Socio-economic impact of Fiber-to-the-home (FTTH) in Sweden

A Longitudinal Analysis

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Stockholm, May 2012

Syed Aal-e-Raza
Abstract

This paper investigates empirical evidences of socio-economic impacts of fiber-to-the-home (FTTH) penetration in Sweden. In the study, longitudinal data has been used from a sample of 290 municipalities (i.e. cross section subjects) throughout Sweden during the time period 2007-2010. The estimations of developed models have shown that FTTH has positive affects over the social and economic situation of the country. The results indicate that high speed internet accessibility through FTTH facilities is a strong differentiating factor in explaining higher employment rate and reduced commuting in a given municipality specifically and the country in general. The study follows a standard cost benefit analysis (CBA) method to evaluate the outcomes of deploying fiber-optic based network (i.e. FTTH) in the country, where results are backed with ordinary least squares (OLS) regression techniques. It has also been significantly found that technological progress (e.g. FTTH), are endogenous in the employment model, it has not been surprising though, given the characteristics and economic structure of the Swedish economy. Author’s own developed model has been applied on employment to remove backward causality; since, given the unique nature of FTTH penetration variable it was found difficult to find a good instrumental variable (IV).

Finally, it is recommended to broaden the spectrum of CBA by incorporating more impact categories (e.g. reduced education sector operating costs, optimized healthcare services, and environmental benefits etc.) into the analysis in future researches in the field.

Key Words: Information and communication technology (ICT), ICT infrastructure, Traditional broadband, Fiber-to-the-home (FTTH), Economic growth, Employment, Commuting, Labor productivity, Quality of life, Panel/longitudinal data, Municipalities, Sweden.
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<th>Full Form</th>
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<tbody>
<tr>
<td>ADSL</td>
<td>Asymmetric Digital Subscriber Line</td>
</tr>
<tr>
<td>BCR</td>
<td>Benefit cost ratio</td>
</tr>
<tr>
<td>CBA</td>
<td>Cost Benefit Analysis</td>
</tr>
<tr>
<td>CLTM</td>
<td>Commuters leaving the municipality</td>
</tr>
<tr>
<td>DSL</td>
<td>Digital Subscriber Line</td>
</tr>
<tr>
<td>ECM</td>
<td>Error Component Model</td>
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<tr>
<td>FEM</td>
<td>Fixed Effects Model</td>
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<tr>
<td>FN</td>
<td>FTTH penetration rate</td>
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<tr>
<td>FTTH</td>
<td>Fiber-to-the-home</td>
</tr>
<tr>
<td>FTTx</td>
<td>Fiber to the x</td>
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<tr>
<td>Gbps</td>
<td>Gigabits per second</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Telecommunication Technology</td>
</tr>
<tr>
<td>IV</td>
<td>Instrumental Variable</td>
</tr>
<tr>
<td>Mbps</td>
<td>Megabits per second</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>PDPSK</td>
<td>Population density per square kilometer</td>
</tr>
<tr>
<td>PTS</td>
<td>Post och Telestyrelsen&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>PV</td>
<td>Present Value</td>
</tr>
<tr>
<td>RAMS</td>
<td>Registerbaserad arbetsmarknadsstatistik&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>REM</td>
<td>Random Effects Model</td>
</tr>
<tr>
<td>SCB</td>
<td>Statistiska Centralbyrån&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>2SLS</td>
<td>Two Stage Least Squares</td>
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<sup>1</sup> Swedish Post and Telecom Authority (In English)
<sup>2</sup> Sweden's register-based labor market statistics (In English)
<sup>3</sup> Statistics Sweden (In English)
CHAPTER 1: INTRODUCTION

This chapter includes an introduction, background and description of the problem area, research questions, and purpose of the study in subject. Aim of the chapter is to equip the reader with necessary background information.

1. Introduction

The Internet is perceived to be a revolutionary technological development among many others that have an impact on numerous dimensions of life. Many believe that new advanced technologies developed in the field of ICT will yield higher economic growth in a given economy, and also world has witnessed it specifically in the last two decades. More recently, the advent and quick growth of broadband access has made a large portion of the world aware of the potential of this technology and its impact on daily life. In some countries this awareness has matured into a political persuasion that is directly or indirectly driving the development of broadband access, and in particular of future-proof fiber-based access network technologies. Comparatively immense investments required to deploy optical fiber however, combined with the pressing calls for future fast access networks to be open to competition, is putting questions on to know the social and economic impact of fiber access networks on the society at large. In many of the recent studies, researchers tried to quantify the impacts of such technology developments in monetary terms; however, due to the unique nature of some attributes and unavailability of data it has been difficult to measure all impacts quantitatively. Since the last decade, copper-based broadband technology has gotten relatively widespread and therefore many scholars have studied its impacts on the economy. This study, nonetheless, is an attempt towards extending the previous research findings of broadband impact (i.e. as Fiber-to-the-home (FTTH)) and quantifying some major socio-economic effects of FTTH in the context of Swedish economy. It should be noted that, despite arguing what specific FTTH benefits are observable in today’s time, it needs to be incorporated with what happens when fiber penetration is (nearly) 100 percent achieved in the country. This is because; as fiber is fully deployed it is rational to think that there will be new innovative businesses offering products and services that do not exist today, termed as un-captured values (Forzati & Larsen 2008).

Among many other socio-economic impacts, this study however, aims to analyze FTTH impact on inter-municipalities commuting trends, and employment growth in Sweden.

*Information and communication technology*
CHAPTER 1: INTRODUCTION

1.1. Background

Information and Communication Technologies (ICT) have visible impacts on social, economical and environmental dimensions of a society, especially within countries with more developed infrastructure. Sound and efficient improvements in ICT sector can boost up the consumption of all products and services in general and ICT based products in specific. Several studies have pointed out that such improvements in ICT can also enhance economic growth, employment, labor productivity and can stimulate economic activities in a given economy (Laitner & Ehrhardt-Martinez 2008; Hagemann 2008; Stare et al. 2006; Mamaghani 2010; Alfaro Cortés & Alfaro Navarro 2011).

In addition, business cases for high speed broadband are often evaluated from a traditional telecom perspective, in which initial investments and operating costs are compared to willingness-to-pay (WTP) of consumers for a specific set of services (Forzati & Mattsson 2011). Consequently investment decisions are based upon expected return on investment (ROI) and net present value (NPV). However, there are several other benefits which accrue to the society at large in result of these investments, which should be accounted in such evaluations to the possible extent. One can risk underestimating the true intrinsic value of such projects by neglecting social welfare benefits and possibly can turn down projects which are potentially social welfare improving. Therefore, benefits that accrue to municipalities, property owners, environment, the state, or the society at large (that can be more difficult to account) should be incorporated in the cost-benefit analysis when evaluating such investment projects and public sector economic policies. This study is, thus an effort towards capturing such benefits, and uncovering additional socio-economic impacts of high speed broadband (i.e. FTTH).

The study is motivated to contribute towards a comprehensive cost-benefit analysis of FTTH deployment, and it is conducted at Acreo AB located in Kista, Stockholm.

1.1.1. About Acreo and Swedish ICT

Acreo AB is one of Europe’s foremost research institutes in Nanoelectronics, Printed Electronics, Fiber Optics and Broadband Technology. The company is operating to transform academic research into commercially viable products through value-added technology solutions for growth, innovation and competitiveness in businesses and society. The missions range from feasibility
studies, long-term research projects, prototypes and small scale production, verification and testing. Currently, Acreo is much active in enhancing optical fiber technologies and keen to expose socio-economic effects of Fiber-to-the-home (FTTH) deployment within the country. Acreo is part of Swedish ICT and an employer of approximately 145 persons with locations in Kista (headquarter), Norrköping and Hudiksvall in Sweden (Acreo AB 2010).

1.1.2. About Optical Fiber and Fiber-To-The-Home (FTTH)

An Optical fiber is made from very thin glass filament that carries properly coded laser signals which are then decoded back into data that is readable by computers at the receiving end. Optical fiber is usually thicker than the size of a human hair which has the capacity to carry different wavelengths simultaneously because of the high bandwidth of light signals being inherently much broader than that of radio signals in wireless radio systems and on copper lines (Forzati 2007). In figure 1.1, the bandwidth capacity is graphically presented.

![Figure 1.1 Potential broadband technologies and their speed](source: Forzati & Mattsson 2011)

In addition, optical fiber networks are often referred to a generic term Fiber-to-the-x (FTTx) in the telecommunication industry, a system that brings optical fiber near to the subscriber’s premises. The last letter ‘x’ is replaced by a specific letter to indicate a particular system (e.g. Fiber-to-the-building (FTTB) and Fiber-to-the-premises (FTTP)). FTTH Council (2011) however, gives a standard definition of the term Fiber-to-the-home (FTTH) as “an access network architecture in which the final connection to the subscriber’s premises is optical
**CHAPTER 1: INTRODUCTION**

fiber.” And in order to classify as FTTH, FTTH Council Europe (2011 p.3) puts forward a certain criterion as below.

“The access fiber must cross the subscriber’s premises boundary and terminate

- **inside the premises**, or
- **on an external wall of the subscriber’s premises**, or
- **no more than 2 meter from an external wall of the subscriber’s premises.**”

Despite the established definition by FTTH council, we have classified the data provided by PTS under the title of “Percentage of homes at or within 353 meters of a fiber-connected property” as FTTH since there was no other data available on fiber penetration.

*1.1.3. Why to invest in FTTH?*

Scholars and policy makers often debate that the benefits claimed with FTTH deployment can certainly be attained by traditional broadband, based on existing copper infrastructure, or even wireless. It is therefore, seems that investments in fiber is not welfare improving and do not have net benefits to society. Many of such views are made in support of traditional broadband without digging much into FTTH potential benefits. However, it is relevant to look closer at the specific effects of high speed fiber-based access networks on all stakeholders in the society.

We will look into the reasons to invest in FTTH networks in more details in coming chapters (see Chap. 2, table 2.4), but it is important to present here a bird-eye view for the reader on some major benefits of FTTH.

**Technically,**

- On FTTH, as compared to copper-based broadband (e.g. xDSL) internet access speed (nearly) does not reduce over long distances to end-user.
- Compared to radio wireless systems (e.g. 3G and 4G cellular) the speed is unaffected by the number of sharing end-users.
- FTTH has a higher bandwidth and better reliability (i.e. very fewer disruptions) as compared to traditional broadband services via cooper cable (FTTH Council Europe 2010).

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5 The Swedish Post and Telecom Authority

6 Translated from Swedish title, “Andel i eller inom 353 meter av en fiberanslutna fastighet”
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- Bandwidth reduces as more users share a copper-based network and the speed decreases in traditional broadband service; however, on the other hand, fiber holds the capacity to provide the same bandwidth regardless the number of people sharing the network in point-to-point (P2P) settings.

Socioeconomically,

- FTTH has positive effect on several attributes for instance, higher economic growth, increased employment opportunities, better health care services, reduced commuting, reduced education sector operating costs, foreign skilled labor immigration, new business setups, less pollution (i.e. air and noise) and many more (why? See table 2.4 and Chap. 2; section 2.3 for details).

- FTTH facilitates and increase end-user satisfaction, which in return creates higher revenue opportunities for service providers, economies of scale, lower operating costs and a future-proof network infrastructure to flexibly upgrade without replacing the cables (i.e. very little up-gradation cost) (See Chap. 2).

In this study, however, our main focus would remain on socio-economic effects and not on technological effects. Previously, some studies have tried to look at socio-economic effects of FTTH but these have been mainly qualitative in nature. To the best of our knowledge there is no comprehensive and robust econometric study measuring the socio-economic impact quantitatively, except one pre-study conducted by Acreo AB (Forzati & Mattsson 2011). Nonetheless, we take a step towards broadening the pre-study and reducing the gap of quantitative findings in the subject area in case of Sweden.

1.2. Problem area

Growing businesses, globalized world, more interlinked economies, needs of fast information sharing, and every second creation of new data across the world, all demands more and higher internet speed access through sophisticated networks. Studies have shown positive effects of high speed internet on major socio-economic indicators in developed economies with mature ICT infrastructure. In the category of positive effects of extensive internet accessibility, higher economic growth is prominent among many others. (Forzati & Mattsson 2011; FTTH Council Europe 2010; Schindler 2011;
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FTTH Council Europe (2011). It has been, however, uncovered on technical grounds that tradition broadband networks on copper can only support data traffic to a certain limit (e.g. 3 Mbps up-to 8 Mbps) and hence not viable for fulfilling growing consumer and business needs who demand high speed and reliable network. Optical fiber, on the other hand allows huge bandwidth (up-to several Gbps), and yields high customer satisfaction. Therefore all stakeholder entities (i.e. research institutes in ICT sector, Swedish ICT, Government, PTS broadband forum, municipalities’/counties’ administrations, and ISPs etc.) are interested in quantitative findings to decide for investments in high speed internet access networks on optical fibers (FTTH in our case). This study has been targeted to solve this problem and produce such findings in order to fill this information gap.

1.3. Purpose of Study

The ambition is to produce a report that puts forth so far observable socio-economic effects of FTTH deployment in Sweden in quantitative terms. Study also aims to provide substance findings to all interested parties, for instance public administration, FTTH industry, researchers in the field of ICT, and the society at large to consider investments in the subject technology if it turns out to be social welfare improving.

1.4. Research Questions

Overall, author attempts to answer the following research questions through empirical analysis.

- How does Fiber-to-the-home (FTTH) impact the socio-economic situation within Sweden at regional level?

  Specifically,
  - How degrees of FTTH penetration effect the following in Sweden?
    - Employment growth
    - Inter-municipalities commuting trends

1.5. Data Collection

In contrast to social sciences, often natural sciences use experimental data which facilitates researchers to control among correlated effects and separate
the causal effects under study. However, experimental data is hard to attain in social sciences and conventionally observational data is used where researchers analyze the expressed behavior of individuals through alternative choices they make. Observational data pose certain deficiencies in the evaluation, for instance isolating causal effects of observed from unobserved effects (Swärdh 2009).

In the same fashion, this study analyzes observational data collected by Acreo AB by means of primary and secondary sources, and author try to address such deficiencies through econometric techniques found in literature. Primary data sources included surveys among municipal administrations⁹, municipal network operators¹⁰, and housing companies¹¹. In addition, secondary data consist of historical data collected from online sources; Eurostat¹², Statistics Sweden (SCB), The Municipal and county database (Kolada)¹³, and the Swedish Post and Telecom Authority (PTS).

The gathered data is of panel / longitudinal nature where cross-sectional subjects consists 290 municipalities of Sweden and time series contains a period 2007-2010. The municipality level data was collected from SCB reports called “Yearbooks for Swedish municipalities”¹⁴ published in 2007-2010 period and stored in Ms Excel worksheets separately. This data was later used to build up a database on one of Acreo’s secure computer servers and linked to Stata® through MySQL scripts. All the results presented in this study are produced using Stata® (version 12).

1.6. Methodology

Cost-benefit analysis (CBA) is the most advance technique that allows one to capture and include social benefits and costs in investment evaluations. The aim of CBA is to rationalize social decision making and increase social welfare through efficient allocation of society’s resources. Most economic policies are judged on the grounds of social welfare improvement for the society at large. Often public sector policies aim to improve social welfare for individuals with standing from national and global perspective. Investment decisions to execute such policies are formed through several sophisticated tools from literature; however one is more or less, always looking for net positive benefits

⁹ Enkat Kommuner
¹⁰ Enkat Stadsnät
¹¹ Enkat Bostadsföretag
¹² European commission statistics
¹³ Kommun- och landstingsdatabasen
¹⁴ Årsbok för Sveriges Kommuner
(Boardman et al. 2011). Correspondingly, if the investment is in public sector with a dominant standing of society, benefits that occur socially are include to the possible extent, besides benefits that are difficult to quantify (e.g. monetizing benefits like reduction in CO₂ emission). Improvements in social welfare are only possible when the policies yield positive net social benefits. However, a large number of public policies aim to provide benefits over an extended period in future; therefore, benefits and costs need to be discounted in today’s time in order to calculate net present value (NPV) of net social benefits. The NPV of a policy is in return serves as a decisive criterion in standard ex-ante CBA studies which determines policy deployment decision.

Keeping in view the public sector nature of FTTH investment, ex-ante cost-benefit analysis (CBA) has been used to economically evaluate effects of FTTH investment in Sweden. Standard nine steps outlined in the literature (Boardman et al. 2011; Svensson 2010) of CBA have been followed in the evaluation as follows;

(1) FTTH deployment is analyzed in contrast with status quo, (i.e. the alternative to FTTH deployment), in which existent internet access opportunities are maintained on the basis of as it is.

(2) Standing has been deliberated to the national level (i.e. Sweden).

(3) Impact categories mainly include benefits to society in terms of reduced commuting, and increased employment. In addition, data and telecommunication cost savings at regional level are incorporated as well. On the other hand, impact categories for cost mainly include cost for deploying FTTH in 290 municipalities.

(4) Such impacts are predicted quantitatively over the estimated life (i.e. 30 years) of FTTH.

(5) Monetary values in SEK¹⁵ are, then, assigned to all impacts. Deployment cost is also expressed in monetary terms on the cost side.

(6) Benefits and costs associated with FTTH deployment are discounted to present values by social discount rate(s) through equation (1.1-1.2) given in the literature by Boardman et al. (2011 p. 138).

¹⁵ Swedish Krona.
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\[ i.)^{16} \quad PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1 + s)^t} \quad \text{Eq. 1.1} \]

\[ ii.)^{17} \quad PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1 + s)^t} \quad \text{Eq. 1.2} \]

(7) Net present value (NPV) of the policy was calculated through the following equation.

\[ NPV = \sum_{t=0}^{n} \frac{B_t}{(1 + s)^t} - \sum_{t=0}^{n} \frac{C_t}{(1 + s)^t} \quad \text{Eq. 1.3} \]

Thus it hereby, yields the decisive ground for making a recommendation for the investment decision.

(8) Sensitivity analysis was performed through varying the useful economic life and social discount rate (s) for FTTH investment (i.e. varying ‘t’ and ‘s’ in equation 1.1-1.3).

(9) Finally, the recommendation was made for the policy proposal of deploying FTTH based on net positive benefit criterion developed in step (7).

Impact categories are quantified using multivariable regression models developed in the analysis chapter (see section 3.3 for model specification and section 3.4 for results). It is important to mark here that CBA method instruct to capture all associated costs and benefits, and most policies at societal level have an extensive range of impact categories which are difficult to account. For some impacts market prices are available, however in-order to account for non-market goods shadow prices are used in literature. Since, FTTH deployment is considered a societal policy; it has a broad range of impact categories which are very versatile in nature; the study nonetheless is restricted to research questions only.

Furthermore, previously found willingness to pay (WTP) values to avoid commuting (i.e. value of travel time estimated by Swärdh (2009) in Sweden) are used to monetize the commuting effects.

\[ ^{16} \text{Present value of Benefits} \]
\[ ^{17} \text{Present value of Costs} \]
CHAPTER 1: INTRODUCTION

1.7. Disposition

The paper comprises of five subsequent chapters, the next chapter encompasses a detailed literature review over the economic impact of ICT infrastructure, traditional broadband technologies (i.e. xDSL, ADSL), and fiber-based broadband access networks (i.e. FTTH). A qualitative base of FTTH’s socio-economic impact is also presented under section 2.3 (in Chap. 2) in order to equip the reader with previous findings and potential impact categories. It is then followed by Chapter 3 (i.e. Analysis) which presents a complete quantitative investigation of the coined impact categories (i.e. employment, commuting). This chapter also includes model specifications, results and critical discussion to build up the base for conclusions. Estimated models and calculation of socio-economic returns are incorporated under this section as well. Analysis section yields adequate findings for the author to produce substance conclusions in Chapter 4. It further gives author the ability to outline recommendations based on personal experience gained throughout the study in Chapter 5. Finally, author presents personal reflections for future research in the subject field in the Chapter 6. Personal reflections presented are based on author’s own thoughts and beliefs developed during the study.

1.8. Constraints

It is important to note here that, the data on FTTH penetration does not exist with PTS\textsuperscript{18} prior to the year 2007. Hence, the period examined consists four years (2007-2010), it is therefore recommended that conclusions should be viewed accordingly.

\textsuperscript{18} Swedish Post and Telecom Authority (Translated from Swedish as; Post- och telestyrelsen)
This chapter describes the theoretical framework the study is based upon. The frame of references, works in conjunction with the empirical data as the basis to analyze results. The contents are inspired from scientific articles and academic books in the field.

2. Theoretical Framework based on Literature Reviewed

In the area of macroeconomics in general and economic infrastructure in specific, determinants that foster economic growth has been detailed in literature, and many consider *ICT infrastructure* to be one of them (Laitner & Ehrhardt-Martinez 2008; Chakraborty & Nandi 2011; Cieslik & Kaniewski 2004; Ding et al. 2008; Qiang 2010; Czernich et al. 2011). Similarly, technological improvements (e.g. FTTH) represented by \((\Delta A/A)\) in neoclassic growth model formed by Robert Solow, are stimulus to foster economic growth as; (Auerbach & Kotlikoff 1998 p. 14)

\[
\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \beta \frac{\Delta K}{K} + (1 - \beta) \frac{\Delta L}{L}
\]

**Eq. 2.1**

Where \(Y\) stands for output, \(A\) for technological level, \(K\) for capital and \(L\) for labor input, \(\beta\) represents the share of profit given to capital owners and \(1 - \beta\) represents the remaining share given to labor. In other words, the equation (2.1) says that the economic growth is equal to the total of 1) growth rate of technological improvements, 2) growth rate of capital multiplied by \(\beta\) and 3) growth rate of labor multiplied by \((1 - \beta)\). However, Solow’s model is a static model, and it predicts what will happen in the long run referred as *steady-state*, in which the economic growth is governed by exogenously given rates of population growth and of *technological progress* \((A)\) (Modén 2011).

Similarly, *Cobb-Douglas production function* Auerbach & Kotlikoff (1998 p.7, 16-22) has outlined the method to quantify the impact of such technological improvements on labor productivity using a simple model as;

\[
Y = AK^\beta L^{1-\beta}e
\]

**Eq. 2.2**

Dividing both sides with \(L\), we get;

\[
\frac{Y}{L} = A(K/L)^\beta
\]

**Eq. 2.3**

Equation (2.3) represents that labor productivity in a given region depends upon multifactor productivity \((A)\)\(^{19}\) and capital to labor ratio that restores the economy to a steady state.

\(^{19}\) Higher the level of \(A\), higher is the labor productivity.
In both the models (i.e. Eq. 2.1 and Eq. 2.3), we see technological progress is directly proportion to economic growth and labor productivity, yielding enough grounds for the current study to be conducted, as we presented before (in section 1.1.2. About optical fiber and FTTH) that FTTH is more efficient compare to copper cable networks and is regarded as improved technology in the category of broadband networks. In order to proximate economic growth, study has analyzed (in Chap. 3) employment growth effects with FTTH deployment at regional level in Sweden.

Despite being relatively new area of research (i.e. broadband technologies), literature review revealed that many scholars have studied the effects of (1) information and communication technology (ICT) infrastructure, and (2) traditional broadband technology. However, some has studied (3) Socio-economic effects of Fiber to the home (FTTH), on the economy. Major research work was done in last decade, especially right after when dot-com bubble exploded in 2000. Majority of such studies have been done in the developed economies (mainly US and Europe) and much less in developing countries for obvious reasons.

Hereby, we start by reviewing the relevant literature in three major categories for the sake of comprehensive literature review and to familiarize the reader with impact categories of ICT and broadband technologies. Literature review consists of;

2.1 Economic impact of ICT Infrastructure

2.2 Economic impact of Traditional Broadband

2.3 Socio-economic impact of Fiber-to-the-Home (FTTH)

2.1. ICT Infrastructure and economic development

In table 2.1, previous findings on economic impact of ICT infrastructure are summarized.

<table>
<thead>
<tr>
<th>Type of study and key findings</th>
<th>Key authors/contributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed-line telecom affects 1980s and 90s</td>
<td>(Röller &amp; Waverman 2001)</td>
</tr>
<tr>
<td>- Telecom penetration compels economic growth. Around 33% of GDP per capita growth is attributed to telecom</td>
<td></td>
</tr>
</tbody>
</table>
infrastructure investments.

- Spill-over advantages let businesses to operate over extensive distances.

**ICT productivity studies, 1980s, 1990s and 2000s**

- ICT infrastructure has a strong impact on private sector productivity in USA.
- Facts from Europe and Canada are further fragile.
- A time lag is existent as firms invest in harmonizing capital and work habits with ICT penetration.

**Future oriented Studies**

- Additional investments in broadband infrastructure create significant employment opportunities and GDP growth.
- Positive employment effects outweigh negative effects.

---

### 2.2. Traditional Broadband and Economic Development

In this specific area, an extensive range of scholars have studied the economic effects of broadband quantitatively mainly in last decade from Europe, US and Japan, it is because broadband technology have flourished in these countries in this period the most. Traditional broadband has been confirmed in all studies to be a driving factor for economic growth (LECG 2009; Crandall et al. 2007; Qiang et al. 2009). Creation and decentralized distribution of information and new thoughts on the network is foster to economic development in a given rather open economy. Closed economies are less likely to experience fast economic growth by endogenous growth theory presented by Romer (1990), who concluded that economic growth acceleration is achieved by innovative reforms in technology through international research and investments.
A recent study done by Czernich et al. (2011) using an instrument variable (IV) regression approach on 20 OECD countries panel data concluded that, after a country had introduced broadband, GDP per capita grew 2.7% to 3.9% on average as compared to the status quo. In addition, by the subsequent years (i.e. after the introduction), a 10% increase in broadband penetration would stimulate GDP per capita by 0.9% to 1.5%. In case of Sweden, the country is among the first countries that realize the significance of phenomenon and started deploying broadband in the mid of 1990s. In order to promote broadband deployment, Swedish government grants financial inducements to municipalities to fund nearly 66% (i.e. two third) of total Next Generation Networks (NGN) which constitutes total investment of EUR 864 million (Katz 2012). Similarly the report by LECG (2009), concluded that the impact of broadband penetration on GDP for each additional broadband line per 100 persons (in 2000 US dollars terms) is $274 million for one additional line, $1,368 million for five additional lines and $2,736 million for ten additional lines\textsuperscript{20}, despite the fact that Sweden already has a broadband penetration that is very high (see figure 9.2 in Appendix C). It is also very clear from the figure 2.1 below, that Sweden has experienced the highest growth in broadband penetration between years 2000-2007 among the category of developed countries in OECD region.

\textsuperscript{20} (LECG 2009) p. 5

---

Figure 2.1 Total broadband subscription per 100 inhabitants in OECD countries
Source: (OECD 2012)
In addition, LECG (2009) also emphasized on the need of complementary investments necessary for a country to benefit most from broadband deployment. The main conclusion there is that, countries that have invested more than simply broadband infrastructure, for example in education and transportation sectors, are also the countries that benefit the most from increasing their broadband deployment.

Now we look at the case of USA, Lehr et al. (2006) presents a study of the effects of broadband on a number of economic activities (e.g. employment, wages, and industry mix), using cross-sectional panel data from all states. The study concluded that broadband has affected economic activity positively. The study used the data from 1998-2002 period and showed that states in which mass-market broadband has been available by December 1999, witnessed higher growth in employment, number of businesses setups, and businesses in IT-intensive sectors.

In table 2.1, we present the summary of previous research on economic impact of broadband for the sake of simplicity and cohesiveness.

<table>
<thead>
<tr>
<th>Study</th>
<th>Regional scope</th>
<th>Key findings</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Czernich et al. 2011)</td>
<td>OECD</td>
<td>- An increase of 10 percent in broadband penetration affects annual per capita growth by 0.9-1.5 percentage points.</td>
<td>- Study covers 1996-2007 period; - Instrumental variable approach to address reverse causality</td>
</tr>
<tr>
<td>(LECG 2009)</td>
<td>Europe, USA</td>
<td>- Countries with good ICT environment, broadband expansion increases GDP substantially. - In countries with lower ICT propensity, causality of broadband penetration on GDP and productivity is not observed.</td>
<td>LECG estimate an aggregate productivity model addressing reverse causality / simultaneity issues</td>
</tr>
<tr>
<td>(Qiang 2010) (Qiang et al. 2009)</td>
<td>120 countries</td>
<td>- Per capita income is affected positively by fixed-line, cellular networks, internet and broadband. - In developing countries</td>
<td>Cross-sectional endogenous growth model</td>
</tr>
</tbody>
</table>
## CHAPTER 2: THEORATICAL FRAMEWORK

Economic growth effects are greater than in developed countries.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Region</th>
<th>findings</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Koutroumpis 2009)</td>
<td>EU-15</td>
<td>Broadband penetration has sound and statistically significant effects on growth in European countries.</td>
<td>Data consists a short time period of 2003-2006.</td>
</tr>
<tr>
<td>(Crandall et al. 2007)</td>
<td>USA</td>
<td>Through 1% increase in broadband penetration (equal to ~3m lines) additional 300,000 jobs are created in USA. Statistically significant effect of broadband penetration on output growth, especially in the service industries.</td>
<td>Cross-sectional data covers 2003-2005 data (48 states).</td>
</tr>
<tr>
<td>(Lehr et al. 2006)</td>
<td>USA</td>
<td>Broadband penetration adds around 1% to 1.4% to employment growth in period 1998-2002. Positive impact of broadband was captured on entrepreneurship trends, and property values.</td>
<td>Longitudinal data set of communities across the U.S. (segmented by zip code); Data covers 1998-2002.</td>
</tr>
<tr>
<td>(Lehr et al. 2006)</td>
<td>Europe, OECD countries.</td>
<td>Econometric studies of broadband</td>
<td>Backward causality problem was addressed through IV regression method and first order differences equations.</td>
</tr>
<tr>
<td>(Crandall et al. 2007)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Qiang et al. 2009)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(LECG 2009)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Czernich et al. 2011)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusively, Katz et al. (2010) has summarized the previous research for broadband impact on economic situation and found that all studies reveal similar results that broadband has an impact on GDP but the degree seems to vary with the ICT maturity of the country.

### 2.3. Socio-economic impact of Fiber-to-the-Home (FTTH)

Extending the same logical boundaries of economic impact of ICT and broadband infrastructure to the *FTTH* domain, we theorize positive economic effects in the same fashion (See section 3.2 for Hypothesis). However, the number of studies in the field of FTTH is limited compared to the traditional broadband and ICT infrastructure and moreover FTTH’s studies were mainly qualitative. Some quantitative findings were uncovered by Guidry et al. (2012), Schindler (2011), Forzati & Mattsson (2011) and Hutcheson et al. (2009) recently.

Nonetheless, the aim of the current study is to develop and analyze socio-economic evaluation of *Fiber-to-the-home (FTTH)* within Sweden at regional level. It is hypothetically assumed however, that an effective FTTH system in-place would prove itself to be significant stimuli in improving socio-economic indicators in the country in general and optimizing employment rate and commuting trends in specific.

However, on the contrary, many question the need of FTTH deployment, and argue in the favor of traditional broadband through copper cable. A little amount of services and consumers available in current times that actually need FTTH becomes a supporting point to their argument against FTTH deployment. However, it is not the full picture and there are many advantages apart from the high speed internet accessibility to the end user.

In table 2.3, for the sake of simplicity, author presents the summary of substantial studies conducted previously, analyzing socio-economic impact of FTTH in different economies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Regional scope</th>
<th>Key findings</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Guidry et al. 2012)</td>
<td>USA</td>
<td>- Experimental design based on cities (with high FTTH penetration) was used and it revealed that employment rate is 4.14% higher than the</td>
<td>-Study uses 2005/2006 cross sectional data through quantitative</td>
</tr>
</tbody>
</table>
**CHAPTER 2: THEORATICAL FRAMEWORK**

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Findings</th>
</tr>
</thead>
</table>
| (Schindler 2011)                           | Europe, USA | - FTTH saves 1.5% costs in electricity, transportation, health and education.  
- FTTH users *work two more days per month from home*.  
- Around 1 million users connected save 1 million tons of CO₂ emission.  
- ARPU\(^{21}\) is 30% more compared to broadband.                                                                                                                                                                                                                   |
| Study presents findings though survey data. |          |                                                                                                                                                                                                                                                                          |
| (Forzati & Mattsson 2011)                  | Sweden   | - A 10% increase in FTTH connected population 0.1% higher employment and 0.25% increase in population in a given municipality.                                                                                                                                                                                                                              |
| Study uses data from 290 municipalities and presents results through multiple-variable regression model. Covers data from 2007-2010.                                                                                                  |
| (Hutcheson et al. 2009)                    | Sweden   | - Nearly 53% choose FTTH among any other traditional broadband.  
- Around 45% think it is the best value for money.  
- Savings of 10-15% on annual telecoms cost in Jonkoping (i.e. €400,000 per year)  
- FTTH users *work one-two days from home per month*  
- Hudiksvall, a clear correlation is found between rolling-out fiber and new business setups.  
- Study concludes that impact will be highest in rural areas with constraint local resources, where end-users have significant travel needs. |
| Data consists of surveys, interviews and municipal case studies. None of econometric model used.                                                                                                                                                                                                                   |

\(^{21}\) Average Revenue Per User due to additional services subscription.
As shown above (i.e. in table 2.3), most researchers were convinced that FTTH has positive effects on economy in general and employment in specific. Some studies also pointed out reduced commuting with FTTH deployment, for instance Schindler (2011) and Hutcheson et al. (2009). Similarly Troulos (2010) also stated that FTTH encourages teleworking and reduces commuting.

After reviewing all previous literature in the field and business models presented by FTTH council Europe (2010), in table 2.4, author summarize some major costs and benefits associated with FTTH to support the analysis in the upcoming chapter. Here note that, both signs (+ and -) represent pros and cons respectively. In addition “high and low” presents the quantitative increase or decrease in the account title respectively.

### Qualitative Cost Benefit Analysis

<table>
<thead>
<tr>
<th>Account</th>
<th>Pros/Benefits (+)</th>
<th>Cons/Cost (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1: Technological Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deployment Cost</td>
<td></td>
<td>High (-)</td>
</tr>
<tr>
<td>Repairing Costs</td>
<td></td>
<td>High (-)</td>
</tr>
<tr>
<td>2: Benefits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1: Socio-Economic Benefits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1.1: Consumer Benefits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bandwidth/Internet Access Speed (up-streaming and down-streaming)</td>
<td>High (+)</td>
<td></td>
</tr>
</tbody>
</table>

---

22 Mega bits per second
23 (+) sign represents “benefits” or pros
24 (-) sign represents “costs” or cons
CHAPTER 2: THEORETICAL FRAMEWORK

- Network reliability
- Multitasking per end-user
- Multi-user support
- Passive networking support

2.1.2: Service Provider Benefits

<table>
<thead>
<tr>
<th>Operational Cost (OPEX)</th>
<th>Low (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Staff</td>
<td></td>
</tr>
<tr>
<td>Electricity consumption</td>
<td></td>
</tr>
<tr>
<td>Reduced network troubleshooting</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>New revenue opportunities</th>
<th>High (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useful economic life of Optical Fiber cables</td>
<td>High (+)</td>
</tr>
<tr>
<td>Future-proof network infrastructure guaranteeing ease of upgrade in the future</td>
<td>High (+)</td>
</tr>
</tbody>
</table>

2.1.3: Economic Growth

<table>
<thead>
<tr>
<th>Employment</th>
<th>High (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor Productivity</td>
<td></td>
</tr>
<tr>
<td>Creation of new businesses (entrepreneurship)</td>
<td></td>
</tr>
<tr>
<td>Educational Services</td>
<td></td>
</tr>
<tr>
<td>Health Care Services</td>
<td></td>
</tr>
<tr>
<td>E-business/e-health/e-government</td>
<td></td>
</tr>
<tr>
<td>Skilled labor immigration</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Commuting</th>
<th>Low (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic congestion and CO₂ emission</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Educational Cost</th>
<th>Low (+)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Saving of data and telecommunication costs in the country</th>
<th>High (+)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Online Security Services</th>
<th>High (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savings of municipal data and telecom costs</td>
<td>High (+)</td>
</tr>
<tr>
<td>Environment Friendly</td>
<td>High (+)</td>
</tr>
</tbody>
</table>

2.3.1. Technological Benefits

2.3.1.1. Consumer Benefits

In the category of socio-economic benefits consumers and service providers constitute a significant share. The major advantage of FTTH for consumers is its bandwidth (high speed and amount of data that can be transferred from

---

25 Verizon in the US reports that its FTTH network showed a decline of 80% in network trouble report rates.
26 Useful economic life of optical fiber is 10 years longer than traditional copper cable (FTTH Council Europe 2011 p.24; ComReg 2009 p.16)
27 These savings are by private/public companies, and regional administrations. (See chapter3, Section 3.2))
28 Fiber optics uses little of resource in manufacturing, transporting and installation because of its lightweight and compact nature as compared to copper cables (ComDesign 2011).
one point to another in a given time). In all of the broadband technologies, FTTH’s users have shown the highest satisfaction level. Troulos (2010) reported that percentage of satisfied users of FTTH is 85%, where other broadband technology’s users have low satisfaction rate (e.g. 60% for DSL users).

Furthermore, FTTH possesses the highest capacity to carry the amount of data, among all developed technologies so far. Today, with just 100 Mbps connection, FTTH subscribers can upload and download contents on the internet over 10 times faster than normal ADSL subscribers (FTTH Council Europe 2010). In table 2.5, different broadband technologies are compared with FTTH to present the idea of high speed with time utilization.

Table 2.5: FTTH speed comparison with other broadband technologies

<table>
<thead>
<tr>
<th>Time taken for:</th>
<th>Mbps Speed</th>
<th>1 GB photo album</th>
<th>4.7 GB standard video</th>
<th>25 GB HD video</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTTH</td>
<td>100 Mbps download 100 Mbps upload</td>
<td>1 min 23 sec</td>
<td>6 min 31 sec</td>
<td>34 min 40 sec</td>
</tr>
<tr>
<td>CATV</td>
<td>50 Mbps download 10 Mbps upload</td>
<td>2 min 46 sec</td>
<td>13 min 2 sec</td>
<td>1 hr 9 min</td>
</tr>
<tr>
<td>DSL</td>
<td>8 Mbps download 1 Mbps upload</td>
<td>19 min 0 sec 2 hr 32 min</td>
<td>1 hr 29 min 11 hr 54 min</td>
<td>7 hr 55 min</td>
</tr>
</tbody>
</table>

From the above table, it is clear that FTTH has a big difference in time required to upload and download data, with any other broadband network.

Secondly, FTTH speed remains constant across long distance users; characteristic like this, is not present in xDSL technologies. In addition, contrary to xDSL, FTTH performance is not affected by noise, interference and cross-talk during operations (FTTH Council Europe 2010). Moreover, FTTH provides highest network reliability, multi-user support (i.e. several

---

29 FTTH Council Europe (2010)
30 Unlike traditional broadband, network speed of FTTH is not affected by multi-user sharing.
users on the same line), multitasking support per single user, and passive networking\textsuperscript{31} support; all yields value addition and increase customer satisfaction.

\subsection*{2.3.1.2. Service Provider Benefits}

Benefits of consumers transform into the benefits of service providers in many ways. However, one should be careful with double counting phenomenon when quantifying costs and benefits, that some of the provider benefits are just transfers from customers to providers. It is therefore recommended by Boardman et al. (2011) that CBA analysts should capture net social benefits that are social welfare improving in such policies. Despite just the transfers, FTTH has increased customer satisfaction which helps to increase willingness to pay (WTP) by consumers.

Overall, benefits that occur to service providers are listed in table 2.4, and the major portion of these benefits stems from reduced operational costs in the form of reduced electricity consumption and maintenance cost by less troubleshooting. Other benefits of service providers include a higher economic life of FTTH cables (i.e. 30 years) and network robustness for future up-gradation\textsuperscript{32}. Nonetheless, these benefits are important but they fall outside the scope of our analysis (due to the unavailability of data), but it has been worth mentioning for a comprehensive analysis.

\subsection*{2.3.1. Environmental Benefits}

Among the all developed broadband technologies through cables, FTTH is proved to be most ecological in among the category of all cable provided broadband technologies. Moreover, it is efficient for utilizing raw material and reduces commuting. For instance, a recent study done by FTTH council (2011) stated that one FTTH connected average household can save up to $CO_2$ emission equivalent to driving 4,600 kilometers per year. Similarly, optical fiber uses little of resource in manufacturing, transportation and installation, because of its lightweight and compact nature as compared to copper cables. However, environmental benefits are not quantified by our study due to the small scope of the thesis.

\textsuperscript{31} It is the bandwidth required by PCs to run background applications (FTTH Council Europe 2010).

\textsuperscript{32} Once the optical fiber cables are deployed, network can be easily upgraded by just replacing the equipment at both ends (i.e. exchange and at end user premises).
2.3.2. Economic Benefits

It is prominent indication from social and economic research reviewed that fiber penetration has a positive impact on employment, commuting, education, health, quality of life and on many other dimensions of life (see table 2.4). Although, there has been very little quantitative investigation of economic impact of FTTH and the reason of less work in the area is that, FTTH has recently proved out to be an appealing investment, and in Sweden FTTH penetration data is not available with PTS33 prior to year 2007 (at municipal or county level). Nonetheless, Sweden is a country in European Union which is among the first countries that started deploying fiber much earlier, for instance, Swedish city Västerås decided to build fiber-optic network in the municipality by 1999, being the first city in Sweden to have fiber-based network. Municipalities with high FTTH can be thought to attain genuine socio-economic benefits more efficiently.

Examples of possible advantages through FTTH penetration, that can occur to municipalities in specific and the country at whole include:

- Increased employment opportunities
- High labor productivity (per hour worked)
- Stimulating a municipality’s capability to innovate new businesses (especially online information services businesses, see fig. 2.3 and 2.4).
- Optimizing efficiency in the delivery of public services (e.g. education, healthcare, e-businesses, e-government etc.) and savings in data and telecommunication costs at regional administrations.
- Municipalities with high FTTH penetration become attractive to skilled labor immigration from abroad and can fill up the gap of professionals needed by the job market.
- Improving the overall quality of life by means of fast and better communications among end-users.
- Reduced commuting among municipalities, traffic congestion and pollution (i.e. CO₂ emission).
- Reduced educational operating costs (i.e. More distance learning programs and online studying on highly reliable network, can reduce operational costs (OPEX) of the education sector)
- Better service in result of high competition among service providers.

33 Swedish Post and Telecom Authority
Fiber being more ecological than copper.

Ideally, CBA studies should capture all impact categories of a policy; however, a technical limitation of CBA as pointed out in literature that it requires all impacts to be quantified in monetary terms, which is difficult with scarce resources and time (Boardman et al. 2011). Therefore, we restrain to evaluate two major impacts, employment and commuting. Let us now, closely examine the both in Swedish economy using historical data provided by SCB.

2.3.2.1. Employment

Sweden often heard the least impacted economy in Europe by the recent financial crises, yet had unemployment increase by the mid to end of 2007, as the number of “not gainfully employed population” started increasing. The significance of unemployment increase is noticeable by the yellow line in figure 2.2. Economic recovery in Swedish labor market has been (as compared to other European countries) better which we can notice by the downward shift of yellow line by the end of 2009. Nevertheless, it is very likely that distortions are existent in the labor market which can increase/decrease with affects of the recent recession.

![Figure 2.2 Population 16+ years (RAMS) by employment status and period](image_url)

In the category of economic benefits of FTTH of public sector policies, it is probable that economists would rank employment growth on top of the

---

34 Page 42
list. Similarly, frequent government policies and politicians claim to increase employment opportunities in a given country. Keeping in mind the structure of Swedish economy it is not surprising to see that ICT sector is a big employer in the country. It indicates that a sound technological optimization in ICT and related businesses, would result increasing employment and labor productivity. Hence, politicians may also motivate FTTH deployment for political reasons.

Since 2006, Sweden has experienced an increasing employment trends in ICT sector, and the information services sector in particular, as shown in figure 2.3 below. The increased number of employees information service companies support the arguments of FTTH advocates to a great extent, that optimized fiber-based networks would lead to new innovative services being offered. However, we do not claim here that upward employment trend such companies are due to FTTH penetration, but nonetheless partial credit goes to optimized communication technologies.

It is also apparent in figure 2.5, that a rapid growth is noticeable in new information services companies’ setups among the total private sector since 2005. In order to differentiate the trends, quarter 1 of year 2000 was used as an index.

Both graphs (i.e. fig. 2.3-2.4), point out that ICT sector is very vibrant in Swedish economy in order to generate employment. Slight improvements in efficiency in this sector can provide multiplicative employment
opportunities. Thus, FTTH is theorized, however, a significant innovation to boost up employment in ICT sector directly and whole economy indirectly. It is believed that un-captured values (i.e. benefits that are not on surface) would become observable as fiber penetrates more. In the coming section (i.e. analysis) study would test some of these assumptions empirically.

### 2.3.2.2. Working from home/Reduced commuting

In 21st century’s metropolitan cities with diverse professions, travel time to work place is fairly a big portion of one’s time schedule. Employed people with high skills, living in remote/rural areas presumably travel (i.e. commute) often to major cities. There are many drawbacks associated with increased travelling in a country, for instance, traffic congestions, road building\(^{35}\) and their higher maintenance costs, pollution (e.g. CO\(_2\) emission, noise pollution) and reduced productivity during travel\(^{36}\) (Swärdh 2009).

The possibility to work from home (i.e. teleworking) and online business settings through FTTH has put forth an option for individuals to commute less and hypothetically speaking, FTTH will encourage individuals to decrease commuting and work remotely, by providing a high speed internet services with high reliability (Schindler 2011). On the other hand, it can also be argued that high speed internet networks would not substitute travels but rather

---

\(^{35}\) However, on the other hand, it is also found that a good road infrastructure yields reduced travel time.

\(^{36}\) According to some sources, people value their travel time as leisure activity and/or some work during traveling.
compliment travels, as FTTH increases the degree of communication and collaboration among the work force and employers. However, these assumptions are to be tested in coming chapters.

Nevertheless, much of time is spent on commuting by individuals in society and if this time could be saved, it could be spent in different productive activities by individuals. Several economists have been working to analyze commuting tendency and have valued travel time in monetary terms. Value of travel time comes from the concept that workers are willing to pay to avoid commuting or require compensation (i.e. willingness to accept) if they commute. For instance, Swärdh (2009), in case of Sweden, has calculated value of commuting time (VOCT) to be SEK 155 per commuting hour for a sample of established men in Swedish labor market. However, previous studies in other countries value travel time fairly less than the estimate of Swärdh (2009), For example Calfee & Winston (1998) has estimated a range for VOTT\(^{37}\) in-between $3.17 to $5.47, in case of USA using stated preferences method. One may also take inflation and currency dynamics into account for the period (i.e.1998-2009) till Swärdh studied VOCT, but Swärdh (2009) has yet a relatively high estimate. Similarly, Small (1992 p.44) estimated value of travel time based on a survey to be 50 percent of the average gross hourly wage rate in USA. In addition, later (Brownstone & Small 2005) also reported a higher range estimate of travel time across $20 to $40 per hour for commuting through car for a sample from USA using revealed preferences. These entire estimates are substantial enough for policy makers to evaluate investments from transport sector perspective, and a big portion of these investments’ returns come from reduced travel/commuting time. Mackie & Jara-Diaz (2001) concluded that 80 percent of benefits incurred by road building investments consist of travel time savings in UK. In Sweden, however, according to a Swedish survey 46 percent of benefits of road investments comprise of travel time saved by users (Persson & Lindqvist 2003).

Up to now, we are certain for a fact that travel time possesses real monetary values and individuals on average have positive willingness to pay (WTP) to avoid commuting or require compensation for commuting. For example, Rouwendal & Meijer (2001) concluded using stated preference through Dutch sample that an employed commuter on average is willing to pay SEK 190 to avoid one hour of commuting. Similarly, evaluation of investments in sectors of the economy, apart from roads network, that reduces commuting often incorporate values of

\(^{37}\) Value of travel time
CHAPTER 2: THEORATICAL FRAMEWORK

travel time saved. For instance, Hensher & Brewer (2001) said that end user benefits of investments in transport sector in general come from over 70 percent from travel time saved.

Therefore, as we come to point of FTTH deployment, it also stands in relevant literature (presented in table 2.4) to contribute savings in commuting (i.e. not by reducing travel time during trips but by reducing number of travel trips) and yet yields positive social welfare for the society. Several scholars have identified them qualitatively (Forzati & Mattsson 2011; Hutcheson et al. 2009) and no quantitative results are found, to the best of author’s knowledge. This study, however, aims to enrich previous findings quantitatively and overall, the idea is that people would have a facility to work from home instead of commuting to the work place, many of the conferences and business meetings (etc.) would be done virtually over a reliable high speed network, and in a result lot of travel time will be saved. For that reason data on distance workers from 290 municipalities was collected through SCB to uncover empirical findings in this matter.

Looking over the Sweden data set of employed commuters (with age 16+ years), it was revealed that 32.79% of the total employed population commuted in the year 2010, which is one third of the total work force. In other words, among 10 employed individuals over 3 workers are distance workers. In the figure 2.5, gainfully employed commuters with age above 16 years are plotted. It is evident that few municipalities are exceptions (i.e. Stockholm and Gothenburg) due to diverse demographics and high economic activities. Commuters are relatively much higher in these municipalities compared to sample mean.

Commuting trends are seen much stagnant and may change relatively very slow over time (see figure 2.6). It depends upon individuals’ preferences and the ability to avoid traveling. In the figure, it is rather shown that since year 2004 employed population in relatively less economic active counties maintain nearly unchanged level of commuting and counties (i.e. Stockholm, Halland, and Västra Götaland) that have higher economic activities and regional GDP tend to increase number of commuters yearly, till the end of 2010.

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38 Such outliers can also make efficient OLS estimation inefficient and have to be taken into account. It has also been recommended by Gujarati & Porter (2009) to drop such an observation if the data set is quite large.
CHAPTER 2: THEORATICAL FRAMEWORK

Figure 2.5 Gainfully employed 16+ years’ commuters leaving the municipality by period and region 2010. (Total Men and Women)

Figure 2.6 Gainfully employed commuters leaving the county by period and region (Total of Men and Women)
CHAPTER 3: ANALYSIS

In this chapter, author has linked the theoretical framework to the empirical data and used the results to construct a discussion to answer the research questions. This chapter would establish a framework for final conclusions to draw in the coming chapter.

3. Analysis

3.1. Cost of FTTH

Estimating the deployment cost for FTTH is fairly a very difficult and far-reaching task; a separate and significant effort has to be made to get correct measures, which is far beyond author’s reach. It is therefore, suitable to take already found estimates in previous studies who attempted to give monetized figures (i.e. SEK) in Sweden. According to (FTTH Council Europe 2012) yet unpublished cost model, the cost of fiber for the connection of a single house is between SEK 15,000 and SEK 25,000. An average cost of SEK 18,000 for single houses and approximately SEK 10,000 to connect an apartment (in multi-dwelling buildings) is estimated in a densely populated area. However, the apartments in the most poorly populated areas can cost more to connect (Forzati & Mattsson 2011), as cost of FTTH deployment follows a simple rule; “higher the degree of urbanization lower the deployment cost.” Therefore, it was not surprising to see in data set that, municipalities with higher urbanization degree or population density per square kilometer (PDP5K) has relatively higher FTTH penetration trends already.

In a pre-study to evaluate socio-economic effects of FTTH by Forzati & Mattsson (2011) in Sweden has projected an average cost for a FTTH connection to be SEK 6250 per capita keeping in mind the houses’ construction characteristics in Sweden. It comes to a total of SEK 58.847 billion (as per population data at the end of 2010 by SCB). It is stated by FTTH council Europe (2012) that up-to 80% of this cost stems from labor costs and rest 20% are equipment installed. In passing note, it is important to keep in mind here that given the nature of geographic and demographic outlay of Swedish population one has to extrapolate up to some extent as last resort, when estimating the total cost. Consequently, one can risk underestimating or overestimating the true values. Nonetheless, the average cost per capita presented above is a rough indicator, but it gives a good estimate of FTTH costs.

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39 Ericsson (September 2011): Email communication by Acreo AB, with Per Olof Ohlsson
40 Ekot AB (September 2011): Email communication by Acreo AB, with Lars Hedberg
41 Swedish houses consists of 42% as single houses and 58% apartments in multi-dwelling buildings
42 Total Labor Cost = Labor Install + Labor Civil

42
CHAPTER 3: ANALYSIS

For this current study, we calculate the total cost through the following equation (3.1). According to SCB provided data, at the end of 2010 around 44% of total dwelling stock consists of single homes and 56% of apartments in multi-dwelling buildings (from a total dwelling stock of 4.50 million). In addition, we rely on figures provided by FTTH Council Europe as presented above in bold letters.

According to data collected from PTS on FTTH, about 33.21% of homes are connected in the country which means that an investment of SEK 41.320 billion is yet to be invested for 100% FTTH penetration. In the study we treat the prior investment as *sunk cost* and do not take into the analysis. The calculation method used is as:

\[
Total\ Cost = (N_{aprt} \times C_{avg\_apart} + N_h \times C_{avg\_house}) \times (1 - F)
\]

Eq. 3.1

Where, total deployment cost is equal to

- number of apartments in Sweden \(N_{aprt}\) times the average cost to connect an apartment \(C_{avg\_apart}\)
- number of houses \(N_h\) in Sweden times the average cost to connect a house \(C_{avg\_house}\)

The sum is then, reduced by the current FTTH penetrated rate (i.e. \(F=0.332\)).

Hence the potential investment of **SEK 41.320** billion is taken as total cost for FTTH deployment. These costs are comparable to those estimated for similar investments in Europe\(^{43}\).

3.2. Benefits of FTTH

3.2.1. Willingness to Pay (WTP)

As we argued in previous chapter, individual in Swedish society may benefit from FTTH through several channels (direct and indirect), hence researchers can come across positive willingness to pay (WTP) for FTTH by a household survey. However, such surveys have not been executed in this study. Thus we make a conservative guess of WTP of average households by examining a

\(^{43}\) To connect an inhabitant in France, it costs approximately SEK 6400 per inhabitant (CDC September 2011) which is similar to per capita cost for Sweden.
CHAPTER 3: ANALYSIS

contract between Swedish tenants’ association\textsuperscript{44}, property owners’ associations and housing companies, where it has been mutually agreed that FTTH provided would lead to an increase in per month rent between 45 SEK and 47 SEK. Hereby, we calculate median value of SEK 46 as willingness to pay for FTTH. This estimate is used to calculate the total WTP for whole dwelling stock (=4.508 million) in whole of Sweden as 2.489 billion SEK annually. Since around 32\% of homes are already connected and thus previous given total WTP has to be reduced proportionally, and we come up with total WTP in return of new investment as SEK 1.687 billion annually.

3.2.2. Regional Savings in Data and Telecommunication Costs

Since, it is believed that FTTH improves efficiency at regional level; there are few examples in support from Sweden. All together it is 30\% of the total data and telecommunication costs. By increased efficiency, we mean here the utilization of less energy consumption, equipment, and per unit of information transmitted. In addition, it is also partially due to the fact that FTTH allows for higher competition. It is believed here that different service providers using the FTTH infrastructure in an open access model, has reduced their marginal costs and they increase the supply of services being provided (Boardman et al. 2011), thus yielding Pareto efficiency. In order to support our assumptions, let us take the example of the city of Stockholm where the external telephony cost was around SEK 150 million per year in 1996. Thereafter, the city started to purchase its own telephony network from open market and by now it has connected its operational sites and offices with its own fiber network. The resultant efficiency on the new fiber-based network has saved the municipality SEK 45 million (i.e. 30\%)\textsuperscript{45} (Forzati & Mattsson 2011).

In the municipality of Jönköping (with relative less extensive FTTH penetration), the savings figure was around 10 to 15 percent (Hutcheson et al. 2009). If we compare the figures for fiber penetration to workplaces in Sweden, 25\% had access to FTTH by the end of 2010 and workplaces in Stockholm municipality, 62\% have access to fiber. Therefore, a positively proportional relationship between fiber penetration rate and savings is observable. Although, there has been no example to quantify the savings brought by 100\% fiber penetration, hence we take Stockholm figures to be only available estimate. If we extrapolate Stockholm’s figures to rest of the

\textsuperscript{44} Hyresgästföreningen
\textsuperscript{45} email communication with Anders Broberg, Informationschef, Stokab AB, (July 2011)
municipalities, SEK 500 million would be saved annual municipal data and telecommunications cost. Reducing this figure by already deployed fiber network we come nearly to SEK 350 million annually as a return to additional investment (Forzati & Mattsson 2011).

Similarly, saving trends are observed at regional administrations also, for instance; The Stockholm County Council minimized its data and telecom costs by 50%, which comes to SEK 60 million due to fiber-based access networks. Furthermore, in the county of Norrbotten, a fiber network has connected 5 hospitals, 33 clinics and 34 dental clinics, which reduced communication cost also by 50%, by offering 50 times faster data transfer and communication. Several service providers have been able to offer solutions for transmission of digital radiography, digitized medical records, digital recipes, IP telephony, video conferencing and lot more. Such savings are difficult to measure with certainty; however if we make a rough extrapolation of the Stockholm’s and Norrbotten’s County Councils savings to rest of Sweden, we come up with a saving of SEK 270 million annually in data and telecommunication costs at by 21 counties (thanks to FTTH) and SEK 190 million as a return on potential investment being considered (Forzati & Mattsson 2011).

**3.2.3. Useful Economic Life of FTTH**

Useful life of the optical fiber cables is estimated to be 30+ years under the land, by FTTH Council Europe (2010), which is also fairly similar to the estimate of (Swindell 2008). It is because that fiber deteriorates at a highly slow rate. Therefore, all the benefits are projected over 30 years and then discounted to present value (i.e. t = 30 in equation 1.1).

**3.2.4. Indirect Socio-economic Benefits**

Despite the extensive range of FTTH’s benefits (see table 2.3), study has captured employment increase and decreased commuting only due to limited time and resources. In this section, study presents the basis of empirical analysis by means of econometric models. Both the econometric models (i.e. for employment and commuting) are guided from literature and the former course book (Gujarati & Porter 2009).

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46 Stockholms läns landsting
47 Stokab (2011): Email conversation by Marco Forzati with Anders Broberg, (Informationschef; Stokab AB)
CHAPTER 3: ANALYSIS

Extending the logical boundaries of positive effects of ICT infrastructure (see table 2.1) and tradition broadband (see table 2.2) on different dimensions of the society, we put forward a rational statement that, high speed internet services through fiber-based access networks (i.e. FTTH) would yield positive effects on socio-economic situation of the country and develop the following hypothesis to be tested.

Hypothesis 1: Employment

\(H_0: \text{FTTH penetration does not increase employment rate in Sweden}
\nonlinebreak
H_1: \text{FTTH penetration does increase employment in Sweden}

Hypothesis 2: Commuting

\(H_0: \text{FTTH penetration does not decrease commuting trends in Sweden}
\nonlinebreak
H_1: \text{FTTH penetration does decrease commuting trends in Sweden}

Now let us look into the models closely and test the above hypothesizes.

3.3. Model Specification

3.3.1. Employment

In the category of economic benefits of FTTH, as Romer (1990) claimed that technological progresses are endogenous and there may be increasing returns to scale on the level of entire economy. In order to separate the causal effects, more and more sophisticated methods are being used and one always has to make the rational choice in selecting the correct estimation method depending upon the underlying data set. The hypothesis of simultaneity has been tested through Hausman simultaneity test (in appendix A) which revealed the existence of simultaneity in employment model at-least. It means that higher employment in a certain municipality over the years in return causes higher FTTH deployment. Hence, author considered different methods from literature to separate the contributory effect of FTTH on employment. It was found difficult to get a very good instrumental variable (i.e. due to the unique nature of FTTH penetration and limited data availability in broadband industry). However the two stage least squares (2SLS) method was found applicable to some extent\(^{48}\), but it does not serve the whole purpose.

In labour market, we believe that there are distortions existent due to government intervention, information asymmetry and different externalities, and an assumption is made that employment increase in one municipality is

\(^{48}\) The method was not reliable as \(R^2\) value in the first stage is fairly low (i.e. \(R^2=0.21\)).
CHAPTER 3: ANALYSIS

not at the cost of another municipality (i.e. not a zero sum game). It is also believed that certain municipality with higher employment trends becomes an attractive place for the work force. However, it is a rough qualitative hypothesis that needs to be tested on separate grounds, but it helps when we try to distinguish the effect of FTTH from other factors affecting employment in the municipality. One indicator that describes the magnetism of the municipality is its last 10 years population growth. Keeping in view the Swedish economy, it is expected that municipalities that had improving trends in population change over the past decade, are more developed and likely to have higher employment trends. It is a hypothesis which requires verification but to optimize author’s confidence, a correlation coefficient of 0.9 was found between population growth and employment growth during last decade in three most attractive municipalities (e.g. Stockholm, Jonköping, Göteborg).

Secondly, there can be a numerous factors that can be identified to construct the model; however, most of the times it is always a compromise between being precise, model robustness, data availability and statistical independence of the factors. Nonetheless, identified factors (i.e. explanatory variables) have a sound validation to describe employment independently in the model. One of the factors that appeared around 2007, as a possible influence on changes in employment is FTTH (as explained in table 3.4). However, author strongly believes that such effects will be exponentially growing and would have more significant effects in longer run.

Other factors that one can identify are; economic equalization among municipalities, excess of skilled labour immigration from abroad, tax changes, education level, wages and other infrastructure maturity in the municipality. Thus we can construct a model to account causal effects of FTTH as below;

$$\Delta \text{Emp}_{\text{share}}_{i,t-t_0} = a_0 + a_1PTS_{FTTH_{i,t}} + a_2\Delta P_{i,t-t} + a_3X_3 + \ldots + a_nX_n + \epsilon_{i,t}$$

**Eq. 3.2**

It is to be noted here that “$\Delta \text{Emp}_{\text{share}}$” is the change in gainfully employed population (aged 16+ years) as a ratio to total employable registered

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49 See appendix for the definition of gainfully employed 16+
based (RAMS)\(^{50}\) population between year 2007 and 2010. The constant term \((a_0)\) accounts for the *national changes* in overall employment change due to *universal* economic conditions which affects all municipalities in the same way (keeping other independent variables in the model constant).

In equation 3.2, \(t = 2010, t_0 = 2007, i = 1,2,3...290\) (i.e. municipality id) and \(T = 10\), where \(\Delta P_{t-T}\) is the population change in period 1998 and 2007. \(FTTH_{it}\) is then, the fiber-to-the-home penetration (in percentage points) in each municipality in 2007. The disturbance term \((\epsilon_{it})\) is the sum of all factors that were not accounted into the model and it is supposed to be normally distributed and *homoscedastic* (which we test using techniques suggested by Gujarati & Porter (2009) in Stata\(^\text{®}\), see appendix 7.2).

The other indicator that is identified based on high immigrant trends in Sweden from abroad. SCB does not provide a cleaned immigration data series for skilled labor immigrants and hence give total immigration. The sum number can lead to positive/negative effects on the economy. One can think of asylum seekers (i.e. unskilled) to have negative impact on employment growth. Therefore, author's own method was developed to categories municipalities into rich (i.e. with higher average income) and poor municipalities and an assumption was made that highly skilled/educated labor has a higher purchasing power and would tend to live in the municipalities that have a higher average income (i.e. rich). These immigrants are represented by \(S_{Immi\_2007}\) in the model based on the criterion described above. In passing note, these immigrants (men and women) have been living in Sweden for 0 to 4 years (i.e. \(t_0\) to \(t_0\-4\)).

Furthermore, *education level* of the employable (RAMS) population presumably has a high degree of influence on employment growth. It was believed that the share of 16+ years population with at-least 3 years of university education has higher causal impact on employment (as compared to other educational levels provided by SCB). It was therefore, taken as a change (\(\Delta\)) between 2007 and 2010. In addition, traditional broadband (xDSL) (i.e. via copper) was also included in the model given in equation (3.3), in order to compare with FTTH effects. SCB's up-to-date available on employment, has been for the year 2010, therefore, the time lag is 4 years. It is expected that more significant results would be observable with longer time lags. Nonetheless, our final model then becomes;

\[^{50}\text{Registerbaserad arbetsmarknadsstatistik (RAMS)}\]
The results are presented in table 3.4 (see section Results and Discussion 3.4).

### 3.3.2. Commuting

Unlike employment, FTTH penetration is assumed to be *exogenous* in the model to analyze commuting trends. An extensive effort was made in order to collect the data at municipality level which has not been an easy task. Again, some rationales were built around independent variables in order to explain inter-municipalities commuting trends. Nevertheless, the selection criterion of particular regressors in equation (3.4) given below, is also inspired by the models developed by Swärdh (2009), where the he is evaluating travel time and commuting time choices in Sweden.

It is often found in literature review (see table 2.4 for details) that FTTH penetration would eventually create the possibility for workers to work from home and reduce commuting. Gainfully employed individuals often are willing to pay (WTP) to spend few days a month with family and work from living room remotely. However, such WTP are to be identified through methods given out in literature (e.g. Choice experiments, stated preference and revealed preferences), which are not done in this study.

It has been important to our model, that we clean out for *non-working* trips and therefore as dependent variable, we take into account employed individuals who commute for work purposes (i.e. reside in a different municipality than work-place municipality). SCB provides such population and hereby termed as commuters leaving the municipality (CLTM)\(^{51}\).

To capture relevant independent variables, again the choice was made upon the degree of accuracy, statistical significance and the availability of data. Factors that affect commuting trends are quite enlarging depending upon each municipality geographic and demographic characteristics. For obvious reasons (explained in chapter 2) by now, FTTH is one candidate. Second most important factor identified is the *degree of urbanization* in a certain municipality.

\[^{51}\text{CLTM population in a municipality (i) has been taken as a share (\%) of the total employed workforce of the municipality.}\]
CHAPTER 3: ANALYSIS

It is measure of the population living in a condensed populated area, which is differentiating factor affecting commuting behavior by the residents of a municipality. On the first sight, one may think that people living in more urbanized areas would have lower tendency to go out from the municipality, since most of the employment opportunities are available locally. However, it is not surprising from the results (see table 3.7) that higher the degree of urbanization the higher the number of commuters leaving the municipality. The phenomenon is because that, employed labor has a higher disposable income and they tend to live in more urbanized areas.

Third important factor incorporated in the model is live births in the municipality, it is taken because employed population (e.g. married couples) with newly born children would have lower tendency to commute.

In addition, *average age* was also incorporated in the model to explain commuting trends. It was hypothesized that a municipality with *slightly* higher age would tend to commute less, since by then employed population are presumed to settle down with family and will not be willing to commute as if they would have been single. Moreover, population density per square kilometer (PDPSK) for each municipality is also introduced in the model. That is, because the degree of urbanization does not take into account the total land area of a certain municipality and hence it was necessary for model robustness. Thus, over model then becomes;

\[
CLTM(\%)_{i,t} = \beta_0 + \beta_F PTS_{FTTH_{i,t}} + \beta_D Urbanization_{Dg_{i,t}} \\
+ \beta_A Avg. Age_{i,t} + \beta_B LBIM_{i,t} + \beta_P PDPSK_{i,t} \\
+ w_{i,t} \quad Eq. 3.4
\]

Where,

\[i \ (municipality \ id) \ = \ 1,2,3,\ldots,290\]

\[t \ (time) \ = \ 1,2,\ldots,4\]

\[CLTM\_Percent = \text{Gainfully employed commuters (16+ age) as a share of total employable population (16+ age) in municipality (i) and time (t)}\]

\[PTS\_FTTH = \text{FTTH penetration rate in municipality (i)}\]

\[Urbanization\_Dg = \text{Degree of urbanization in municipality (i) and time (t)}\]
 CHAPTER 3: ANALYSIS

Avg. age = Average age in the municipality \((i)\) and time \((t)\)

\(LBIM\) = Live births in municipality \((i)\) and time \((t)\)

\(PDPSK\) = Population density per square kilometer in municipality \((i)\) and time \((t)\)

The above equation \((3.4)\), outlays the *Error Component Model (ECM)* in the category of *panel data regression models* hereby, used to evaluate the commuting trends. The choice of selecting ECM has been based on the first and foremost criterion that the study does not aim to check heterogeneity of each municipality and instead attempted to measure overall effects (i.e. by taking a mean value of intercept \((\beta_0)\)). Secondly, given the small time period of data set, introducing dummy variables for each municipality (i.e. 289 intercepts)\(^52\) would cut on *degree of freedoms* which can be counterproductive to a precise estimation and could risk falling into *dummy variable trap*.

Furthermore, introduction of high number of dummy variables (i.e. 290) in the model, are risk to high multicollinearity, which make efficient estimation of parameters difficult. The choice of ECM is also moderated by the selection method of choosing the cross sectional subjects, as Appelgren\(^53\) stated that, underlying assumption to adopt ECM is that subjects are selected randomly (from a large universe of such subjects) and that they have a common mean intercept \((= \beta_0)\), therefore the individual differences in subject specific constants are reflected in the error term \((= w_{i,t})\).

---

\(^{52}\) Usually dummy variables introduced in fixed effects model are \(n-1\) (i.e. 290-1), where \(n\) is number of cross sectional subjects.

\(^{53}\) Jari Appelgren; Karlstad University, Lecture on the 12\(^{th}\) of October 2011.
This sub-chapter consists of results produced using statistical package Stata® 12. The results presented here are discussed on the base of models developed in previous sections in accord with research questions.

3.4. Results and Discussion

3.4.1. Employment

Variables given in employment model (eq. 3.3), are summarized in the below table through descriptive statistics. It can be seen that FTTH has a relatively high standard deviation, which is not surprising as few municipalities have nearly 100% fiber penetration and some have very little. For example, Sundbyberg has 96% fiber penetration and on the other hand Vansbro has nearly 0%; however, remaining variables have very low rate of standard deviations. It is important to note here that the employment changes between 2007 and 2010 has been negative overall (due to recent recession) in the economy as shown by the mean value of Delta (Δ) Emp_share and it makes difficult to separate the effects of FTTH in such distortion.

Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta (Δ) in Empty_Share</td>
<td>290</td>
<td>-0.008502</td>
<td>0.0243373</td>
<td>-0.116</td>
<td>0.0641</td>
</tr>
<tr>
<td>PTS_FTTH_2007</td>
<td>290</td>
<td>0.1666838</td>
<td>0.180531</td>
<td>0</td>
<td>0.9626</td>
</tr>
<tr>
<td>Delta_POP10_2007</td>
<td>290</td>
<td>-0.008578</td>
<td>0.0796299</td>
<td>-0.169</td>
<td>0.2992</td>
</tr>
<tr>
<td>I_plus_2007</td>
<td>290</td>
<td>0.0010264</td>
<td>0.0043339</td>
<td>0</td>
<td>0.0312</td>
</tr>
<tr>
<td>Delta_EduLevel_PS3or More_07_10</td>
<td>290</td>
<td>0.10279</td>
<td>0.0310719</td>
<td>-0.0091</td>
<td>0.2305</td>
</tr>
<tr>
<td>BroadbandxDSL_PTS_2007</td>
<td>290</td>
<td>0.9535</td>
<td>0.0762811</td>
<td>0.52</td>
<td>1</td>
</tr>
</tbody>
</table>

In order to verify the independence of regressors, we test the Pearson correlations with significance p-values in the following table 3.2. Through the test, it was revealed that all correlations are under acceptance range, and employment model does not have a problem with multicollinearity.
Table 3.2 Pearson Correlations

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Emp_share_RAMS</th>
<th>PTS_FTTH_2007</th>
<th>Delta_P OP10_2007</th>
<th>I_plus_2007</th>
<th>Delta_EduLevel_P S3orMore_07_10</th>
<th>BroadbandxDSL_PTS_2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emp_share_RAMS</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTS_FTTH_2007</td>
<td>0.166 (0.004)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta_POP10_2007</td>
<td>0.5664 (0.000)</td>
<td>0.0853 (0.1475)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_plus_2007</td>
<td>0.3287 (0.000)</td>
<td>0.4125 (0.000)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta_EduLevel_P S3orMore_07_10</td>
<td>0.1453 (0.0132)</td>
<td>0.1294 (0.0276)</td>
<td>-0.1411 (0.016)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BroadbandxDSL_PTS_2007</td>
<td>0.0263 (0.6557)</td>
<td>-0.035 (0.5475)</td>
<td>-0.0215 (0.7159)</td>
<td>-0.0016 (0.978)</td>
<td>-0.0007 (0.9908)</td>
<td>1</td>
</tr>
</tbody>
</table>

-Values in parenthesis are p-values

Now we move on to the estimation of our employment model and results are presented below (see table 3.4). Despite the decreasing trends in employment (vice versa increased unemployment) as shown by pink line in figure 2.2 (see section 2.3.2.1 employment), starting to appear in 2007, FTTH has yet contributed in increasing employment in the period of financial crisis (see highlighted coefficient for PTS_FTTH_2007 in the below table). The overall model is statistically significant as shown by low p-value of the F test. Model's coefficient of determination (R-square) is fairly low, which is evident that several other unknown factors affect the employment changes, which are not included in the model. As explained in previous sections, estimate able model is given blow for the reader's ease.

---

54 All coefficients are simultaneously equal to zero under F-test null hypothesis, which is rejected by the p-value=0
$\Delta Emp (RAMS)_{share, t-t_0}$

$= \alpha_0 + \alpha_F FTTH_{t, t} + \alpha_P \Delta P_{t, t-T} + \alpha_S S_{Immi, t_0}$

$+ \alpha_E \Delta Edu\_Uni_{t-t_0} + \alpha_B xDSL_{t_0} + \epsilon_{i, t}$

Eq. 3.5

Table 3.4 Results of Employment

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Number of obs = 289</th>
</tr>
</thead>
<tbody>
<tr>
<td>F( 5, 283) = 32.31</td>
<td>Prob &gt; F = 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>0.057433</td>
<td>5</td>
<td>0.0114866</td>
<td>R-squared = 0.365</td>
</tr>
<tr>
<td>Residual</td>
<td>0.099912</td>
<td>283</td>
<td>0.0003556</td>
<td>Adj R-squared = 0.3537</td>
</tr>
<tr>
<td>Total</td>
<td>0.157345</td>
<td>288</td>
<td>0.0005502</td>
<td>Root MSE = 0.01886</td>
</tr>
</tbody>
</table>

Regressand: Emp\_share\_RAMS

<table>
<thead>
<tr>
<th>Regressors</th>
<th>Coef.</th>
<th>Std. Err.</th>
<th>t</th>
<th>P&gt;t</th>
<th>[95% Conf. Interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTS_FTTH_2007</td>
<td>0.019462</td>
<td>0.00678</td>
<td>2.87</td>
<td>0.004</td>
<td>0.0061159 0.0328082</td>
</tr>
<tr>
<td>Delta_Pop_10_2007</td>
<td>0.138446</td>
<td>0.015916</td>
<td>8.7</td>
<td>0.000</td>
<td>0.1071165 0.1697745</td>
</tr>
<tr>
<td>I_plus_Jun_2007</td>
<td>0.962509</td>
<td>0.308307</td>
<td>3.12</td>
<td>0.002</td>
<td>0.3556244 1.569394</td>
</tr>
<tr>
<td>Delta_EduLevel_PS3orMore_07_10</td>
<td>0.105774</td>
<td>0.037545</td>
<td>2.82</td>
<td>0.005</td>
<td>0.0318697 0.1796779</td>
</tr>
<tr>
<td>Broadband_DSL_PTS_2007</td>
<td>0.017466</td>
<td>0.014972</td>
<td>1.17</td>
<td>0.244</td>
<td>-0.01200 0.04693</td>
</tr>
<tr>
<td>_cons</td>
<td>-0.03873</td>
<td>0.014928</td>
<td>-2.5</td>
<td>0.01</td>
<td>-0.06811 -0.009343</td>
</tr>
</tbody>
</table>

The estimated coefficients ($\alpha_i$) through Stata® are presented below with 95% confidence intervals.

$\alpha_F = 0.0195 \pm 0.0133$

$\alpha_P = 0.1384 \pm 0.0313$

$\alpha_S = 0.9625 \pm 0.6069$

$\alpha_E = 0.1058 \pm 0.0739$

$\alpha_B^{55} = 0.0175 \pm 0.0295$

$\alpha_0 = -0.0387 \pm 0.0294$

$^{55}$ Broadband coefficient is not significant at 5% level of significance.
Recent dip of economic cycle has been shown by our model, keeping everything else constant, employment declines by 3.87% (i.e. $\alpha_0 = -0.0387$) from 2007 to 2010. Most importantly, FTTH has statistically significant contribution to affect employment change positively. Although, the impact ($\alpha_F$) has relatively smaller intensity, than educational level ($\alpha_E$) and skilled labor immigrants ($\alpha_S$).

Parameter of FTTH, means that a 10% increase in household that have that have access to FTTH, correspond to an positive increase of 1.95% in employment after four years. Similarly, according to 95% confidence intervals, the impact on employment is between 0.6% to 3.2%.

Our developed rational was proved true that, highly skilled immigration has a positive effect on employment; 1% higher share of immigrants in the "rich" municipalities in 2007 represents a 0.96% higher employment after four years. Such high estimate is due to the reason that this population has not unemployed. Furthermore, we can see that employment change after four years is affected by the last ten years (1998-2007) population change positively. It also supports the assumption that increased population over ten years is a good indicator of municipality attractiveness.

In addition, education level (Post secondary 3 years or more) change has also substantial affect on employment change (for obvious reasons). $zE$ means that 1% increase in the share of population with post secondary education led to 0.1% increase in employment in four years. Lastly, the traditional broadband (xDSL) has shown insignificant results, as expected. It is because that traditional broadband has reached its maturity level, at which it does not cause an impact to employment change. It is not that traditional broadband has zero impact, but since the employment is taken as delta ($\Delta$).

Let us analyze the effects of FTTH more closely. In figure 3.11, a graph is presented where each municipality is shown by a dot whose y coordinate is the employment change from year 2007-2010 and on x coordinate, fiber penetration rate in the municipality. The pink regression line follows the slope estimated by our model $\alpha_F = 0.0195$. It is expected that in long run, that FTTH investments will show higher positive effects on employment through indirect channel, therefore it will be worthwhile to follow improvement in coming years and see if $\alpha_F$ increases significantly.
When it comes to analyze inter-municipality commuting trends, FTTH was expected to have positive effects (in Hypothesis 2) by reducing the number of commutes per year. We test this assumption here. Commuting Model explained in equation (3.4) has been summarized in the below table (3.5), where we have relatively large number of observations than employment model. Since, it was assumed that FTTH penetration rate is exogenous in this model which gives us the opportunity to take advantages of panel data.

In passing note that around 32% of the total labor-force in Sweden are commuter workers who leave their municipality and go to another municipality each day for job. According to SCB (2009) an average household spend SEK 70,000 per year on traveling. This is quite large portion of the household budget, and can be potential savings. As described in literature review, a big chunk of FTTH returns can be yielded from reduced commuting.

Variables incorporated in the commuting model are summarized below in table 3.5.

Figure 3.1 Linear Prediction of Employment and FTTH

### 3.4.2. Commuting
Table 3.5 Descriptive Statistics for Commuting Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLTM_Percent</td>
<td>1160</td>
<td>0.205192</td>
<td>0.117458</td>
<td>0.027250</td>
<td>0.527367</td>
</tr>
<tr>
<td>FN_Bef</td>
<td>1160</td>
<td>0.22313</td>
<td>0.210174</td>
<td>0</td>
<td>0.9972</td>
</tr>
<tr>
<td>Degree of Urbanization</td>
<td>1160</td>
<td>0.738148</td>
<td>0.147455</td>
<td>0.295348</td>
<td>1</td>
</tr>
<tr>
<td>Averag Age</td>
<td>1160</td>
<td>42.73181</td>
<td>2.494964</td>
<td>36.1</td>
<td>48.9</td>
</tr>
<tr>
<td>Live birth in Municipality</td>
<td>1160</td>
<td>382.9</td>
<td>964.0764</td>
<td>12</td>
<td>13896</td>
</tr>
<tr>
<td>Population desnsity/skm</td>
<td>1160</td>
<td>133.8092</td>
<td>457.2125</td>
<td>0.2</td>
<td>4504.3</td>
</tr>
</tbody>
</table>

Now we move on to estimate the developed model using Random Effects Model (REM)\textsuperscript{56} below in table 3.7. Based on Wald chi\textsuperscript{2} test the whole model is statistically significant.

\[
CLTM(\%)_{it} = \beta_0 + \beta_FPTS_{FTTH}_{it} + \beta_UUrbanization_{it} \\
+ \beta_AAvg.Age_{it} + \beta_LLBIM_{it} + \beta_PDPSK_{it} + w_{it}
\]

Eq. 3.6

Table 3.7 Results of Commuting Model

<table>
<thead>
<tr>
<th>Random-effects GLS regression</th>
<th>Number of obs = 1148</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group variable: K01</td>
<td>Number of groups = 287</td>
</tr>
<tr>
<td>R-sq: within = 0.0243</td>
<td>Obs per group:</td>
</tr>
<tr>
<td>between = 0.4479</td>
<td>min</td>
</tr>
<tr>
<td>overall = 0.4465</td>
<td>avg</td>
</tr>
<tr>
<td>corr(u_i, X) = 0 (assumed)</td>
<td>max</td>
</tr>
<tr>
<td>Wald chi2(6)</td>
<td>= 178.88</td>
</tr>
<tr>
<td>Prob &gt; chi2</td>
<td>= 0</td>
</tr>
</tbody>
</table>

Regressand: CLTM_Percent

| Regressors   | Coef.  | Std. Err. | z     | P>|z|  | [95% Conf. Interval] |
|--------------|--------|-----------|-------|------|----------------------|
| PTS_FTTH     | -0.01405 | 0.002359 | -5.95 | 0.000 | -0.01867 to -0.00942 |
| Urbanization_Dg | 0.063122 | 0.033694 | 1.87 | 0.061 | -0.00292 to 0.129162 |
| Avg. Age     | -0.00735 | 0.000778 | -9.45 | 0.000 | -0.00888 to -0.00583 |
| LBIM         | -0.000024 | 4.40E-06 | -5.61 | 0.000 | -3.3E-05 to -1.6E-05 |
| PDPSK        | 0.000096 | 0.000018 | 5.17 | 0.000 | 5.99E-05 to 0.000133 |

\textsuperscript{56} See the appendix 7.2 for Breusch and pagan lagrange multiplier test
CHAPTER 3: ANALYSIS

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>_cons</td>
<td>0.487</td>
<td>0.047</td>
<td>10.26</td>
<td>0.000</td>
<td>0.394</td>
</tr>
<tr>
<td>sigma_u</td>
<td>0.064</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sigma_e</td>
<td>0.004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rho</td>
<td>0.994</td>
<td></td>
<td></td>
<td></td>
<td>(frac)</td>
</tr>
</tbody>
</table>

The estimated parameters are given below with 95% confidence intervals.

\[
\begin{align*}
\beta_F &= -0.0140 \pm 0.0046 \\
\beta_U &= 0.0631 \pm 0.0660 \\
\beta_A &= -0.0073 \pm 0.0015 \\
\beta_L &= -0.000024 \pm 0.0000087 \\
\beta_P &= 0.0000965 \pm 0.0000366 \\
\beta_0 &= 0.4872841 \pm 0.0931036
\end{align*}
\]

Nonetheless, FTTH has a statistically significant affect on commuting trends in a municipality. Zero p-value supports our hypothesis of causal impact of fiber, however the intensity is low. The value of \( \beta_F \) (= - 0.014) means that an increase of 10% in FTTH penetration leads to 1.4% less employed commuters leaving the municipality on yearly basis.

Urbanization on the other hand, has yet surprising results, the positive value of \( \beta_U \) means that the employed population tends to commute more if the residing municipality is more urbanized. A 10% increase in urbanization of the municipality leads to 6.3% higher commuters per year. Similarly, average age \( (\beta_A) \) has shown results somewhat similar to expectations, as it means that municipalities with higher average age have slight less commuting tendency. The estimated value of \( \beta_A \) (= -0.0073) means that 1 year increase in average age leads to 0.73% decrease in number of commutes. Furthermore, growth in live births in the municipality, also impact commuting behaviors, on average one unit increase in live births leads to 0.000024 units decrease in commuting, which is rational, if we think that couples tend to live home with newly born children; although, the degree of impact is very small.

Lastly, the population density per square kilometer has been influencing the commuting trends of the municipality. In other words, larger the land area of
municipality, higher the commuters commuting. The estimated value of $\beta_p (=0.0009)$ means that one unit increase in PDPSK leads to 0.0009 units increase in commuting behavior in a municipality.

Now we look closely, the relationship of FTTH and commuting trends in figure 3.2 below. The x-coordinate is scaled by the FTTH penetration rate in a given municipality and y-coordinate represent the employed commuters leaving the municipality as a share of employable population (RAMS) with 16+ years of age. The red fitted line represents the slope of FTTH, which is negatively sloped.

![Figure 3.2 Linear Prediction of CLTM (%) and FTTH](image)

3.5. Calculation of Socio-economic returns

In the above section of chapter 3 (i.e. 3.1), we have presented the total investment of SEK 41.320 billion required to deploy FTTH in rest of the country’s area where FTTH is non-existent. FTTH deployment is not usually done instantaneously (e.g. it involves digging up the ground etc.) and hence requires an extended time period in future. Keeping in mind the technicalities of FTTH deployment and labor work needed, a deployment scenario was developed where FTTH network is to be built over next four years. It was hypothesized that 40% investments are done in year 1, 30% in year 2, 20% in
year 3 and 10% in the year 4. However, operating costs are neglected for simplicity and due to unavailability of data.

\[
\begin{align*}
Year 0 & \quad I (0) = 0.4 \times Total \ Investment, \\
Year 1 & \quad I (1) = 0.3 \times Total \ Investment, \\
Year 2 & \quad I (2) = 0.2 \times Total \ Investment, \\
Year 3 & \quad I (3) = 0.1 \times Total \ Investment, \\
Year 4 & \quad I (4) = 0
\end{align*}
\]

**Eq. 3.7**

However, all the benefits and costs are discounted to year \( (0) \) (i.e. today) through the social discount rate \((s)\) (see next section 3.2.1). It is assumed here, that the FTTH penetration in each year \( t \), is relatively proportionate to the collective investments in the prior years. The figures are in real terms and do not take inflation into account. Calculation of benefits are done through the following equation (3.8) over 30 years the useful life of FTTH.

\[
B_t(\text{tot}) = \sum_{t=1}^{30} (KS + LS + WTP.N_h + 0.019 \times y \times N_l + 0.014 \times H_{WTP} \times 2 \times 240 \times N_c) \times (1 - F0)
\]

**Eq. 3.8**

Where KS are municipality total telecommunication costs savings, LS are the county’s regional councils total savings, WTP.N_h is willingness to pay per household times \((N_h)\) number of total dwelling stock/households. In addition, \(N_l\) is the total labor force, \(y\) is average income per capita. \(H_{WTP}\) is average willingness to pay to avoid one hour of commuting (i.e. \(WTP= SEK\) 153 taken from Swärdh), \(N_c\) is the total number of gainfully employed commuters at national level, \(F0\) is the existent fiber penetration (32.21% according to PTS). In addition, numeric value of 0.019 represents the estimated coefficient for employment, 0.014 for commuting, 240 is the average number of working days\(^{57}\) per year and 2 is the number of average commuting hours\(^{58}\) travelled a day.

\(^{57}\) These days were calculated by reducing weekends and annual leaves as per labor norms.
\(^{58}\) By calculating land area of an average municipality, it was estimated that commuter travels 2 hours per day from home to work place, since there is no previous estimate found.
In passing note that accumulated benefits also follow the same projections as of investments in equation (3.5), with one year delay. For example, 40% of total investment made today \((t=0)\) yields 40% of total benefits in next year \((t=1)\), additional 30% of total investment made in year 1 \((t=1)\) yields additional 30% of total benefits in year 2 \((t=2)\), so on and so forth. Hence, accumulated benefits become as,

\[
\begin{align*}
\text{Year 0} & \quad B(0) = 0.0 \times B_1(tot) \\
\text{Year 1} & \quad B(1) = 0.4 \times B_1(tot) \\
\text{Year 2} & \quad B(2) = 0.7 \times B_1(tot) \\
\text{Year 3} & \quad B(3) = 0.9 \times B_1(tot) \\
\text{Year 4} & \quad B(4) = 1.0 \times B_1(tot) \\
\text{Year } n & \quad B(n) = 1.0 \times B_1(tot)
\end{align*}
\]

Where \(n = 5,6,\ldots,30\).

The calculated returns in nominal values as a function of time are presented in figures (3.3) below. We can note that a total investment of about **SEK 41.320 billion** giving a cumulative return of about **SEK 90.498 billion** after ten years. In other words, **SEK 1** invested between now and about four years, brings back a minimum of **SEK 2.19** in ten years (considering everything else constant).

![Figure 3.3 Socio-economic returns of FTTH](image)

However, operating costs are ignored here which can reduce the returns in future if incorporated in the analysis.
Let us now, execute analyzes of benefits and costs in present value terms.

### 3.5.1. Social Discount Rate

Facing scarce resources/budget constraints in societal policy evaluations, it is always that capital has *opportunity cost* with time preferences. Therefore, projects with different returns are compared in present value terms discounted through appropriate *social discount rate*. It is also beneficial in guiding the optimized allocation of resources. Nevertheless, the choice of discount factor in evaluating investments is very *sensitive*, which can over or understate the true intrinsic value of the project. Often FTTH investments are being evaluated by the social discount rate recommended by the ICT and transport administration entities in a given country. For instance, (Takachi 2010) has used 4% as recommended by “Ministry of Land, Infrastructure and Transport” (MLIT) in Japan to evaluate FTTH investment. Another, way to get a good estimate of SDR is through market interest rates or taking the risk free rate for a longer maturity bond (i.e. treasury bond with 10 years maturity). Swedish national debt office has offered 3.5% coupon rate on a ten years maturity bond (Riksgälden, Swedish National Debt Office 2012). However, to be certain and follow the already develop norm in FTTH industry we take the recommended SDR from Swedish Transport Administration (Trafikverket), which is 4% (Trafikverket 2012 p.4)

### 3.5.2. Net Present Value of FTTH Investment

This method calculates NPV by subtracting present value of all costs from present value of all benefits that occurs over the useful economic life of the project (see equation 3.9 below). This method is assumed to be most effective and often used in economic evaluations as compared to benefit-cost ratio (BCR) (Boardman et al. 2011). Positive NPV value then becomes the decisive criterion to select a project.

\[
NPV = \sum_{t=0}^{30} \frac{B_t(tot)}{(1 + SDR)^{30}} - \sum_{t=0}^{3} \frac{C_t}{(1 + SDR)^3}
\]

Eq. 3.9

Where \( B_t(tot) \) are the total nominal benefits, and \( C_t \) is the total nominal deployment cost. SDR (=0.04) is the social discount rate.

---

59 maturing 01-06-2012
In order to calculate the NPV value, benefits are forecasted on a future horizon of 30 years, on the other hand costs are projected on four years starting from \( t=0 \) (i.e. \( t=0,1,2,..4 \)) as presented in equation (3.7). Present value of annuity method was used in years where cash flows become constant. Hence, we arrive to a NPV value as;

\[
NPV = 66.6559 - 39.7612 = \text{SEK} \ 26.8946 \ \text{billion}
\]

Since we have neglected gradual maintenance/operating cost over the life of FTTH, we only subtract the present value of initial investment from present value of all socio-economic benefits (PV (B)). Conclusively, positive net benefits shows that the policy is potentially social welfare improving.

In figure 3.4, present values are presented graphically over the useful life of FTTH.

\[\text{MSEK} \]

<table>
<thead>
<tr>
<th>Present Values of Investments and Socio-economic Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Socio-economic returns&quot;</td>
</tr>
<tr>
<td>&quot;Investments in FTTH&quot;</td>
</tr>
</tbody>
</table>

**Figure 3.4 Present values comparison of benefits and costs**

3.5.3. Benefit Cost Ratio (BCR)

Many studies have used benefit-cost ratio complementary to NPV method, and often analysts order alternative projects in terms of benefit-cost ratios (Boardman et al. 2011). In case of FTTH we calculate benefit-cost ratio as;

\[
BCR = \frac{\sum_{t=0}^{30} \frac{B}{(1 + SDR)^{30}}}{\sum_{t=0}^{3} \frac{C}{(1 + SDR)^{3}}}
\]

Eq. 3.10
CHAPTER 3: ANALYSIS

\[
\text{Benefit/cost ratio} = \frac{66.6559}{39.7612} = 1.67
\]

Calculated ratio of 1.67 means that net benefits are 1.67 times higher than the initial cost incurred, yielding us to recommend adopting the policy. In contrast, a cost-benefit ratio of lower than 1 would have guided the decision to not adopting the policy and similarly cost-benefit ratio of exactly 1 (borderline case) makes one indifferent between status quo and adopting the policy (holding all other things constant).

However, according to most literature of CBA, benefit-cost ratio is considered unreliable and many criticize it to be a guiding rule for decision making, because of its sensitivity to whether negative willingness to pay (WTP) is added to cost or benefits. Also, it can be misleading if alternative policies are of different scales (i.e. High cost differences across projects). Moreover, Boardman et al. (2011) has recommended analysts to avoid benefit-cost ratios and has advised to rely instead on net benefits (i.e. NPV) to select policies.

### 3.5.4. Sensitivity analysis

Sensitivity analysis is very often performed through varying the estimated useful life of FTTH as well as social discount rate. Since, we have calculated positive net benefits; we reduce the economic life to 20 years and increase the social discount rate to 5%. The calculated value that we arrive for NPV and BCR are as follow;

\[
\text{NPV} = 46.287 - 39.399 = \text{SEK 6.888 billion}
\]

\[
\text{Benefit/cost ratio} = \frac{46.287}{39.399} = 1.17
\]

Investment in FTTH deployment still remains beneficial.
CHAPTER 4: CONCLUSIONS

4. Conclusions

In the study, we have quantified two major socio-economic benefits of fiber-based access network (i.e. FTTH), using data from 290 municipalities in Sweden over four-years time span (2007-2010), by means of multivariate regression analysis. Author found that fiber-based access networks are already showing statistically significant effects on socio-economic indicators of the country (after four years). Specifically, a 10% increase in the proportion of the employable (RAMS) population with age 16+ years, connected with fiber-based network corresponds to a positive change of 1.95% in employment after four years and of 1.405% decrease in the share of gainfully employed commuters leaving the municipality on yearly basis. Author has run robustness tests for these results and found them statistically sound.

Among other candidates (apart from FTTH) affecting employment, it was found that demographic changes (i.e. population change, economically advantageous immigrations) have sound effects on the employment change in a municipality between year 2007 and 2010. Nonetheless, changes in the share of population with post secondary education level (3 years or more) derives employment growth in a certain municipality. Broadband xDSL, on the contrary has been unsuccessful in yielding significant results on employment change, it has been revealed by the model that xDSL has reached its maturity level (see figure 9.2 in appendix C) and nearly all benefits have been captured by the economy already (i.e. casual effects of xDSL Broadband on employment are in somehow steady state).

Secondly, it was surprising to see that nearly one third of employed population consists of commuters, who leave the municipality for work purposes. Willingness to pay to avoid one hour of commuting, estimated as SEK 153 by Swärdh (2009) was taken to monetize FTTH effects, which comes nearly 25% of the total benefits of FTTH investment. Hence, FTTH is believed to be strong factor that reduces commuting trends among other factors. One of the interesting findings in commuting analysis has been the degree of urbanization of a municipality, which revealed that people living in urbanized municipalities tend to commute more as compared to less urbanized municipalities. In author’s opinion it is due to the high purchasing power/disposable income of
the gainfully employed commuters who prefer to live in urbanized municipalities and have workplace in different municipality.

In addition, it has been found that in order to reach 100% FTTH penetration in all municipalities; it requires an investment of SEK 39.761 billion and the returns are yielded for 30 years which amount to SEK 66.656 billion (all in discounted values).

Cost-benefit analysis revealed that the investment made in FTTH deployment over an extended period of four years in future, has net positive benefits of **SEK 26.89 billion** for the society in present value terms. Calculated value of benefit-cost ratio (BCR)\(^{60}\) has been 1.67, which complements the NPV results. In nominal terms, **SEK 1** invested in FTTH between now and about four years in future, brings back a minimum of **SEK 2.19** in ten years (considering everything else constant). Similarly, return on investment (ROI) in real terms is 67.64% percent over 30 years of time horizon, and the payback period is around 13.5 years.

Sensitivity analysis performed, revealed that investments in FTTH remains beneficial at useful economic life of 20 years (instead of 30 years) and social discount rate of 5% (instead of 4%). Net value calculated under sensitivity analysis, has been SEK 6.88 billion. In passing note that the operating and maintenance costs were neglected in this study, if included may result in different net returns over the life of FTTH.

Lastly, and most importantly, it was found that FTTH penetration rate is *endogenous* in the Swedish economy, due to spill-over\(^{61}\) effects of employment increase or decrease and hence multi-variable regression model had to be constructed with great care.

\(^{60}\) Calculated BCR can be used for alternative projects if claimed substitute to FTTH in further studies.

\(^{61}\) These effects can often be due to knowledge spill-over among companies and individuals, since Swedish society has high degree of ICT maturity.
CHAPTER 5: RECOMMENDATIONS

This chapter presents author’s recommendations based on personal experience, which is learnt throughout the study.

5. Recommendations

From the Cost-Benefit Analysis performed in the study, it is believed that FTTH has net positive benefits which are due to increased efficiency in the economy and not on the cost of certain population and/or municipalities. Hence, positive NPV gives author the basis to recommend the investment in deploying FTTH over four years of time span in future.

According to author’s opinion, it is highly important to incorporate more socio-economic effects in the analysis to show the complete picture to concerned authorities, administrations and private sector. In addition, among categories of benefits, willingness to pay (WTP) by tenants should be surveyed on a broader scale from a large sample of municipalities using choice experiments method in which internet speed and price can be traded-off as choice among alternatives.

Furthermore, to exclude backward causality/simultaneity, in further studies instrumental variable regression method is recommended. One potential instrumental variable (IV) that may also yield sound and reliable causal effects of FTTH is the existence or nonexistence of fiber-based broadband network policy in the municipality; nonetheless, it also requires a comprehensive survey at municipal level which is recommended hereby.

Savings of municipality data and telecommunication costs are quantified to (100%) in monetary terms in the study due to only available estimate at the time study was conducted; still, there is a risk of overestimating than the true value, because such savings can be due to some decreased profits of certain entities/companies in the society which should be reduced in such CBA studies. It is recommended to account for net savings in further research in the field.
CHAPTER 6: PERSONAL REFLECTION ON THE FUTURE OF FTTH

Personal reflections presents the author’s own view about future research in the subject field, based on personal interpretations, thoughts and beliefs, about what is presented in conclusion. The purpose is to stimulate constructive debate for the creation of a new theory and future research.

6. Personal Reflections on Future of FTTH

Fiber-to-the-home (FTTH) broadband penetration is still in its initial-to-medium term stage (i.e. 32%) in Sweden and it has already started impacting the socio-economic indicators in a very positive manner. Municipalities that have condensed population and high PDPSK require relatively lower investments and should be deployed with FTTH in the next stage, as it is very common that already existent broadband structure (i.e. underground cable networks) would be used in some cases. In addition, the subscription rate is expected to be higher in such municipalities.

It was found during the data search that Sweden have a very rich databases on almost every demographic and social grounds (thanks to SCB, PTS and Kolada62), which would make the future researchers’ task much easy.

Fore-mostly, there are number of economic impacts that are not observable (i.e. un-captured values) on ground as of current times. However, these impacts can be huge and expected to grow exponentially, for example, in future there can be certain value added services that may require higher broadband speed (e.g. 500 Mbps 1 Gbps) which FTTH only has the capability to support among so far developed broadband technologies. These services’ businesses can add up a large portion into the economic growth and national accounts of Sweden. In passing note, Google is deploying ultra63 high speed fiber optics network in the city of Kansas in USA, through which such enclosed impacts are expected to be unshielded. However, the results are awaited till the time, it runs with open access64.

Lastly, FTTH deployment is chicken and egg dilemma, if FTTH is deployed extensively, benefits can be realized to optimum level.

---

62 Kommun- och landstingsdatabasen (Swedish Municipality and county database)
63 A speed (i.e. 1 Gbit/s) that is 20,000 times faster than a dialup and 100 times faster than a traditional broadband.
64 It means that all service providers have the right to use the network in order to provide service to the end user.
CHAPTER 7: APPENDIX

7. Appendix A

Employment

7.1. Test for Simultaneity

Hausman Specification test (Employment)\(^ {65} \)

H\(_0\) : Fiber Penetration is exogenous and there is no problem of simultaneity.

H\(_1\) : Fiber Penetration is endogenous and there is problem of simultaneity.

Table 7.1 Stage 1. Hausman Simultaneity Test

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Number of obs = 1157</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>7.35095532</td>
<td>4</td>
<td>1.83773883</td>
<td>F( 4, 1152) = 48.43</td>
</tr>
<tr>
<td>Residual</td>
<td>43.7181774</td>
<td>1152</td>
<td>.037949807</td>
<td>Prob &gt; F = 0.0000</td>
</tr>
<tr>
<td>Total</td>
<td>51.0691327</td>
<td>1156</td>
<td>.04417745</td>
<td>R-squared = 0.1439</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Adj R-squared = 0.1410</th>
</tr>
</thead>
</table>

Table 7.2 Stage 2. Hausman Simultaneity Test

<table>
<thead>
<tr>
<th>Source</th>
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<th>df</th>
<th>MS</th>
<th>Number of obs = 1157</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>2.99311728</td>
<td>5</td>
<td>.598623455</td>
<td>F( 5, 1151) = 62.48</td>
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<tr>
<td>Residual</td>
<td>11.0281688</td>
<td>1151</td>
<td>.00958138</td>
<td>Prob &gt; F = 0.0000</td>
</tr>
<tr>
<td>Total</td>
<td>14.0212861</td>
<td>1156</td>
<td>.01212914</td>
<td>R-squared = 0.2135</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Adj R-squared = 0.2101</th>
</tr>
</thead>
</table>

| Empoyed_Pop_share | Coef. | Std. Errr. | t   | P>|t| | [95% Conf. Interval] |
|-------------------|-------|------------|-----|-----|-------------------|
| fitted            |       |            |     |     |                   |
| Eud_level_PostSec_Prct | .0104412 | .00011454 | 9.12 | 0.000 | .0081939 .0126884 |
| Core_Operation_total | 6.59e-06 | 1.64e-06 | 3.71 | 0.000 | 2.87e-06 9.32e-06 |
| I_Plus_0to4years | .0000107 | 1.94e-06 | 5.49 | 0.000 | 6.85e-06 .0000145 |
| Delta_Pop_last10years | -.0032941 | .0011972 | -2.75 | 0.006 | -.0056431 -.0009452 |
| _cons | -.2610838 | .071651 | -3.64 | 0.000 | -.401665 -.1205027 |

| Empoyed_Pop_share | Coef. | Std. Errr. | t   | P>|t| | [95% Conf. Interval] |
|-------------------|-------|------------|-----|-----|-------------------|
| fitted            |       |            |     |     |                   |
| Eud_level_PostSec_Prct | .0037474 | .00057555 | 6.51 | 0.000 | .0026182 .0048766 |
| Core_Operation_total | -.321e-06 | 8.26e-07 | -3.88 | 0.000 | -.4.83e-06 -1.59e-06 |
| I_Plus_0to4years | .0000107 | 9.75e-07 | 10.92 | 0.000 | 8.74e-06 .000126 |
| Delta_Pop_last10years | -.004587 | .0006016 | -7.63 | 0.000 | -.0057673 -.0034068 |
| _vt | .1315413 | .0148041 | 8.89 | 0.000 | .1024952 .1605874 |
| _cons | .5376024 | .0360024 | 14.93 | 0.000 | .4669646 .6082401 |

Since coefficient of “vt” is statistically significant, thus we reject the null hypothesis and conclude that simultaneity problem is existent.

\(^{65}\) Gujarati & Porter (2009 p.703)
CHAPTER 7: APPENDIX

7.2. Heteroscedasticity Test (Employment)

```
. estat hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
   Ho: Constant variance
   Variables: fitted values of Emp_share_RAMS

    chi2(1)    =    0.45
   Prob > chi2 =    0.5015
```

P-value does not give the power to reject the null hypothesis. Test concludes that disturbance term has constant variance (i.e. homoscedastic) and Heteroscedasticity in inexistent in the model.

7.3. Graphical Test for Normal Distribution of Residuals (Employment)

![Graphical presentation of Normal Distribution of residuals](image)

Figure 7.1 Graphical presentation of Normal Distribution of residuals

Result: Residuals are normally distributed.
7.4. Graphical Test for Autocorrelation of Residuals (Employment)

![Graphical method to test Autocorrelation](image)

Figure 7.2 Graphical method to test Autocorrelation

Result: No pattern of autocorrelation was found.
8. Appendix B

Commuting

8.1. Choice between FEM and REM

Breusch and Pagan Lagrange Multiplier Test for Commuting: choice between FEM and REM

Table 8.1 Breusch and Pagan Lagrange Multiplier Test

<table>
<thead>
<tr>
<th></th>
<th>Var</th>
<th>sd - sqrt(Var)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLTM_Pe-t</td>
<td>.0137966</td>
<td>.1174588</td>
</tr>
<tr>
<td>e</td>
<td>.000024</td>
<td>.0048989</td>
</tr>
<tr>
<td>u</td>
<td>.0029523</td>
<td>.0543353</td>
</tr>
</tbody>
</table>

Test: \( \text{Var}(u) = 0 \)
\( \text{chibar}^2(01) = 1510.64 \)
\( \text{Prob} > \text{chibar}^2 = 0.0000 \)

Conclusion

The null hypothesis here is that, there are no random effects and based on low p-value, Breusch and Pagan Lagrange Multiplier Test rejects the null hypothesis and concludes that REM is appropriate.
Correlations (Commuting)

Table 8.2 Pearson Correlations

<table>
<thead>
<tr>
<th></th>
<th>CLTM(%)</th>
<th>FN_Bef</th>
<th>Urbanization (%)</th>
<th>Averag Age</th>
<th>LBIM</th>
<th>Employees (share)</th>
<th>Pop_RAMS (%)</th>
<th>PDPSK</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLTM(%)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FN_Bef</td>
<td>-0.185</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urbanization (%)</td>
<td>0.2468</td>
<td>0.28</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Averag Age</td>
<td></td>
<td>-0.16</td>
<td>-0.564</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LBIM</td>
<td></td>
<td>0.265</td>
<td>0.341</td>
<td>-0.32</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employees (%)</td>
<td>-0.5464</td>
<td>-0.012</td>
<td>-0.480</td>
<td>0.54</td>
<td>-0.302</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population RAMS (%)</td>
<td>-0.7584</td>
<td>0.0457</td>
<td>-0.380</td>
<td>0.8538</td>
<td>-0.06</td>
<td>0.4265</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>PDPSK</td>
<td>0.3076</td>
<td>0.266</td>
<td>0.3989</td>
<td>-0.32</td>
<td>0.6186</td>
<td>-0.452</td>
<td>-0.1253</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 8.3 Average expenditure per household in different municipalities by groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Metropolitan areas</th>
<th>suburban municipalities</th>
<th>larger municipalities</th>
<th>commuting municipalities</th>
<th>other municipalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>99500</td>
<td>89500</td>
<td>77600</td>
<td>71000</td>
<td>63400</td>
</tr>
<tr>
<td>Leisure and culture</td>
<td>75300</td>
<td>82100</td>
<td>63200</td>
<td>59100</td>
<td>53400</td>
</tr>
<tr>
<td>Transport</td>
<td>66600</td>
<td>73300</td>
<td>67300</td>
<td>81200</td>
<td>63300</td>
</tr>
<tr>
<td>Food</td>
<td>45300</td>
<td>45000</td>
<td>41500</td>
<td>42000</td>
<td>36300</td>
</tr>
<tr>
<td>Furniture and equipment</td>
<td>24100</td>
<td>27100</td>
<td>24600</td>
<td>24400</td>
<td>19200</td>
</tr>
<tr>
<td>Clothing and shoes</td>
<td>22300</td>
<td>22800</td>
<td>17100</td>
<td>16700</td>
<td>13200</td>
</tr>
<tr>
<td>Meals out</td>
<td>13900</td>
<td>14700</td>
<td>10900</td>
<td>8900</td>
<td>8300</td>
</tr>
</tbody>
</table>

Source: (SCB 2009)
9. Appendix C

9.1. SCB’s hierarchical definition for gainfully employed

Figure 9.1 SCB’s hierarchical definition of gainfully employed

---

66 Email conversation with Karolina Andersson, SCB (April 2012)
9.2. Regional Growth of FTTH Penetration and xDSL

Figure 9.2 Regional Growth of FTTH Penetration and xDSL
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10. Appendix D

10.1. 2SLS Model for Employment (An Experiment)

Two stage least square (often referred as 2SLS) method has been outlined in this appendix, which should be considered just as experiment. This model is not reliable to large extent; it is because that in the first state coefficient of determination ($R^2$) has much low value, which leaves out the credibility of the method (Gujarati & Porter 2009).

Model

2SLS model has been attempted to see simultaneity effects, however, two equations were crafted in the system equation, with predetermined and exogenous variable. It was tried to separates the causal effects of FTTH on employment using Panel data. The model here used is inspired by Gujarati & Porter (2009 p.718), where the authors outline a method to estimate an over-identified\footnote{According to the rules of identification, equation 10.1 is over-identified as it excludes more than $M-1$ exogenous or predetermined variables that are found in equation 10.2.} equation.

\[
Y_{1(i,t)} = \beta_{10} + \beta_{11}Y_{2(i,t)} + \gamma_{11}X_{1(i,t)} + \gamma_{12}X_{2(i,t)} + \gamma_{13}X_{3(i,t)} + \gamma_{14}X_{4(i,t)} + \gamma_{15}X_{5(i,t)} + \mu_{1(i,t)} \tag{Eq. 10.1}
\]

\[
Y_{2(i,t)} = \beta_{20} + \beta_{21}Y_{1(i,t)} + \gamma_{26}X_{6(i,t-1)} + \gamma_{27}X_{7(i,t-1)} + \gamma_{28}X_{8(i,t)} + \gamma_{29}X_{9(i,t)} + \mu_{2(i,t)} \tag{Eq. 10.2}
\]

Where;

$Y_1 =$ Employed Population as share of total employable population over 16 years of age in municipality $(i)$ in a given time $(t)$.

$Y_2 =$ FTTH penetrated share of the total households in municipality $(i)$ and time $(t)$

$X_1 =$ Education level (Post secondary education of 3 years or more) in municipality $(i)$ and time $(t)$

$X_2 =$ Net education cost per inhabitant in municipality $(i)$ and time $(t)$
CHAPTER 7: APPENDIX

\( X_3 = \) Share of Foreign residents from employable population (living since 0-4 years) in municipality \((i)\) and time \((t)\)

\( X_4 = \) Change \((\Delta)\) in total population in last ten years in municipality \((i)\) and time \((t)\)

\( X_5 = \) Economic equalization per inhabitant in municipality \((i)\) and time \((t)\)

\( X_6 = \) Municipal income per inhabitant in municipality \((i)\) and time \((t-1)\)

\( X_7 = \) Net infrastructure cost in municipality \((i)\) and time \((t-1)\)

\( X_8 = \) xDSL broadband penetration rate in municipality \((i)\) and time \((t)\)

\( X_9 = \) Kable-TV penetration rate in municipality \((i)\) and time \((t)\)

In Stage 1, we derive the reduced forms of equation (10.1) and (10.2) as below, by regressing \(Y_1\) and \(Y_2\) on all predetermined \((i.e. t-1)\) and exogenous variables in the system.

\[
\hat{Y}_{1,(i,t)} = \hat{\mu}_{10} + \hat{\mu}_{11}X_{1(i,t)} + \hat{\mu}_{12}X_{2(i,t)} + \hat{\mu}_{13}X_{3(i,t)} + \hat{\mu}_{14}X_{4(i,t)} + \hat{\mu}_{15}X_{5(i,t)} \\
+ \hat{\mu}_{16}X_{6(i,t)} + \hat{\mu}_{17}X_{7(i,t)} + \hat{\mu}_{18}X_{8(i,t)} + \hat{\mu}_{19}X_{9(i,t)} + \mu_{1(i,t)}
\]

Eq. 10.3

\[
\hat{Y}_{2,(i,t)} = \hat{\mu}_{10} + \hat{\mu}_{11}X_{1(i,t)} + \hat{\mu}_{12}X_{2(i,t)} + \hat{\mu}_{13}X_{3(i,t)} + \hat{\mu}_{14}X_{4(i,t)} + \hat{\mu}_{15}X_{5(i,t)} \\
+ \hat{\mu}_{16}X_{6(i,t)} + \hat{\mu}_{17}X_{7(i,t)} + \hat{\mu}_{18}X_{8(i,t)} + \hat{\mu}_{19}X_{9(i,t)} + \mu_{2(i,t)}
\]

Eq. 10.4

In Stage 2, we replace \(Y_2\) in equation (10.1) with fitted values estimated by the reduced form in equation (10.4) \((i.e. where FTTH is as dependent variable)\) and estimate the original (structural) equation (10.1). Estimates are presented in table 10.3 below. Heteroscedasticity was also checked with the help of Breusch-Pagan/Cook Weisberg test, and at 5% level of significance the error term is homoscedastic.
Estimated model:

\[ Y_{1,(t,t)} = \beta_{10} + \beta_{11} Y_{2,(t,t)} + \gamma_{11} X_{1,(t,t)} + \gamma_{12} X_{2,(t,t)} + \gamma_{13} X_{3,(t,t)} + \gamma_{14} X_{4,(t,t)} + \gamma_{15} X_{5,(t,t)} + \mu_{1(t,t)} \quad \text{Eq. 10.1} \]

In other words;

\[ \text{Employed}_{\text{Pop share}} = \beta_{0} + \beta_{1} FTTH_{fitted (t,t)} + \beta_{2} Edu_{share (t,t)} + \beta_{4} Net_{EduCost (t,t)} + \beta_{5} I_{Plus} + \beta_{6} Delta_{Pop_{10years} (t,t)} + \beta_{8} Econ_{EquiInhab (t,t)} + \mu_{1(t,t)} \quad \text{Eq. 10.5} \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employed_Pop_Share</td>
<td>1148</td>
<td>0.487555</td>
<td>0.098712</td>
<td>0.239176</td>
<td>0.878880</td>
</tr>
<tr>
<td>FN_Bef</td>
<td>1148</td>
<td>0.220151</td>
<td>0.208644</td>
<td>0</td>
<td>0.9972</td>
</tr>
<tr>
<td>Mun_TaxIncome_InhbLag</td>
<td>1148</td>
<td>34521.25</td>
<td>3584.794</td>
<td>25420</td>
<td>57357</td>
</tr>
<tr>
<td>Net_InfraCost_Lag</td>
<td>1148</td>
<td>2826.833</td>
<td>753.2659</td>
<td>1061</td>
<td>7751</td>
</tr>
<tr>
<td>Broadband_Penetration_rate</td>
<td>1148</td>
<td>0.956986</td>
<td>0.071065</td>
<td>0.52</td>
<td>1</td>
</tr>
<tr>
<td>Kable_TV</td>
<td>1148</td>
<td>0.176968</td>
<td>0.212454</td>
<td>0</td>
<td>0.8761</td>
</tr>
<tr>
<td>PostSecondry_3orMore_Share</td>
<td>1148</td>
<td>0.108188</td>
<td>0.045530</td>
<td>0.050559</td>
<td>0.351005</td>
</tr>
<tr>
<td>Net_Edu_Cost_Inhb</td>
<td>1148</td>
<td>14977.08</td>
<td>1426.68</td>
<td>10012</td>
<td>20688</td>
</tr>
<tr>
<td>I_Plus_Oto4years_Share</td>
<td>1148</td>
<td>0.025696</td>
<td>0.013661</td>
<td>0.004086</td>
<td>0.094752</td>
</tr>
<tr>
<td>Delta_Pop_last10years</td>
<td>1148</td>
<td>-0.100960</td>
<td>7.896852</td>
<td>-17.5</td>
<td>29.9</td>
</tr>
<tr>
<td>Economic_EqualizationLag</td>
<td>1148</td>
<td>8023.385</td>
<td>4910.332</td>
<td>-14708</td>
<td>24640</td>
</tr>
</tbody>
</table>
Table 10.2 Correlation Matrix

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Emp_share_RAMS</th>
<th>PTS_FTTH_2007</th>
<th>Delta_POP10_2007</th>
<th>I_plus_2007</th>
<th>Delta_EduLevel_PS3orMore_07_10</th>
<th>Broadband_xDSL_PTS_2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emp_share_RAMS</td>
<td>1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTS_FTTH_2007</td>
<td>0.1664</td>
<td>1</td>
<td></td>
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<td></td>
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<tr>
<td>Delta_POP10_2007</td>
<td>0.5664</td>
<td>0.0853</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_plus_2007</td>
<td>0.3287</td>
<td>-0.0158</td>
<td>0.4125</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta_EduLevel_PS3orMore_07_10</td>
<td>0.1453</td>
<td>-0.1515</td>
<td>0.1294</td>
<td>-0.1411</td>
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<td></td>
</tr>
<tr>
<td>Broadband_xDSL_PTS_2007</td>
<td>0.0263</td>
<td>-0.0355</td>
<td>-0.021</td>
<td>-0.0016</td>
<td>-0.0007</td>
<td>1</td>
</tr>
</tbody>
</table>

Stage 1

Table 10.3 Stage 1 of 2SLS

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Number of obs</th>
<th>F( 9, 1135)</th>
<th>Prob &gt; F</th>
<th>R-squared</th>
<th>Adj R-squared</th>
<th>Total</th>
<th>Root MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>11.14948</td>
<td>9</td>
<td>1.238831</td>
<td></td>
<td>36.37</td>
<td>0</td>
<td>0.2239</td>
<td>0.2177</td>
<td>49.80778</td>
<td>0.18455</td>
</tr>
<tr>
<td>Residual</td>
<td>38.6583</td>
<td>1135</td>
<td>0.03406</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>49.80778</td>
<td>1144</td>
<td>0.043538</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explained Variable: **FN_Bef**

<table>
<thead>
<tr>
<th>Coef.</th>
<th>Std. Err.</th>
<th>t</th>
<th>P&gt;t</th>
<th>[95% Conf. Intervals]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mun_TaxIncome_InhbLag</td>
<td>2.99E-06</td>
<td>2.13E-06</td>
<td>1.4</td>
<td>0.161</td>
</tr>
<tr>
<td>Net_InfraCost_Lag</td>
<td>2.68E-07</td>
<td>7.28E-06</td>
<td>0.04</td>
<td>0.971</td>
</tr>
<tr>
<td>Broadband_Penetration_rate</td>
<td>-1.07905</td>
<td>0.10624</td>
<td>-10.16</td>
<td>0.000</td>
</tr>
<tr>
<td>Kable_TV</td>
<td>0.069328</td>
<td>0.025812</td>
<td>2.69</td>
<td>0.007</td>
</tr>
<tr>
<td>PostSecondry_3orMore_Share</td>
<td>1.206922</td>
<td>0.201138</td>
<td>6</td>
<td>0.000</td>
</tr>
<tr>
<td>Net_Edu_Cost_Inhb</td>
<td>-4.4E-05</td>
<td>4.79E-06</td>
<td>-9.21</td>
<td>0.000</td>
</tr>
<tr>
<td>I_Plus_Oto4years_Share</td>
<td>0.97071</td>
<td>0.426982</td>
<td>2.27</td>
<td>0.023</td>
</tr>
<tr>
<td>Delta_Pop_last10years</td>
<td>0.000244</td>
<td>0.001161</td>
<td>0.21</td>
<td>0.833</td>
</tr>
<tr>
<td>Economic_EqualizationLag</td>
<td>2.49E-06</td>
<td>2.33E-06</td>
<td>1.07</td>
<td>0.286</td>
</tr>
<tr>
<td>_cons</td>
<td>1.622101</td>
<td>0.157989</td>
<td>10.27</td>
<td>0.000</td>
</tr>
</tbody>
</table>
CHAPTER 7: APPENDIX

2nd Stage

Table 10.4 Stage 2 of 2SLS

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Number of obs</th>
<th>Number of obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>2.79777</td>
<td>6</td>
<td>0.466329423</td>
<td>Prob &gt; F</td>
<td>F(6, 1138) = 63.97</td>
</tr>
<tr>
<td>Residual</td>
<td>8.295494</td>
<td>1138</td>
<td>0.007289538</td>
<td>R-squared</td>
<td>0.2522</td>
</tr>
<tr>
<td>Total</td>
<td>11.09347</td>
<td>1144</td>
<td>0.00969709</td>
<td>Root MSE</td>
<td>0.08538</td>
</tr>
</tbody>
</table>

Explained Variable: Empoyed_Pop_share

| Explanatory Variables          | Coef.  | Std. Err. | t   | P>|t|   | [95% Conf. Interval] |
|--------------------------------|--------|-----------|-----|------|----------------------|
| fitted_FNBeef                  | 0.10559| 0.043418  | 2.43| 0.015| 0.0204021 - 0.1907786|
| PostSecondry_3orMore_Share     | 0.098923| 0.117111 | 0.84| 0.398| -0.130853 - 0.3286998|
| Net_Edu_Cost_Inhb              | -2.3E-05| 2.48E-06 | -9.32| 0    | -0.000028 - -0.000018|
| I_Plus_0to4years_Share         | 1.646243| 0.200888 | 8.19| 0    | 1.252091 - 2.040395 |
| Delta_Pop_last10years          | -0.00395| 0.000493 | -8.01| 0    | -0.004918 - -0.002982|
| Economic_EqualizationLag       | -2.2E-06| 9.64E-07 | -2.37| 0.018| -4.17E-06 - -3.89E-07|
| _cons                          | 0.775272| 0.036653 | 21.15| 0    | 0.7033563 - 0.8471874|

Linear Prediction

Figure 10.1 Two-way scatter plot with linear prediction
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Conclusion

2SLS model has overestimated the coefficient of FTTH by 0.091, which is quite high. As mentioned before, above results are not relied due to low $R^2$ value in first stage, however given here for readers to understand the phenomenon of simultaneity and how results can be very misleading.
References


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