

# Socio-economic return of FTTH investement in Sweden, a prestudy

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## Abstract

There is a wide range of FTTH initiatives throughout Sweden, with investments made by both telecom operators and public actors. The benefits of the investments are often discussed, especially when the investment is made by municipalities or other public bodies.

This preliminary study analyses the socio-economic impacts of the investment in FTTH. The goal of the study was: *Is it possible to calculate how much a krona (SEK) invested in fibre will give back to society?* The conclusion is that a more comprehensive statistical data and more calculations are needed to give an exact estimate. The study, however, provides an indication that 1 SEK invested over four years brings back a minimum of 1.5 SEK in five years time. The study estimates the need for investment to achieve 100% fibre penetration, identifies and quantifies a number of significant effects of fibre deployment, and then calculates the return on investment.

We recommend a more extensive study, in which the proposed model is refined and expanded with more detailed and updated data.

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# 1 Background

The business case for broadband access and FTTH is often evaluated from a traditional telecom perspective, in which investment decisions are made based on what the average consumer is willing to pay for a specific set of services (ARPU).

There are however other benefits which accrue the municipality, property owners, the state, or society in general, that may be more difficult to evaluate, and yet should be considered in the cost/benefit calculation when making the investment decision.

## 1.1 Internet, broadband and fibre

Many perceive broadband as only one connection to the Internet. But there are more uses for a broadband-Internet connection, as communications between company branches, end-user services both traditional like TV and telephony, and new ones like tele-presence, gaming, video-surveillance etc. These are typically using the same broadband infrastructure used for Internet, but generally run parallelly to Internet traffic itself, out of reasons as disparate as security, confidentiality, Quality of Service and Quality of Experience constraints. An example of a broadband network use is in Stokab carrier-neutral network in Stockholm, which is used by 500 different companies, organizations, etc., in addition to about 100 traditional telecom operators<sup>1</sup>.

An argument often heard is that "given is broadband important, and we already have broadband with us, so we do not need fibre." So why is fibre important? While it is possible to deliver broadband over existing infrastructure (such as coaxial cable, e.g. using DOCSIS technology or over twisted pair, e.g. using ADSL), or over the ether (for example, through Wi-Fi/WiMax, 3G or 4G mobile network), so the question is very relevant. The answer can be given at different levels. First, the fibre-based access networks (often referred to as *Fibre To The Home*, FTTH<sup>2</sup>) is a future-proof

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<sup>1</sup> [www.stokab.se](http://www.stokab.se)

<sup>2</sup> The FTTH concept is not completely unambiguous: sometimes one means that the fibre reaches all

infrastructure that is easy to upgrade, and provides virtually unlimited capacity. An illustrative comparison with other access technologies is shown in [Figures 1, 2, 3](#).

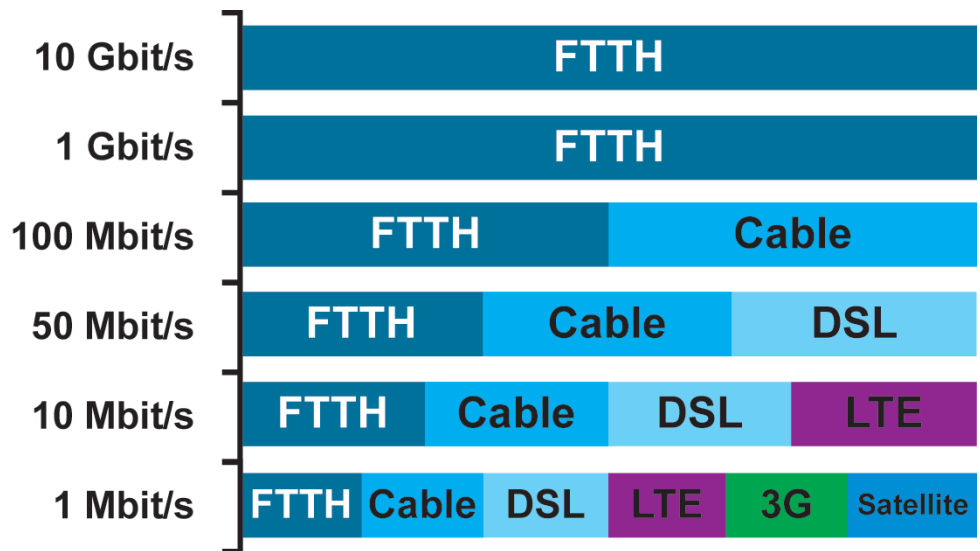


Figure 1 – Potential technologies that can deliver a particular access speed (bandwidth).

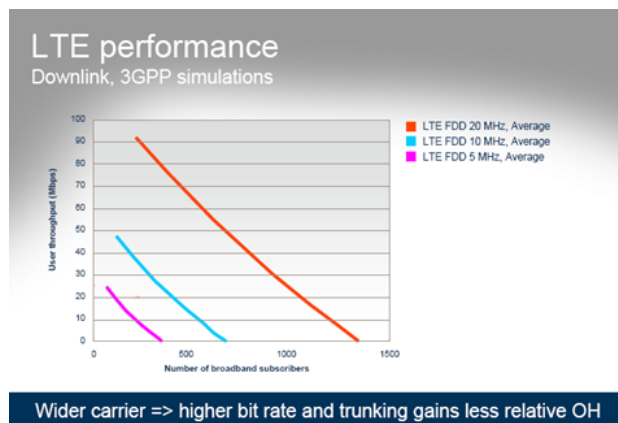


Figure 2 – Connection speed of each user decreases the number of active users in mobile 4G networks. Source: *Ericsson*

the way to the household, sometimes it is enough to reach the property, and sometimes it is enough that the fibre is within a short distance from the property; the latter cases are sometimes referred to, more exactly as fiber to the building, FTTB, and fiber to the cabinet, FTTC; in the report, however, we make use only of the well traveled FTTH term, but we indicate what applies in each case.

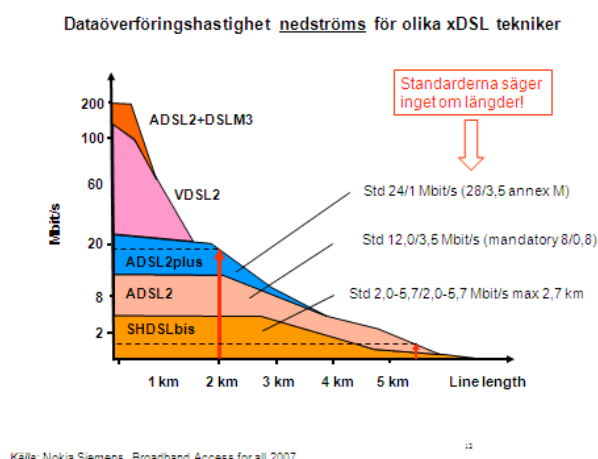


Figure 3 – Connection speed for xDSL decreases with distance from the node. Source: *Nokia Siemens Networks*

## 1.2 Benefits of broadband and fibre – previous studies

There are several studies that try to prove the benefits of broadband, but very little about fibre, and in any case, no one has tried to make an economic calculation of the at least some of the return of fibre investment, which is what preliminary study aims to achieve. In this section, however we give an overview of some relevant studies and results.

Various studies<sup>3</sup> show that there is a correlation between GDP and investment in telecommunications. Also, the OECD has calculated that broadband-related GDP growth in Europe was 100 million euros in 2006, and will increase to between 600 and 1000 million in 2015. And according to the OECD as economic growth is greater in countries that have a high proportion of broadband compared to countries with low broadband connection. The authors of the present study have also examined the issue in 2008 and found a positive and robust correlation between broadband and International Trade<sup>4</sup>

That there is a correlation says nothing about causality, of course. But there are

<sup>3</sup> see for example Micus (2008), a study commissioned by the European Commission

<sup>4</sup> Forzati and Larsen, 2008

several scientific studies that examined the actual effects of broadband (mainly copper-based), both from the academia, and the industry.

An interesting read is Arthur D Little (2010), featuring a compilation of current research in the field of economic impact of broadband, particularly on employment. Similar work was done even by LECG, in the 2009 report *Connectivity Scorecard*, which focuses on the impact of broadband in 15 OECD countries.

The results are similar: broadband has an impact on GDP, but the degree seems to vary with the IT maturity in the country. In particular the report from LECG focuses on the additional investment required for a country that will have the full benefits of broadband. The main conclusion is that the countries that have invested in more than just infrastructure, such as education, are also the countries that benefit most from the increase in broadband deployment.

The LECG report also shows that increased broadband development can have a significant impact on productivity and economic growth. Research indicates that with the right skills and infrastructure in place broadband strategies could increase national productivity and growth by up to 15%. This improvement in productivity will increase GDP without increasing the resources used in production. For example, the United States would increase their GDP by \$100 billion through an increase of 10 additional broadband lines per 100 individuals (around \$3,500 for each connected people).

Another study by Czernich et al. on a panel of 25 OECD countries over the period 1996-2007 finds strong evidence that the emergence and spread of broadband significantly increase economic growth. A 10 percentage point increase in broadband connectivity increases the annual *per capita* growth by 0.9 to 1.5 percentage points.

Katz et al. (2009) calculates the impact of investments in broadband on employment and production in the German economy, with the help of the *input-output* method<sup>5</sup>.

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<sup>5</sup> Which is a good method to calculate the economic activity generated in response to investment in building an infrastructure, if we have good data on trade (input-output) across different industry sectors and have been involved in the building, we will use some results from this study in our calculations, we will tell you later in the report.

The study analyses two investment scenarios: the first is based on the government's objective to ensure that 75% of German households have broadband access of least 50 Mb/s by 2014. The second investment scenario is based on 50% of German households having access to 100 Mb/s and an additional 30% to 50 Mb/s in 2020. The study estimates that to achieve the first goal for 2014 will require an investment of €20.2 billion and create 407,000 new jobs. The more ambitious target for 2020 would create 968,000 new jobs in total. In the case of GDP, broadband investments over a ten year period (2010-2020) lead to an incremental 0.60% annual GDP growth. The financial implications are based mainly on two levels, economic activity directly generated to deploy the network, and network effects, see Katz et al (2009).

To summarise, there is substantial evidence that investment in broadband is a powerful engine for growth and employment. In the present study we turn our attention to fibre access networks as a future-proof platform to provide high-speed high-quality broadband as well as increased competition for service provision<sup>6</sup>, and we try to quantify some of the socio-economic benefits which this is believed to bring about<sup>7</sup>. We do so by studying the situation in Sweden, a market that has gone farther than most European countries, and which has rich and updated data bases on key economic figures on the municipal level, which allows for quality statistical analysis.

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<sup>6</sup> Forzati et al (2010)

<sup>7</sup> Forzati et al (2011)

## 2 Methodology and Data Collection

In order to answer the question "how much does a euro invested in FTTH give back in one, two, or five years" we need to

1. Estimate the **cost** of FTTH deployment
2. Estimate the investment **effects** on different time periods
3. Converting these effects to return in monetary terms (the actual **calculation**)

This means a collection of data about the installation process and costs, current and previous fibre penetration, and certain socio-economic indicators.

In this chapter we present the problem and describes possible mechanisms of how the economy is affected, as well as different analytical methods to verify and quantify these benefits.

### 2.1 Cost of FTTH

Our estimate of the cost of FTTH deployment refers to fibre to every household, but only includes the installation of passive infrastructure, for several reasons:

- Passive infrastructure is a long-term investment, and represents the largest portion of the investment
- The active cost depends on the technology choice, which in turn depends on the operator's strategy<sup>8</sup>

At this stage, we assume that the operational cost of passive network is negligible compared to the installation cost. We estimate the total cost as the sum of

- the average cost to connect an apartment,  $k_l$ , times the number of apartments in Sweden,  $N_l$
- the average cost of a house online,  $k_v$ , times the number of houses in

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<sup>8</sup> OASE (2010)

Sweden,  $N_v$ .

We then discount the deployment cost in view of the current fibre penetration,  $F$ , (which, according to the Swedish regulator, PTS, is 30%). In mathematical terms, the need for investment is:

$$K = (N_l C_l + N_v K_v)(1 - F).$$

## 2.2 Fibre Investment's Effects: *Uncaptured Values*

In the traditional telecom operator perspective the investment decision is based on a simple cost/benefit calculation in which the benefit is the revenue that the operator gets from selling services over the network. This calculation becomes more complicated in the converging network scenario, in which several service types are increasingly provided over one and the same network, by competing service providers. Moreover, concentrating on the revenue from the end-users, leaves out an important portion of benefits which are not necessarily internalised and represented by the end-user willingness to pay for specific services: we call these the uncaptured values. In order not to make the wrong, it is important to take into account all effects, direct and indirect, of the various stakeholders and for society as a whole. Effects related to the construction of FTTH, can be divided into direct, indirect and induced effects. In this section we review some of these effects, and we identify the various stakeholders and what advantages they can benefit from FTTH and its effects.

### 2.2.1 *Direct, indirect and induced effects of FTTH*

**Direct effects** of the construction of FTTH are

- significantly higher access capacity,
- access to a new future-proof infrastructure and
- Direct economic value generated by the network build up, construction, fibre cables and active equipment.

These values are available immediately at construction (and we can therefore expect that they are visible already after 1 year), leads in turn to view other **indirect**

**effects**, such as:

- higher access capacity allows better service quality, which in turn may lead to increased use and development of new services: some of these services may depend on high bandwidth in itself, for example, some video-based services;
- higher capacity can enable new services, including services that work on other types of broadband connections which can nonetheless benefit from the higher bandwidth provided by FTTH because the total available bandwidth is not saturated by other services delivered at the same time (such a current example can be sensor networks with services video surveillance, smart grid systems, traffic and congestion charges, accident avoidance through the monitoring of buildings and social functional infrastructure<sup>9</sup>: many of these services can be individually operate over copper infrastructure, but the aggregate bandwidth of the growing number and the increase in data-intensive services, are best supported by fibre connection).
- FTTH represents a future-proof infrastructure that provides higher bandwidth and lower signal loss compared with radio and micro wavelength, therefore leading to higher housing value;
- The installation of a new infrastructure offers the ability to more easily abandon traditional business models (in favour of more open access models) and to solve marketing problems in the presence of ownership, long-term agreements and established benefits<sup>10</sup>

The direct and indirect effects of FTTH in turn has a positive impact in areas other than ICT: we call these **induced effects**. For example,

- services like high-quality cloud computing, video-conferencing and tele-presence have a positive impact on productivity<sup>11</sup> e-learning (with benefits on

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<sup>9</sup> Some such examples, we see already in the municipalities that invested (see Chap. 4) and in some cases, quantify them)

<sup>10</sup> To grasp this is largely a matter for regulators and the public sector (Forzati et al., 2010).

<sup>11</sup> Katz et al (2009) refers to a number of studies that demonstrate increased productivity in the service

education and competence development) and distance working, which in turn reduces traffic congestion, increases virtual labour mobility, and reduces the cost of doing business. Reliable and high-quality e-health services reduce the need for expensive hospitalisation and home visits; while e-government services increase efficiency and transparency in public administration, which in turn strengthens democracy, increases transparency and decreases corruption and the burden of bureaucracy;

- widespread use of advanced ICT services brought about by FTTH increases ICT maturity of the population, which creates both new potential customers of, and new human capital for the production of new services and products;
- This in turn leads to the creation of new ICT companies, which in turn increases the level of entrepreneurship, favouring the creation of more companies, or the improved management of existing ones;
- putting in place the correct business model induces other benefits back on the ICT sector: if network and service providers are freed from the heavy upfront investments required to deploy the passive infrastructure they can scale investments with the number of users served, and therefore achieve profitability in the short-medium term;
- This, together with the availability of end users with very high access speeds will allow the provision of bandwidth-hungry, but profitable services like HDTV, 3D TV, Video-on-Demand (VoD). Those profits will then propagate down the value chain to the network providers (NP) and the physical infrastructure provider (PIP).

Figure 4 describes the complex interactions between factors that are affected by and have an impact on FTTH.



estimated through an agreement between tenants and landlords on the value for fibre connectivity

- Higher employment that leads to increased GDP, calculated by means of statistical analysis of the situation in different municipalities
- Population growth (currently not quantified in monetary terms)

## **2.3 The calculation method**

The effects that we have chosen to analyse occur in various forms and are therefore best estimated using different methods:

- The direct economic activity from construction work was calculated using the results of the input-output analysis made by Katz et al (2009)
- The indirect savings have been calculated by extrapolation of examples from some local governments
- The direct positive impact on value for end users has been estimated in the form of an agreed rent increase.
- The indirect employment effects are estimated by, by multivariable regression analysis (a statistical method that we will return to)

The impact of FTTH on population evolution was also calculated using multivariable regression analysis, but we refrained from quantifying the financial return, due to the lack of a robust method for this.

### ***2.3.1 Statistical analysis of the impact of Swedish municipalities***

A way to verify and quantify the benefits of fibre is to collect relevant data for a large number of municipalities with different fibre penetration, and relate fibre penetration to how some economic indicators have changed over time. Of course, the socio-economic development in a municipality depends on more than fibre investment. A relevant analysis of the effects of the fibre must be based on a model that takes into account as many relevant factors as possible. Such a model can be described as a

function

$$Y = f(X_1, X_2, \dots, X_N), \quad (1)$$

where  $Y$  is the socio-economic indicator that one wishes to explain (the *dependent variable*), and  $X_n$  are the various factors that have impact on the indicator.

When such a model has been developed, one can observe how well it reflects reality by measuring  $Y$  and  $X_1, X_2, \dots, X_N$  in a number of different municipalities. The difference between  $Y$  and  $f(X_1, X_2, \dots, X_N)$  gives the error,  $e$ , which depends partly on the model's limitations and partly to errors in the measurement of  $Y$  and  $X_1, X_2, \dots, X_N$  (measurement error). The smaller  $e$ , the better the model. In Chapter 3.2 we propose an exact form of Equation (1), and presents estimates where the effect of fibre and other factors enumerated.

## 2.4 Data Sources

Data for fibre penetration was collected by the Swedish telecom regulator's (PTS) online database (PTS 2011), and from a survey conducted by Acreo (Acreo 2011). PTS 2011 provides fibre penetration in each municipality for the years 2007, 2008 and 2009 in terms of percentage of population in the community who are able to adhere to the fibre network<sup>13</sup> and for the year 2010 in the form of connected customers. Acreo's survey collects data for a number of municipalities in terms of percentage of population in the community who are able to fibre, as well as with pre-fibre connector, and active customers, for the year 2011. It also collects other relevant information such as IT policies, technical and business solutions, prices and services, and more. We have also collected demographic and socioeconomic data from Statistics Sweden's (SCB) annual report<sup>14</sup>. Data from PTS and SCB used in regression analysis.

Another important source of information has been the OECD, and the FTTH Council

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<sup>13</sup> PTS definition: interest in or within 353 meters of a fiber-connected property

<sup>14</sup> SCB (2006), SCB (2007), SCB (2008), SCB (2009), SCB (2010), Statistics (2011A)

Europe, as well as Acreo's network of contacts among key players in the fibre market, from the city network, to systems manufacturers, installers, research institutes, local authorities and operators. From these latter sources, we have collected data to estimate the investment required to build out FTTH to all of Sweden. We have used the research findings from the literature to estimate the direct economic activity generated by the investment will result in.

## 3 Analysis and results

### 3.1 The cost of FTTH

According to sources from the fibre and system manufacturers and installers, the cost to fibre connect a house is between 15,000 and 25,000 SEK, with an average cost estimated at 18,000 SEK<sup>15</sup> and around 6,000 SEK to connect a flat in a densely populated urban area<sup>16</sup> while apartments in the more sparsely built areas may cost more<sup>17</sup>. The cost of connecting an average apartment is therefore roughly estimated to SEK 10,000 (average between 6,000 and 15,000), and given that Sweden's housing consists of 42% single houses and 58% of the apartments, we can estimate the cost of fibre to connect all homes in the country to about 56 billion SEK, i.e. 6,250 per capita. The average cost per capita is a rough indicator but gives a good picture of FTTH cost. According to PTS, is about 30% of the homes in the country<sup>connected-</sup><sup>18</sup> which means that an investment of 39 billion remaining to invest to get all homes connected. These costs are comparable with the figures estimated for similar investments in Europe<sup>19</sup> even if that Sweden is more sparsely populated<sup>20</sup>

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<sup>15</sup> Of which 3,000 for local area networks, Ericsson (2011)

<sup>16</sup> The in-building cabling was calculated in all cases cost around 3000 SEK per apartment, taking fiber all the way (FTTH), or 2000 SEK on the use of CAT6 cables in the building (FTTB), Netel (2011)

<sup>17</sup> Ekot (2011)

<sup>18</sup> FTTH (2011) estimates, however, 14%

<sup>19</sup> For example, France's Caisse des Depots et de Consignations (CDC), expects investment needs to cover the country with FTTH to €45 billion, ie approximately 6400 SEK per inhabitant, CDC (2011), Katz et al (2009) have calculated the cost of broadband for all to €35.9 billion, ie about 4000 SEK per capita (but through a mix of FTTH and copper technology VDSL), a FTTH deployment in 2004 in Neunen, outside Eindhoven in the Netherlands, cost around 19,300 SEK per household Kramer et al (2006).

<sup>20</sup> This may be because Sweden has accumulated more experience and climbed "learning curve" in FTTH deployment faster than continental Europe (for example, France had 9% fiber penetration against Sweden's 14% in December 2010, FTTH (2011)), this is also confirmed by that FTTH costs have gone down over the past two years (eg estimates from 2009 quantified the total cost of Sweden to 67 billion SEK, Eklund (2009)).

### 3.2 Direct economic returns generated by FTTH deployment

The most direct effect of FTTH investment is the economic activity needed to build FTTH. This is displayed as soon as the build-up starts and disappears when the network is completed. Its effect is short lived, but may be large. The best way to make the calculation is to use the multiplier from *Input-Output Approach*<sup>21</sup>. As a first approximation, we use the results of a study from 2010 on the German economy<sup>22</sup> where it is found that the investment will result in a GDP increase of 0.93 times the investment. This figure may differ slightly for fibre-only deployments and between countries, so it would therefore need to be recalculated for FTTH deployment in Sweden in a more comprehensive study. We decide nonetheless to use this figure as a first approximation, which leads to an increase in GDP in Sweden to **52 billion SEK**, or **36.5 billion SEK** as the return on the total fibre investment (the current fibre penetration is 30%).

### 3.3 Return from indirect effects, extrapolation from examples

There are many municipalities and housing companies in Sweden, which over the past 10 years have installed fibre to the home/building (FTTH / FTTB). This provides a selection of examples of how FTTH can affect society and the economy. In this section we present a number of facts that we have observed in the years around the country. We group them into three categories:

- savings in the municipal administrations' data and telecommunication costs,
- savings in the regional administrations' data and telecommunications costs;
- savings/added value for households/individuals

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<sup>21</sup> Schaffer (2010)

<sup>22</sup> Katz et al. (2010)

### 3.3.1 Savings on local data and telecommunications costs

There are several examples, and all point to the fact that fibre allows a saving of around 30% of the total municipal data and telecommunication costs. This is partly due to increased efficiency (reduced equipment, energy consumption, and *footprint* per unit of transmitted information), partly due to the fact that the fibre network with high capacity allows for more competition<sup>23</sup>.

**The city of Stockholm** in 1996 started purchasing telephony from an open market. A prerequisite for the procurement of telephony in full competition (which was unique to public organizations in Europe at this time) and to drive down costs for was that the city had recently connected its operational sites and offices with its own fibre network. The city's external telephony cost at this time was 150 million SEK per year. The competition made available on its fibre-optic network, resulted in a savings of 30%, i.e. 45 million<sup>24</sup>. However, this is a conservative estimate, and savings have probably grown larger than that over time, says Per-Olof Gustavsson, who at that time was active in the City of Stockholm's city council office.

In Jönköping, where the fibre connection has been less extensive, the saving figure was around 10 to 15 percent<sup>25</sup>. If one compares the figures for fibre penetration (25% of workplaces had access to fibre in 2010) with the municipality of Stockholm (62%) one can see a nearly proportional relationship between fibre penetration and savings rate. We have no examples to quantify the savings brought about by 100% penetration, so we work with the Stockholm figure. If one extrapolates this figure from Stockholm to all municipalities, FTTH would lead to savings of approximately **SEK 500 million in annual** municipal data and telecommunication costs<sup>26</sup> or **SEK 350 million** annually, as a return on the total fibre investment.

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<sup>23</sup> e.g. in Stockholm, there are about 90 different operators in the network

<sup>24</sup> Stokab (2011)

<sup>25</sup> Ovum (2009)

<sup>26</sup> Calculated using a simple linear extrapolation, given Stockholm Municipality's and Sweden's population being 855,361 and 9,446,812 respectively, in June 2011, Statistics (2011b)

### 3.3.2 Savings of municipality data and telecommunications costs

Similar savings have been observed at regional administration as well. The **Stockholm Regional Council** (*Stockholms läns landsting*) reduced its data and telecommunications costs by 50%, equivalent to 60 million thanks to the fibre network<sup>27</sup>. In **Norrbottn**, a fibre network has been installed, linking five hospitals, 33 clinics and 34 dental clinics, which reduced communication cost also by 50%, while providing a fifty times faster communication<sup>28</sup>. Service providers have been able to create solutions for digitised medical records, transmission of digital radiography, digital recipes, video conferencing and IP telephony. If we extrapolate the Stockholm's and Norrbotten's Regional Council savings to all of Sweden, FTTH would result in a saving of around **270 million SEK** of **annual** data and telecommunications costs by<sup>29</sup> counties, or **190 million SEK** annually as a return of the total fibre investment.

### 3.3.3 Savings/added value for individuals

As we argued in paragraph 2.2, the individual benefits of FTTH in various direct and indirect ways: high-quality services at lower prices, especially entertainment and communications, the ability to work remotely and more free choice of work and housing, improved individual health, reduced need for hospitalization, simpler and more transparent interaction with public services, etc<sup>30</sup>. It is difficult to estimate the value of FTTH for end users in dollars and some of the effects may show up later (indirect and induced effects). We can still estimate a conservative figure for the direct effects, in terms of willingness to pay, by observing that the Swedens tenants' association (*Hysesgästföreningen*) has agreed with property owners' associations and

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<sup>27</sup> Stokab (2011)

<sup>28</sup> IT Norrbotten (2011)

<sup>29</sup> Calculated with a simple linear extrapolation, given Stockholm County's and Sweden's population being 2,073,952 and 9,446,812, respectively, in June 2011, Statistics (2011b)

<sup>30</sup> See for instance, results from end users in Ovum (2009)

housing companies to an increase in rent between 45 SEK and 47 SEK per month (equivalent to estimating the value of FTTH to an average 46 SEK per household per month<sup>31</sup>). This would lead to a value of **2.3 billion SEK per year** for Sweden's 4.2 million homes connected to fibre-optic network, or **1.6 billion SEK** annually as a return of the total fibre investment.

### 3.4 Return from indirect effects, statistical analysis

In this section we analyze the statistical link between FTTH and two important economic factors, using multivariable regression<sup>32</sup>. First, we look at the evolution of a municipality's population, and then at how fibre affects employment.

#### 3.4.1 Population evolution

We can expect that the evolution of population size has a tendency to continue in the trend it is in, unless something else happens, i.e.:

$$P(t) / P(t_0) = \{P(t_0) / P(t_0 - T)\}^K, \quad (2)$$

where  $K$  is a factor that tends to be equal to  $(t - t_0)/T$ . The trend may be affected by various factors, which may increase or decrease the attractiveness of the municipality, such as housing rent, improvement/deterioration of various services and infrastructure, economic situation in the region and more. We can model the effect of these changes as a contribution in terms of percentage increase/decrease in population, which translates into an exponential term in our equation for any such effect. Equation (2) therefore becomes

$$P(t) / P(t_0) = \{P(t_0) / P(t_0 - T)\}^K \exp \{ \kappa_1 X_1 + \kappa_2 X_2 + \dots + \kappa_N X_N \} \quad (3)$$

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<sup>31</sup> Through the agreement, tenants accept – through their representative association – to pay a SEK 46 higher rent if fiber is installed in the apartment, Hyresgästföreningen (2011),

<http://www.hedemorabostader.se/kundinformation/fastighetsnat> 194,

<http://www.stockholmshem.se/Boende/Boendeservice/Bredband/Vad-ar-Stockhomshems-nya-oppna-bredbandsnat/>

<sup>32</sup> Stock & Watson (2003)

If we take the logarithm of both sides of the equation we obtain:

$$\Delta P(t) = \log P(t_0) + K \cdot \Delta P_T + \kappa_1 X_1 + \kappa_2 X_2 + \dots + \kappa_N X_N, \quad (4)$$

where  $\Delta P_T = \{P(t_0) - P(t_0 - T)\} / P(t_0 - T)$  is the population change until time  $t_0$  over the time period  $T$ , where we have used  $\log(x) \cong x - 1$  for  $x \ll 1$ . Which ones, among all possible factors, we choose to include in the model is determined by a compromise between model accuracy and availability, reliability and accuracy of factor measurements. Statistical independence between factors is also an important parameter for the model to be applicable. In this study, the measurement data available to us, allow us to specify the model to<sup>33</sup>

$$\log P(t) = \log P(t_0) + K \cdot \Delta P_T(t_0) + \kappa_F F(t_0) + \kappa_s \Delta s(t) + \kappa_u u(t_0), \quad (5)$$

where  $t = 2010$ ,  $t_0 = 2007$ ,  $T = 10$ , so that  $P(t)$  and  $P(t_0)$  are the population of the municipality in the years 2010 and 2007, respectively,  $\Delta P_T(t)$  is the relative population change between 1997 and 2007,  $F(t-3)$  is the proportion of the population of the municipality provided for connection to fibre-optic network<sup>34</sup>.

$\Delta s(t) = s(t) - s(t_0)$  is the change in tax set, and  $u(t)$  is the share of foreign citizens in 2007 (with residence in Sweden two years, according to SCB definition)<sup>35</sup>. That is, the model looks for a correlation between the situation in the municipalities in 2007 (namely, population trend, fibre infrastructure, and demographics) and the change in the population three years later. We introduced the time shift for two reasons. One is that the effects of the changes is usually not instantaneous (except taxation changes<sup>36</sup>). The second is that it eliminates the problem of reverse causality (although not the possibility that a third factor is the cause of both fibre investment and change in

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<sup>33</sup> Other factors that we considered is the cost of pre-training costs, costs of elderly and disabled population in the age group 20-64 years, proportion of population aged 65 years, and average income, but all showed either non-significant correlation with  $P(t)$ , or high correlation with  $\Delta P_T$  or both; measurements of educational attainment (which we judged as possibly relevant) was not available.

<sup>34</sup> PTS definition: interest in or within 353 meters of a fiber-connected property

<sup>35</sup> We observe that  $U(t)$  as well as  $\Delta s(t)$  and  $F(t_0)$  are uncorrelated with  $\Delta P_{10}(t)$  for  $t = 2010$ ,  $t_0 = 2007$

<sup>36</sup> That's why we look at the  $s(2010) - s(2007)$ ; we have actually run the analysis by taking into account taxation changes in previous years, but found much less strong correlation.

population trend)<sup>37</sup>.

We can now use the model to quantify the impact of each effect. Equation (5) has the merit of being linear, which allows us to verify the model using linear multi-variable regression<sup>38</sup>, which consists of estimating the unknown coefficients  $\kappa_n$  that minimize the error<sup>39</sup>,  $\varepsilon$ . More specifically, for each municipality  $i$ , we measure  $P(t)^{(i)}$ ,  $P(t_0)^{(i)}$ ,  $\Delta P_{10}^{(i)}$ ,  $F(t_0)^{(i)}$  and  $\Delta s(t)^{(i)}$  and then measure the error as<sup>40</sup>:

$$\varepsilon^{(i)} = \log P(t)^{(i)} - \{ \log P(t_0)^{(i)} + K \cdot \Delta P_{10}^{(i)} + \kappa_F F(t_0)^{(i)} + \kappa_S \Delta s(t)^{(i)} + \kappa_U u(t_0)^{(i)} \}. \quad (6)$$

We can compute an error indicator as  $\sigma_i = \Sigma |\varepsilon^{(i)}|^2$  and then look for the smallest values of  $\sigma_i$  by varying  $K$ ,  $\kappa_F$ ,  $\kappa_S$ ,  $\kappa_U$ . The values  $\beta_K$ ,  $\beta_F$ ,  $\beta_S$ ,  $\beta_U$  which minimise  $\sigma_i$  define our estimate of the effects of  $K$ ,  $\kappa_F$ ,  $\kappa_S$ ,  $\kappa_U$ .

When we run the calculations in the software environment *MATLAB*®, using a linear regression toolbox, we get the following results:

$$\beta_K = 0.27 \pm 0.02$$

$$\beta_F = 0.025 \pm 0.008$$

$$\beta_S = -0.50 \pm 0.42$$

$$\beta_U = 0.18 \pm 0.13,$$

where we have also indicated the 95% confidence interval. We can see that much of the population evolution is explained, as expected, by the prior trend (and  $\beta_K$  is close to the value which we would expect, if the trend from 1997 to 2007 remained unchanged in the period 2007–2010, i.e.  $3/10 = 0.3$ ). We can then observe that FTTH has a positive effect: a 10% increase in the proportion of the population that have access to fibre, corresponds to a positive change in the population after three years of

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<sup>37</sup> Stock & Watson (2003)

<sup>38</sup> Stock & Watson (2003)

<sup>39</sup> That is,  $\beta_n$  is the estimate of the unknown factor  $\kappa_n$ .

<sup>40</sup> we will have a specific error for each municipality, because even Except as regards measurement error, each community is unique and will therefore be described better or worse by the model than other municipalities.

0.25%. Not surprisingly, tax cuts also have a positive effect in the short period (3 years), though their significance is not strong, as shown by the large confidence interval. Finally, perhaps less expected, high proportion of foreign nationals has a positive effect on the population development (although also with a weak significance).

Let us now analyse the effect of fibre in more detail. Figure 5 shows a graph in which each municipality is represented by a point whose *x-coordinate* shows the municipality's fibre penetration (measured as a proportion of the population with a fibre connection) in 2007, and whose *y-coordinate* shows the adjusted change in its population between 2007 and 2010. The adjustment represents a “*cleansing*” of other factors, and a removal of the average<sup>41</sup>. The black line follows the model’s forecast, with  $\beta_F = 0.025$ . Each municipality deviates from the forecast with a certain error,  $\epsilon^{(i)}$ , which is explained by other factors that the model does not take into account.

It is important to recall that 95% margin of error 0.008 means that a municipality’s population would have increased between 0.17% and 0.33% (ie  $[0.025 \pm 0.008] \times 10\%$ ) if it had 10% more fibre and if everything else had been exactly the same; and this statement is true with a 95% certainty. The fact that a particular municipality shows a population development that is greater or less than the model’s prediction does not depend on the confidence interval, but because everything else that the model did not take into account *was not* exactly the same in all municipalities, as well as measurement errors. The reader who is more familiar with multi-variable regression can see more details of the calculations in Table 1 below.

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<sup>41</sup> In mathematical terms:  $y(i) = \log P(t)^{(i)} - \log P(t_0)^{(i)} - \beta_K \cdot [\Delta P_{10}^{(i)} - \langle \Delta P_{10} \rangle] - \beta_s \cdot [\Delta s(t)^{(i)} - \langle \Delta s(t) \rangle] - \beta_u \cdot [u(t_0)^{(i)} - \langle u(t_0) \rangle]$ , where  $\langle x \rangle = \sum_i/N x(i)$  is the mean value of the factor *x* over the *N* = 290 municipalities; *t* = 2010, *t*<sub>0</sub> = 2007

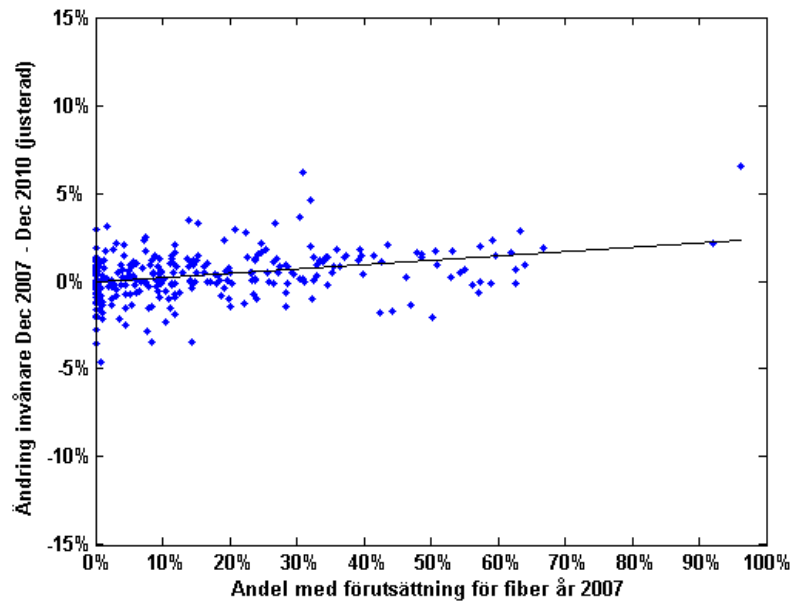


Figure 5 – Effect of fibre installation in the municipality aktraktivitet: one can see that higher fibre penetration in 2007 (measured as a percentage of pre-condition for fibre according to PTS definition) point to a higher occupancy (or lower emigration from) the local authority (measured as percent change in population, adjusted for other effects).

TABLE 1: PERFORMANCE OF LINEAR MULTI VARIABLE REGRESSION

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Number of observations: 290
R-square: 0.77335
Adj. R-square: 0.77017
Explained variable: log(pop_Dec_2010 ./ pop_Dec_2007)
-----
beta coeff | std. err | tstat | 95% conf int | parameter
-----
0.02548 | 0.0042499 | 5.9954 | 0.017116 0.033845 | PTS_FN_2007
-0.50148 | 0.21558 | -2.3262 | -0.92579 -0.077174 | (s2010 - s2007 )
0.27269 | 0.0105 | 25.971 | 0.25203 0.29336 | Delta_pop_10_2007
0.18092 | 0.066612 | 2.716 | 0.049817 0.31202 | foreign_share_Jun_2007
-0.0013712 | 0.0017409 | -0.78766 | -0.0047977 0.0020552 | ones(length(K01),1)
-----

```

### 3.4.2 Employment

When it comes to employment, we make the assumption that a municipality with high employment is also an attractive place. This is a rough qualitative argument, but it will help when we try to separate the effect of FTTH from other factors. An indicator describing a municipality's attractiveness is its population change over the decade 1998–2007 (see previous section). One can thus expect that a municipality that has had a positive evolution for a decade has great potential to have a positive economy, which can lead to positive development of employment. This is currently only a working hypothesis that needs to be verified in the calculation. We can then identify a number of *new* factors, i.e. factors that appeared around 2007 (or a short period around it) as a potential due to the change in employment. Fibre is one such candidate, as discussed in Chapter 3 (although we expect most of its effects on employment to occur in a period longer than three years). Other factors that we can identify is immigration, tax changes from 2007 to 2010, education, and other infrastructure and services in the municipality. Therefore, we can construct a similar equation as we did for the population development

$$\Delta w(t) = K \cdot \Delta P_T + \kappa_1 X_1 + \kappa_2 X_2 + \dots + \kappa_N X_N + \Delta_0, \quad (7)$$

where we have now added a term,  $\Delta_0$ , which accounts for the national change in employment due to general economic conditions, and that affects all municipalities.

Again, which ones among all possible factors we choose to include in the model is determined by a compromise between model accuracy and availability, reliability and accuracy of factor measurements, and statistical independence. Our model then becomes<sup>42</sup>

$$\Delta w(t) = K \cdot \Delta P_T(t_0) + \kappa_F F(t_0) + \kappa_u^+ u^+(t_0) + \Delta_0, \quad (8)$$

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<sup>42</sup> Here also, we have tested the effect of pre-training costs, costs the elderly and disabled, population in the age group 20-64 years, proportion of population aged 65 years, and average income, but all showed either non-significant correlation with  $P(t)$ , or high correlation with  $\Delta P_T$  or both; neither changes in taxation nor taxation level in  $t_0$  showed any correlation with  $w(t)$  either; neither did immigration (as defined by SCB): however, there was significant correlation between  $w(t)$  and  $u^+(t_0)$ ; again, measurement of educational attainment (which we judged as possibly relevant) was not available.

where  $t = 2009$ ,  $t_0 = 2007$ ,  $T = 10$ , so that  $\Delta P_T(t)$  is the relative population change between 1998 and 2007,  $F(t_0)$  is the proportion of the population of the municipality provided for connection to fibre-optic network<sup>43</sup>, and  $u_+(t)$  is an indicator of “*economic advantageous*” immigration, defined as:

$$u^+(t_0) = u(t_0) \cdot [i(t_0) > i_R]. \quad (9)$$

The indicator is based on the observation that immigration can lead to positive and negative effects, depending on its nature. One can expect that asylum based immigration has a negative effect on employment in the short term, while the immigration of highly educated people have a positive effect. The statistics about the type of immigration is missing, so we used average income  $i(t_0)$  for a municipality as a guide: we make the assumption that highly educated immigrants have higher purchasing power and therefore to settle in the area with higher average income (and typically higher housing prices). If a municipality has an average income exceeding a certain threshold  $i_R$ , the municipality is classified as “*rich*” and its share of foreign citizens<sup>44</sup>  $u(t_0)$  is equal to the “*economic advantageous*” immigration  $u^+(t_0)$ . Otherwise, is  $u^+(t_0) = 0$ . However, we could not find an indicator of “*economic disadvantage*” immigration.

Again, we look for effects on employment after a certain time. SCB's latest data on employment, however, was November 2009, therefore, the time lag is 2.5 years. We expect stronger results with longer lags. Again, we are looking for  $\beta_K, \beta_F, \beta_u^+, \beta_0$  which minimise the error variance  $\sigma_\epsilon$  which estimates the effects  $K, \kappa_F, \kappa_u^+$  and  $\kappa_0$ . *Matlab* ® calculations give us the following results:

$$\beta_K = 0.11 \pm 0.02$$

$$\beta_F = 0.0011 \pm 0.0010$$

$$\beta_u^+ = 0.51 \pm 0.44$$

$$\beta_0 = -0.017 \pm 0.002,$$

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<sup>43</sup> PTS definition: portion of population within 353 meters of a fiber-connected property

<sup>44</sup> Again,  $U(t)$  as well as  $\Delta s(t)$  and  $F(t_0)$  are uncorrelated with  $\Delta P_{10}(t)$  for  $t = 2010$ ,  $t_0 = 2007$

where we have also indicated the 95% confidence interval. We can see that some of the employment change is correlated to population change between 1998 and 2007, which supports our hypothesis that this is a good indicator of the municipality's attractiveness (and margin of error for  $\beta_K$  is relatively low). The economic cycle also has a significant but less powerful influence: all other factors being equal, employment declines by 1.7% (and in the years 2007 to 2009 actually showed a reduction in employment in Sweden).

We can then observe that fibre has a positive effect, although with less intensity and significance than on population development: a 10% increase in the proportion of the population that have access to FTTH, corresponding to a positive change in employment after two and a half years between 0% and 0.2%. Finally, high "*economic advantageously*" immigration has a positive effect on employment: 1% higher share of immigrants in the "rich" municipalities in 2007 represents a 0.5% higher employment.

Let us now analyse the effect of fibre in more detail. Figure 6 shows a graph in which each municipality is represented by a point whose *x-coordinate* shows the municipality's fibre penetration (measured as a proportion of the population with the condition of fibre) in 2007, and whose *y-coordinate* shows the adjusted change in its population between 2007 and 2010. The black line follows the model's forecast, with  $\beta_F = 0.0011$ . Details of the calculations are shown in Table 1 below. Fibre investment are expected to show positive effects on employment through indirect and induced effects, so it will be interesting to follow developments in order to verify if  $\beta_F$  increases significantly in the coming years.

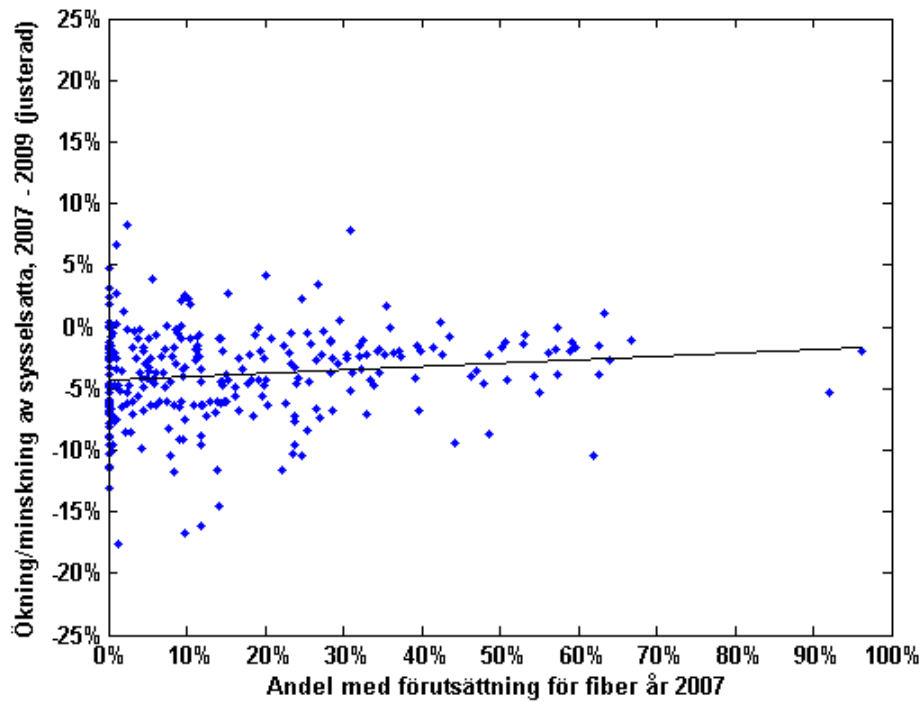


Figure 6 – Effect of fibre installation in municipal jobs: one can see that higher fibre penetration in 2007 (measured as a percentage of pre-condition for fibre according to PTS definition) point to a better development of employment in the municipality (measured as percent change in employment rates in the municipality, adjusted for other effects).

TABLE 2: RESULTS OF LINEAR MULTI VARIABLE REGRESSION

Number of observations: 290

R-square: 0.30812

Adj. R-square: 0.30087

Explained variable: (w\_Nov\_2009 - w\_May\_2007)

beta coeff	std. err	tstat	95% conf int		parameter
0.010579	0.0049547	2.1351	0.00082698	0.020331	PTS_FN_2007
0.10806	0.012329	8.7646	0.083794	0.13233	Delta_pop_10_2007
0.50822	0.22574	2.2514	0.06393	0.95252	I_plus_Jun_2007
-0.016827	0.0012631	-13.322	-0.019313	-0.014341	ones(length(K01),1)

## 4 Results Discussion and conclusions

In chapter 3 we have estimated the annual impact during the years after the fibre infrastructure has been built. Here we show a scenario where the investment is divided in four years, and calculate returns year by year, up to five years after the investment commenced.

### 4.1 Calculation of the overall socio-economic returns

In chapter 3, we have calculated the investment needed to connect the entire Swedish population with FTTH to 39 billion SEK. We consider a rapid deployment scenario in which the FTTH network is built in four years, with a 40 percent investment in the first year and the remainder distributed over the year 2-4 with gradually decreasing intensity (see Figure 7), specifically the investment in year  $t = 1, 2, 3, 4, 5$  is

$$\begin{aligned}I(1) &= 0.4 K, \\I(2) &= 0.3 K, \\I(3) &= 0.2 K, \\I(4) &= 0.1 K, \\I(5) &= 0.\end{aligned}\tag{10}$$

We assume that the resulting fibre penetration of each year, is proportional to the cumulative investment up to the year before, and we do not include operating costs. Similarly, we take no account of inflation, and capital, but make our calculations in real terms.

With these assumptions we can take the figure calculated in Chapter 3, and weigh them with fibre penetration reach at each year. Direct returns for year  $t$  are given as:

$$A_d(t) = 0.93 I(t-1),\tag{11}$$

according to the calculation results that Katz et al (2009) has developed for direct return for investment in broadband infrastructure (where  $I(t-1)$  is the investment in

the previous year).

Indirect returns are counted as:

$$A_i(t) = (b_k + b_l + b_i N_h + 0.01 y N_a) R_i(t) [1 - F(0)], \quad (12)$$

where  $b_k$  is the municipalities' total savings,  $b_l$  is the municipality total savings,  $b_i$  is the individuals' savings/added value per household,  $N_h$  is the number of households,  $y$  and  $N_a$  are Sweden's current average income and labour force).  $F(0)$  is the current fibre penetration (30% according to PTS), and  $R_i(t-1)$  is the accumulated years before<sup>45</sup>. The total return in year  $t$  is simply:

$$A_{tot}(t) = A_d(t) + A_i(t). \quad (13)$$

The resulting returns as a function of time are presented in figures below. We can note that a total investment of about 39 billion SEK giving a cumulative return of about 59 billion SEK after five years. In other words, one SEK invested between now and about four years, brings back a minimum of 1.5 crowns in five years. We expect that the returns to be greater than that, due to other effects that are difficult to quantify. We plan to tackle this in a more extensive study.

## 4.2 Investment and return over five years

We use the results generated in Chapter 3 in Equations (10) – (13) to calculate the investment and return over time. The results are presented in graphs that show how the investment and return may look like in five years.

Figure 7 shows the investment and returns in a year. It can be seen that during the first year investment is highest, but decreases in the following years, according to the assumed investment plan of Equation (10). In the other hand, a significant return starts appearing as early as at year two, thanks to the direct economic activity generated by fibre deployment.

The return due to direct effects starts decreasing with time (Figure 8), while indirect and induced economic effects increase. Induced effects are likely to grow larger with

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<sup>45</sup> In mathematical terms  $\sum_0^t I(t-1)$

time, but a more comprehensive study is needed to quantify this.

In Figure 9 we see that the cumulative investment reaches "breakeven" in terms of societal impact of 3.5 years, and after five years the total return to 1.5 times the total investment.

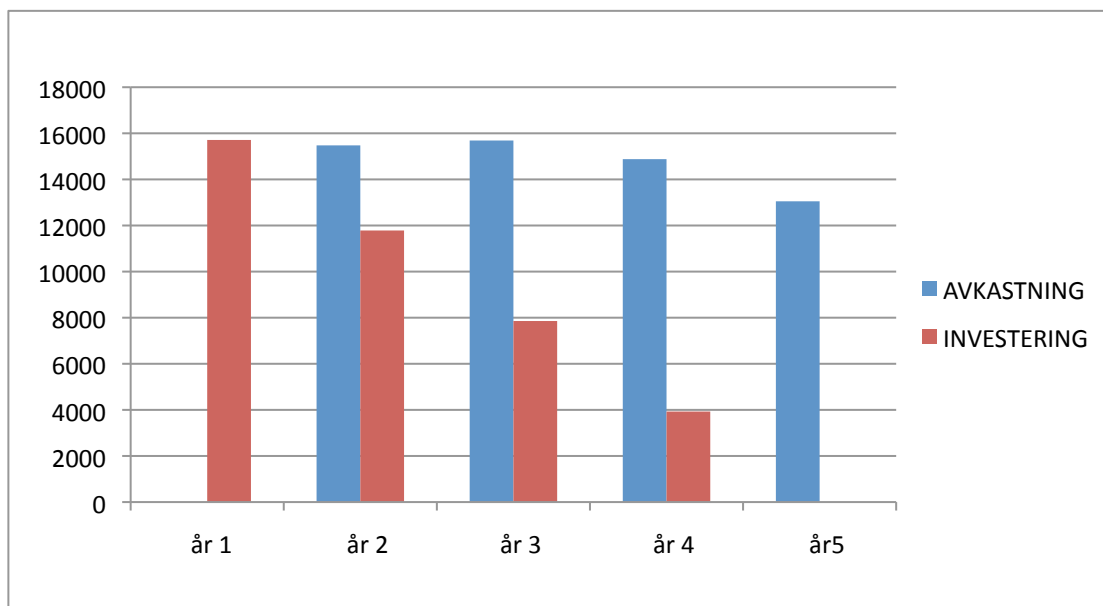


Figure 7 – Investment and socioeconomic returns (million SEK)

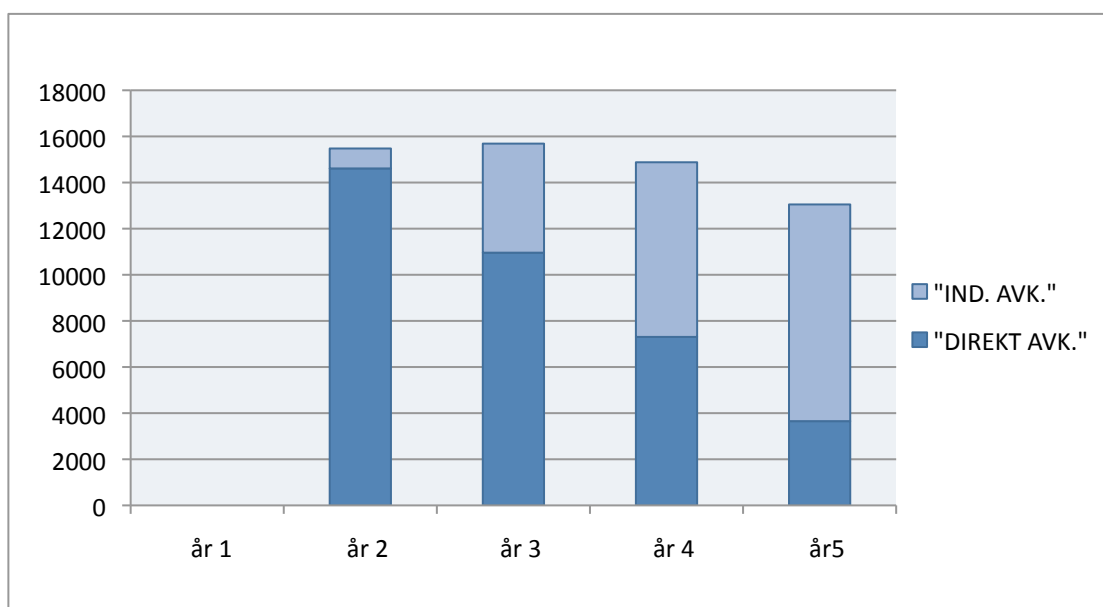


Figure 8 – Direct and indirect socioeconomic yield (million SEK)

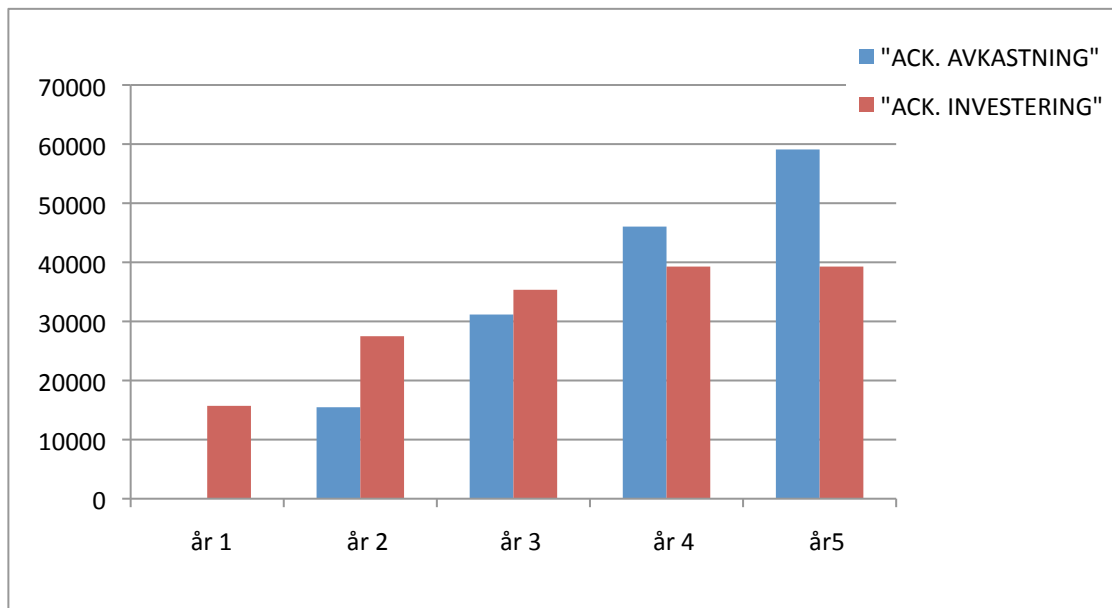


Figure 9 – Cumulative Investment and socioeconomic returns (million SEK)



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