A Cost-Benefit Analysis of Alberta Rural Broadband Deployment

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Executive Summary

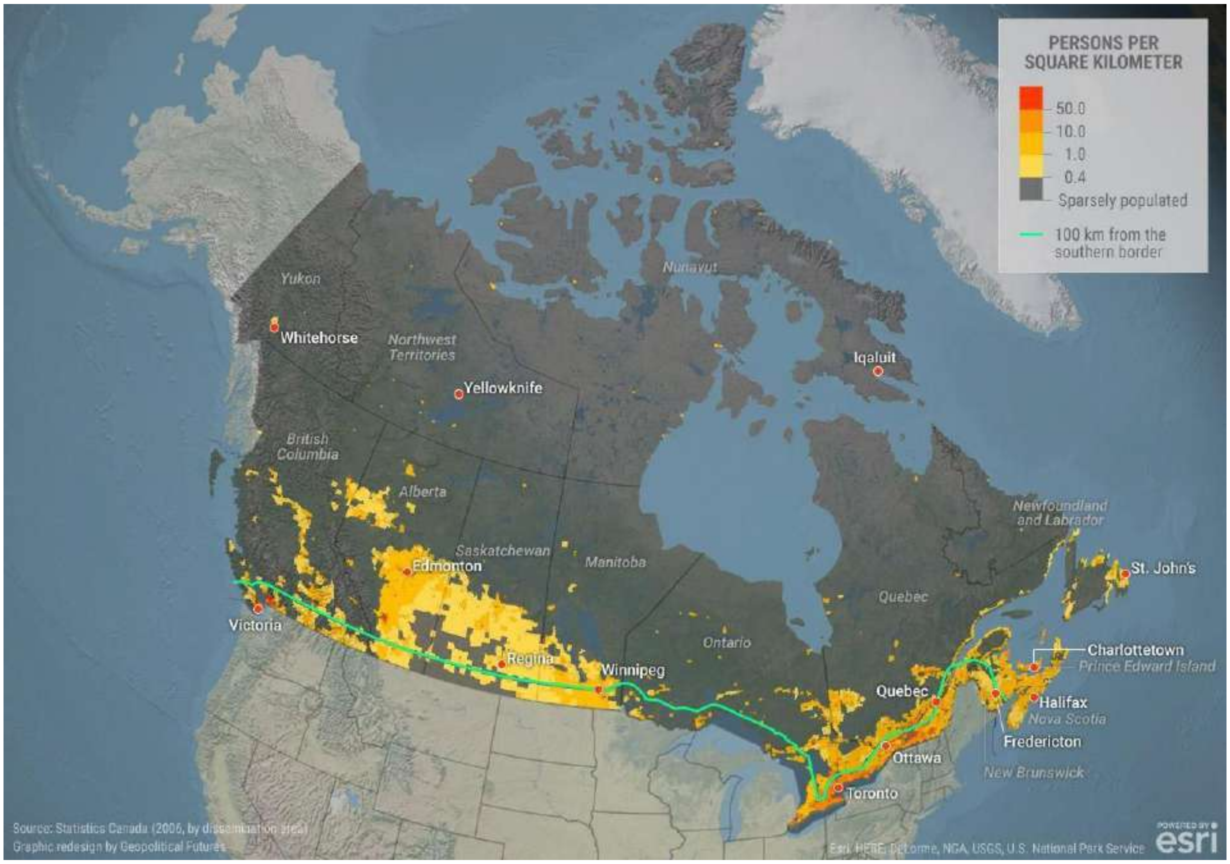
The Canadian Radio-television and Telecommunications Commission (CRTC) has officially recognized that a well-developed broadband infrastructure is essential for Canadians to participate in society. In 2016, It mandated that Canadian homes and businesses have access to broadband Internet speeds of at least 50 Mbps for downloads and 10 Mbps for uploads, as well as the option to subscribe to a service offering with an unlimited data allowance. The CRTC subsequently dialed back their minimum standards to 25 and 5, following significant push-back from consumer groups' as well as pushback from major providers, suggesting the 50/10 goal was too aggressive to be reached by 2021. On the most current website the CRTC claims: "we want all Canadian homes to have access to broadband internet speeds of at least 50 Mbps for downloads and 10 Mbps for uploads…we expect 90% of Canadian homes and business (to reach this Universal standard) by 2021." In addition to the basic Universal service objective for individual residents and businesses, the CRTC regulatory policy also mandates that the latest generally deployed mobile wireless technology also be available on as many major transportation roads as possible in Canada.

"… a well-developed broadband infrastructure is essential for Canadians to participate in society."

Alberta must develop a provincial broadband strategy in response to the Commissions new universal service objective. Alberta is uniquely situated to respond to the new CRTC policy. The province created its own 'SuperNet' in 2006, which is a network of fiber-optic cables and wireless connections that connects over 4200 schools, hospitals, libraries, and government offices in 429 communities. However, despite the existence of one of Canada's biggest fiber optic networks, only 105 of Alberta's 825 communities met this new universal service standard as of December 2018 (Dobson, 2018). In order to complete the original SuperNet, the province entered a public/private partnership with Bell, who now controls access to the SuperNet until after 2030. Despite the SuperNet, the challenge remains for how to ensure quality, affordable high-speed internet connections to everyone in Alberta.

Only 105 out of Alberta's 825 communities meet the CRTC standard.

Canada's perpetual problem with deploying essential infrastructure continues to be the low density of its population in relation to its large geographical footprint. Simply put, there are too few people spread out over too much space. When it comes to building infrastructure, this means that, relative to more densely populated jurisdictions, Canadians must build more infrastructure further, with fewer ratepayers to cover the costs. In practice, this means that private companies typically neglect deploying new facilities in low-density areas until the ROI can be justified, and that the public sector has often intervened to ensure that essential infrastructure reaches lower density regions. Throughout our history as a country this trend has held true for every type of essential infrastructure, including rail, highways, water infrastructure, gas, telephones, and now broadband.



Historical scenarios, such as the deployment of telephone infrastructure, cause us to suspect that there is a significant return on investment to society from investing in broadband deployments, even beyond our ability to foresee or even measure in the present moment. For all the infrastructure components mentioned above, numerous ways to further monetize their use were invented after the initial need was identified and the expense to build them justified. For example, the invention of the fax machine added significant economic value long after the deployment of telephone networks, an invention that the original investors were unlikely to have foreseen when justifying the expense to build the infrastructure. Further, we can already see the monetization and economic impact of data transportation evolving in front of us in real time. However, private businesses, municipal governments, provincial administrations, and federal decision makers continue to balk at the cost of large-scale investments in broadband infrastructure to connect all Canadians.

The natural question to ask is: Well, what is the return on our investment, as a society, if we spend the money to connect every Canadian? When we asked this question, we were surprised that no one had yet done the calculations in the Canadian context. This study begins with that question and attempts to quantify the return on our investment so that decision makers can move forward informed with defensible estimates.

What is the return on investment to society if we connect every Albertan?

To answer this, we looked at 2 hypothetical scenarios that help illustrate the importance of public investment in broadband infrastructure. Our first case study looked at the construction of a brand-new province wide fiber optic network. This would provide the public infrastructure that could deliver world-class high-speed internet connectivity anywhere in Alberta. Our model found over a 20-year horizon just over 35 billion dollars' worth of potential benefits compared to just over 11 billion dollars in costs. This is results in a C/B ratio of 3.17 dollars in benefits for every dollar invested. Our second case study looks at completing the same infrastructure but utilizing the existing SuperNet and building out to the remaining communities. The cost benefit ratio produced for the extension of the existing SuperNet was $3.47 in potential benefits for every dollar invested. Our second scenario highlights the importance of investment in rural broadband infrastructure. Communities not on the existing SuperNet are generally too small or isolated to attract private investment in broadband on their own.

An important consideration to bear in mind is that deploying broadband infrastructure is easily the least expensive of the various essential public infrastructures we have mentioned. Canadians have figured out how to fund roads, water, and power. We can certainly figure out how to fund broadband if we perceive it to be a high enough priority.

Why these two case studies?

There are numerous ways in which broadband can be deployed, with a wide mix of technologies, equipment, and software worked together into a complicated grid that pieces together components from multiple public and private players. It is a complex environment. We picked two of the most expensive, hypothetical scenarios available as test-cases for our number crunching under the assumption that most real-world projects will be far more affordable, smaller in scope, and achieve similar returns. We also based our calculations on today's conditions, and the savvy critic will understand that future use-cases of the infrastructure are likely to add to the return on investment. If building the infrastructure makes sense in today's context, the argument in favor of investment ought only to increase as time goes by.

The reader should be aware that there are two parts to a broadband network, backhaul transport, and access. Backhaul is the 'highway system' that connects your community with the global network, while 'Access' connects the buildings in your community to the backhaul. In the first case-study, we looked at what it would cost to build out an entirely new backhaul network that connects every community in Alberta with an access point to the global network, while also providing access in each community by running fibre to the premises. In the second case-study, we looked at what it would cost to just extend the existing SuperNet backhaul network to all Albertan communities that are not currently included, and extend fibre to the premises of all of those new communities (assuming for simplicity that existing connected communities already have access). Both cases assume that once a community has backhauled access that communities are within reach of getting local networks that get them to the CRTC objectives.

How this study should not be read.

The reader should be reminded that the case-studies we illustrate below are hypotheticals only. The researchers and their funders are not necessarily advocating for the deployment of either scenario in the real world.

Acknowledgments

First, we are in great debt to Craig Dobson of Taylor Warwick Consulting Ltd. for providing us with the original data on Alberta Communities and stimulating discussions and suggestions on the cost side of the project. Second, we would like to express our gratitude and thanks to Dr. Aaron Christie for providing us with the calculations of the distance and updated the data. Third, we thank Keenan Geib for providing excellent assistance with the summary of recent literature on broad-band. Finally, we would like to thank the SouthGrow Regional Initiative, and their sponsoring communities, for providing the funding of this project. Without their support, this project would not be possible.

1. Introduction

1.1 Background

Access to high-speed broadband Internet has become a necessity for Canadians. Communities with broadband access experience a wide array of economic, educational, and social advantages. While most Canadians today have access to high-speed Internet, many rural and remote regions in Canada do not share this access due to a lack of suitable broadband infrastructure. This growing gap in access to high-speed broadband Internet is often referred to as the 'Digital Divide'. At the federal level, the Canadian Radio-television and Telecommunications Commission (CRTC) has officially recognized that a well-developed broadband infrastructure is essential for Canadians to participate in society. In 2018, it originally mandated that Canadian homes and businesses have access to broadband Internet speeds of at least 50 Mbps for downloads and 10 Mbps for uploads, as well as the option to subscribe to a service offering with an unlimited data allowance. The CRTC subsequently dialed back their minimum standards to 25 and 5, following significant push-back from consumer groups' as well as pushback from major providers, suggesting the 50/10 goal was too aggressive to be reached by 2021. On the most current website the CRTC claims: "We want all Canadian homes to have access to broadband internet speeds of at least 50 Mbps for downloads and 10 Mbps for uploads…we expect 90% of Canadian homes and businesses (to reach this Universal standard) by 2021." In addition to the basic Universal service objective for individual residents and businesses, the CRTC regulatory policy also mandates that the latest generally deployed mobile wireless technology also be available on as many major transportation roads as possible in Canada.

> **dig·it·al di·vide**
> *noun*
> 1. the gulf between those who have ready access to computers and the Internet, and those who do not.

What does a broadband connection of 50/10 represent in terms of typical household internet usage? Basic surfing and browsing the web requires 5 Mbps download, streaming high definition content requires 15-25 Mbps download minimum. Streaming 4k content and playing competitive on-line games requires 40-100 Mbps download and if you are working with large files you would require 200 + Mbps to be efficient. Most connected business applications require 100 Mbps, to effectively move files and video conference. To put it into perspective, Netflix recommends a 5 Mbps download speed to stream regular videos, and 25 to stream 4K videos. That is the typical usage per device connected. A minimum Universal standard of 25/5 is really at the absolute minimum required right now for a reasonable internet connection. It is easy to imagine requiring 100 Mbps download speeds as being the bare minimum anyone doing business online or working from home will require soon if they don't already. While a 50/10 standard might have seemed like an aggressive goal 2 years ago, it is quite easy to conceive of people requiring access to even higher bandwidth connections in the very near future.

Yet, for many rural Albertans who continue to lack high-speed broadband Internet access, the prospect of receiving the CRTC mandated service levels by 2021 seems unlikely. Several factors contribute to this view. Almost all wireless Internet service offerings do not meet CRTC mandated service levels. Furthermore, local ISPs in Alberta have proven to be unwilling or unable to invest in the broadband infrastructure required for many rural Albertans to access the CRTC mandated Internet service offerings. Lastly, there is the perception among Albertans of anti-competitive behavior among local ISPs regarding ownership of broadband infrastructure. As a result, for many rural Albertans, accessing high-speed Internet service offerings has become either exceptionally costly, impractical or outright unattainable.

Ensuring high-speed broadband Internet access for rural Albertans will be a challenge. Canada's low population density, diverse geographic terrain, and its regulatory framework have made it difficult for the private sector to offer mandated service levels at an affordable price.

Investing in rural broadband infrastructure also has numerous economic payoffs. One of the most visible benefits in Rural Alberta are the potential increases in Agricultural productivity. The advent of the connected farm is upon us, with boundless possibilities for productivity and efficiency growth as new technology spurs agricultural innovations. In addition to direct benefits of increased agricultural productivity in Rural Alberta, are all the benefits that come with increased connectivity in general. These include but are not limited to things like increased access to Alberta's public services in remote areas, drastically decreasing travel costs for access to basic education and health care. One of the biggest challenges that Alberta and Canada have always faced are low population densities spread out over vast geographical distances and difficult terrain. Once connected to the world through affordable reliable high-speed internet access, we all but erase the main difficulties presented by our large country. The benefits section of this report provides a more detailed account and analysis of these benefits.

1.2 Challenges

The monopolistic-style control of broadband infrastructure that currently exists in Canada has a stifling effect on expansion and innovation within the industry. The barriers to access for small companies is very high, and when or if they enter competition with the incumbents, they operate at a significant disadvantage that stifles industry growth and innovation. Policy decisions that facilitate shared access to existing infrastructure in order to move the industry away from facilities-based competition and towards service-based competition would help provide a more competitive environment in which businesses can thrive.

In the early 1900's, the provincial government partnered with local municipalities and industry in Southern Alberta to embark on an ambitious project of canal and irrigation building. The foresight of government and industry leaders in building this network enabled a century of economic prosperity, innovation, and created an economic environment that continues to provide a high quality of life for the people of southern Alberta. Before the irrigation canals were built the Canadian government connected the west with a network of rail lines built with both public and private partnerships. That network provided the infrastructure to connect the west to markets they would not have had access to and allowed the west to grow. The railroad was really what allowed Canada to become a country. Today, the Province has a chance to embrace an even grander project. Bold policy decisions today that enable the rapid expansion of broadband infrastructure throughout rural

Alberta will yield immeasurable dividends in the decades to come. Alberta's rural municipalities stand ready to partner on this project.

1.3 Project Overview

The CRTC has recognized that High speed access to the internet has become a necessity to participate in society. It is a requirement to be a part of the new economy. In 2005 Alberta built one of the most comprehensive fiber networks stretching thousands of kilometers across the province. This original SuperNet was conceived and constructed before anyone understood the true ramifications of internet connectivity. The world has changed very quickly since 2005, very few saw how smart phones were about to consume the economy. Facebook and social media were just beginning, and no one could have predicted how companies like Amazon, Airbnb and Uber were about to completely disrupt the world. What will happen in the next 10 years? Connected networks will be pervasive and necessary. While we already know things like self-driving cars and precision agriculture are on the eve of widespread deployment, and productivity technologies like them are being created every day and will continue to disrupt in ways we do not know. The 'Internet of Things', connected every-day devices that rely on being tied into the global network, is also growing rapidly. What other internet-based technologies are on the verge of being created? Algorithms are being created that can sift through social media posts and help identify teens at risk of suicide, these same algorithms can be used to help identify potential criminal activity. The world has never had access to a virtually unlimited amount of real time data that can be accessed anywhere.

> In the next ten years connected networks will be pervasive and necessary.

Alberta needs to address this new CRTC universal standard for internet access. The main objective of this report is to answer the question of what the return on investment is to society if we were to achieve this standard for every Albertan. We will do this by providing a comprehensive cost-benefit analysis of a province wide network, with fiber connections built to every dwelling as a hypothetical test-case for crunching the numbers. Such a network would be capable of taking Albertans into the next decades. We will use two case studies to do this. The case studies themselves are hypothetical in that it is unlikely that either will be the new provincial broadband strategy. They are designed to illustrate what could happen if the province went beyond the minimum investment that will be required to meet the new minimum universal standards of 25/5 but instead built a world class network capable of connections 4 x or 10x the speed. They also show the potential advantages to being forward looking and building a world class network, one of the largest of its kind. These case studies will illustrate the potential of investment into this type of public infrastructure.

The two hypothetical case studies we consider are:

1) *SuperNet 2.0*.

What are the costs and benefits associated with building a brand-new Alberta-wide fibre optic network connecting every community in Alberta? These new fibre optic line routes would all end at one of two main hubs in Calgary or Edmonton. We have calculated the shortest distance collection of paths that would accomplish this.

2) *Hybrid SuperNet 2.0*.

429 communities in Alberta are currently on the existing SuperNet that was built in 2005. Our second scenario assumes these 429 communities will be able to meet the new universal standard by tying in to the existing SuperNet, and the remaining communities are tied into end points along the existing SuperNet in Alberta.

In reality, there are a multitude of delivery systems available. Fiber, cable, wireless and combinations of them all already exist in different regions of the province. It is likely that the least expensive way of providing high speed access to Albertans will include a combination of these delivery methods. While there may be less costly specific approaches once micro studies are done for each region, this study is looking specifically at the cost benefit of building new fiber network infrastructure. Fiber may be costlier but provides the most upside potential in terms of potential expansion of the network for the future. The costs for Fibre are also mostly up-front and the network requires very little maintenance over a 40+ year lifespan, while other types of network will require continual upgrading every few years. Hence, on a total cost of ownership basis over the lifespan of a network fibre is the best bet.

The cost and benefit analysis will be conducted for both scenarios and compared using the net present values of benefits. The report will quantify the amount of net benefits and the risks (if any) associated with the project; thus, this report can provide decision/policy makers to make informed decisions.

An overview of the report is as follows: This introduction is followed by Section 2, which provides an overview of the methodology used in estimating costs and expected benefits associated with rural broadband deployment in Alberta. Section 3 summarizes the study findings. Concluding remarks and recommendations for the next steps are given in Section 4. Appendix A provides a brief description of generating the distance data whilst literature review is gathered in Appendix B.

2. Cost and Benefit Methodology

2.1 Literature review

Studies have been done in several US regions as well around the world that attempt to estimate the costs and benefits of providing rural broadband infrastructure. While the costs of building and maintaining a fiber optic network are known at any given time, the technology is changing rapidly, and so are the costs associated with the technology. Far more difficult, is a reasonable estimate of future benefits that can be attributed solely to low cost access to high speed internet. While we can give real numbers and projections of costs and returns based on today's numbers, a reasonable assumption to keep in mind is that future costs will be lower, and new returns on investment will arise that cannot currently be predicted. This same scenario has been observed with other national infrastructure projects such as telephone lines, gas lines, highways, rail, and more. A more detailed literature review can be found in appendix B.

"A reasonable assumption to keep in mind is that future costs will be lower, and new returns on investment will arise that cannot currently be predicted."

Previous studies on broadband adoption typically measure the net present value of the costs of building the fiber optic infrastructure against the potential benefits. Estimations of benefits become dated quickly but the methodology for calculating costs is well established.

Previous studies also help us identify potential benefit categories and ways to measure things like the benefits provided by increased access to education or health care. The methodology for calculating the costs in this project have been informed by previous estimates and are discussed in more detail in that section. The previous estimates in other studies about the benefits are used as background to generate and compared to our estimates for Albertans. These can be found and are referred to in the Benefits section

What we cannot learn from previous studies.

Any Cost Benefit Study about internet usage becomes immediately dated once published. While accurate cost estimates can be derived at the time of construction. It is impossible to calculate the benefits from things that have not been invented yet. The original Alberta SuperNet was completed in 2006. On September 2006 Facebook was opened to everyone 13 years of age or older and had roughly 2 million users worldwide. After exponential growth over the last 13 years Facebook now serves over 2 billion people worldwide. No one predicted how important social media would become in the daily lives for the majority of Canadians. How could anyone estimate the benefits associated with being part of a 4-billion-person network when that network didn't exist when cost benefit studies about potential SuperNet benefits were undertaken in 2004? Twitter was also created in 2006, no one could predict the benefits to instantaneous worldwide news availability, and its effect on global democracy. Amazon sales went from 8 billion to over 250 billion over this same time frame 2006 -2018. Widespread access to the internet has radically changed the way people live since the original SuperNet was constructed. Airbnb and Uber were still companies forming in the minds of 13-year-old kids! There is no question that improved accessibility will result in a host of benefits we can't even comprehend now. This is an important part of the equation, however impossible to put an actual number on. The first iPhone was available in 2007 a full year after the SuperNet construction. No one could have possibly predicted the massive amounts of data being shared amongst smart phones and how important and engrained our lives have been intertwined with these devices that require access to high speed networks.

Predicting the future with certainty is futile. This study will focus on the benefits as they can be defined and described as they exist today. We have used previous studies to help define our benefit categories. However, benefit estimates become dated very quickly as the internet and the way we use it changes. We provide estimates of these traditional categories in the benefits section to inform and compare our estimates for the benefits. These are discussed in more detail in the benefits section.

2.2 Methodology

A traditional Cost Benefit Analysis (CBA) allows the decision (or policy) makers to consider the trade-offs and decide if the community is better or worse off if the project be undertaken under several different technical scenarios. The problem facing Alberta's policy makers right now is very different. In our current scenario, it is not whether to pursue the project, but rather how will the government pursue providing all Albertans with the minimum basic service levels mandated by the CRTC. The main difference is that Alberta has been tasked with finding a way to meet these new requirements, regardless of the potential benefits. This makes the policy makers decision easier in one sense. However, this report still utilizes the traditional approach. It is important to identify the potential benefits as accurately as possible, because the traditional CBA ratios will help inform policy makers to the veracity with which they should pursue the investment. For example, if the benefits exceed the costs it may be conceivable that a fiber optic network capable of more than the minimum 50/10 required be constructed. Or, if the costs exceed the benefits, perhaps the province should try to meet the new minimum requirements as cheaply as possible. Either way, the net present values presented in this project are valuable data points.

Therefore, the methodology used in this report is based on the approaches that previously discussed in the literature review section. Specifically, the approach used in this report combines various approaches in the literature for estimating benefit-cost of implementation of rural broadband. However, before we provide details of the CBA approach, it is beneficial to briefly define the cost-benefit analysis problem clearly.

In general, a CBA estimates the equivalent money value of the benefits and costs to the community of a project, to determine whether it is worthwhile. That is, it is an analysis of expected balance of benefits and costs including an account of foregone alternatives and the *status quo*.

Both costs and benefits can be diverse. Financial costs (or direct costs) are typically include capital costs and operating costs. Whilst benefits may include cost saving and public willingness to accept compensation (implying that public has the right to benefit of the project) for the welfare change resulting from the project. The impact of a project is the difference between what the situation in the study area would be with and without the project. That is, when a project is being evaluated, the analysis must estimate not only what the situation would be with the project but also what it would be without the project. Thus, CBA allows the decision (or policy) makers to consider the trade-offs and decide the community as a whole is better off or worse off under these technical scenarios.

The main criterion for the project's decision is to examine the difference between the discounted present value of benefits and the discounted present value of costs (i.e., net present value). If the net present value is positive, or equivalently, the ratio of discounted present value of benefits to the discounted present value of costs exceeds one, then the project is worthwhile.

It should be noted that an important aspect of CBA is that it can highlight the sensitivity of the outcomes to changes to the key parameters (or assumptions) affecting the computations of costs and benefits. And that makes it useful in dealing with the inevitable uncertainty as it clarifies the extent of the risks and helps structure the options for managing them.

For this report, there are three major components of the study that combine to obtain the overall estimates of benefits and costs of Alberta rural broadband deployment.

(1) The first component will be the cost of implementing the broadband services for the remaining Alberta rural communities. The cost estimates will include all the capital cost as well as operating costs as well as maintenance costs for the system. We envision a base speed of 50 Mbps for download and 10 Mbps for upload or higher as set out the CRTC recently.

(2) The second component will study the price and the broadband service providers will charge, and the anticipated participation rate given that price.

(3) Finally, the third component will provide the estimates of benefits that would be realized from the provision of the rural broadband in Alberta rural communities. These benefits represent the value to society in terms of provision of broadband service.

2.3 Description of the Data

The original data were provided to us by Craig Dobson of Taylor Warwick Consulting Limited[1]. It consists of 826 communities within the province of Alberta which include the population for each community in 2016. By matching with 2016 Alberta Population Census, approximately 0.44% of the data were double counted[2]. Subsequently, we adjusted this data and removed the 0.44% of double counting. In addition, for each community, we also collected the data on number of dwellings, neighboring community, distance to either the City of Calgary or The City of Edmonton (i.e., two main hubs) and local internet exchange, endpoint of route to local exchange (yes or no), on SuperNet path (yes or no), connectivity to the SuperNet (fibre or Wi-Fi) and distance to its neighbor[3]. We identified the 429 communities that are currently connected to the SuperNet. Appendix A provides a brief description of the process for obtaining the distance data.

2.4 Benefits

In 1998 Paul Krugman, a Nobel prize winning economist, suggested that:

"The growth of the Internet will slow drastically, as the flaw in 'Metcalfe's law' becomes apparent: most people have nothing to say to each other! By 2005, it will become clear that the Internet's impact on the economy has been no greater than the fax machine's"

Very few believed the internet would profoundly change the way the world's economy operates in its brief history. After the widespread introduction of the personal computer did not result in transforming the economy the same way as initially expected, why would anyone expect the sharing of information between all of these personal computers to result in anything different. One of the authors of this study was involved in a study done in 2002 which attempted to identify how southern Alberta farmers were utilizing personal computers for on farm operations. (Walburger/Davidson, 2002) Consistent with other studies done at the time, it was found that outside of bookkeeping and accounting and perhaps an odd spreadsheet to help analyze past performance, the personal computer was of little help in day to day farming operations. Access to personal computers did not result in huge productivity gains. It also did not fundamentally change how people live and communicate with each other. Transport 15 years later and now computers, smart phones and access to the internet are all important parts of daily life. While it can be said that the personal computer did not result in the huge productivity gains people had suspected or hoped for, the internet is what turned the computer into something not only useful but now arguably necessary to just be part of society, let alone be competitive.

In 2016 the CRTC justifies this new universal service standards with the following:

[1] We are grateful to Craig Dobson for providing us with this data.
[2] Craig Dobson (2018), "What is the Current State of Broadband in Alberta?"
[3] We would to express our gratitude to Dr. Aaron Christie for the assistance in the construction of these additional data.

> *Modern telecommunications services are fundamental to Canada's future economic prosperity, global competitiveness, social development, and democratic discourse. In particular, fixed and mobile wireless broadband Internet access services are catalysts for innovation and underpin a vibrant, creative, interactive world that connects Canadians across vast distances and with the rest of the world.*
>
> *Canadians are using these services to find jobs, manage their investments, conduct business, further their education, keep informed on matters of public concern, consult with health care professionals, and interact with all levels of government. In general, fixed and mobile wireless broadband Internet access services improve the quality of life for Canadians and empower them as citizens, creators, and consumers.*
>
> *A country the size of Canada, with its varying geography and climate, faces unique challenges in providing similar broadband Internet access services for all Canadians. Private sector investments, as well as funding programs from various levels of government, support the expansion of these services outside densely populated urban centres. Despite these efforts, many Canadians, particularly in rural and remote areas, do not have access to broadband Internet access services that are comparable to those offered to the vast majority of Canadians in terms of speed, capacity, quality, and price.*

Between 2006 and 2019, two major shifts have occurred that very few could have predicted in 2005. The use of smart phones, and the importance of using the internet for business. These have changed Alberta, Canada and the entire world drastically. Access to the internet is not a luxury anymore, it is an important part of everyday life, people plan their lives around it. The CRTC recognizes this, they suggest that access to affordable high-speed internet is necessary for Canadians to participate not only in the digital economy but to participate in society itself. The CRTC clearly believes the costs exceed the benefits to Canadians of having high speed access to the internet.

But how can you measure the benefits associated with something that is fundamental to social development and democratic discourse? You can put a dollar value on increased access to health care and education, how can you put a dollar value on increased democracy? What is the value of connecting isolated northern communities and potentially decreasing suicide rates? The answer is you cannot estimate a dollar value for many of the benefits that will be realized after the minimum standard is met. These things cannot be included in the calculus, but it is important to realize that they are there and very significant. Much the same as the original SuperNet builders, would have been unable to see just how important the internet was about to become, surely, we can anticipate that new inventions and technological advancements that we cannot anticipate will and are happening. Two problems that mean any estimate of current benefits will likely be lower than what occurs; many of the very real benefits that will occur are simply unmeasurable, and many of the things that's will result in benefits haven't been invented yet.

In order to generate a reasonable estimate of benefits we are then faced with two additional questions:

(1) What are the identifiable benefits that rural Albertans can expect from low cost accessibility to high speed connections?

The following section will look at how previous studies have defined and measured benefit categories. We will use these to create an estimate of the net benefit per person. The traditional categories that typically calculated in similar studies include GDP gains from agriculture and business gains, public service gains from health and education savings, and even estimates for increased civic engagement.

(2) How much of these benefits can be attributed solely to the existence of a new SuperNet 2.0?

Many of the advantages that high-speed internet with unlimited data provide, will still occur given the status quo, even if a new fiber network is not constructed. For example, many rural farmers are introducing more precision agriculture techniques and will continue to do so whether they must pay $200 per month for internet access or $50 per month for internet access. The real question is how many additional farmers will pursue these things only if given cheap access or cheaper access to high speed connections. The same applies to all the following traditional benefit categories; how much of the benefits will occur regardless of the building of the new SuperNet, and how many of the benefits will only occurs if the SuperNet is built. On the flip side, at what point do farmers who have access to high speed internet have such an overwhelming advantage that everyone without is no longer competitive. Several connected technologies promise returns that are so incredibly lucrative that any farmer would pay much more to stay connected and benefit from yield and/or productivity increases. It is possible to imagine this being a necessity to remain competitive in the future as opposed to incurring extra benefit if they do pursue the technology.

2.4.1 Traditional Benefit Categories

Previous CBA’s have used some or all the following benefit categories. This section looks at the general approaches taken in the past and is then used to inform our specific benefit calculations in the results section.

(a) Contribution to Alberta Gross Domestic Product (GDP) Growth.

Estimates of the internet’s effect on GDP growth in general are wildly different depending on where and when the study was completed. Estimates for increases in GDP because of access to higher speed connections with unlimited data are even fewer. While it may be possible to estimate an increase in agricultural productivity which will directly affect Alberta’s GDP, it is much harder to estimate the benefits from increased access to the global market for other rural based industries both small and large. Increased rural connectivity will undoubtedly create new business opportunities for both new and existing small and large companies in rural Alberta.

One report, conducted jointly by Ericsson and the Chalmers University of Technology, looks at 33 OECD countries, and quantifies the isolated impact of broadband speed, showing that doubling the broadband speed for an economy increases GDP by 0.3%. The authors also suggest that in

OECD countries, gaining 4 Mbps of broadband increases household income by USD 2,100 per year. Upgrading from 0.5 Mbps to 4 Mbps increases income by around USD 322 per month. The key drivers of the increases in household income linked to internet access speed are personal productivity increases from more flexible work arrangements, more advanced home-based business become possible and faster broadband speed enables people to be more informed, better educated and socially and culturally enriched – ultimately leading to a faster career path. Sosa in 2014 in a paper entitled "Early evidence suggests Gigabit Broadband drives GDP" found In MSAs with widely available gigabit services, the per capita GDP is approximately 1.1 percent higher than in MSAs with little to no availability of gigabit services.

A study by the Hudson Institute looked at the contributions rural broadband companies make to the states where they operated in 2015. They found that around 70,000 jobs were directly supported by Rural broadband companies in the US, and that the broadband companies contributed 24 billion dollars to the economies of the states they operated in. The authors also found that rural broadband supported over 100 billion dollars' worth of e-commerce in the US. Once SuperNet 2.0 is constructed, the end of the line individual subscriptions will be sold and administered by private internet provider services who will then tap into the SuperNet. These companies will hire employees and purchase advertising and contribute to the economies where they operate.

(b) Education, Telehealth and Access to other Government public services:

A Bell news release from September 30, 2005:

> *The high-speed Alberta SuperNet is now built and operational in thousands of facilities in 429 communities across Alberta, making the province more connected than ever before.*
>
> *All Alberta SuperNet communities are connected to the network, and ready to carry Internet service. Many of the 4,200 learning and health facilities and government offices connected across the province are already using the network for high-speed services such as video conferencing. Restructuring and Government Efficiency Minister Luke Ouellette said, "The network will now be continuously evolving, just like roads or any other infrastructure - for example, adding a new school once it is built. While we're pleased to have met this final milestone, it's the future possibilities of Alberta SuperNet that are truly exciting."*

Alberta's original SuperNet connected 429 communities. All the hospitals, schools and public institutions in these areas have high speed access and are connected. Being connected provides opportunities that were not previously possible. A grade school class can go on a live guided field trip to the Tyrrell museum in Drumheller without ever leaving the school. A patient in fort McMurray can get access to a specialist at a hospital across the province. The benefits from Alberta SuperNet 2.0 come from tying in the remaining 364 communities to this valuable network of

"Despite the SuperNet existence, many of the benefits have failed to materialize because of the privatization of the network."

knowledge and ideas. Despite the SuperNet existence, many of the benefits have failed to materialize because of the privatization of the network and the subsequent high-cost of access. High access fees have stifled many smaller communities' ability to participate. This will be discussed in more detail during the discussion of our second case study later in the paper.

Online education is now important at all levels. Many parents are required to access school's online information systems daily and the students often submit assignments through school network systems. This is becoming part of the way basic education is delivered in real classrooms. The remote education possibilities are endless. Retraining programs, University and college degrees, high school diplomas, can all be acquired on line. This is most important and valuable in the furthest regions of our province, where traveling for education is impossible. One of the four main research-based Universities in Alberta – Athabasca- delivers online degrees and programs that would be accessible to every Albertan no matter where they live. High speed broadband is the only requirement to participate.

Alberta Health services currently has over 1600 telehealth sites in Alberta. Broadband has made medical care and medical information more convenient and more accessible, particularly for Rural residents. Previous studies have shown that broadband-enabled virtual visits with trained medical professionals can improve patient outcomes at lower cost and often with a lower risk of infection than comes with care provided in person. Telemedicine is particularly valuable for rural patients who may lack access to medical care, as telemedicine allows them to receive medical diagnoses and patient care from specialists who are located elsewhere. Broadband can also be used to more accurately track disease epidemics. In a 2011 paper entitled "Estimating the Economic Impact of Telemedicine in a Rural Community," Whitacre estimated that each community that had the telehealth infrastructure recognized an impact of at least $20,000 per year in savings or other economic opportunities generated by the telemedicine equipment

(c) Farm income and profitability:

In 2019 Farm cash receipts in Alberta represent just under 4 billion dollars out of a total GDP of around 350 billion dollars. It is difficult to find anything written about what is happening in the agriculture industry today without hearing about *Precision Agriculture* and *Smart Farming*. These broadly refer to the careful use of accurate data to improve farming decisions. Never in the history of agriculture has so much micro-data been available to farmers. During the last decade, GPS technologies, sensors, drones and control devices have provided literally millions of data points in fields and livestock operations across this country, and the world. A new era in Agriculture is beginning. We are currently witnessing the digitization of an entire industry. In the past, this data was used primarily to analyze past performance with an eye on improving things for the future, or the next crop cycle or the next feedlot cycle. Now, technologies are being developed industry wide to incorporate and take advantage of the multitudes of data available. New tools are being developed that combine historical data with live data for optimal real time decision making. While Humans will always be a big part of higher-level agricultural activities, it is predicted that machines will largely take over many of the common operational activities. These will be Smart machines that rely on both historical and real time data to make optimal decisions. While farmers used to make decisions field by field, the introduction of more smart machines and even more data, it is becoming possible to farm inch by inch. For this to be possible, access to high speed rural internet is a necessity. Farmers and their smart machines of the future will require high speed access to the internet. The future is happening now. If the infrastructure is not developed quickly, opportunities for improvement will be lost. Those farmers that do not have high speed broadband accessible, will lag behind those that do have access. With the global demand for food set to nearly double by 2050, prioritizing rural broadband deployments to enable productivity growth in the coming years would be a wise decision.

High speed broadband is a requirement for precision farming. Alberta's Agriculture Industry is experiencing technology gains as more farmers adopt new precision farming techniques. Many of these farmers are adopting these practices despite high remote connectivity costs. While it may be true that cheap access might be the turning point for a few small farmers, Ultimately the difference directly attributable to a new SuperNet would be the lower monthly access costs. Whether a farmer pays $50 per month or $250 per month for high speed access will likely not be the deciding factor about whether to implement a precision agriculture technology for most significant size operations. However, the savings in connectivity are real and measurable.

(d) Business investment and economic development:

Previous studies have found that broadband access is one of the important factors contributing to business investment and job creation as well as general economic development and growth. For example, Whitacre et al. found that broadband adoption has positive impact on economic growth but negatively impacted unemployment in rural area. They also found that, broadband adoption leads to improved median household incomes and increased share on non-farm rural businesses. Lobo et al. provide multiplier impacts on broadband investment.

(e) Consumer savings via broadband:

Existing studies suggest that consumers can save money through various types of consumer purchases by using broadband. Affordable Access to high speed networks will increase the amount of ecommerce in rural Alberta as well. Retail ecommerce has been steadily growing. According to Statista, an online provider of market and consumer data, retail sales from worldwide electronic commerce are expected to grow from 2.3 trillion U.S. dollars in 2017 to almost 4.9 trillion in 2021. Revenue is expected to surpass 55 billion Canadian dollars by 2023, up from 40 billion in 2018. What is the portion of the increase in ecommerce that would be attributable to the existence of cheap high-speed internet? Retail ecommerce is going to continue to grow rapidly even without the SuperNet 2.0, there will be an increase that is difficult to measure, however, we can measure how much money rural Albertans will save on their monthly internet bills. That savings is what is directly attributable to a new SuperNet 2.0 and CRTC guidelines.

(g) Civic engagement

One of the unique features of broadband is that it enables people to connect and collaborate. "the whole world is watching" has become an anthem for justice. When governments attempt to limit protestors ability to communicate by shutting down internet access, protestors use their phones to create instantaneous networks that allow them to continue to expose injustices. The "Arab spring" illustrated how important social media can be in taking down corrupt governments. Democracy around the world is growing because of people being connected. This is an extremely difficult benefit to quantify but applies very specifically to Alberta's vast geography. If isolated areas are able to connect to the world, they will be more active participants in our provincial political system, and it becomes far more difficult to ignore the remote regions. Being connected also means a whole host of other mental health benefits difficult to quantify. We want all Albertans to have equal access to contribute to the political process. Other studies have shown that these types of benefits accrue largely to women, as well as lower income and less qualified workers.

2.4.2 Total Benefits to Alberta

While only 12 % of the 800 communities in our study regions have access to the CRTC mandated service, over 62% of Alberta's population currently lives in the areas that do already have access to the new universal service guidelines. Around 705,000 people currently residing in rural areas of Alberta do not have access to the minimal CRTC service standards. If the SuperNet 2.0 was built, Alberta would have the infrastructure to be able to provide more than the mandated minimum service requirement to all Albertans. Our scenarios assume that a publicly owned infrastructure would provide subsidized or very cheap access to the network for end of line service providers. This would mean that the market would be competitive for providing end of line services, because all companies would have the similar fees for accessing the infrastructure. The total Net Benefits to these Albertans include real and measurable benefits and real but unmeasurable benefits. The most basic benefit is the direct cost savings in terms of their monthly access costs and include all the benefits of increased connectivity in general.

Grant and Tyner (2018) estimated that the Net Present Value (NPV) of benefits of rural broad-band in rural areas in Indiana far exceed the costs over a 20-year time horizon. They estimated net benefits of $24,757 and $2,158 per member per year. This generated a benefit-cost ratio of 3.96 meaning that approximately $4 is returned for every $1 spent. This study was expanded to the entire state of Indiana and the Authors found Benefit-cost ratios range from 2.97 to 4.09, depending in the areas. They concluded from a societal perspective; the rural broadband investment is attractive. However, the anticipated revenue from customers would not be adequate to cover the total system costs, so some form of external assistance would be needed to incentivize the investments.

A similar 2018 study in Indiana found benefit-cost ratios that ranged from 2.97 to 4.09

A final benefit of this new province wide fiber network is that it is run along all the major roadways in Alberta. This will help satisfy the second part of the CRTC standards that mandates high speed wireless connections also be available along as on as many major transportation roads as possible. SuperNet 2.0 would be very capable of providing the infrastructure that may be required in the future for self-driving or assisted-driving car networks. What is the net present value of a province wide network capable of supporting self-driving cars? The specific benefit categories and estimates used in this study are explained in more detail in section 3.1.2

2.5 Costs vs Benefits

Key Assumptions of the Analysis:

Having defined the cost and benefit categories, and in order to compute the net present values of benefits and costs, some assumptions need to be made. There are some common assumptions that are used for all benefit and cost calculations such as benefit forecast horizon, and the discount rate. For this project, we will assume the following:

(1) Forecast horizon: 20 years after the broadband has been deployed.
(2) The discount rate is taken as 5% in real term.
(3) Monthly fee for broadband service, and the take rate (or participation rate).
(4) Population growth rate and growth on take rate.

To determine the worthiness of the project, the following criteria are used:

1. Net Present Value (NPV) which is defined as the difference between the present value of benefits (PVB) and the present value of costs (PVC). The project is worthy if the value of NPV is *positive* and not worthy if it is negative. Or equivalently, the project is worthy if the ratio of PVB to PVC exceeds one (i.e., (PVB/PVC > 1), otherwise it is not worthy.

2. Internal rate of return (IRR) which is defined as a rate of interest that sets the NPV equal to zero. If IRR is *larger* than the discount rate used in the calculations of PVB and PVC, then the project is worthy, otherwise, it is not worthy.

3. Case Study Findings

Before we begin to discuss the cost and benefits estimates, it should be noted that the system cost for all Alberta communities is quite complex to disentangle. It depends on may factors and the communities' decision on the deployments of broadband. For example, many communities have pursued local solutions, partnering with existing ISPs to undertake the deployment of infrastructure and operation of internet service, or creating their own solutions in-house. (some of these communities include Town of Taber, Town of Vulcan, Town of Olds, Grand Prairie, Waterton Lake)[4]. The costs of deployment can vary widely depending on the infrastructure choice/need as well as the operation of internet service. Given the lack of information for the cost structure, price and access fee for each community under consideration, it is not plausible to obtain accurate estimate of total cost for each community. Thus, for simplicity, we assume in this analysis that only fiber infrastructure is deployed. The estimated of present value of total cost (PVC) of deployment for the communities below is based on the extrapolations of the existing costs of the covered communities adjusted for inflation. In addition, the estimate of PVC is also based on the total of the average cost across the uncovered communities. We recognized that by using total average costs, we placed equal weights on each community and consequently, the value of PVC might have been overestimated[5]. However. if the net present value of benefit (NPVB) is positive[negative] (or the benefit-cost ratio (BCR) exceeds [less than or equal] one), then the overestimated PVTC can only further enhance the value of NPVB.

3.1 Scenario 1: SuperNet 2.0

3.1.1 Cost Estimates

In this scenario, we assume that the new SuperNet 2.0 is built to provide access for all 826 communities in Alberta that will exceed the CRTC standard. The system cost for this scenario consists of capital costs, operating costs and maintenance costs. The capital costs are assumed to include fiber distribution and installation. We extrapolate this cost based on the construction of the previous SuperNet (cost per kilometer) adjusted for inflation to obtain the current 2019-dollar value. In addition, we assume on average a cost $2000 per household to install fiber-to-premise, and an additional $1000 to provide drop, ONU and inside wiring[6]. It has been reported that the total capital cost for SuperNet is between 300 to 400 million dollars to build which consist of 15,000 kilometers in 2005. Thus, the capital cost per kilometer is between $20,000 to $26,667. In this analysis, we assume the capital per kilometer is $26,667 adjusted for inflation (assuming 2 percent inflation

[4] McNally et al. (2017). "Understanding Community Broadband: The Alberta Broadband Toolkits"

[5] One alternative approach to use weighted averages, where the optimal weights need to be determined by some type of optimization algorithms. Given the lack of data and large number of communities under consideration, it may not be feasible to obtain these weighted averages in our analysis.

[6] Aerially, the cost of would be approximately a third less. We thank Craig Dobson for providing this information,

rate) which approximately equals to $35,186. Based on the estimate of the total number of kilometers to be built (approximately 23,000), and assuming it will take 5 years to complete, the present value of total cost of capital over 5-year period is approximately $3.97 billion.

For operating and maintenance costs calculations, we assume the take rate is 15 percent in year one, 40 percent in year two, 60 percent in year three, 82 percent in year four and remain constant thereafter. That is, the full anticipated take rate of 82 percent is reached in year four. In addition, we also assume on average, the price of $55 and the access fee of $40 per customer per month or $480 per customer per year on average, 1.0 percent on the customers growth rate per year until year 10 and remains constant thereafter (this value is based on the annual average population growth of 1.45 percent between 2011-2016 in Alberta)[7]. Based on our estimation from the data, there are approximately 1,616,876 households to be considered. Table 1 below summarizes the assumptions made for system cost calculations.

Table 1: Common Assumptions Used in the Analysis

Assumptions	Value
Discount rate	5%
Monthly fee (on average)	$55
Access fee/month (on average)	$40
New Subscribers (on average)	$15
Base take rate	82%
Growth on take rate (year 4-20)	1.0%
Take rate year 1	15%
Take rate year 2	40%
Take rate year 3	60%
Take rate year 4	82%

Under these assumptions, the estimated present value (PV) of operating and maintenance costs of SuperNet 2.0 over 20-year period are approximately $7.06 billion and $127 million, respectively. Table 2 below provides the present value of various components of the total cost. The largest component of the operating costs is the access fee which made up about 82.5% of the operating cost.

[7] Alberta Population Estimates, Government of Alberta, 2018.

Table 2: Estimated PV of Total Cost: SuperNet 2.0 (5% Discount Rate, 2019 Dollar)

System Cost	Value
Capital costs	**$5,145,932,605**
Operating costs	**$7,058,708,671**
Access Fees	$5,827,027,261
Billing ($10/year/household)	$145,675,681.5
New Subscribers: $15/new member	$143,658,897.8
Tax (8% of Revenue)	$697,782,643.7
Bad Debt (1% of revenue)	$80,121,624.83
Marketing	$165,068,309.1
Maintenance costs	**$126,880,526.7**
TOTAL COST	**$12,331,521,533**

Source: based on authors' calculations

3.1.2 Benefit Estimates

As previously mentioned in the Methodology section, this analysis estimates key benefits categories regarding contribution to Alberta GDP growth, education, telehealth and access to other government services, farm income and profitability, business investment and economic development, and consumer saving. We also include the system revenue as well as income multiplier from broadband investment. The multiplier benefits are derived from the fact that any investment induces spending and income increases elsewhere in the provincial economy. As shown in the methodology section there are numerous unmeasurable benefits that will occur but cannot be quantified. This will result in our estimate of the benefits as the minimum of the benefits that are likely to occur. In reality the benefits must necessarily be higher. The detailed calculations of the measurable benefits are given below by category.

(1) Contribution to Alberta Gross Domestic Product (GDP) Growth.

As mentioned previously, the impact of broadband to the GDP growth is approximately 0.3%. However, because growth in DGP consists of many components including for example, growth on farm income, so to avoid double counting on the benefit, we decide to exclude this category in the calculation of benefit.

For the next three benefit categories, we follow similar approach of either Grant and Tyner (2018)[8] or Dobson (2013)[9] or combination of both to derive the net benefit.

[8] Grant, A. and Tyner, W.E. (2018). "Benefit-cost analysis for implementation of rural broadband in the Tipmon Co-operative in Indiana." *Research & Policy Insight*, Center for Regional Development, Purdue University.
[9] Dobson, C. (2013). "The true economics of broadband." *TaylorWarwick Consulting Limitted.*

(2) Telehealth (or E-Health).

The calculation of net benefit from telehealth follow directly from Dobson (2013) approach adjusted for inflation (assuming 2%). His approach is based on the information in a recent survey by Canada Health Infoway (CHI) to estimate the savings from the reduction of hospital stays and emergency visits. We modify his approach slightly and scale it for analysis. Assuming there are 135,000 patients with 0.97 reduction in hospital stays since 2009, one visit per patient, $9,009 per stay, 67% reduction in emergency visit and $155 per visit. The general formulas used in our calculations are as follows.

For savings from reduction of hospital stays:

$$Savings\ from\ hospital\ stays = 135{,}000 \times 0.97 \times 1 \times \left(\frac{Alberta\ pop.}{Canada\ pop.}\right) \times 9{,}009.$$

For savings from reduction of emergency visits:

$$Savings\ from\ emergency\ visits = 135{,}000 \times 0.97 \times (4 \times 0.67) \times \left(\frac{Alberta\ pop.}{Canada\ pop.}\right) \times 155.$$

The total saving is the sum of the above savings which is $1.42 billion over the 20-year period.

(3) E-Government Services

This calculation is based on Dobson (2013) approach. For e-government service, we use Dobson's assumptions adjusted for inflation (assuming 2%). In-person transaction cost reduction of $34/person, telephone transaction cost reduction of $10/person to $1 per transaction via internet. The government processes 12 transactions per year (for every woman, man and child). Assuming 0.1:0.9 in-person to phone split and 75% of the subscribers using the service, the present value of total saving from the government and users of the service is approximately $1.62 billion.

(4) Education.

There are various approaches to calculate the impact of broadband on education. Grant and Tyner (2018) in analyzing the education benefit for the Tipmon area in the U.S., use the minimum of U.S. $365/year ($487 Canadian) multiplied by the number of connected customers or five percent improvement in the teacher function using 2016-2917 K12 budget for the area multiplied by the number of connected customers. They also included the impact of adult education using average income and assuming 20% of households would either get new jobs or better jobs valued at five percent of average household income. Dobson (2013) analyzed the impact of broad band and education for six rural communities in northern Alberta using the spilled-over effects associated with improved of education outcomes in which educational and labour market gap between Aboriginal and non-aboriginal in 2001 were to be closed in 2026 as reported by Sharpe and Arsenault (2010). His estimate showed that the Canadian aboriginal communities would see an increase of $1.07 billion (2012 dollar). Scaling this value to the six communities under consideration, assuming 25% of the population to be either aboriginal people or able to benefit from improved educational outcome, he derived the annual net benefit of education. In this analysis, we combined the above two approached. First, using Dobson (2013) approach, we adjusted $1.07 billion to 2019 dollar and scaled this value to all communities in Alberta using 2016 population census, assuming 30% of the connected households to be either aboriginal or able to benefit from improved educational outcome. Next, follow from Grant and Tyner (2018), we use $487/ year adjusted to 2019 dollar multiplied by the number of connected households. Finally, we take the minimum of the two values. The estimated present value education benefit over the 20-year period is approximately $2.31 billion.

(5) Social Savings

In the same report, Dobson (2018) also calculated the social saving using the same approach as in education benefit. We follow his approach here and by scaling the social-wellbeing similarly to the education benefit. The present value of social saving is approximately $1.04 billion over 20-year period.

(6) Consumers Saving

A recent study conducted in the United Kingdom by Price Waterhouse Coopers[10] estimates consumer save £560 (or $903 Canadian) per year in insurance, energy, general shopping and services online. We will apply this value less the value of government on-line services (calculated in category (3) to avoid overlapping) to the annual connected household. For simplicity we assume this value remains constant in real terms over the life cycle of the investment, albeit it is likely to grow. Our estimated present value of consumers saving is approximately $4.68 billion over 20-year period.

(7) Farm Income Increase

Kandilov et al. (2017) discussed how internet can provide better access to weather information ad price information which can help to improve management decisions in the US agriculture[11]. They also discussed the process of using high-speed internet to help diffuse new management information or technologies. They estimated that farmers can realize increase in net income of approximately 1.28 percent per year over a seven-year period. This value applies to the counties near metropolitan area, but remote counties distant from the metropolitan center do not realize the benefits. In 2016, there are 40,438 farms in Alberta, and the net farm income is $1.82 billion[12]. Adjusted for inflation (2%) and assuming the percentage of applicability farm is 50, and overage, 5 percent of connected household are farmers and 60 percent of farms are near metropolitan centers, the net benefit of farm income increase over 20-year period is approximately $5.44 billion.

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[10] UK Government. *Government digital inclusion strategy.* 2014. (https://www.gov.uk/goernment/publications/government-digital-inclusion-strategy/government-digital-inclusion-strategy#contents).

[11] Kendilov, A.M. et al. (2017). "The impact of broadband of US agriculture: an evaluation of the USDA broadband loan program." *Applied Economic Perspective and Policy*, 39(4), pp. 635-661.

[12] Census of Agriculture: Provincial Profiles (https://open.alberta.ca>download).

(8) Total Revenue

The system total revue is calculated as the assumed price of internet per month multiplied by the number of connected households which is $8.01 billion over the life cycle of the investment.

(9) Multiplier Impact

As mentioned, the multiplier benefits are derived from the fact that any investment induces spending and income increases elsewhere in the provincial economy. For this type of multiplier analysis, Alberta expenditures typically end up getting counted both as benefit and as cost. For instance, when Alberta spends (say) $100 million, that spending becomes income for workers and businesses within the province. Moreover, that income is spent and re-spent so the multiplier is greater one. Following Grant and Tyner (2018), we take a more conservative approach and apply the multiplier of 0.99 to the system cost, and not count it as direct expenditures. We will conduct sensitivity analysis for the multiplier in later section of report. The present value of the impact multiplier is approximately $10.06 billion over 20-year period.

Table 3 below summarizes the present values of all the benefit categories. The present value of total benefit of implementing broadband is approximately $36.6 billion over 20-year period at 5 percent discount rate.

Table 3: Estimated PV of Total Benefit: SuperNet 2.0 (5% Discount Rate, 2019 Dollar)

Benefit Categories	**Value**
E-Health	$1,424,582,987
E-Government	$1,617,698,140
Education	$2,308,921,897
Social Saving	$1,041,683,096
Consumers Saving	$4,679,831,269
Farm Income Increase	$5,436,818,994
Revue	$8,012,162,483
Multiplier Impact	$12,082,594,864
TOTAL BENEFIT	**$36,604,293,730**

Source: based on authors' calculations.

3.1.3 Characterization of SuperNet 2.0 Net PV of Benefits

In this section, we summarize the calculation of present value of net benefits and present the overall results for the analysis of SuperNet 2.0 scenario. Table 4 contains the present value (PV) of total benefit, total cost and other measures to determine the worthiness of the broadband investment in Alberta. The result in Table 4 shows that the NPV of benefit of SuperNet 2.0 over 20 years is approximately $24.27 billion dollars. The benefit-cost ratio is 2.97 implying that approximately $2.97 is returned to the provincial economy for each dollar invested. For the reason stated earlier in section 2.4, we believe this is to be very *conservative estimate*. The internal rate of return (IIR) which is defined as a rate of interest that sets the NPV equal to zero. If IRR is *larger* than the discount rate used in the calculations of PVB and PVC, then the project is worthy, otherwise, it is

not worthy. Our result indicated that the IIR is 89.5% which far exceeds the value of the discount rate of 5%. These NPV of benefits can be expressed in various ways. For example, dividing the NPV of benefit by the number of subscribers give per subscriber NPV benefit of $15,613. Alternatively, the annualized benefit (which is computed as $(r \times NPV)/(1-(1+r)^{-20})$ where r is the discounted rate) is $1.948 billion implying that the net benefit can be seen as annual flow of approximately $1.948 billion to the province of Alberta.
An interesting exercise is to determine what percentage of the NPV of benefits accrued from rural area. In 2016, according to Alberta Census, approximately 19% of the population are from the

> Scenario 1 yields a benefit-cost ratio of 2.97.
>
> For the reasons described, this is a *conservative* estimate

rural area. If we use this percentage and multiply it to the value of NPV of benefits, then approximately $4.61 billion net benefits are accrued from the rural communities in Alberta.

Another indicator that emerges from the analysis is the system revenue from the province subscribers as a fraction of total expected costs over 20-year period. The ratio of net PV of revenue divided by net PV of total costs is 0.650. This result suggests that many of the benefits accrue to the province economy and not to the broadband provider. Thus, this highlights the fact that public support will be needed to achieve as much of public benefits as possible from the broadband investment.

On the hand, from the provider's perspective, for the system revenue to offset the total expected costs, the initial subscribers for the first two year need to rise to 23.2% and 31.5% respectively. Alternatively, either the price charge or the access fee needs to be increased. However, doing so would reduce the initial number of subscribers.

Finally, the PV of total operating costs is approximately 88% of the revenue which is consistent with previous findings in the literature.

Table 4: Summary of Analysis: SuperNet 2.0 (5%Discount Rate, 2019 Dollar)

PV of Total Benefits	**$36,604,293,730**
PV of Total Costs	**$12,331,521,533**
Net PV Benefits	***$24,272,772,197***
Benefit-Cost Ratio	***2.97***
Internal rate of Return	***0.895***
Annualized Net PV Benefit	***$1,947,710,039***
PV Operating Cost/Revenue	***0.881***
PV Revenue/Total Cost	***0.650***

Source: based on authors' calculations

3.2 Scenario 2: Existing SuperNet Extension

3.2.1 Cost Estimates

The existence SuperNet provides service to 429 communities in Alberta, and in this scenario, we assume that all 429 communities' infrastructure satisfied the CRTC 50/10 requirement. Thus, the analysis conducted here is for the remaining communities in Alberta which consists of mostly rural areas. The total number of households in this scenario is approximately 264,045 (or equivalent population of 705,000). We assume that, for simplicity, the existence SuperNet can be extended to these communities using fiber optic infrastructure only. Thus, the system cost can be calculated analogously as in the case of SuperNet 2.0. The remaining number of kilometers to be built is approximately 10,320. As in the case of SuperNet 2.0, we assume on average, a cost of $2000 per household for constructing fiber-to-premise, and an additional $1000 to provide drop, ONU and inside wiring, and it will take 3 years to complete. Therefore, the present value total capital cost for this scenario over 3-year period is approximately $772.5 million.

Regarding the operating and maintenance costs, we maintain the assumptions previously made for the case of SuperNet 2.0. Thus, the present value of operating and maintenance costs for this case over the 20-year period are approximately $1.3 billion and $25.6 million, respectively. Table 5 below provides the breakdown of the estimated present value of system cost.

Table 5: Estimated PV of Total Cost: SuperNet Extension (5% Discount Rate, 2019 Dollar)

System Cost	Value
Capital costs	**$1,101,115,448**
Operating costs	**$1,300,974,699**
Access Fees	$1,044,763,027
Billing ($10/year/household)	$27,768,575
New Subscribers: $15/new member	$58,409,072
Tax (8% of Revenue)	$125,631,893
Bad Debt (1% of revenue)	$14,425,454
Marketing	$29,976,678.97
Maintenance costs	**$25,623,949**
TOTAL COST	**$2,427,714,096**

Source: based on authors' calculations

3.2.2 Benefit Estimates

All the calculations of benefit categories for this scenario are similar to that of scenario 1, and hence we will not repeat the details here. We scaled the benefit calculations to the population and the number of households in this scenario. Table 5 below summarizes all the estimated PV of total benefit categories. The PV of total benefits is approximately $7.85 billion over 20-year period.

Table 6: Estimated PV of Total Benefit: SuperNet Extension (5% Discount Rate, 2019 Dollar)

Benefit Categories	Value
E-Health	$256,663,941
E-Government	$335,175,628
Education	$777,912,304
Social Saving	$187,549,260.3
Consumers Saving	$842,577,648
Farm Income Increase	$1,631,448,478
Revue	$1,442,545,390
Multiplier Impact	$2,378,069,245
TOTAL BENEFIT	**$7,851,941,894**

Source: based on authors' calculations

3.2.3 Characterization of SuperNet Extension of Net PV of Benefits

In this section, we summarize the calculation of present value of net benefits and present the overall results for the analysis of Existing SuperNet Extension scenario. Table 7 below contains the present value (PV) of total benefit, total cost and other measures to determine the worthiness of the broadband investment for the remaining communities in Alberta. The result in Table 7 indicates that the NPV benefit for this scenario over 20 years is approximately $5.42 billion dollars. The benefit-cost ratio is 3.23 implying that approximately $3.23 is returned to these local economies for each dollar invested. The internal rate of return (IIR) is 112% which far exceeds the value of the discount rate of 5%. As before, these NPV of benefits can be expressed in various ways. Per subscriber NPV benefit is $21,365. The annualized benefit is approximately $435.3 million implying that the net benefit can be seen as annual flow of approximately $435.3 million to these local communities.

It is interesting to note that, most of the communities in this scenario consist of rural areas, and the value of NPV benefits that are accrued from this scenario ($5.42 billion) is somewhat comparable to the value obtained in previous scenario for the percentage of rural communities ($4.61 billion). The ratio of net PV of revenue divided by net PV of total costs is 0.594. Again, this result highlights that many of the benefits accrue to the local economies and not to the broadband provider. Thus, public support will be needed to achieve as much of public benefits as possible from the broadband investment to these communities.

Scenario 2 yields a benefit-cost ratio of 3.23.

For the reasons described, this is a *conservative* estimate

Table 7: Summary of Analysis: SuperNet Extension (5%Discount Rate, 2019 Dollar)

PV of Total Benefit	**$7,851,941,894**
PV of Total Cost	**$2,427,714,096**
Net PV Benefit	***$5,424,227,799***
Benefit-Cost Ratio	***3.23***
Internal rate of Return	***1.12***
Annualized Net PV Benefit	***$435,254,072***
PV Operating Cost/Revenue	***0.902***
PV Revenue/Total Cost	***0.594***

Source: based on authors' calculations

3.3 Sensitivity Analysis

To account for the sensitivity of the results due to the choice of the real discount rate and the impact multiplier, we perform sensitivity analysis with respect to these two choices for each scenario considered.

For scenario 1 of SuperNet 2.0, Table 8 presents the total present values of benefits, the total present values of costs and the benefit-cost ratios for various real discount rates: 1% to 10%; whilst Table 9 provides the NPV of multiplier impact, NPV of total benefits and the benefit-cost ratios for six different values of multiplier. As can be seen from Table 8 and Table 9, regardless of the real discount rate choices, or the multiplier used, the benefit-cost ratio is always greater than 1. Therefore, the sensitivity analysis of the real discount rate reinforces the worthiness of the project's investment.

Table 8: Sensitivity Analysis of Real Discount Rate-SuperNet 2.0 (2019 Dollars)

Discount Rate	PVB	PVC	NPV	B-C Ratio
1%	$56,203,745,357	$18,607,683,501	$37,596,061,856	3.02
2%	$49,939,479,747	$16,613,757,712	$33,325,722,034	3.00
3%	$44,704,878,921	$14,940,392,663	$29,764,486,258	2.99
4%	$40,310,405,458	$13,528,693,255	$26,781,712,203	2.98
5%	**$36,604,293,730**	**$12,331,521,533**	**$24,272,772,197**	**2.97**
6%	$33,464,546,208	$11,310,999,745	$22,153,546,463	2.96
7%	$30,792,713,067	$10,436,570,962	$20,356,142,105	2.95
8%	$28,509,040,391	$9,683,487,339	$18,825,553,052	2.94
9%	$26548672406	$9031627524	$17517044882	2.94
10%	$24858668277	$8464568279	$16394099998	2.94

Source: based on authors' calculations.

Table 9: Sensitivity Analysis of Multiplier – SuperNet 2.0 (5% Discount Rate, 2019 Dollars)

Multiplier	NPV Multiplier Impact	NPV Benefit	B-C Ratio
0.99	**$12,082,594,864**	**$24,272,772,197**	**2.97**
1.2	$14,645,569,532	$26,835,746,865	3.18
1.4	$17,086,497,787	$29,276,675,120	3.37
1.6	$19,527,426,043	$31,717,603,376	3.57
1.8	$21,968,354,298	$34,158,531,631	3.77
2.0	$24,409,282,553	$36,599,459,886	3.97

Source: based on authors' calculations.

For scenario 2 of existing SuperNet extension, the same conclusion is reached, and the results are presented in Table 10 and Table 11.

Table 10: Sensitivity Analysis of Real Discount Rate-SuperNet Extension (2019 Dollars)

Discount Rate	PVB	PVC	NPV	B-C Ratio
1%	$12,450,367,646	$3,319,808,752	$9,130,558,893	3.75
2%	$11,009,968,870	$3,043,010,964	$7,966,957,905	3.62
3%	$9,787,049,985	$2,806,342,544	$6,980,707,441	3.49
4%	$8,744,455,252	$2,603,075,772	$6,141,379,480	3.36
5%	**$7,851,941,894**	**$2,427,714,096**	**$5,424,227,799**	**3.23**
6%	$7,084,807,223	$2,275,751,660	$4,809,055,563	3.11
7%	$6,422,803,291	$2,143,482,365	$4,279,320,926	3.00
8%	$5,849,276,072	$2,027,847,769	$3,821,428,303	2.88
9%	$5,350,480,533	$1,926,315,576	$3,424,164,958	2.78
10%	$4,915,033,909	$1,836,782,244	$3,078,251,666	2.68

Source: based on authors' calculations.

Table 11: Sensitivity Analysis of Multiplier – SuperNet Extension 2.0 (5% Discount Rate, 2019 Dollars)

Multiplier	NPV Multiplier Impact	NPV Benefit	B-C Ratio
0.99	**$2,378,069,245**	**$5,424,227,799**	**3.23**
1.2	$2,882,508,176	$5,928,666,729	3.44
1.4	$3,362,926,205	$6,409,084,759	3.64
1.6	$3,843,344,234	$6,889,502,788	3.84
1.8	$4,323,762,264	$7,369,920,817	4.04
2.0	$4,804,180,293	$7,850,338,847	4.23

Source: based on authors' calculations.

CONCLUSION

Our first case study looked at a brand-new province wide fiber optic network. This would provide the public infrastructure that could deliver world-class high-speed internet connectivity anywhere in Alberta. Our model found over a 20-year horizon just over 36 billion dollars' worth of potential benefits compared to just over 12 billion dollars in costs. This results in a C/B ratio of 2.97 dollars in benefits for every dollar invested. Our second case study looks at completing the same infrastructure but utilizing the existing SuperNet and building out to the remaining communities. The cost benefit ratio produced for the extension of the existing SuperNet was $3.23 in potential benefits for every dollar invested.

It is important to note that our estimated costs represent one of the most expensive up-front ways Alberta could provide high speed services. As mentioned previously, there already exists a mixed infrastructure, and the real costs of building a province wide network will be significantly cheaper than building a brand-new fiber network. At the same time, our benefit estimates are necessarily on the low side because of the impossibility of quantifying many of the benefits that will occur. What these hypothetical case studies show therefore, is that investment in this type of infrastructure has great potential, even if we look at a conservative estimate of the benefits and compare them to cost estimates that represent the most expensive way to build a new network. If we start to imagine the potential benefits not included in our model, as well as the potential for the actual costs to be significantly lower, it further emphasizes the importance and potential returns to this type of investment.

Typically, a cost benefit study is done to evaluate a projects potential. If the benefits exceed the costs, the project is recommended and if the costs exceed the benefits the project is not undertaken. The situation facing Alberta, as the province tries to meet the new 50/10 service standard is unique. Alberta must provide a basic level of service, regardless of the cost benefit ratio. Many communities in Alberta are currently looking at increasing access to high speed wireless already. Every community has different geographic complications and will require a unique approach that may or may not include fiber.

The CRTC has already determined that the benefits of providing this level of service exceed the costs. Our study supports this for Albertans. High-speed connectivity is an essential service for people to be a part of society.

Scenario 1: SuperNet 2.0 yields a benefit-cost ratio of 2.97

Scenario 2: SuperNet Extension yields a benefit-cost ratio of 3.23

Limitations of the study

As mentioned before, these are hypothetical scenarios. They help illustrate the importance of investing in broadband access in rural Alberta. In Scenario two we assumed that the existing 429 communities on the SuperNet could all tie into the existing network. This is naïve. If the SuperNet was publicly owned, access fees could be regulated. With private ownership of the infrastructure it changes the incentives. If I have exclusive rights, what is my incentive to sell those rights to my competitors. As a result, many of the 429 communities on the existing SuperNet have failed to fully utilize its potential.

> Why has the existing SuperNet failed to result in a plethora of cheap low-cost access points for High speed service along the provinces existing SuperNet highway?

This leads to an important question that requires additional study. Why has the existing SuperNet failed to result in a plethora of cheap low-cost access points for High speed service along the provinces existing SuperNet highway? Alberta is sitting on one of the largest most capable fiber networks of its type in the world. However, this network has been controlled by private companies and providing cheap access to your direct competitors is rarely in your best interest. There are billions of dollars of potential benefits not being realized. Other companies are building broadband infrastructure directly over top of the existing high-quality fiber. The only way this makes sense is if the access fees being charged exceed the costs of building. Our study highlights the potential costs of the SuperNet 1.0 contract.

Another major assumption in our scenarios is about end of line service providers. Building a new SuperNet or extending the existing one is the first step in providing the necessary infrastructure to allow all Albertans to have access to the internet at the minimal standards mandated by the CRTC. While we do consider the costs of building the infrastructure including a connection to each dwelling, we assume that once the fiber optic network is completed a mix of private and public internet providers must then tap into the SuperNet and provide the actual service to consumers. The town of Viking recently negotiated access through bell (the current gatekeeper of SuperNet 1.0) and we may see similar arrangements in other communities. An important part of the equation is how to ensure a competitive market for the end of the line service providers. This is not dealt with in this study. This is a very important part of the equation given the lack of use of the existing SuperNet.

> "An important part of the equation is how to ensure a competitive market for the end of the line service providers."

This country, and particularly this province, have benefited from the forward-thinking pioneers who undertook large public infrastructure investments in irrigation and railroads at critical junctions in history. We are now faced with a similar choice. Do we build the bare minimum to provide Alberta with affordable high-speed access or do we look further and build something for the future?

The internet is only going to become more engrained in our daily activity both personally and in business. Investment in public broadband infrastructure not only provides significant future benefits but is necessary to ensure Alberta's economy remains competitive. It is becoming such a part of our daily lives that the digital connections are as important or more important than physical connections. Internet connectivity is as basic a necessity as being able to physically access areas.

APPENDIX A: Brief Description of Generating the Distance Data

All the distance data comes from the Google Maps API, using Pythons scripts which was written by Dr. Christie. The script queries Google Maps for the shortest driving route between the two locations and then the distance information was extracted for that route from the response. That distance is returned in meters. The process is outlined as follows:

1) For each community, find the distance to Calgary and to Edmonton, and record the smaller of these two figures in the Local Internet Exchange column.

2) Divide the communities into two sets, one with the communities closer to the Calgary exchange and the other with the communities closer to the Edmonton exchange. The rest of the process is done for each set separately and then the results are combined.

3) Order the communities according to decreasing distance from the exchange. So, the first community is the farthest away, and the exchange city itself is last.

4) Run through the list in order and find the nearest neighbor on the way to the internet exchange for each community by applying the following criterion:

$$distance(C, exchange) - distance(D, exchange) \leq distance(C, D) + 5000.$$

Once this is done, the routes are built, and one can find a specific route by following the chains of nearest neighbours to the exchange as described above.

5) Repeat step 4 for the list of communities connected to the other exchange, and then combine the results.

APPENDIX B: Review of Recent Literature.

There is some literature review on the impact of mobile broadband deployments and the economic benefits for rural areas in the US. For example, Prieger (2013) provided an update of literature on the rural broadband digital divide, with special attention paid to mobility and discussed the potential benefits that the mobile broadband brought to the rural areas through economic development. Rembert et al. (2017) summarized what is the best broadband policy in Ohio going forward at the state and municipal level. Their recommendation is to establish a state broadband office, a broad band investment fund, and accept what is known as a "dig once" policy. In what follows, we will provide a summary of most recent literature on the relationship between broadband deployment and its economic benefits.

Grant, A. and W. E. Tyner (2018) provided the estimated of the costs and benefits of rural broadband for the Tipmont Rural Electric Cooperative service territory. They analyzed the "real world" costs and benefits of providing broadband service to households in a targeted multi-county area of Indiana. The authors found that the NPV of benefits of rural broadband in service area far exceed the costs over a 20-year time horizon – benefit is $24,757 and $2,158 per member per year. The benefit-cost ratio is 3.96 meaning that approximately $4 is returned for every $1 spent by Tipmont.

Grant, A., W. E. Tyner, and L. DeBoer (2018) extended the work of Grant and Tyner (2018) to provide the estimation of the Net Benefits of Indiana Statewide Rural Adoption of broadband infrastructures. Their analysis draws heavily upon an initial analysis that was done for the Tipmont Cooperative. Six additional Indiana REMCs were added, then the benefit-cost results of these seven REMCs were extrapolated to the state of Indiana. Benefit-cost ratios range from 2.97 to 4.09 for the seven REMCs. From a societal perspective, the rural broadband investment is attractive. However, the anticipated revenue from customers would not be adequate to cover the total system costs, so some form of external assistance would be needed to incentivize the investments.

Kandilov, A.M., et al. (2017) examined the impact of USDA's low-cost broadband loan program on the US agricultural sector. They used US country-level data on farm sales and expenditures in 2000 and 2007 to employ an inverse probability weighting technique to control for endogenous selection in an econometric model that also accounts for spatial dependence among farmers. Their results indicated that two USDA broadband loan programs have had positive causal impacts on farm sales, expenditures, and profits in a subset of rural counties—those adjacent to metropolitan counties - but not in other types of counties - implying that there were positive external benefits from the low-cost broad band program.

Kim, Y. and P.F. Orazem (2017) measured the effect of broadband deployment on location decisions of new rural firms. Location-specific fixed effects are controlled by a counterfactual baseline that measures how local broadband service in the early 2000s affected local new firm entry in the early 1990s before broadband was available anywhere. The change in location choice probability of new firms from the counterfactual baseline to the actual response ten years later is the difference-in-differences estimate of the effect of broadband deployment on locations of new firms. Their results showed that broadband availability has a positive and significant effect on location decisions of new firms in rural areas. The broadband effect is largest in more populated rural areas and those adjacent to a metropolitan area, suggesting that this effect increases with agglomeration economies.

Houngbonon, G. V. and F. Jeanjean (2016) analyze the relationship between competition and investment in the wireless industry using firm level data. Using econometric modelling, they found an inverted-U relationship between competition and investment. Investment is maximized when the profit margin is 37 or 40 per cent. Significant long run effect is 3 or 4 times larger than the short run effect.

Ong and Jambulingam (2016) used personal experience in using online learning and evidence gathered from available literature to examine the role of online learning, in particular, the use of massive open online courses (MOOC), on the reducing costs related to employee training and development. They showed that a major benefit of using MOOC for employee training and development programs is the potential for huge cost savings for employee training.

Schneir and Xiong (2016) provided a cost study of fixed broadband access networks for rural areas in Europe. They employed a cost model to determine the cost of a home passed and the cost of a home connected for various fibre- and copper-based networks in the European rural areas. Their results are inconclusive and indicated that some fixed networks will not meet the 30 Mbps target of the European Digital Agenda. There is the risk of an internal digital divide within the same rural community. A combination of different broadband networks will probably need to be employed. More broadband demand studies for rural areas are needed.

Audretsch, D.B., D. Heger, and T. Veith (2015) examined the link between infrastructure and entrepreneurship using the data constructed from different sources of the smallest regional authority level of counties in Germany. They found that broadband infrastructure is more conducive to infrastructure than others, such as highways and railroads. Types of infrastructure have varying influences in different sectors. Particular infrastructure policies can be used to facilitate regional start-up activities and foster start-up activities in desired industries.

Ovando et al. (2015) examined the feasibility for an LTE operator to deliver a 30 Mbps fixed service in rural areas in Spain and whether passive network sharing could make it feasible. They used techno-economic assessment in an infrastructure competition scenario, i.e., a discounted cash flow method is used to determine the total cost of the deployment for the operator and the minimum average revenue per user (ARPU), which would be required to recover the investment in both approaches: passive network sharing and non-sharing. They considered three demand scenarios, depending on the envisaged Spanish broadband penetration by 2020, to calculate what take-up rate and ARPU are likely to be in the targeted rural areas. They found that, given the socio-economic characteristics of the assessed area, demand is very sensitive to price, and that the existence of other broadband products forces the operator to lower the ARPU, and only very high take-up ratios would make the deployment feasible. Passive network sharing does not constitute a solution, but a single network deployment could solve the unfeasibility problem in rural areas.

Sosa (2014) tried to address the question of whether the deployment of gigabit broadband can be expected to produce economic benefits like the previous transition from dial-up to "always on" broadband? He examined economic output in relation to unemployment, metropolitan statistical area (MSA) and year fixed effects, and whether or not gigabit broadband was widely available. If the widespread availability of gigabit broadband speeds (defined as more than 50 percent of households have access to gigabit services) has a positive impact on economic higher output levels in areas that adopted gigabit broadband expected to be observed. Uses a fixed effects panel data regression model that controls for idiosyncratic differences across MSAs and over time, he provided evidence that that in MSAs where gigabit broadband service was introduced between 2011 and 2012, GDP per capita levels were significantly higher. In MSAs with widely available gigabit services, the per capita GDP is approximately 1.1 percent higher than in MSAs with little to no availability of gigabit services. His results suggest that the 14 gigabit broadband communities in the study enjoyed approximately $1.4 billion in additional GDP when gigabit broadband became widely available. Extending the results to the 41 MSAs in the study that did not have widely available gigabit broadband suggests foregone GDP in 2012 of as much as $3.3 billion.

Whitacre et al. (2014a) examined the relationship between high-speed broadband and economic growth in US rural areas. They used recent data on broadband availability and adoption in the U.S. to model the broadband's impact on economic growth from 2001 to 2010. Specifically, they used propensity score matching to compare "treated" versus "control" non-metro counties. Their results suggested that high levels of broadband adoption are (arguably) causally associated with higher incomes. Broadband adoption is more important than availability for economic growth measures.

Whitacre et al. (2014b) examined the relationship between broadband and jobs/income in non-metropolitan counties in the US. They employed spatial and first-differenced regressions using recent data from the Federal Communications Commission and the National Broadband Map to analyze the relationships between broadband adoption/availability and jobs/income in rural areas after controlling for a host of potentially influential variables such as age, race, educational attainment, transportation infrastructure, and the presence of natural amenities. They found that there is evidence that high levels of broadband adoption in non-metro counties are positively related to the number of firms and total employees in those counties. The first-differenced regressions use data from 2008 and 2011 to suggest that increases in broadband adoption levels are associated with increases in median household income and the percentage of non-farm proprietors in non-metro counties. Interestingly, simply obtaining increases in broadband availability (not adoption) over this time has no statistical impact on either jobs or income.

Kolko, J. (2012) analyzed the Relationship between broadband expansion and local economic growth for the US during the period of 1996 to 2006. Hi analysis relied on the uneven diffusion of broadband throughout the United States, allowing comparisons between areas with greater and less growth in broadband availability by combining broadband data from the Federal Communications Commission, employment data from the National Establishment Time-Series database, and other economic data from the US Census and Bureau of Labor Statistics to examine broadband availability and economic activity in the US. His results indicated that there is a positive relationship between broadband expansion and local economic growth, and that the relationship is stronger in industries that rely more on information technology and in areas with lower population densities. Moreover, instrumenting for broadband expansion with slope of terrain leans in the direction of a causal relationship between broadband expansion and local economic growth.

Whitacre (2011) provided the estimates the economic impact of Telemedicine in rural communities in the US. He used a random utility framework to model the decision to implement telemedicine where an alternative is chosen if its associated benefits outweigh the cost. Four distinct categories were used to estimate the economic impact of a telemedicine center in a rural community. Three of these categories deal with the "opportunity costs" that telemedicine presents (i.e., the costs that telemedicine helps to avoid), while the last category focuses on supplementary work that the presence of telemedicine may bring into a community. The four categories are: (1) Hospital cost savings from outsourcing telemedicine procedures; (2) Transportation savings to center patients; (3) Missed work income savings to center patients; (4) Lab/pharmacy work performed locally. His results showed that each community recognizes an impact of at least $20,000 per year in savings or other economic opportunities generated by the telemedicine equipment implying the average annual impact is around $522,000 and the maximum impact is over $1,300,000. Most communities tend to obtain the majority of their savings from increased lab/pharmacy revenues, due to additional work now performed locally, which is heavily influenced by the number of annual encounters. Personnel costs for some hospitals is actually negative due to telemedicine. This implies that the physician situation did not dramatically change after telemedicine use began, and now the hospital is paying an additional fee for external reads. In some cases, the personnel savings can be significant, but the savings from missed work and transportation costs rarely add up to more than 20 percent of the total impact.

Lobo, B.J., A. Novobilski, and S. Ghosh (2008) made an attempt to quantify the economic effects of first- and second-generation broadband availability in Hamilton County in Tennessee, US. They used a regional input-output model to estimate the impact of broadband deployments. They found that household broadband expenditures over the period 2001-2005 supported 548 jobs and contributed $109.8 million in income and taxes to Hamilton County – new fiber-to-the-home project would cost $195.5 million over ten years, and the economic impact of such a project would result in income and taxes exceeding $352 million while creating over 2,600 new jobs. Based on these findings, they concluded that Hamilton County would benefit from the adoption of this technology.

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