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High-Speed Broadband Expansion in Rural Sweden

Effects on population and workplaces

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Authors: Thim Andersson & Alexander Stenfeldt
Tutors: Sara Johansson & Helena Nilsson
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Authors:	Thim Andersson Alexander Stenfeldt
Tutors:	Sara Johansson Helena Nilsson
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Abstract

This paper examines the effect of high-speed broadband expansion on the rural population and number of rural workplaces in Sweden in the years 2009 and 2014. Previous studies conducted on the subject have found positive correlations between broadband expansion and economic growth. However, most previous studies have been focused on urban areas and the transition from no broadband to basic broadband. This study focuses on the shift from basic broadband to high-speed access in rural areas in all 290 municipalities of Sweden. This paper uses cross-sectional data to perform OLS regressions to test the effect that an expansion of high-speed broadband has on rural population and rural workplaces. An accessibility measure is constructed to control for different access that each municipality has to the rest of the population as well as to control for spatial dependencies. The results of this paper show that there is a significant correlation between high-speed broadband expansion and the number of rural workplaces.

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1. Introduction

With an ever-increasing array of Internet based services, relating to communication, entertainment, and e-commerce high-speed broadband access is vital. Geographical access to broadband can be of great importance for both firms and private customers. Sweden is a country with an unevenly distributed population. The northen part of the country Norrland covers aproximatley 60% of Sweden's total area. However, only 12% of the population (SCB, 2015) resides in the region. Most of northern Sweden is sparsely populated and rural. Whereas, most areas in the south are urban and densly populated. Areas with lack of broadband connection or connection of low quality might lag behind areas that are well connected in terms of economic growth. Most areas with poor access to broadband are located in the rural parts of Sweden. Many of these regions already struggle to keep and attract residents and firms. Lack of access to a quality broadband connection might amplify the problem.

Private-sector firms primarily drive the broadband technology expansion forward. Private-sector firms are first and foremost striving to make profits. Hence, expansion of broadband and the development of high-speed networks are for the most part focused on urban areas where the potential profits are higher. This creates a "digital divide" where rural areas run the risk of being left behind. The "digital divide" phenomenon is confirmed by several studies (Dickes, Lamie, & Whitrace, 2010; Strover, 2011) done in the U.S. The issue is not something that is easily solved. Development of broadband technology in rural areas is costlier per customer than development in urban areas, due to the dense nature of urban areas. The fact that the potential customer base is lower in rural areas makes it even more difficult to anticipate rural broadband expansion. Nevertheless, the Swedish government has set up goals for the development of broadband in Sweden. By 2020 the goal is that more than 90% of all households and firms should have access to at least a 100 mbit/s broadband connection. In an effort to reach the goal and speed up the rural development of broadband the government has committed 3.25 billion SEK (Jordbruksverket).

Previous research (Holt & Jamieson, 2009; Koutroumpis, 2009) indicates a positive relationship between broadband access and economic growth in rural areas. However, most research on this topic has been conducted in USA and similar studies done for Sweden are hard to come by. Most previous studies have focused on urban areas and we are interested to find out how broadband expansion has affected the rural regions of Sweden. Therefore, it is in the interest of this paper to test if the results from studies done in other countries apply to Sweden as well. Hence, the purpose of this paper is to explore the effects, specifically on number of rural workplaces and rural population that the broadband expansion has had in Sweden. To test this, we will use data from Post- och telestyrelsen (Swedish Post and Telecom Authority) on the number or rural workplaces and rural population for the years 2009 and 2014.

The gap between urban and rural areas in terms of broadband access has increased as the expansion has progressed. The government recognized the increasing gap and on November 2nd 2009 the Swedish Government decided that Sweden should have world leading broadband access. Setting the goal that 90% of Swedish households should have access to a broadband connection that supports at least 100 Mbit/s speeds (PTS, 2013). In order to achieve this goal, the Swedish Government has put aside 3.25 billion SEK in grants between the years 2014 and 2020. In order to promote the development of broadband in rural areas, the money cannot be granted to what is known as urban localities[1]. Urban localities are areas with a minimum of 200 inhabitants and a maximum of 200 meters between houses. The subsidy is aimed towards trying to narrow the gap between urban and rural areas. In 2015, 73.78% of the population in urban areas had access to a connection that met the goals set up by the government, while only 20.84% of the population in rural areas had access to a 100 mbit/s connection (PTS, 2015).

Several studies have been made regarding the economic effects of broadband expansion in different countries. Even though most of them have found some positive effects they are almost exclusively focused on the country as a whole and little research has been done focusing on rural areas and the effects broadband has there. Gillet, Lehr, Osorio and Sirbu (2006) and Kolko (2012) suggest that access to broadband have positive effects on employment and economic growth. Kolko (2012) also notes that the relationship is stronger in industries that are more reliant on information technology and in areas that have lower population densities. Gillet et al. (2006) find that while broadband access has a positive impact on population and employment growth, wage levels seem to be unaffected by broadband expansion. Kolko (2012) also notes that access to broadband can have heterogeneous effects on employment, due to the fact that the reliance on IT differs between industries. Industries that employ more high-skilled labor are generally more reliant on access to broadband compared to industries that mostly employ low-skilled labor. Broadband access can increase the productivity of a high-skilled workforce, as access to resources and information are easier to obtain. Databases and computers can have a negative effect on employment, as they might be able to replace some routine labor tasks. In rural areas where the labor market is dominated by industries that employ mostly low-skilled labor, increased broadband access might have a negative effect on employment.

Earlier studies (Lehr et al. 2005; Gillet et al. 2006) found positive effects from broadband expansion on employment and number of businesses. However, many of these studies were written almost a decade ago and do, as is the case with Lehr et al. (2005), focus on data from around the year 2000. The effects from these studies are therefore focused on the transition from no broadband at all to basic broadband. The results from these studies may not be the

[1] Known as Tätort in Sweden

same as when looking at the transition from low speed to high-speed access, as is the case in Sweden today.

The outline of this thesis is as follows: In section 2, the theoretical framework is presented. At the end of section 2 the hypothesis is stated. The method part in section 3 presents descriptive statistics, the empirical design, how the data was gathered and describes the variables included in the regressions. In section 4, the results from the regressions are put forward and analyzed. Section 5 concludes the thesis as well as provides suggestions for futher research.

2. Theoretical Framework

Broadband affects the labor market in several ways; job searching through the internet can increase job opportunities for workers, improving the matching of workers and firms, as well as increase employment by helping firms to find workers outside of the geographical restriction that previously existed (Autor, 2001). Widespread adoption and use of broadband has led to a change in the way firms and customers operate by moving large parts of the commerce online. This has led to the establishment, continued survival and growth of several niche markets beyond the customer base that existed in the geographical space in which the firm previously operated (Poon & Jevons, 1997). Firms with access to broadband can make use of e-commerce. This gives them the option of expanding the market beyond the local demand for their products. However, e-commerce can also cause issues for firms, especially in rural areas. Most firms in rural areas rely on a local demand for their products, competition from large e-commerce websites might hurt local stores. If the competition is too fierce it might lead to retail stores closing down due to lack of customers.

The ability to be connected with access to higher data speeds in more locations also enables new types of services to establish and grow. Access to basic Internet connections led to many innovations in how both firms and people operate on a daily basis. With Silicon Valley companies like Google and Amazon leading the way with a market well outside any geographical boundaries. The same innovation can be enabled by the access of high-speed Internet access. Companies like Uber enable users to send their location to a taxi driver using the Internet. We can also see that powerful computers and fast Internet have enabled research in areas not before possible. A notable example is NASA using people all over the world to improve the design of the equipment to be sent into space. Also Folding@Home, a Stanford project in which its users help researchers understand and simulate protein folding to be used in order to find cures for common diseases. Telemedicine and Telehealth both bring great improvements to rural health care by expanding the possible selection of health care services in areas where traditional health care is lacking. By reducing transportation times and expenses, medical emergencies can be efficiently treated and generating savings for health facilities that can outsource medical procedures (Sternberg et al. 2009). When authors Forzati and Mattson (2014) evaluate the effect of digital services in elder care implemented in Västerås. It is estimated that savings of 53 Billion SEK between 2014 and 2020. All of these are examples of ways that location matters less and less and the access to high speed Internet does. One can sit in a cabin in the north of Sweden and do an increasing amount of work and recreational activities as long as there is access to high speed broadband. One could say that the spatial geography is becoming less important but digital geography and how well users can connect to one another is of increasing importance.

There is evidence that industries with higher fractions of high-skilled labor benefits more from access to broadband than industries with high fractions of low-skilled labor. Kolko (2012) notes that broadband access can have heterogeneous effects on employment due to the varying levels of usefulness broadband access has for different industries and tasks. Access to broadband can increase the productivity for skilled labor, as access to resources and information are easier to obtain. This might increase the need for skilled labor. Databases and computers can have a negative effect on employment, as they might be able to replace some routine labor tasks. In rural areas where industries with high fractions of low-skilled labor are dominating the labor market, broadband access might have a negative effect on employment.

Growth in endogenous models is driven by technological change that arises from intentional investment decisions made by profit-maximizing agents (Romer, 1990). Most endogenous growth models consider investment in human capital, knowledge, and innovation as the driving forces behind economic growth. Lucas (1988) and Romer (1990) constructed models that try to explain growth by other factors than technological change. Their models focused on human capital investment decisions. Human capital investment will according to the models create spillover effects for the economy. These spillovers will then lead to economic development.

Broadband infrastructure allows the generation and distribution of information and ideas in markets increasingly relying on information as an input (Czernich, Falck, Kretschmer & Woessmann, 2011). According to endogenous growth theory this would mean that improvement and innovation of broadband could facilitate economic growth. Development of broadband infrastructure could lead to improvement of business models as well as creation of new products. Broadband also makes it easier to obtain knowledge and information. Cheap and easy access to information can lead to faster adoption of new technology and production processes developed by others. This would be an example of spillovers that were created by innovation of broadband infrastructure.

Spillovers are traditionally viewed as the benefits that arise when firms and people locate close to one another in geographical space. The closeness and clusters yields savings in transportation costs leading to agglomeration economies (Glaser, 2010). There are two types of agglomeration economies; urbanization economies and localization economies. Urbanization economies is when people and firms locate close to one another in order to share the same infrastructure and other common structures without them necesarily conducting the same types of work. Localization economies on the other hand is when a clustering occurs of firms within the same industry in order to benefit from a shared base of high skilled labour known as labor pooling as well as the sharing of ideas and knowledge, known as knowledge spillovers.

The central place theory aims to explain the size and distribution of cities and smaller towns within a system. The primary purpose of the city or town (central place) is to provide goods and services to the surrounding areas. The central places are divided into high order and low order central places depending on the amount of goods and services that they provide. High order places, that is, the ones that provide a greater volume of goods and services tend to have a wider distribution and being fewer in number compared to low order places. Consumers will act rationally and purchase from where they can minimize transport costs. Central place theory explains that production is dependent on human capital as well as real capital. In order to benefit from and increase the amount of human capital, a certain size of the city and an established method of transportation is necessary. This explains the benefits of locating in urban areas (Christaller, 1966). The central place theory is also relying on increasing returns to scale when explaining why certain goods are being produced in more locations than other. The higher the increasing returns to scale a product has the more likely it is to be produced in smaller places compared to goods with lower increasing returns to scale which will be produced in the larger cities only.

Since the central place theory is also heavily dependent on transportation costs, one could assume that the widespread adoption of broadband and digitalization would have an impact on the distribution of settlements due to the fact that the Internet makes us less sensitive to distances. The Internet makes it easier to purchase goods in situations where the buyer and seller are not geographically close to one another. The access to high speed broadband is therefore more important to rural areas which does not benefit from the traditional agglomeration economies that comes from closeness in space. The rural areas may however benefit from closeness that arises from being connected. Broadband may change the economic geography to step away from transport costs in terms of moving a physical object or person from point A to point B towards transportation costs in terms of the ability and ease of which firms and people can connect digitally to one another. This would result in a slower rate of urbanization and enabling more people and firms to locate in rural areas.

2.1 Hypothesis

Endogenous growth theory and central place theory imply a positive effect of broadband expansion on the attractiveness of rural regions. Hence, expanding high-speed broadband may stimulate growth in rural population and rural workplaces. However, as mentioned earlier, access to high speed Internet and computers can lead to the replacement of human labor for certain routine tasks. This might cause negative effects in some areas that are heavily dependent on routine tasks. As stated in section 2, it is expected that the location of the rural area in relation to urban areas can explain variation in growth across different types of locations. However, while growth depend on locational factors it is expected, in accordance with location theory that expansion of high-speed Internet access can disrupt the relevance of geography.

Previous literature (Kolko, 2012) also suggests a positive effect of broadband expansion on population. Hence, one is inclined to assume that the same is true for Sweden as well, unless proven otherwise. All in all, the overall results are expected to show a positive relationship between broadband access and rural workplaces as well as rural population growth

3. Method

Using the report, “En ny landsbygdsindeling” (2015), each of the 290 municipalities in Sweden have been divided into four categories: metropolitan, urban, rural and distant rural. Each of the four categories has then been divided into urban areas and rural areas. An urban area is defined as an area with a minimum of 200 inhabitants and a maximum of 200 meters between the houses. Areas that do not meet the criteria for urban areas are considered rural areas. The following section 3.1, shows some descriptive statistics regarding the different types of municipalities.

3.1 Descriptive Statistics

The map in Figure 1 below illustrates the population characteristics of Swedish municipalities. The map displays four different categories of municipalities: distant rural (white), rural (light grey), urban (dark grey) and metropolitan (black). The map illustrates that almost all urban and metropolitan municipalities are located in the southern third of Sweden. Whereas, almost all distant rural municipalities are located in the northern part of the country, more specifically the northern inland. It is predominantly the distant rural municipalities in the north that struggle to retain population and firms, although, there are municipalities in the southern part of the country that have the same issue. However, many of the rural municipalities in the south have neighboring urban municipalities. This might render them more desirable for firms and population, as commuting is possible due to the small distance between them. Most rural municipalities in the north, however, have other rural municipalities as their neighbors. They are thus rather isolated and the population there is relying on the local labor market to a greater extent. High-speed broadband expansion could possibly negate some of the issues the rural municipalities face, as the digital world gets more accessible.

Figure 1. Map of Sweden

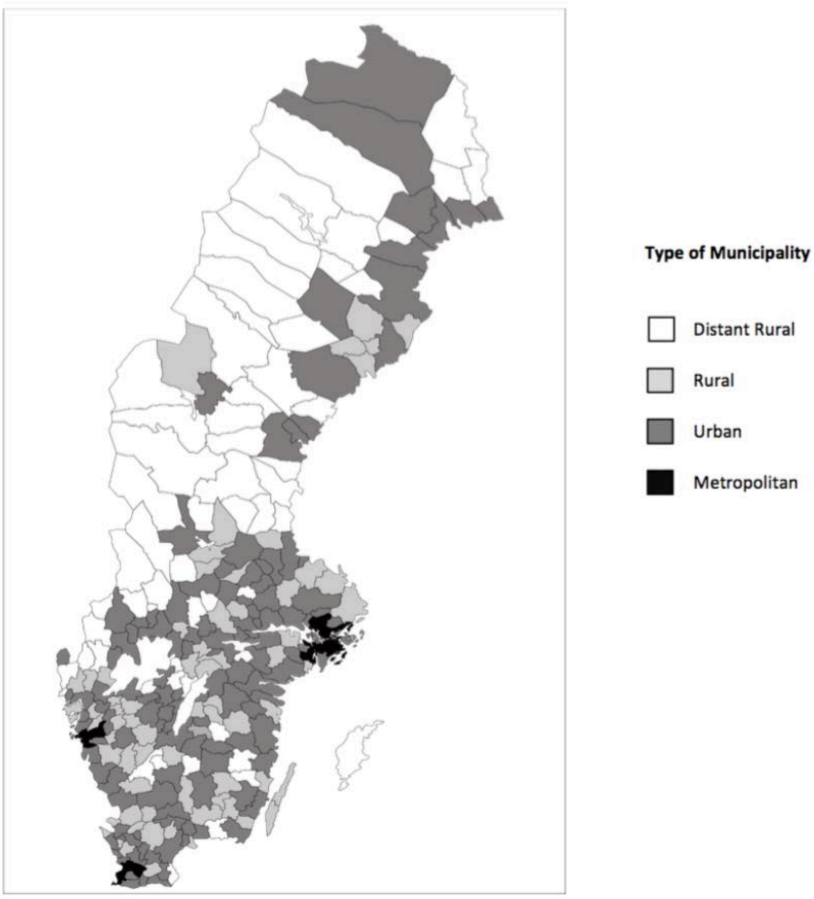

Table 1 to Table 3 below illustrate the average of each municipality category in population growth from 2009 to 2014, number of workplaces per 1000 inhabitants in 2009, percentage share of population with access to 100 Mbit/s broadband connection in 2009 and 2014.

Table 1 Average Population growth in Sweden 2009-2014.

Type of Municipality	Urban Areas	Rural Areas
Metropolitan Municipalities	8.7%	-1.8%
Urban Municipalities	4.0%	-1.6%
Rural Municipalities	1.2%	-2.0%
Distant Rural Municipalities	-1.8%	-4.3%

Table 1 above displays the average population growth between 2009 and 2014 for the four different municipality categories. One can observe a trend in both urban and rural areas. For the urban part of the municipalities a stronger population growth can be seen in areas that already have a higher population. One can also note that all categories except for distant rural municipalities have a positive population growth in the urban areas. The rural areas of all four categories have negative population growth. As shown in Figure 1 almost all distant rural municipalities are located in the northern inland of Sweden and as one can see from Table 1 it is these regions that have the largest issues with retaining their population. It is probable that a large part of the negative population growth in the rural parts of the metropolitan, urban and rural municipalities can be attributed to relocation to urban areas within the municipality. For the distant rural municipalities, however, it seems that parts of the population are leaving the region altogether.

Table 2 Workplaces per 1000 inhabitants in 2009.

Type of Municipality	Urban Areas	Rural Areas
Metropolitan Municipalities	81	392
Urban Municipalities	80	249
Rural Municipalities	99	289
Distant Rural Municipalities	130	318

Table 2 illustrates number of workplaces per 1000 inhabitants in 2009. One can observe that metropolitan and urban municipalities have roughly the same number of workplaces per 1000 inhabitants within the urban areas while rural and distant rural municipalities have a higher number. One probable reason that rural and distant rural municipalities have a higher number of workplaces per 1000 inhabitants is that many firms in these regions have a small number of employees. For example, a small town needs to have a grocery store, gas station, car workshop etc. In a small town most of these establishments only need one or a few employees as the customer base is fairly small. This leads to a situation where there are many small firms in the town and thus a high amount of workplaces per 1000 inhabitants. Larger cities, however, normally have a higher population density. One workplace can thus serve a larger number of customers, which explains why cities in metropolitan and urban municipalities have a lower number of workplaces per 1000 inhabitants. Looking at rural part of the four categories one can observe a similar pattern as within the urban areas except for the rural part of the metropolitan municipalities. This deviation could possibly be explained by rent and land prices. Many firms have probably chosen to locate just outside the city to take advantage of a lower rent or land price. While doing so, the firms are still within reach of their customers, but their costs are significantly lower.

Table 3 Percentage share of population with access to 100 mbit/s connection in 2009 and 2014.

Type of Municipality	Urban Areas		Rural Areas	
	2009	2014	2009	2014
Metropolitan Municipalities	57.0%	67.2%	5.1%	5.6%
Urban Municipalities	48.7%	49.2%	3.7%	10.3%
Rural Municipalities	30.8%	34.1%	4.1%	13.4%
Distant Rural Municipalities	33.3%	37.0%	5.2%	14.8%

Table 3 illustrates the percentage share of population with access to a 100 mbit/s broadband connection. Roughly half of the population in urban areas within metropolitan and urban municipalities had access to a 100 mbit/s connection in 2009. Whereas, around 30% had access in urban areas in rural and distant rural municipalities. The percentage share of population with access in rural areas, however, is miniscule in comparison. The average share of the population with access in rural areas ranges from 3.7% to 5.2%. Due to the fact that private firms mostly drive broadband expansion this result is expected. One can clearly see that the broadband expansion has come farthest in areas where the potential customer base is larger and profit potential is higher. The government hopes to lessen the gap in access between rural and urban areas with the 3.25 billion SEK set aside to subsidize broadband expansion in rural areas. For 2014 one can observe an increase in the share of population with 100 mbit/s access across all categories and areas. There has only been a slight increase of access within urban areas as well as the rural areas of metropolitan municipalites between the years. However, for the rural areas in urban, rural and distant rural municipalities there has been a substantial increase in access. Especially in rural and distant rural municipalites where the percentage share of population with 100 mbit/s access in rural areas have increased from 4.1% to 13.4% and 5.2% to 14.8% respectively. The percentage share of workplaces with 100 mbit/s access is very similar to the share of population with 100 mbit/s access. This holds true across all four municipalty categories as well as the urban and rural parts of the municipalties in both years. The percentage share of workplaces also displays the same trend in growth of access between the years.

3.2 Empirical Design

In order to test for the effects that the broadband expansion has on the employment, several OLS regressions will be conducted on the data gathered from Post- och Telestyrelsen (Swedish Post and Telecom Authority) and, Statistiska Centralbyrån (Statistics Sweden) as well as data on travel times from Vägverket (Swedish Road Administration) and time sensitivity from Johansson, Klaesson and Olsson, (2002). The following models were constructed and used as base regressions which was then added upon later:

$$\Delta \mathrm{WP} = \beta_0 + \beta_1 \mathrm{IBWP} + \beta_2 \Delta \mathrm{BWP} + \beta_3 \mathrm{Accessibility} + \varepsilon$$

and,

$$\Delta \mathrm{POP} = \alpha_0 + \alpha_1 \mathrm{IBPOP} + \alpha_2 \Delta \mathrm{BPOP} + \alpha_3 \mathrm{Accessibility} + \nu$$

Where, ΔWP and ΔPOP are the logged change in number of rural workplaces and rural population respectively in Swedish municipalities between 2009 and 2014. IBWP and IBPOP represent the initial share of workplaces and population respectively that had access to a 100 mbit/s connection in 2009. ΔBWP is the logged change of workplaces with access to a 100 mbit/s connection between 2009 and 2014. ΔBPOP represents the logged change the population with access to a 100 mbit/s connection between 2009 and 2014. ε and ν represent the error terms in the regressions, the error terms are expected to be independent and follow a normal distribution with a mean of zero. For detailed descriptions of the variables, see Table 5.

The two models above represent the base models for the regression analyses. Three dummy variables have been included in some regressions to test the difference between municipalities with different characteristics. The dummies have been created according to the municipality categories introduced in section 3. Dummy 1 represents distant rural municipalities. Dummy 2 represents rural municipalities. Dummy 3 represents urban municipalities. Two interaction variables have also been included in some of the regressions. The interaction variables IVDR and IVR have been included in the model to test if the effect of the broadband expansion is different across different types of municipalities.

The OLS regressions will then be used to estimate values for the beta coefficients associated with each variable. The estimated values for each beta coefficient will be given along with the corresponding test for statistical significance. The principal focus will, however, be on the correlation between broadband expansion and its effects on the dependent variables.

Table 4 List of all variables

Variables	Description	Definition
ΔPOP	The logged growth in population from 2009 to 2014 in rural areas within each municipality.	$Ln\left(\frac{Population_{2014}}{Population_{2009}}\right)$
ΔWP	The logged growth in the amount of workplaces from 2009 to 2014 in rural areas within each municipality.	$Ln\left(\frac{Workplaces_{2014}}{Workplaces_{2009}}\right)$
IBPOP	The initial share of the rural population within the municipality that had access to at least 100 Mbit/s in 2009.	$\frac{Users\ with\ 100\ Mbits_{2009}}{Inhabitants_{2009}}$
IBWP	The initial share of the rural workplaces within the municipality that had access to at least 100 Mbit/s in 2009.	$\frac{Workplaces\ with\ 100\ Mbits_{2009}}{Total\ no.workplaces_{2009}}$
ΔBPOP	The logged growth in number of connected people in rural areas within the municipality between 2009 and 2014.	$Ln\left(\frac{Broadband_{2014}}{Broadband_{2009}}\right)$
ΔBWP	The logged growth in number of connected workplaces in rural areas within the municipality between 2009 and 2014.	$Ln\left(\frac{Broadband_{2014}}{Broadband_{2009}}\right)$
Accessibility	A measure for the accessibility that each municipality has to the rest of the population in Sweden.	See Section 3.5 for a detailed definition.
D1	Dummy variable to control for distant rural municipalities.	D1=1 if municipality is classified as distant rural.
D2	Dummy variable to control for rural municipalities.	D2=1 if municipality is classified as rural.
D3	Dummy variable to control for urban municipalities	D3=1 if municipality is classified as urban.
IVDR	Interaction variable to interact broadband expansion with distant rural municipalities	ΔBPOP*D1
IVR	Interaction variable to interact broadband expansion with rural municipalities.	ΔBPOP*D2

3.3 Relationship Between Variables

In order to test the economic effects of broadband expansion in rural areas, the variables presented in Table 5 will be included in the regression analyses. This paper will test the effects on number of rural workplaces rather than rural employment. As stated in section 3.1 workplaces in rural areas generally have a small number of employees. Therefore, access to high-speed broadband might not increase the employment in existing workplaces considerably. However, high-speed broadband access could lead to new firms starting up. For this reason the number rural workplaces are of greater importance for this study.

Broadband is expected to be positively correlated with workplaces. It is to be expected that, as the access to broadband grows larger it benefits the economy and firms in ways previously stated. Which would increase both demand for goods as well as increased employment through better matching (Autor. 2001). Although, there are instances where broadband access has a negative correlation with employment. This can occur when databases and computers can substitute some routine labor tasks.

Population varies by birth and death rates as well as by migration patterns. Business investment, public spending as well as economic opportunities cause jobs. Furthermore, population growth is associated with the need for more services, such as: schools, health centers, shops etc. Which means that higher population levels are associated with more economic activity. Population is expected to be positively correlated with employment as an increase in the population increases the demand for all goods. This in turn leads to the need for firms to hire more workers. Some business owners may want to locate their business close to where they live, even though their customers predominantly live in other areas. Access to broadband makes this a valid option for some, which could lead to an increase in employment in the area.

Population and broadband access are also expected to be positively correlated. This is due to the nature of the free market. Broadband expansion is an expensive undertaking and to be as profitable as possible it is beneficial for the firms to focus their efforts on areas with high population density. In areas with higher population density the cost of expansion per capita is less than it is in areas with low density as there are more potential customers in the area. Therefore, areas with higher population density tend to have higher levels of broadband accessibility.

3.4 Data gathering

The data used in order to evaluate the effects of broadband in rural areas in Sweden is gathered from the Swedish Post and Telecom Authority known as Post & Telestyrelsen, also referred to as PTS. PTS is tasked with gathering data related to different types of telecommunications, which includes broadband on a yearly basis. The data is gathered and accessible on municipality level and includes the number of people who has access to broadband, sorted by what type of connection they have. Ranging from wired DSL access to fiber optic connection to wireless 4G or LTE access. The data ranges from 2007-2014. For obvious technological reasons, not all data for all connection types is available for all years due to the fact that some technologies were implemented after 2007. PTS also provides the total population for each year along with the total number of workplaces.

3.5 Accessibility Measure

It is expected that different municipalities will have different growth depending on their location in relation to other municipalities. The access of which the inhabitants in one municipality have to the rest of the population will affect the location decision of both people and workplaces. People and firms are expected to locate close to one another and thus generating growth through spillovers. Therefore, a measure of accessibility of the same form as used in Johansson (2010) has been constructed. The measure of accessibility uses the concept of functional urban regions, also known as FA-regions in Sweden. The boundaries of the FA-regions are constructed based on the amount of interaction and infrastructure within its borders, implying that the functional regions are equivalent to a regional labor market (Johansson. 2010).

Johansson, Klaesson and Olsson, (2002) estimate parameters for time sensitivity when traveling locally, within the region and outside of the region. These sensitivity parameters are denoted as $\lambda_1, \lambda_2,$ and λ_3 for local, intra-regional and inter-regional respectively.

The accessibility measures the intra-regional and inter-regional accessibility namely the proximity of each municipality to the population in the other municipalities within that region and the proximity to the population in all other regions respectively.

The accessibility measure contains three parts; the first one is the local. This is defined as:

$$A_{sL}^{P} = \exp(-\lambda_1 t_{ss}) P_s$$

Where the average time distance between different zones in municipality s, in region R is denoted as t_{ss} and the population of that municipality is denoted P_s.

The second part is the access that one municipality has to the population in the rest of the functional region. This is defined as:

$$A_{sR}^{P} = \sum_{r \in R, r \neq s} \exp(-\lambda_2 t_{sr})\, P_r$$

Where t_{sr} is the time distance between municipality s and municipality r within R and P_r is the population in municipality r.

The final part is the accessibility to all other regions, the inter-regional accessibility. This is defined as:

$$A_{sER}^{P} = \sum_{k \notin R} \exp(-\lambda_3 t_{sk}) P_k$$

Where t_{sk} is the time distance between municipality s and municipality k where k is not included in set R. P_k is the population in k.

By adding the three measures of accessibility, A_{sL}^{P}, A_{sR}^{P} and A_{sER}^{P} we get one unified measure of accessibility for each municipality that we include in our regression.

3.6 Limitations

The 1st Law of Geography as stated by Tobler (1970) says that everything in space is related but the relatedness of things decreases as the distance increases. In other words, the activities in one region have an effect on the activities in other regions, the effect is however diminishing with distance (Andersson & Gråsjö, 2009). It is expected that different rural areas will have different growth in both population and number of workplaces depending on where they are located in relation to others. Denser municipalities do, per definition, have access to a larger share of the total population yielding higher economic growth through spillover effects. The accessibility variable measures the access that each municipality has to the rest of the population.

Accessibility measure can also be seen as the spatial counterpart of discounting. It represents the spatial distribution of activity and their environment (Karlsson & Gråsjö, 2013). The geographical distance between economic agents affects the option to trade, interact and commute. It is therefore also used to control for spatial dependencies, which is done by the inclusion of the time travel distance in the measure. Hence the inclusion of accessibility measures also serves the purpose of reducing spational autocorrelation in the error terms.

There are limitations in the gathering of data not only due the actual gathering of data but also due to the rapid development of new technologies. Broadband is not homogenous and it is therefore hard to make comparisons regarding different types of broadband over longer periods of time. This combined with the goal set up by the government has lead us to look at the number of users who have access to 100 Mbit/s or more, in order to encapsulate different technologies and focus on the end result of the user.

As stated in section 3.3, the data gathered from Post- och Telestyrelsen ranges from 2007-2014. However, since fiber connections and 100 Mbit/s Internet connections were not established during the first years, the actual data ranges from 2009-2014. The limited span of data might affect the results and due to the inherent lag of broadband expansion, all effects might not be captured in the regressions.

Heteroscedasticity occurs when the variance in the residuals of the regression is increasing as the independent variables increase and leads to problems within the regressions if not accounted for. While in an ordinary least square regression the estimators will still be unbiased in the pressence of heteroscedasticity the true variance and covariance will be understimated. Using the Breusch-Pagan test it can be concluded that there is heteroscedasticity present within the models. Due to this fact, robust standard errors are used in order to take the heteroscedasticity into account. The results from the Breush-Pagan tests can be found in appendix A.1.

Multicollinearity implies that two or more independent variables in the regression are highly correlated with each other. The pressence of heavy multicollinearity can cause problems with the variance of the coefficient estimates of the regression. When calculating variance inflation factors we can conclude that there is no multicollinearity present within the models as defined by Williams (2015) and Gujarati (2003)[2]. The variance inflation factors (VIF) can be found in appendix A.2.

[2] Williams (2015) and Gujarati (2003) define multicollinearity as VIF exceeding 10.

4. Analysis

The following section will present the results from the regression analyses using both rural population (ΔPOP) and rural workplaces (ΔWP) as dependent variables.

Table 5 Regressions with logged change in rural population as dependent variable.

Dependent Variable: ΔPOP	Base Regression	With Dummy Variables	With Interaction Variable Distant Rural	With Interaction Variable Rural
Variables (t-values)				
Initial Broadband (IBPOP)	-0.232 (1.047)	-0.235 (1.074)	-0.239 (1.097)	-0.232 (1.083)
Broadband Variable (ΔBPOP)	0.009 (1.527)	0.008 (1.517)	0.011 (1.657)*	0.013 (1.859)*
Access to Population (Accessibility)	7.925E-007 (1,049)	1,027E-006 (0.906)	1,043E-006 (0.917)	1,053E-006 (0.927)
Interaction Variable Distant Rural (IVDR)	X	X	-0.014 (1.643)	X
Interaction Variable Rural (IVR)	X	X	X	-0.019 (2.237)**
Dummy for Distant Rural (D1)	X	0.106 (0.568)	0.139 (0.697)	0.104 (0.561)
Dummy for Rural (D2)	X	0.082 (0.598)	0.080 (0.585)	0.131 (0.862)
Dummy for Urban (D3)	X	0.067 (0.575)	0.065 (0.566)	0.064 (0.559)
R^2	0.149	0.159	0.164	0.170
Observations	290	290	290	290

*Significant at 10%
**Significant at 5%

Table 5 shows the four regressions that are run with rural population growth the dependent variable. The first regression uses three independent variables excluding the intercept. The broadband variable (ΔBPOP) has the expected positive sign throughout all four regressions however not significant in the first two regressions.

Adding three dummy variables to the regression to control for the four different types of municipalities as stated in section 3.1 yields the results in column two in table 6. Adding interaction variables to interact the broadband variable with the distant real areas and broadband with rural areas close to urban areas in the third and fourth regressions in table 5 respectively yields positive correlations between broadband expansion and rural population growth. We observe 0,011 and 0,013 correlations respectively, both of which are significant at the 10% level. Indicating that a 10% increase in broadband expansion corresponds to a 0,11% and 0,13% increase in rural population respectively. One can also note that accessibility has a robust positive relation to rural population growth, however, not significant.

The third regression that includes interaction variable distnt rural (IVDR) has an R^2 of 0,164. Meaning that 16,4% of rural population growth can be explained by the included explanatory variables. The fourth and final regression in table 5 show a R^2 of 0,17 showing that 17% of the change in rural population growth can be explained using said variables.

Table 6 Regressions with logged change in rural workplaces as dependent variable.

Dependent Variable: ΔWP	Base Regression	With Dummy Variables	With Interaction Variable Distant Rural	With Interaction Variable Rural
Variables (t-values)				
Initial Broadband (IBWP)	0.186 (2.035)**	0.190 (2.054)**	0.189 (2.055)**	0.185 (2.060)**
Broadband Variable (ΔBWP)	0.009 (1.851)*	0.009 (1.954)*	0.010 (1.653)*	0.013 (2.174)**
Access to Population (Accessibility)	4.576E-007 (1.224)	5.067E-007 (0.908)	5,084E-007 (0.910)	5.233E-006 (0.937)
Interaction Variable Distant Rural (IVDR)	X	X	-0.002 (0.227)	X
Interaction Variable Rural (IVR)	X	X	X	-0.013 (1.838)*
Dummy for Distant Rural (D1)	X	0.023 (0.211)	0.027 (0.230)	0.024 (0.218)
Dummy for Rural (D2)	X	0.024 (0.261)	0.024 (0.260)	0.052 (0.532)
Dummy for Urban (D3)	X	0.047 (0.562)	0.047 (0.562)	0.047 (0.570)
R^2	0.061	0.070	0.070	0.074
Observations	290	290	290	290

*Significant at 10%
**Signifcant at 5%

Table 6 shows the results of four different regressions with workplace growth as the dependent variable. One can see that both the initial broadband variable (IBWP) and the growth of broadband (ΔBWP) are significant across all four regressions. In the base regression the broadband growth variable has a coefficient estimate of 0.009 indicates that a 1% increase in the growth of broadband leads to a 0.009% increase in the growth of workplaces. In other words, a 10% increase in broadband growth will increase workplace growth by approximately 0.1%. Adding three dummy variables to the regression to control for the four different types of municipalities as stated in part 3.1 yield the results in column two in table 6.

Interaction variables that interact the broadband variable with the distant rural areas and broadband with rural areas have been added in the third and fourth regressions respectively. In these two regressions the coefficient estimate for broadband growth are 0.010 and 0.013 respectively. This indicates that a 10% in broadband growth induces a rural workplace growth of 0.1% and 0.13%. The later coefficient estimate of 0.013 is significant at the 5% level.

As hypothesized, the broadband variables (ΔBPOP and ΔBWP) have the expected positive sign in all eight regressions. However, only significant at 5% in the final regression using rural workplaces as the dependent variable in table 6. The regressions show an overall stronger significant correlation between broadband expansion and number of rural workplaces compared to rural population. The positive correlation between broadband expansion and rural workplaces is in line with previous research conducted. However, the coefficient estimates of ΔBWP, expanding broadband only have a marginal effect on rural workplaces.

It is also important to note and consider the causality in this study. Theory suggest that that the expansion of high-speed broadband will lead to an increase in the number of rural workplaces and the rural population. Due to the nature of this cross-sectional study, one cannot conclude whether an increase in access to high-speed broadband will cause an increasing number of workplaces or that an increasing number of rural workplaces will lead to the establishment of more high-speed broadband. Previous studies such as Gillet et al. (2006) and Kolko (2012) are careful not to claim causality and notes that we do not know. The causality is especially important when looking at policy implications and evaluating the effects of the government subsidy. It van be almost impossible to evaluate the effects of a policy in the event that the causal direction cannot be determined.

The low R^2 in all of the regressions using both rural population and rural workplaces as dependent variables indicate that there is a problem with omitted variables. The variables included in the regression analyses do not explain rural population growth or rural workplace growth to a large extent. Other factors not included in the model are thus the largest contributors to both rural population and rural workplace growth.

As previously mentioned, growth in broadband access has different effects for different industries. In our model the impact of broadband has been tested on the labor market as a whole. It is probable that the results would be different if one broke down the labor market in segments based on type of industry. Research previously done by Kolko (2012) finds that there are significant differences between industries. Manufacturing, for expamle, has a weak positive relationship with broadband. Finance and insurance, however, has a stronger positive correlation with broadband. Therefore, it is important to note that there could be significant differences in the results between municipalities even within the same category. Two distant rural municipalities, for example, could benefit differently from high-speed broadband expansion. Depending on which industries that are present in the municipality.

As stated in section 2, it is expected that broadband will affect location decsisions based on central place theory and agglomeration economies. The results, however, indicate that location and transportation costs still affect location decisions of both population and workplaces. The decrease in digital distance does not appear to yield the same benefits as traditional agglomeration economies. That is, people are still locating geographically close to one another to benefit from agglomeration economies. The benefits of broadband expansion can to some extent drive growth by itself but it is also dependent on other factors to gain full effect. Broadband growth yields more growth in the number of firms in areas that already benefit from spillover effects compared to those that are lacking spillovers. (Mack, Anselin & Grubesic, 2010)

5. Conclusion

The findings of this thesis illustrate a positive correlation between the broadband expansion and rural population as well as the number of rural workplaces. The results show that the correlation between broadband and rural population is not significant. We can however note a significant correlation between broadband and the number of rural workplaces. We can therefore conclude that the expansion of high-speed broadband in rural Sweden has had positive effects on the number of rural wokplaces while we can find no such effect on the rural population. In accordance with previous research and the theoretical framework one can observe that expanding high-speed broadband access yield several benefits in terms of location decisions. Firms can use high-speed broadband to locate in less central places in ways that does not apply to people. The results show that broadband enables firms to locate in rural areas to a greater extent while people still tend to locate close to other people. In relation to previous research (Kolko, 2012) conducted in the U.S the effect of access to high-speed Internet is smaller than the effects of expanding basic low-speed Internet access. Suggesting that it is more important to be able to access basic Internet services compared to the accessing serives requiring high-speed broadband.

The small effect of high-speed broadband expansion in rural areas might suggest that we have not yet reached the point where broadband has been able to disrupt the importance of location and geographical distances. The limited time span of this paper have not been able to show a paradigm shift in which access to high speed broadband changes the way location is viewed upon.

"The economic benefits of the Internet could yet turn out to be far different than what we are able to observe today" Jed Kolko (2012)

Suggestions for further research within this topic are for a similar study to be conducted after 2020 when the government's policy goal has been achieved in order to investigate the effect over larger time span. This would encapsulate the slow moving effects that broadband expansion has on rural population growth and the number of rural workplaces. Also as stated in section 4 the low R^2 throughout all regressions indicate problems with omitted variables in the regression analyses. It would thus be of interest to include more explanatory variables in the regression. Also testing the effect of broadband on different industry sectors as it is expected that different sectors benefit differently from high-speed broadband as stated in section 2.

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Appendix

A.1 Heteroscedasticity test for ∆POP

ANOVA[a]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.482	7	.640	16.697	.000[b]
Residual	10.815	282	.038		
Total	15.298	289			

A.2 Heteroscedasticity test for ∆WP

ANOVA[a]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.777	7	.111	10.147	.000[b]
Residual	3.085	282	.011		
Total	3.863	289			

A.3 Multicollinearity test for ΔPOP

Dependent Variable: ΔPOP	Tolerance	VIF
290 Observations		
Initial Broadband (IBPOP)	0.792	1.263
Broadband Variable (ΔBPOP)	0.442	2.260
Access to population (Accessibility)	0.459	2.181
Interaction Variable Distant Rural (IVDR)	0.372	6.239
Interaction Variable Rural (IVR)	0.338	5.715
Dummy for Distant Rural (D1)	0.160	5.003
Dummy for Rural (D2)	0.175	2.692
Dummy for Urban (D3)	0.200	2.959

A.4 Multicollinearity test for ΔWP

Dependent Variable: ΔWP	Tolerance	VIF
290 Observations		
Initial Broadband (IBWP)	0.831	1.203
Broadband Variable (ΔBWP)	0.420	2.382
Access to population (Accessibility)	0.455	2.199
Interaction Variable Distant Rural (IVDR)	0.334	2.990
Interaction Variable Rural (IVR)	0.303	3.301
Dummy for Distant Rural (D1)	0.154	6.501
Dummy for Rural (D2)	0.164	6.115
Dummy for Urban (D3)	0.201	4.965