adopting broadband, a 0.1% increase in crop sales can be expected, presumably due to advances in precision agriculture and crop marketing. Crop sales base data comes from the U.S. Department of Agriculture.

Employment

Employment, from new and expanding firms, is expected to rise as a county increases household broadband adoption. A study shows that employment growth was 3.4% less, over ten years, for nonmetro counties with household adoption rates below 40% when compared to counties with higher adoption levels (Whitacre et al. (2014)[10]). The study did not find a meaningful relationship between jobs and broadband adoption in metro counties. This suggest that metro counties, typically with higher adoption levels, have already seen the gains of broadband expansion or that those gains are too intertwined with other factors to distinguish a causal relationship. This analysis uses the 2014 study findings as the foundation for employment growth assumptions. Based on other research findings (Kolko (2012),[15] Mack & Faggian (2013)[18]), we assume that direct employment increases are concentrated in knowledge-intensive industries, such a professional and business services.

It is assumed that over ten years knowledge-intensive employment will increase by 3.4%, if there is a significant expansion of broadband adoption from the base county level in 2019. But that rate of increase is adjusted based on a couple of underlying factors:

- Employment increases by 3.4% over ten years if a county significantly gains in broadband adoption levels by 20 percentage points or more and the county is below a base adoption rate of 60 percent. If a county base adoption rate is 60 percent or higher the employment growth rate is half, or 1.7%, over ten years under the assumption that much of the economic gains from broadband have already been realized.
- Employment increases by 1.7% over ten years if broadband adoption gains are less than 20 percentage points over ten years and the county is below a base adoption rate of 60 percent. If a county base adoption rate is 60 percent or higher the employment growth rate is half, or 0.85%, over ten years assuming that much of the economic gains from broadband have already been realized.

In addition to the direct economic benefits from broadband expansion detailed in this section, there will be spillover effects from the new investments, savings, income, and jobs that provide further gains. An economic model is used to estimate these additional spending impacts within each county.

Economic Model

An economic input-output model is used to understand the total benefits derived from broadband adoption. Without an economic model, only direct spending or savings activities could be described and that would miss important beneficial impacts. Economic models consider typical spending patterns, such as what types of goods or services are purchased locally, to follow the flow of income that stays within a county and spurs additional gains in income, employment, taxes, and gross domestic product.

IMPLAN, provided by the IMPLAN Group, LLC, is a common economic input-output model and it is used in this study. Key outputs from IMPLAN analysis include:

- **Employment** estimates that describe the annual average full- or part-time jobs in a county. The jobs can be held by county residents or workers commuting into the area for employment.
- **County Taxes** are an estimate of county sales and property taxes. It is based on U.S. Census state-level data that is allocated to counties using a variety of factors. Due to the tax allocation process, IMPLAN tax figures should be considered a broad estimate that may not be suitable for fiscal cost-benefit analysis without further refinement.
- **Labor Income** describes wages and benefits, such as healthcare and retirement, along with the income to sole proprietors.
- **Gross Domestic Product (GDP) or Value Added**. Gross domestic product represents the value of all final goods and services produced in the county. It is also equal to total sales minus the input cost of those goods and services—called Value Added—that leaves money to pay for labor income, rents, interests and taxes.

Economic Benefits of Broadband Expansion in Select Missouri Counties

This section reviews the county selection process and provides the direct inputs and total economic benefit estimates for the selected Missouri counties. Two adoption growth scenarios are modeled to demonstrate how sensitive the economic benefits are to gains in household broadband adoption.

County Selection Process

The economic benefits of fixed broadband expansion are modeled for three Missouri counties—Bollinger, Henry and Nodaway. Bollinger had the state's lowest level of broadband adoption, Henry had an average level, while Nodaway had a relatively high adoption level. Nodaway was similar in size to Henry, which was beneficial for comparing results from difference growth scenarios.

Bollinger and Henry counties

Bollinger County is in southeast Missouri. Bollinger's base broadband adoption level is the lowest in the state at 19.3%. FCC data also show the poorest broadband access in the state. Given this low level of adoption and need for broadband infrastructure, it was a good candidate for analysis.

Henry County, located in west central Missouri, has a base broadband adoption level of 48%, just below the 49.7% median for all Missouri counties. But FCC data also show the county has poor broadband access, compared to other Missouri counties, so broadband infrastructure expansion is clearly needed. Given this, along with the its average broadband adoption level, larger population, and geographic distance from Bollinger, made it another good county to analyze for this study.

Nodaway County

The broadband adoption level of 65.4% in Nodaway County is relatively high – that level is above all but eight other counties in the state. Nodaway is home to Northwest Missouri State University,

which explains the relatively higher levels of adoption compared to other nonmetro Missouri counties. Even so, FCC data indicate Nodaway has only average broadband access so can still benefit from continued broadband investment.

Nodaway serves as a good comparison with Henry, given that both counties have similar population and employment sizes – see Exhibit 4. Due to its higher levels of broadband adoption, Nodaway is assumed to have realized many of the economic benefits of broadband, whereas Henry has not. That provides a case study for how economic gains, in counties of similar size, compare if it is assumed that a county at lower levels of broadband adoption will have more to gain economically than a community that has already seen many of the benefits of broadband.

Exhibit 4. 2019 County Characteristics and 10-Year Model Inputs by County

	Bollinger	Henry	Nodaway
2019 County Characteristics			
Population	12,133	21,824	22,092
Employment	3,888	11,009	11,975
Labor Income *(in Millions)*	$99.3	$468	$448
GDP *(in Millions)*	$182	$722	$823
Households	4,593	9,328	8,395
Household Broadband Adoption	19.3%	48.0%	65.4%
Minimum Scenario			
10-Year Direct Model Inputs			
10-Year Broadband Adoption Gain *(in Percentage Points)*	10.0%	10.0%	7.5%
Broadband Investment *(in Millions)*	$14.1	$18.5	$11.1
Total Direct Income Gains *(in Millions)*	$5.2	$11.6	$12.4
Direct Employment Gain by Year 10	66	187	102
Maximum Scenario			
10-Year Direct Model Inputs			
10-Year Broadband Adoption Gain *(in Percentage Points)*	20.0%	20.0%	15.0%
Broadband Investment *(in Millions)*	$14.1	$18.5	$11.1
Total Direct Income Gains *(in Millions)*	$10.7	$24.1	$23.5
Direct Employment Gain by Year 10	132	374	204

Notes: Input dollar values represent 10-year total benefit in nominal figures.

Selected County Characteristics and Direct Model Inputs

With a population just over 12,000, Bollinger represents a smaller-sized county—the median Missouri county population is 18,302. Henry and Nodaway have similar populations and employment levels but differ significantly in household fixed broadband adoption. See Exhibit 4 for details. The minimum scenarios assume a household fixed broadband adoption gain of 10 percentage points over ten years for Bollinger and Henry counties. The gain is less (7.5%) for Nodaway as the county already has a relatively high adoption level above 60 percent. The maximum

scenarios assume an adoption gain of 20 percentage points over ten years for Bollinger and Henry, and 15 percentage points for Nodaway.

The direct model inputs show the total broadband investment, income gains, and employment used in the analysis under each scenario. These direct inputs spur additional, indirect spending in the county economy that generate further economic benefits.

Broadband investment is assumed to cost $3,500 per household and is scaled to the number of households that did not have fixed broadband. The investment level is the same in the minimum and maximum scenarios, and assumes that all remaining households without fixed broadband are served. Henry County has the largest investment value, followed by Bollinger and Nodaway.

Direct income gains are derived from the telemedicine, education productivity, household and farm income benefits. The number of new households adopting fixed broadband generate these benefits. Income gains will therefore be greater in counties where more households adopt fixed broadband.

Direct employment gains represent an annual employment increase that scales up over ten years for a maximum gain of 3.4% from the base year. The maximum employment gains, however, are sensitive to the base household broadband adoption level. Nodaway County, with a base household adoption level above 60%, is assumed to see smaller employment gains as a percent of total employment than Bollinger and Henry counties.

Economic Benefits Summary for the Select Missouri Counties

Four measures show the total gains to each county in: employment, county taxes, labor income, and gross domestic product (see Exhibit 5). The average annual gain in jobs, income, and gross domestic product (GDP) is compared to 2019 figures for context. The annual average increase in GDP is also compared to the 2014 to 2019 annual average growth rate.

Employment gains

Under the minimum scenario, by the tenth year employment increases by 79, 261 and 143 jobs in Bollinger, Henry and Nodaway counties, respectively. The annual average increase in jobs during the ten years represent a 1.6%, 1.5% and 0.8% gain in employment over 2019 levels in Bollinger, Henry and Nodaway counties, respectively. While the job increases may seem modest, these gains would represent a positive trend for the selected counties given that, between 2009 to 2019, they experienced employment declines.

Employment gains are more significant in the maximum scenario. Jobs increase in the tenth year by 159, 524 and 287, in Bollinger, Henry and Nodaway counties, respectively. In Bollinger and Henry counties these gains represent an annual average increase of 2.7% to 2.9%, respectively, from 2019 employment levels. Nodaway county annual average jobs gains are significant but less, at 1.5% of 2019 employment, due to the assumption that overall growth will be more modest in counties that already have higher broadband adoption levels.

Exhibit 5. 10-Year Total Economic Benefits Summary by County

	Bollinger	Henry	Nodaway
Minimum Scenario			
10-Year Total Economic Benefits of Broadband Expansion			
Employment Gain in Year 10	79	261	143
Total County Taxes *(in Millions)**	$1.0	$3.0	$1.8
Total Labor Income *(in Millions)*	$16.4	$78.8	$37.3
Total Gross Domestic Product *(in Millions)*	$23.3	$109.4	$55.7
Average Annual Gains of Broadband Expansion Compared to 2019 Figures			
Annual Avg. Employment as % of 2019 Emp.	1.6%	1.5%	0.8%
Annual Avg. Labor Income as % of 2019 Income	1.8%	1.9%	0.9%
Annual Avg. GDP as % of 2019 GDP	1.4%	1.7%	0.8%
*For Reference: Annual GDP % Change, 2014-2019***	*2.2%*	*-3.4%*	*-1.2%*
Maximum Scenario			
10-Year Total Economic Benefits of Broadband Expansion			
Employment Gain in Year 10	159	524	287
Total County Taxes *(in Millions)**	$1.8	$5.7	$3.4
Total Labor Income *(in Millions)*	$26.7	$148.4	$68.8
Total Gross Domestic Product *(in Millions)*	$38.7	$205.9	$102.8
Average Annual Gains of Broadband Expansion Compared to 2019 Figures			
Annual Avg. Employment as % of 2019 Emp.	2.7%	2.9%	1.5%
Annual Avg. Labor Income as % of 2019 Income	3.0%	3.5%	1.7%
Annual Avg. GDP as % of 2019 GDP	2.4%	3.2%	1.4%
*For Reference: Annual GDP % Change, 2014-2019***	*2.2%*	*-3.4%*	*-1.2%*

*Notes: All income and GDP totals are in 2021 dollars. *County tax estimates based on state-level sales and property tax data from the U.S. Census Bureau that is allocated to counties. **Reference source is U.S. Bureau of Economic Analysis, 2014-2019. GDP is compound annual growth rate in real dollars.*

County tax gains

The model estimates that county-level sales and property tax gains, under the minimum scenario, provides Bollinger with an additional $1.0 million in tax collections over the ten years. Henry County would see $3.0 million more in tax collections while Nodaway's gain is estimated at $1.8 million. Under the maximum scenario, tax collections increase to $1.8 million for Bollinger, $5.7 million for Henry, and $3.4 million for Nodaway. Tax figures are based on U.S. Census Bureau state-level data that is allocated to counties using a variety of factors, so should be considered a broad estimate.

Labor income gains

Labor income gains over the ten years, which include all employee compensation and proprietor income, is estimated to be approximately $16 million in Bollinger and nearly $80 million in Henry, under the minimum broadband adoption scenario. Nodaway's income gain is $37 million. For Bollinger and Henry, the annual increase in labor income is about 1.8% to 1.9% higher than 2019 levels. Nodaway's average labor income increase is 0.9% higher. In the maximum scenario, labor income gains total nearly $27 million for Bollinger, $148 million for Henry, and $70 million for Nodaway over the ten-year period. Annual income increases are 3.0%, 3.5%, and 1.7% higher, respectively, for the three counties.

Labor income does increase significantly in both scenarios and is slightly higher, in percentage terms, than the increases in employment. This is due to the influence of the direct, knowledge-intensive jobs that represent the greatest share of new employment assumed to increase due to expanded broadband adoption. Those jobs typically pay more than other employment in a community.

Gross Domestic Product gains

Gross domestic product (GDP) is a key indicator used to capture the total economic gains a community is expected to see from fixed broadband adoption. The minimum scenario shows expected GDP gains of $23 to $109 million over ten years, for Bollinger and Henry counties, respectively. Nodaway gains nearly $56 million in GDP in this scenario.

Under the maximum scenario, total GDP increases by $39 to $206 million, for Bollinger and Henry counties, respectively. Nodaway's gains $103 million in new GDP over the ten years.

The annual average GDP growth rate puts the GDP gains in context. In the minimum scenario the annual average GDP growth rate is expected to be between 0.8% and 1.7% higher than 2019 GDP levels. For the maximum scenario, the growth rates increase from 1.4% to 3.2% of 2019 GDP levels.

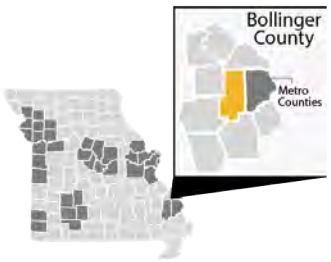
Annual increases to GDP growth are especially significant over time. For example, Henry and Nodaway counties have seen GDP decline annually over the 2014 to 2019 time-period. Under the maximum scenarios the expected annual increase in GDP, 3.2% and 1.4% respectively, would largely wipe out these declines. For Bollinger County, with a 2.2% annual average GDP growth rate from 2014 to 2019, the expected annual GDP gains (+2.4%) would climb to 4.6 percent under the maximum scenario. That rate of growth would be exceptional given that only two Missouri counties had higher annual GDP growth levels from 2014 to 2019.

Individual County Summaries

The following pages provide a two-page summary of each county to include a location map, the two fixed broadband adoption scenarios, direct model inputs by category, and the economic benefits by year for the study period.

Bollinger County, Missouri, Broadband Expansion Economic Benefit Analysis

Located in southeast Missouri, Bollinger County sits within the Cape Girardeau metropolitan statistical area. At 19.3%, the county has the lowest percent of households with fixed broadband service (fiber, cable or DSL) compared with other Missouri counties. Bollinger County's 2019 population totaled 12,133, ranking it 79th in Missouri for population size.



Two 10-year expansion scenarios estimate the benefits to Bollinger County if it increased household broadband adoption by 10 (minimum) and 20 (maximum) percentage points. Exhibit B1 shows the number and percent of households assumed to have fixed broadband by year ten. Exhibit B2 shows the total benefit model inputs for each scenario.

Exhibit B1. 10-Year Fixed Broadband Household Adoption Scenarios

Characteristic	Base Value	Minimum Scenario	Maximum Scenario
Households without Fixed Broadband Service	3,705	3,246	2,787
Households with Fixed Broadband Service	888	1,347	1,806
Percent of Households with Fixed Broadband Service	19.3%	29.3%	39.3%

Sources: Demographics from U.S. Census Bureau, ACS, 2019 5-Year Summary Data.

Exhibit B2. 10-Year Economic Benefit Direct Model Inputs

Basic Assumptions	Minimum Scenario	Maximum Scenario
Percent of Households that Adopted Broadband by Year 10	29.3%	39.3%
Broadband Installation Investment to Serve Remaining Households	$14,149,197	$14,149,197
Telemedicine Benefits		
Patient Savings from Reduced Use of Emergency Departments	$1,874,903	$3,749,806
Patient Savings from Initial Health Consultation via Internet	$786,213	$1,572,425
Patient Transportation Savings due to Telemedicine	$10,702	$21,403
Missed Work Income Savings to Patient	$13,335	$26,670
Education Productivity Benefits		
K12 Teacher Productivity Savings	$680,857	$680,857
Income and Employment Benefits		
Household Income Increases	$479,474	$1,920,713
Farm Income Changes	$1,344,406	$2,688,813
Annual Average Direct Employment Increases by Year 10	66	132

Notes: See Methodology section for details. Dollar values represent 10-year benefit in nominal figures.

Bollinger County 10-Year Broadband Expansion Benefit Results

Benefits arise from both fixed broadband infrastructure construction and household broadband adoption. In year two, the construction investments and household adoption expansion benefits begin. The temporary construction activity concludes in year six. In each scenario, new jobs, labor income and GDP include the total impact of direct inputs (from Exhibit B2) and indirect purchases, such as new local spending in the county spurred by those inputs.

Minimum Scenario: 10 Percentage Point Gain in Fixed Broadband Adoption over 10 Years

In the minimum scenario, the annual average increase of 79 jobs is realized in year 10. On average, annual employment is 1.6% higher than 2019 county employment. Annually, this scenario adds 1.8% and 1.4%, respectively, to county labor income and GDP on average compared with 2019 levels.

Exhibit B3. Minimum Scenario – Total Economic Benefits by Year

Characteristic	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	10-Year Total*	Avg. Annual Change**
New Annual Average Employment	N/A	39	48	58	66	75	53	62	71	79	**79**	**1.6%**
New Labor Income *(in Millions)*	N/A	$1.5	$1.7	$1.9	$2.1	$2.4	$1.4	$1.6	$1.8	$2.0	**$16.4**	**1.8%**
New GDP *(in Millions)*	N/A	$1.9	$2.2	$2.6	$2.9	$3.3	$2.1	$2.4	$2.8	$3.1	**$23.3**	**1.4%**

*Notes: All income and GDP figures in 2021 dollars. *Total employment is for year 10 as jobs are not cumulative, and other figures are cumulative totals. **Average annual change compared to 2019 county employment, income and GDP totals.*

Maximum Scenario: 20 Percentage Point Gain in Fixed Broadband Adoption over 10 Years

In the maximum scenario, the annual average increase of 159 jobs is seen in year 10. On average, annual employment is 2.7% higher than 2019 county employment. This scenario adds an annual average of 3.0% and 2.4%, respectively, to labor income and GDP compared with 2019 levels.

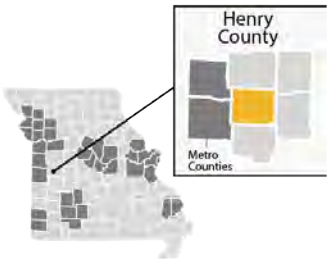
Exhibit B4. Maximum Scenario – Total Economic Benefits by Year

Characteristic	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	10-Year Total*	Avg. Annual Change**
New Annual Average Employment	N/A	49	67	85	103	120	107	125	142	159	**159**	**2.7%**
New Labor Income *(in Millions)*	N/A	$1.7	$2.2	$2.6	$3.1	$3.5	$2.8	$3.2	$3.7	$4.1	**$26.7**	**3.0%**
New GDP *(in Millions)*	N/A	$2.2	$2.9	$3.6	$4.3	$5.0	$4.2	$4.8	$5.5	$6.1	**$38.7**	**2.4%**

*Notes: All income and GDP figures in 2021 dollars. *Total employment is for year 10 as jobs are not cumulative, and other figures are cumulative totals. **Average annual change compared to 2019 county employment, income and GDP totals.*

Henry County, Missouri, Broadband Expansion Economic Benefit Analysis

Located in west central Missouri, Henry County sits adjacent to the Kansas City metropolitan statistical area. At 48% adoption, the county is near the Missouri county median value (49.7%) for percent of households with fixed broadband service (fiber, cable or DSL). Henry County's 2019 population totaled 21,824 people, ranking it 52nd in Missouri for population size.



Two 10-year expansion scenarios estimate the benefits to Henry County if it increased household broadband adoption by 10 (minimum) and 20 (maximum) percentage points. Exhibit H1 shows the number and percent of households assumed to have fixed broadband by year ten. Exhibit H2 shows the total benefit model inputs for each scenario.

Exhibit H1. 10-Year Fixed Broadband Household Adoption Scenarios

Characteristic	Base Value	Minimum Scenario	Maximum Scenario
Households without Fixed Broadband Service	4,848	3,915	2,982
Households with Fixed Broadband Service	4,480	5,413	6,346
Percent of Households with Fixed Broadband Service	48.0%	58.0%	68.0%

Sources: Demographics from U.S. Census Bureau, ACS, 2019 5-Year Summary Data.

Exhibit H2. 10-Year Economic Benefit Direct Model Inputs

Basic Assumptions	Minimum Scenario	Maximum Scenario
Percent of Households that Adopted Broadband by Year 10	58.0%	68.0%
Broadband Installation Investment to Serve Remaining Households	$18,514,253	$18,514,253
Telemedicine Benefits		
Patient Savings from Reduced Use of Emergency Departments	$3,342,700	$6,685,401
Patient Savings from Initial Health Consultation via Internet	$1,596,732	$3,193,465
Patient Transportation Savings due to Telemedicine	$44,519	$89,038
Missed Work Income Savings to Patient	$40,931	$81,862
Education Productivity Benefits		
K12 Teacher Productivity Savings	$1,239,061	$1,239,061
Income and Employment Benefits		
Household Income Increases	$1,009,870	$4,045,417
Farm Income Changes	$4,359,576	$8,719,152
Annual Average Direct Employment Increases by Year 10	187	374

Notes: See Methodology section for details. Dollar values represent 10-year benefit in nominal figures.

Henry County 10-Year Broadband Expansion Benefit Results

Benefits arise from both fixed broadband infrastructure construction and household broadband adoption. In year two, benefits from construction investments and household adoption expansion begin. Temporary construction activity concludes in year six. In each scenario, new jobs, labor income and GDP include the total impact of direct inputs (from Exhibit H2) and indirect purchases, such as new local spending in the county spurred by those inputs.

Minimum Scenario: 10 Percentage Point Gain in Fixed Broadband Adoption over 10 Years

In the minimum scenario, the annual average increase of 261 jobs is realized in year 10. On average, annual employment is 1.5% higher than 2019 county employment. This scenario annually adds 1.9% and 1.7%, respectively, on average to county labor income and GDP compared with 2019 levels.

Exhibit H3. Minimum Scenario – Total Economic Benefits by Year

Characteristic	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	10-Year Total*	Avg. Annual Change**
New Annual Average Employment	N/A	68	98	128	157	185	175	204	233	261	**261**	**1.5%**
New Labor Income *(in Millions)*	N/A	$3.4	$5.0	$6.5	$8.1	$9.6	$9.3	$10.8	$12.3	$13.8	**$78.8**	**1.9%**
New GDP *(in Millions)*	N/A	$4.6	$6.8	$9.0	$11.2	$13.3	$13.0	$15.1	$17.2	$19.2	**$109.4**	**1.7%**

*Notes: All income and GDP figures in 2021 dollars. *Total employment is for year 10 as jobs are not cumulative, and other figures are cumulative totals. **Average annual change compared to 2019 county employment, income and GDP totals.*

Maximum Scenario: 20 Percentage Point Gain in Fixed Broadband Adoption over 10 Years

In the maximum scenario, the 524-job annual average increase is seen in year 10. On average, annual employment is 2.9% higher than 2019 county employment. Annually, this scenario adds 3.5% and 3.2%, respectively, on average to county labor income and GDP compared with 2019 levels.

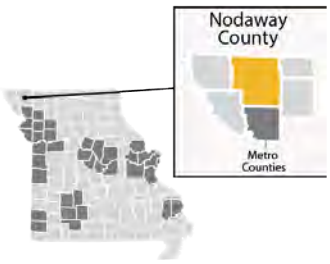
Exhibit H4. Maximum Scenario – Total Economic Benefits by Year

Characteristic	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	10-Year Total*	Avg. Annual Change**
New Annual Average Employment	N/A	98	156	218	276	333	352	409	466	524	**524**	**2.9%**
New Labor Income *(in Millions)*	N/A	$5.0	$8.1	$11.2	$14.3	$17.3	$18.5	$21.6	$24.6	$27.7	**$148.4**	**3.5%**
New GDP *(in Millions)*	N/A	$6.8	$11.1	$15.6	$19.9	$24.1	$25.8	$30.0	$34.2	$38.4	**$205.9**	**3.2%**

*Notes: All income and GDP figures in 2021 dollars. *Total employment is for year 10 as jobs are not cumulative, and other figures are cumulative totals. **Average annual change compared to 2019 county employment, income and GDP totals.*

Nodaway County, Missouri, Broadband Expansion Economic Benefit Analysis

Nodaway County is adjacent to the St. Joseph metropolitan statistical area in northwest Missouri. Nodaway County's 65.4% rate of households with fixed broadband service (fiber, cable or DSL) is relatively high compared to other Missouri counties' rates. The county's 2019 population totaled 22,092, ranking it 51st in Missouri for population size.



Two 10-year expansion scenarios estimate the benefits to Nodaway County if it increased household broadband adoption by 7.5 (minimum) and 15 (maximum) percentage points. Exhibit N1 shows the number and percent of households assumed to have fixed broadband by year ten. Exhibit N2 shows the total benefit model inputs for each scenario.

Exhibit N1. 10-Year Fixed Broadband Household Adoption Scenarios

Characteristic	Base Value	Minimum Scenario	Maximum Scenario
Households without Fixed Broadband Service	2,907	2,277	1,648
Households with Fixed Broadband Service	5,488	6,118	6,747
Percent of Households with Fixed Broadband Service	65.4%	72.9%	80.4%

Sources: Demographics from U.S. Census Bureau, ACS, 2019 5-Year Summary Data.

Exhibit N2. 10-Year Economic Benefit Direct Model Inputs

Basic Assumptions	Minimum Scenario	Maximum Scenario
Percent of Households that Adopted Broadband by Year 10	72.9%	80.4%
Broadband Installation Investment to Serve Remaining Households	$11,101,678	$11,101,678
Telemedicine Benefits		
Patient Savings from Reduced Use of Emergency Departments	$2,246,459	$4,492,918
Patient Savings from Initial Health Consultation via Internet	$1,077,769	$2,155,537
Patient Transportation Savings due to Telemedicine	$29,919	$59,838
Missed Work Income Savings to Patient	$26,209	$52,417
Education Productivity Benefits		
K12 Teacher Productivity Savings	$1,317,445	$1,317,445
Income and Employment Benefits		
Household Income Increases	$658,381	$1,316,762
Farm Income Changes	$7,064,158	$14,128,316
Annual Average Direct Employment Increases by Year 10	102	204

Notes: See Methodology section for details. Dollar values represent 10-year benefit in nominal figures.

Nodaway County 10-Year Broadband Expansion Benefit Results

Benefits arise from both fixed broadband infrastructure construction and household broadband adoption. In year two, the construction investments and expanded household adoption benefits begin. The temporary construction activity concludes in year six. In each scenario, new jobs, labor income and GDP include the total impact of direct inputs (from Exhibit N2) and indirect purchases, such as new local spending in the county spurred by those inputs.

Minimum Scenario: 7.5 Percentage Point Gain in Fixed Broadband Adoption over 10 Years

In the minimum scenario, the annual average increase of 143 jobs is realized in year 10. On average, annual employment is 0.8% higher than 2019 county employment. This scenario adds an annual average of 0.9% and 0.8%, respectively, to county labor income and GDP relative to 2019.

Exhibit N3. Minimum Scenario – Total Economic Benefits by Year

Characteristic	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	10-Year Total*	Avg. Annual Change**
New Annual Average Employment	N/A	41	57	75	91	106	97	113	128	143	**143**	**0.8%**
New Labor Income *(in Millions)*	N/A	$1.9	$2.6	$3.3	$4.0	$4.7	$4.2	$4.9	$5.6	$6.2	**$37.3**	**0.9%**
New GDP *(in Millions)*	N/A	$2.6	$3.7	$4.9	$5.9	$6.9	$6.5	$7.5	$8.4	$9.4	**$55.7**	**0.8%**

*Notes: All income and GDP figures in 2021 dollars. *Total employment is for year 10 as jobs are not cumulative, and other figures are cumulative totals. **Average annual change compared to 2019 county employment, income and GDP totals.*

Maximum Scenario: 15 Percentage Point Gain in Fixed Broadband Adoption over 10 Years

In the maximum scenario, Nodaway County sees the annual average increase of 287 jobs in year 10. On average, annual employment is 1.5% higher than 2019 county employment. This scenario adds an annual average of 1.7% and 1.4%, respectively, to labor income and GDP relative to 2019.

Exhibit N4. Maximum Scenario – Total Economic Benefits by Year

Characteristic	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	10-Year Total*	Avg. Annual Change**
New Annual Average Employment	N/A	57	90	126	158	188	194	225	256	287	**287**	**1.5%**
New Labor Income *(in Millions)*	N/A	$2.6	$4.0	$5.5	$6.9	$8.2	$8.4	$9.8	$11.1	$12.4	**$68.8**	**1.7%**
New GDP *(in Millions)*	N/A	$3.6	$5.8	$8.1	$10.2	$12.2	$12.7	$14.7	$16.7	$18.7	**$102.8**	**1.4%**

*Notes: All income and GDP figures in 2021 dollars. *Total employment is for year 10 as jobs are not cumulative, and other figures are cumulative totals. **Average annual change compared to 2019 county employment, income and GDP totals.*

Conclusion

The COVID-19 pandemic made the need for broadband expansion more apparent and urgent as residents shifted to remote work, learning, shopping and health care. Federal and state efforts have rolled out programs to fund broadband expansion and adoption in hopes of closing the gap between communities that benefit from broadband and those that feel left behind. Given these changes, estimating future broadband benefits is a challenge. However, causal research provides a reasonable approach to understanding broadband expansion's economic benefits. It can serve as a foundation for further research.

In this study, broadband expansion's economic gains resulted from the temporary boost in broadband infrastructure spending within the community and the longer-term economic impacts resulting from higher broadband adoption levels among area households. Adoption benefits stemmed from more telemedicine service, elevated education productivity, greater household and farm incomes and employment growth.

This analysis found that large increases in broadband adoption can spur significant economic gains over time, especially for counties with lower base levels of broadband adoption. Modest 10-year adoption gains of 10 percentage points for Bollinger and Henry counties increased annual GDP growth by 1.4% and 1.7%, respectively. When adoption gains reached 20 percentage points, average annual GDP growth was 2.4% and 3.2% higher than base 2019 levels, respectively.

Even counties with higher adoption base levels that have already benefited economically from broadband can gain from expanding broadband to more households. Nodaway County, which currently has above-average adoption levels, would see annual GDP gains of an estimated 0.8% to 1.4% under the minimum and maximum broadband adoption growth scenarios, respectively.

Annual employment increases were often similar to GDP in percent gains. In the minimum broadband adoption scenario, Bollinger and Henry counties had annual job increases averaging 1.5% of their 2019 employment levels. With broadband adoption gains of 20 percentage points, annual employment increases averaged 2.8%. Nodaway County had annual job gains, relative to 2019, of 0.8% and 1.5% under the minimum and maximum growth scenarios, respectively.

This study provides a practical method for analyzing broadband expansion's economic benefits to a community. It assumes that gains are driven primarily from a population that adopts and uses the technology once it is accessible. Investing in broadband clearly benefits a community, but access alone will not spur economic gains. Building out broadband to communities represents a first step. However, arguably more important are successful efforts to increase adoption and digital literacy skills needed to harness these economic benefits.

Endnotes

[1] Congressional Research Service. (2019). Broadband Data and Mapping: Background and Issues for the 116th Congress. Retrieved at: https://fas.org/sgp/crs/misc/R45962.pdf
[2] U.S. Census Bureau, American Community Survey, 2019 5-Year Estimates, Table S2801
[3] Whitacre, B.E. (2011). Estimating the economic impact of telemedicine in a rural community. *Agricultural and Resource Economics Review*, 40(2): p. 172.
[4] Gordon, A.S., W.C. Adamson, and A.R. Devries. (2017). Virtual visits for acute, nonurgent care: a claims analysis of episode-level utilization. *Journal of Medical Internet Research* 19(2).
[5] Nord, G., Rising, K., Band, R., Carr, B., Hollander, J. (2019). On-demand synchronous audio video telemedicine visits are cost effective. *The American Journal of Emergency Medicine*, 37(5), 890-894.
[6] Hanushek, E. and Woessmann, L. (2020). The Economic Impacts of Learning Losses. Organization for Economic Co-operation and Development. Retrieved at: https://www.oecd.org/education/The-economic-impacts-of-coronavirus-covid-19-learning-losses.pdf
[7] "Rural school districts can be creative in solving the internet connectivity gap – but they need support". (Aug. 2020). The Brookings Institute, Brown Center Chalkboard blog. Retrieved at: https://www.brookings.edu/blog/brown-center-chalkboard/2020/08/10/rural-school-districts-can-be-creative-in-solving-the-internet-connectivity-gap-but-they-need-support/
[8] Smith, P., Rudd, P. and Coghlan, M. (2008), Harnessing Technology Schools Survey 2008: Report 1 . Coventry: Becta. Retrieved at: https://dera.ioe.ac.uk/1549/1/becta_2008_htssanalysis_report.pdf
[9] Hampton, K., Fernandez, L., Robertson C., and Bauer, J. (2020) Broadband and Student Performance Gaps. Michigan State University, Quello Center. Retrieved at: https://quello.msu.edu/wp-content/uploads/2020/03/Broadband_Gap_Quello_Report_MSU.pdf
[10] Whitacre, B., Gallardo, R., & Strover, S. (2014). Broadband's contribution to economic growth in rural areas: Moving towards a causal relationship. *Telecommunications Policy*, 38(11), 1011-1023.
[11] Kandilov, A., Kandilov, I., Xiangping, L., and Renkow, M. (2011). The impact of broadband on US agriculture: an evaluation of the USDA broadband loan program. *Applied Economic Perspectives and Policy*. 39(4): 635-661.
[12] LoPiccalo, K. (2020). Impact of Broadband Penetration on US Farm Productivity. Office of Economics and Analytics, Federal Communications Commission working paper. Retrieved at: https://docs.fcc.gov/public/attachments/DOC-368773A1.pdf
[13] See for example: Kim, Y., & Orazem, P. F. (2016). Broadband internet and new firm location decisions in rural areas. *American Journal of Agricultural Economics*, 99(1), 1-18.; and Conroy, T. & Low, S.A. (2021). Broadband, Entrepreneurship and Gender: Evidence from Establishment Births in Rural America. *International Regional Science Review*. In press.
[14] Mack, E. A., Anselin, L., & Grubesic, T. H. (2011). The importance of broadband provision to knowledge intensive firm location. *Regional Science Policy & Practice*, *3*(1), 17-35.
[15] Kolko, J. (2012). Broadband and local growth. *Journal of Urban Economics*, 71(1), 100-113.
[16] Whitacre, B., Gallardo, R., & Strover, S. (2014). Does rural broadband impact jobs and income? Evidence from spatial and first-differenced regressions. *The Annals of Regional Science*, 53(3), 649-670.
[17] Lobo, B. J., Alam, M. R., & Whitacre, B. E. (2020). Broadband speed and unemployment rates: Data and measurement issues. *Telecommunications Policy*, 44(1), 101829.
[18] Mack, E., and Faggian, A. (2013). Productivity and broadband: The human factor. *International Regional Science Review*, 36(3), 392-423.
[19] Gallardo, R., Whitacre, B., Kumar, I., & Upendram, S. (2020). Broadband metrics and job productivity: A look at county-level data. *The Annals of Regional Science*, 1-24.
[20] Lobo, B. (2020). Ten years of fiber optic and smart grid infrastructure in Hamilton county, Tennessee. University of Tennessee at Chattanooga. Retrieved at: https://epb.com/about-epb/news/articles/new-economic-study-documents-269-billion-in-benefit-from-chattanoogas-community-fiber-optic-network
[21] Grant, A., and Tyner W. (2018). Benefit-Cost Analysis for Implementation of Rural Broadband in the Tipmont Cooperative in Indiana. Research and Policy Insights, Publication 005. Purdue University. Retrieved at: https://pcrd.purdue.edu/wp-content/uploads/2018/12/005-RPINsights-Tipmont-Broadband.pdf
[22] "Internet/Broadband Fact Sheet." Pew Research Center, Washington, D.C. (2021). Retrieved at: https://www.pewresearch.org/internet/fact-sheet/internet-broadband/?menuItem=89fe9877-d6d0-42c5-bca0-8e6034e300aa#who-uses-the-internet

[23] Center for Disease Control. (2017). National Hospital Ambulatory Medical Care Survey: 2017 Emergency Department Summary Tables. Retrieved at: https://www.cdc.gov/nchs/data/nhamcs/web_tables/2017_ed_web_tables-508.pdf
[24] Missouri Department of Health and Senior Services. (2015). Missouri Public Health Information Management System. Missouri Resident Emergency Room Profile. Retrieved at: https://healthapps.dhss.mo.gov/MoPhims/ProfileHome
[25] Lam, O., Broderick, B., and Toor, S. (2018). "How far Americans live from the closest hospital differs by community type." The Pew Research Center. Retrieved at: https://www.pewresearch.org/fact-tank/2018/12/12/how-far-americans-live-from-the-closest-hospital-differs-by-community-type/
[26] Missouri Department of Elementary and Secondary Education. (2019-2020). District faculty employment and salary information by county. Retrieved at: https://apps.dese.mo.gov/MCDS/FileDownloadWebHandler.ashx?filename=787d45d7-15b5District%20Faculty%20Information.xls

This research was funded by the University of Missouri's Office of Engagement in support of the University of Missouri System Broadband Initiative. Special thanks to the University of Missouri System Broadband Initiative Committee for their guidance; to Catherine Isley, MU Exceed graduate research assistant, for literature research and assumption development support; and Mark White for internal peer review.

Authors Information:
Alan Spell, Assistant Extension Professor
Division of Applied Social Sciences
College of Agriculture, Food and Natural Resources,
University of Missouri
alan.spell@missouri.edu

Sarah A. Low, Associate Professor of Regional Economics
Fred V. Heinkel Chair in Agriculture and Director, Exceed
Division of Applied Social Sciences
College of Agriculture, Food and Natural Resources,
University of Missouri