Impact of Superfast Broadband on Local Economic Growth: Empirical Evidence Using a Matching Estimator

Maude Hasbi*

Abstract

I estimate the impact of high speed and very-high speed broadband networks on local economic growth in France. I use two specific estimators, the nearest neighbor matching and the propensity score matching to estimate, on some measures of local economic growth, the impact of (i) superfast broadband networks deployed by private operators (ii) public initiative broadband networks. I show that regardless of the type of network ownership, the effects of both broadband networks display the same trends, in terms of signs: for both types, I find a positive average impact on the number of establishments of all non-farm markets sectors and on consumer surplus, with a positive average impact on households' income. In addition, the estimation results show a positive impact of broadband networks on unemployment reduction. However, the impact of private broadband networks are more pronounced.

Key Words: *FttH; Superfast Broadband; Public Initiative Networks, Local Economic Growth; Territorial Dynamics*

JEL Classification: L13, L50, L96

* *Corresponding author:* Telecom ParisTech, Department of Economics and Social Sciences, 46 rue Barrault, 75013 Paris, France. E-mail: maude.hasbi@telecom-paristech.fr

1 Introduction

Very high speed broadband networks are seen as a key enabler for socio-economic development. Their roll-out has been made a priority worldwide and is considered as an investment for the future. Over the last few years, many countries, such as the US,[1] Australia,[2] Japan,[3] Mexico[4] and a multitude of African countries[5] have adopted a national broadband plan to ensure the whole coverage of their territory. In the European Union, the Commission has defined in 2013 a Digital Agenda for Europe, with the objective to provide by 2020 every household with access to at least 30 Mbps connection and half of the households with a subscription at 100 Mbps.[6] In September 2016, the Commission reiterated its vision to turn Europe into a Gigabit Society by 2025.[7]

Higher connection speeds would allow all users, households, businesses and administrations, regardless of their size or geographic location, to benefit from enhanced and more efficient broadband services. It shapes the way companies do business, enhancing their capacities, broadening their markets. It improves households online experience, allowing them to use multiple connected devices at the same time, benefit from faster download speeds, carry on online transactions.

The contribution of this paper is to analyze whether very-high speed broadband availability has a causal impact on measures of local economic growth. Specifically, I investigate whether superfast broadband networks have an effect on new business establishments, on the evolution of households income and on the unemployment rate. In addition, this paper also assesses how the deployment of public initiative networks affects local economic growth. To the best of my knowledge, this is the first paper to estimate the impact of superfast broadband network and especially public initiative networks on economic growth at a granular local level. Our results provide policymakers with better insights on the role of superfast broadband for the local economy.

'Digital technology currently represents 5.5% of the French GDP', it share may increase by

[1] "Connecting America: The National Broadband Plan, Federal Communications Commission," March 2010
[2] "The National Broadband Network" April 2009, modified in 2013
[3] "E-Japan Strategy" 2001
[4] "Mexican Digital Agenda" 2011
[5] "National Information and Communication Technology Policy", final draft Nigeria, 2013; "National Projects for Broadband Connectivity" Burundi 2011
[6] "A Digital Agenda for Europe," European Commission, COM(2010) 245.
[7] "State of the Union 2016: Towards a Better Europe - A Europe that Protects, Empowers and Defends"

€100 billion by 2020.[8] The digital economy contributed to $79 billion to the Australian economy in 2013-2014, representing 5.1% of the Australian's GDP.[9] The deployment of new generation access networks (NGA) constitutes a major stake for economic and social development. Infrastructure investments have always been regarded as a tool of economic recovery in the short-term and as a factor of competitiveness and attractiveness in the long-term. The question is no longer whether broadband is important, it is already a must-have technology, but rather why not having it would be detrimental for a country economy.

The concept of digital divide is becoming more and more complex as access to the Internet and ICT literacy grow over time. Though we observe a rapid penetration of superfast broadband in urban areas, new concerns emerge about a gap increase to the disadvantage of both households and businesses, especially those located in rural areas. Superfast broadband is seen as a way to increase social and rural inclusion by reducing the distance between people and territories. But the absence of sufficient broadband connection speed may impede the establishment of companies, contributing to the desertification of some areas with low job prospects.

To ensure the complete coverage of a country, local Authorities have a role to play. They are entitled, in Europe, to promote and facilitate fiber networks roll-out, by enhancing competition and creating a favorable climate for investment.[10] Beyond their role of active intermediaries, local governments are also directly involved in broadband deployment, either with the deployment of local FttH network or with the upgrade of existing network infrastructures to increase the broadband speed received by residents and local companies in areas classified as "non-commercially" viable by private operators.[11] Public Initiative Networks (PIN) are the main contributors in the achievement of national broadband plans. ConnecTourisme is a French public-private initiative launched in 2014 to boost economic and touristic activities in mountain areas, where Internet coverage is insufficient to enhance the territory attractiveness.[12] Internet access will be a mean to attract customers, who can experience high speed connection even in

[8] French Government's website, March 2015 "9 things you didn't know about France and digital technology". Results taken from a 2012 study by McKinsey.

[9] "The Connected Continent II" 2015 Deloitte Access Economics Report, commissioned by Google

[10] RECOMMANDATION ON SUBSIDY

[11] This could be achieved either via copper upgrade to VSDL technology or via cable upgrade to the DOCSIS3.0 standard.

[12] ConnecTourisme is national convention signed in May 2014 by Orange (Nordnet subsidiary), Eutelsat and the National Association of the Elected Representatives from Mountain Areas

remote areas. Meanwhile, it will boost the visibility of the city and its local touristic companies through the creation of well-designed websites and allow for the use of electronic payment services and highly reliable localization services.

This study relies on panel data covering more than 36,000 municipalities located in metropolitan France over 5 years, from 2010 to 2014. Panel data allows to control for municipal- and time-specific heterogeneity. The three French largest cities, Paris, Lyon and Marseille are excluded from the analysis. First, because these cities are attractive by themselves for companies and households. The average income is higher compared to the rest of France. Second, it would be dubious to match them with a reasonably similar control group, considering their inherent characteristics.

To estimate the impact of superfast broadband networks on local economic growth, I use matching estimators techniques. These evaluation methods are commonly used to estimate the average effect of a treatment or policy intervention. I use two specific estimators, the nearest neighbor matching and the propensity score matching (i) to match municipalities with different types of superfast broadband networks, namely fiber optical network (Fiber to the Home; FttH), upgraded cable (Fiber to the Last Amplifier; FttLA) and upgraded copper network (VDSL or Fiber to the Neighborhood; FttN) with otherwise similar municipalities in terms of observable characteristics, (ii) using a sub-sample, to match municipalities in which a public initiative network has been deployed, with otherwise similar municipalities. The outcome of the socio-economic variables of interest is then compared with the one of their control groups. While the use of matching estimators is a mean to attenuate reverse causality, some concerns remain, notably due to the potential effects of unobservables.

I find evidence of the benefits of superfast broadband networks for local economic growth. They enhance municipalities attractiveness for companies, especially for companies from the tertiary sector, which rely more on ICTs. They also have a positive average effect on the number of companies operating in the construction sector, as their roll-out leads to an increase of the workload and may require the creation of direct jobs. I also highlight the existence of positive spill overs for the local population. Households gain additional income compared to a municipality without superfast broadband network. Besides, I observe a positive average effect

on unemployment reduction.

Not surprisingly, the impacts on local economic growth are much higher for superfast broadband deployed by private operators, than for public initiative broadband networks. This might be explained by the inherent characteristics of the municipalities in which public initiative broadband networks are deployed, as they are "non-commercially" viable for private operators that can not recoup their investment costs.

The remainder of the paper is organized as follows. Section 2 discusses the relevant literature on the effect of broadband on economic growth and deployment. Section 3 presents the data. Section 4 introduces the econometric framework. Section 5 presents the estimation results. Finally, Section 6 concludes.

2 Literature Review

There is a substantial literature on the effect of ICT on GDP and more generally on economic growth at the national and regional level (see Czernich et al. (2014) and Kretschmer (2012) for broad literature reviews). It is widely accepted that, at the national level, ICT adoption has a positive effect in increasing productivity.[13] However, ICT is a fairly large category regrouping basic equipments, such as computer, PCs, along with different types of Internet connections from narrowband to broadband of all speeds and more advanced fiber-optical broadband technologies.

With the steadily growing international enthusiasm for broadband deployment and today for the roll-out of high speed broadband networks, researchers are becoming more interested in evaluating the role of broadband on economic growth. There is an extensive range of macro-level studies which bring empirical evidence on the positive impact of broadband adoption on economic growth (see Greenstein et al. (2011) and Holt et al. (2009) for comprehensive literature reviews). Gruber et al. (2014) evaluates the net economic benefits that would derive from the achievement of the objectives of the 2020 Digital Agenda for Europe. They find that the economic benefits outweigh the costs of investment. Besides, they show that the economic benefits are only marginally appropriable by firms, as they mostly spill over to users and to

[13]There are only few studies analyzing the effect of broadband adoption on productivity at the business level, see for example Haller et al. (2015) or Akerman et al. (2015)

the national economy. This result confirms other studies which found a positive impact of broadband availability on consumer surplus (see for example Crandall et al. (2001), Dutz et al. (2009)). Thus, Gruber et al. (2014) highlight the rationale for public subsidies in the roll-out of broadband networks. Other studies for the US have found a positive association between broadband availability and employment (Crandall et al. (2007), Gillett et al. (2006)). However, there is limited empirical evidence of the effect of broadband availability on economic growth at the local level, especially in rural areas.

Usually, studies realized at the local-level assess the impact of ICT on variables of local economic growth (see for example Kolko (2012)[14]). There are only few papers focusing specifically on the effect of broadband adoption on local economic growth. Czernich (2014) for German municipalities and Jayakar et al. (2013) for eight States in the US find no evidence that broadband availability reduces the unemployment rate. Ahfeldt et al. (2014), show that in areas covered with broadband house prices are higher, which is in line with Kolko (2012) findings, that expanding broadband coverage tends to increase property values and local taxes.

On the contrary, Whitacre et al. (2014) find that broadband adoption, availability and download speeds have an impact on economic growth in rural areas. They use a propensity score matching estimator on local-level data for non-metropolitan US counties for the years 2001 to 2010. They highlight a positive impact on unemployment reduction and on median household income. They also show that rural areas with high levels of download speeds tend to attract more creative class workers and to have a lower poverty level. In her analysis, Mack (2014) evaluates the correlation between broadband speed and the establishment presence in Ohio. She finds a positive impact of broadband speed for agricultural and rural establishments. However, she does not establish any causal relationship. Using local-level data, McCoy et al. (2016) analysis the impact of local infrastructure and of broadband networks on new business establishments in Ireland, excluding the Dublin city region. They find that on average areas covered by broadband are more attractive for firms.

[14] Using instrumental variables techniques on local-level data for the US for the period 1999-2006, Kolko (2012) finds a positive relationship between broadband expansion and population growth and local economic growth, especially in industry which rely more on ICT and in lower densely populated areas. Though, they cannot conclude on a causal relationship. Interestingly, they don't find any significant impact on wage, unemployment rate and on telecommuting.

This paper is related to the latter stream of literature. However, most of the studies on the impact of broadband on local economic growth focuses on the impact of old generation broadband technologies, such as DSL or co-axial cable technologies. I attempt to fill this gap by assessing the impact of superfast broadband technologies, including fiber optical technology (Fiber to the Home), upgraded cable technology (DOCSIS 3.0 or Fiber to the Last Amplifier) and VDSL technology (Fiber to the Neighborhood). Besides, though realized at the local level, most of the studies are performed at a rather aggregated level, which is either the State or the county. I use data on more than 36,000 municipalities over 5 years, from 2010 to 2014. To the best of my knowledge, this paper the first paper, which at such a granular local level, analyzes the impact of superfast broadband network on local economic growth. I specifically focus on the effect of superfast broadband networks on firms' establishment, income and unemployment rate.

3 Data

The main data on optical fiber deployment constitutes a panel of fiber deployment in metropolitan France (Corsica excluded) over 5 years, from 2010 to 2014. They have been extracted from Orange's Information System, SFR's website and Free users' community websites. Orange is the historical fixed-line incumbent operator owning the legacy copper network, which is used to provide DSL broadband services. SFR and Free are entrants which do not possess their own copper network. They provide broadband services by leasing access to the incumbent's local access network via local loop unbundling (LLU). Orange, SFR and Free are also the main competitors on the mobile market. All databases provide information at the municipality level with each municipality identified by a unique geographic code (the INSEE code). I have information on 36,082 French municipalities out of the 36,192 municipalities counted in metropolitan France in 2014. For each municipality, we know whether Orange and/or SFR has deployed an FttH network.[15]

Regarding Free's data, they have been extracted on an unofficial website updated by Free's

[15]The database used in this study is similar to the one in Bourreau, Grzybowski and Hasbi "Unbundling the Incumbent and Entry into Fiber: Evidence from France". For further details upon the database construction and data collection, please refer to the aforementioned paper.

users community. The data are consistent with information gathered on other websites, as well as with Free's Annual Reports. For each municipality, we know whether there are active fiber connections.

Regarding data on public initiative broadband networks, they have been collecting on different sources, from policy reports to region broadband plans and other public datasets from various web's communities. All sources have been checked with report from ARCEP (the French National Regulatory Authority) and the 'mission tres haut debit', a public body in charge of monitoring the deployment of high speed and very-high speed broadband in France and from datasets coming from Orange information's system and SFR websites. Although we know for each municipality whether there is a public initiative network, we don't know which technology has been deployed (VDSL, upgraded cable, fiber or wireless networks).

This database has been completed with four other sources. First, data on cable upgrade to FttLA have been extracted from Numericable's website for the years 2010 to 2014. Numericable, is the French cable-operator[16]. For each municipality, we know whether Numericable has upgraded its cable network to provide very high speed broadband services.

Second, variables on the copper network have been taken from two databases coming from Orange's Information System for the years 2010 to 2014. They inform us on the number of VDSL lines both at the Main Distribution Frame (MDF) and at the municipality level.

Third, socio-demographic characteristics come from INSEE, the French National Institute for Statistics and Economics Studies. Data on the number of companies and establishments, as well as the number of companies and establishments creations have been collected for each municipality for the years 2010 to 2015. For both companies and establishments, we have information for three main non-farm market sectors: the industrial sector, the construction sector and the commerce, transport, service and administrative sector, i.e. the tertiary sector.

Also come from INSEE, economic data such as the unemployment rate, which is measured at the employment zone level. I have information for the years 2010 to 2015. In France, the employment zone is a higher administrative unit than the municipality.[17] There are 297 em-

[16]Numericable's cable network covers 30% of the population living mostly in urban areas.

[17]According to INSEE definition an employment zone represents a geographical area within which most of the labor force lives and works and in which establishment can find the main part of the labor force.

ployment zones in metropolitan France. Some other municipality characteristics have also been extracted from INSEE databases, such as population density, population, number of housing, the municipal urbanization degree. These information have all been collected by INSEE for the years 2008 to 2012.

Besides, I have collected data on typological and economic classification of municipalities located in the countryside on the French territorial observatory portals, a government website (DATAR). For all municipalities, which do not belong to an urban unity of more than 10,000 employments, DATAR has developed two indexes that provides a typological and an economic classification. (Indexes are detailed in Annex.)

Finally, data on the average fiscal income per municipality has been collected from the General Direction of Public Finance's website (Gouvernment Taxes Services, DGFIP) for the years 2010 to 2014. The average fiscal income is measured in the previous year, as people pay taxes on the year before. In other words, the amount of taxes paid for the year 2015 are calculated on the income received in 2014. As such, for the year 2015, we use the income of the year before, 2014. See descriptive statistics in Annex.

4 Econometric Strategy

I use propensity score matching techniques to address my main question, which is whether very-high speed broadband availability has a causal effect on measures of local economic growth. These matching techniques are commonly used to deal with endogeneity issues, so as to measure the average impact of a treatment or a program intervention. Specifically, I investigate whether superfast broadband networks and public initiative broadband networks have an effect on new business establishments, on the evolution of households income and on the unemployment rate.

4.1 Propensity Score Matching Technique

Propensity score matching are non-parametric estimators used to estimate average treatment effect (ATE). ATE measures the difference in outcome between a treated group and a control group (Rosenbaum and Rubin (1983)). The treatment variable consists in a dummy variable

indicating whether a treatment has been applied. The control group consists in otherwise similar municipalities in terms of observable characteristics.

$Y_{it+1}(1)$, $(Y_{it+1}(0))$ denotes an outcome which is realized in time $t+1$ if municipality i receives (doesn't receive) at time t a treatment $d_{it} = 1$ ($d_{it} = 0$). Then, the average treatment effect on the treated (ATT), which represents the average gain from the treatment for those who actually were treated, writes as follows:

$$ATT = E(\Delta Y_{it+1}(1) \mid d_{it} = 1) - E(\Delta Y_{it+1}(0) \mid d_{it} = 1) \tag{1}$$

The first term represents the expected value of the outcomes of interest, in time $t+1$, in municipalities where a superfast broadband network has been deployed in time t, which is observable. However, the second term in Eq.(1) is non-observable. It represents the expected value of the outcomes of interest, in time $t+1$, for the control group, had a superfast broadband network been deployed in time t. When evaluating the impact of a policy, or here of an investment decision, the researcher faces an identification issue. Besides, the treatment distribution may suffer from a selection bias that has to be accounted for.

To alleviate these issues, matching estimators seek to reproduce the treatment group among the non-treated group using observable characteristics. They allow to evaluate the effects of a treatment by comparing outcomes between a treated group, and a control group made of municipalities with similar characteristics. Then the treatment could be considered as randomly assigned conditional upon observable characteristics. To obtain unbiased estimates, propensity score estimators rely on an assumption of conditional independence (Imbens (2004)), which means that there are no unobservable differences between the treated and the control groups[18]. Therefore the key component in the modeling is to determine the relevant set of matches.

$$Y_{it+1}(1), Y_{it+1}(0) \perp d_{it} \mid \boldsymbol{X} \tag{2}$$

Propensity score techniques represents the conditional probability of receiving a treatment given pretreatment characteristics: $Pr(outcome_{it}|X_{it})$. They are based on an overlap assump-

[18]This is a somehow stringent assumption, as the deployment of a network could also be the result of a political impulse or a consequence of a previous regional policy program. This is why a claim for strict causality is arguable.

tion, according to which each unit in the population has some chance of being treated and not being treated.

$$0 < Pr(d_{it} = 1 \mid X_{it}) < 1 \tag{3}$$

The overlap assumption can be assessed by examining the marginal distribution of propensity scores in both treatment groups. Two matching estimators are commonly used, the nearest neighbor matching estimator and the propensity score matching estimator. I use both estimators.

The nearest neighbor consists in matching treated and non-treated units displaying the closest propensity score. It offers a choice of distance metrics. I use the mahalanobis metric, which is the inverse sample covariate covariance. It also includes the possibility to have exact matching. A function, I use to match municipalities for the same year. I also use the correction for large-sample bias, that appears when matching on more than one continuous covariate. In the case of propensity score matching, the logistic treatment model is used. Similarity between units is based on estimated treatment probabilities, named the propensity scores.

4.2 Application of Propensity Score Matching

I use propensity score techniques to answer my main question which is whether very high speed broadband networks have a causal effect on some socio-demographical variables of policy relevance: the number of municipal establishments and their type, the average municipal income and the unemployment rate.

The treatment variable consists in a dummy variable indicating whether a fiber optical network (FttH) has been deployed and/or whether the cable network has been upgraded to FttLA and/or whether the copper network has been upgraded to VDSL in municipality i at time t. Considering this last network, I consider that at least 15% of DSL lines should have been upgraded to VDSL to consider that the DSL network has been upgraded to VDSL. Therefore, $superfastbb_{it}$ equals one if there is a superfast broadband network deployed in the municipality i at time t and zero otherwise. The control group consists in otherwise similar municipalities in terms of observable characteristics.

A second treatment variable has been built to evaluate the impact of public initiative net-

works (PIN) on local economic development. Yet, there is no information related to the type of technology deployed. In other words, it is not possible to distinguish between fibre network (FttH or FttLA), VDSL or the deployment of a wireless network. Therefore, PIN_{it} equals one if there is a public initiative network deployed in the municipality i at time t and zero otherwise. The estimation is run on a sub-sample of municipality where no superfast broadband network has been deployed (FttH and/or FttLA) by private operators and with a low percentage of upgraded VDSL lines.[19] The control group consists also in otherwise similar municipalities in terms of observable characteristics.

Besides, to control for potential issues of reverse causality and endogeneity resulting from a selection bias in the treatment distribution, i.e. the deployment of superfast broadband networks, I use lag variables. Considering the high costs of deployment, operators will select the municipalities in which to invest first depending on their return prospects.

In their decision to invest in a new infrastructure, I expect operators to take account of the potential market size and the quality of demand, in terms of expected purchasing power. I also expect cost factors to enter the investment decision. Therefore, to match municipalities, I use relevant demographic characteristics such as the log of population and the log of copper lines, which are measures of the market size. The density of population as well as the two indexes on typological and economic classifications described Annex. These latter variables are proxies for the costs of deployment. Depending on which outcome I seek to evaluate the impact of superfast broadband, I add the following variables to the set of matching characteristics: the income, the number of companies and the unemployment rate in the employment zone. Besides, to account for the panel nature of the data, years are also included in the set of matches.

Then, following equation (2), we have:

[19] There are no municipalities with more than 30% of DSL lines upgraded to VDSL, only 1% of municipalities in our sample, accounting for 36 municipalities, have at least 15% of DSL lines upgraded to VDSL.

Considering the number of establishments,

$$\Delta establishment_{it+1}(0),\ \Delta establishment_{it+1}(1) \perp d_{it} \mid company_{it},\ perc\_estab\_commserv_{it},\ log\_pop_{it-2},\ log\_copperlines_{it},\ density_{it-2},\ unempl_{it},\ income_{it},\ typology_i,\ eco_i,\ year. \tag{4}$$

Where $establishment_{it+1}$ represents the number of establishments operating in municipality i at time $t+1$ and $company_{it}$ represents the number of companies operating in municipality i at time t. Unlike the establishment, which is a production unit geographically independent but juridically dependent of a company, the company is the smallest combination of legal and production unit. Therefore, the number of companies is smaller or equal to the number of establishments in a municipality. Hence, I ensure that municipalities are comparable in terms of economic environment. In addition, to match municipalities with the same type of economy, I introduce the percentage of establishments from the commerce and service sector, denoted by $perc\_estab\_commserv_{it}$ to match municipalities with the same type of economy.

So, the average effect of superfast broadband deployment on the number of establishments in municipalities where such networks have been deployed writes as follows:

$$ATT = E(\Delta establishment_{it+1}(1),\ \mid\ d_{it} = 1) - E(\Delta establishment_{it+1}(0),\ \mid\ d_{it} = 1) \tag{5}$$

I control for firm characteristics by disaggregating the establishments belonging to the non-farm market sectors in three main sub-sectors: the construction sector, the industrial sector and the tertiary sector. I could not distinguish further between administrative establishments and establishments from the commerce and service sector, as INSEE modified the classification for the third group in 2015. As such, the introduction of the variable indicating the percentage of establishments from the commerce and service sector is not correlated with the third sub-dependent variable.

Considering the average municipal income,

$$\Delta income_{it+1}(0),\ \Delta income_{it+1}(1) \perp d_{it} \mid log\_pop_{it-2},\ density_{it-2},\ log\_copperlines_{it},\ company_{it},\ perc\_estab\_commserv_{it},\ unempl_{it},\ establishment_{it},\ typology_i,\ eco_i,\ year. \tag{6}$$

So, the average effect of superfast broadband deployment on the average income in municipalities where such networks have been deployed writes as follows:

$$ATT = E(\Delta income_{it+1}(1), \mid d_{it} = 1) - E(\Delta income_{it+1}(0), \mid d_{it} = 1) \tag{7}$$

Considering the unemployment rate,

$$\begin{aligned} &\Delta unempl_{it+1}(0),\ \Delta unempl_{it+1}(1) \perp d_{it} \mid log\_pop_{it-2},\ density_{it-2},\ log\_copperlines_{it},\\ &company_{it},\ perc\_estab\_commserv_{it},\ income_{it},\ establishment_{it}, typology_i,\ eco_i,\ year. \end{aligned} \tag{8}$$

So, the average effect of superfast broadband deployment on the unemployment rate in municipalities where such networks have been deployed writes as follows:

$$ATT = E(\Delta unempl_{it+1}(1), \mid d_{it} = 1) - E(\Delta unempl_{it+1}(0), \mid d_{it} = 1) \tag{9}$$

I expect to find a positive average effect of superfast broadband networks on local economic growth. Municipalities would appear more attractive for companies, especially for those operating in the tertiary sector, in which most of the businesses using ICTs belong. On the short-term, it is also expected that the roll-out of superfast broadband networks enhances activities in the construction sector. The benefits of superfast broadband networks are also expected to spill over to households, which should be reflected in an increase of the average municipal income. As far as unemployment is concerned, it is difficult to expect any significant impact in such a short time period. Investment in broadband network is seen by economists and policy makers as a way to increase productivity in the short-term, reducing employment. However, it should lead to the creation of new high-skill jobs in the long term, having a net positive effect. Therefore, if a positive average effect could be expected in the long-term, it would take time to materialized in the statistics. In addition, the roll-out and presence of superfast broadband network should have a higher impact on local economic growth than public initiative broadband networks, considering the inherent characteristics of the municipalities in which such networks are deployed. Another reason may be the impossibility to distinguish which type of technology has been deployed in

those municipalities.

5 Estimation Results

Tables 4 to 6 show the estimation results for the impact of superfast broadband networks, either fiber optical networks, upgraded cable networks or upgraded DSL networks on local economic growth. Tables 7 to 9 show the estimation results for the impact of public initiative networks on local economic growth in France. Finally, Tables 10 to 12 show the estimation results for the impact of public initiative networks on local economic growth for a particular region, Auvergne, which defined and implemented an ambitious broadband plan relatively early compared to other French regions. With its project, Very high speed Auvergne (Auvergne THD) the region could be regarded as a precursor in the roll-out of public initiative broadband networks.[20] For clarity purposes, for percentage change in local economic growth are shown respectively in Tables 13 to 15, Tables 16 to 18 and Tables 19 to 21.

5.1 Impact of Superfast Broadband Networks

Model 1 is estimated using the nearest neighbor matching estimator on the full dataset, which excludes the three main French agglomerations Paris, Lyon and Marseille. Model 2 is estimated on a sub-sample of the dataset also using the nearest neighbor matching estimator. The sub-sample has been build by selecting the four closest or most similar municipalities in the control group to reduce the size of the dataset. Model 3 has been run on this latter sub-sample using the propensity score matching estimator.[21] Model 1 is the preferred model as it is runs on the whole sample allows for exact matching for years and includes a correction for large sample bias.

For all models, I report the estimated average treatment effect (ATE) and the estimated treatment effect on the treated municipalities (ATT). As mentioned previously, ATE is obtained as the mean difference in outcomes between treated municipalities, where there is a superfast

[20] Auvergne THD: http://www.auvergnetreshautdebit.fr/ only available in French.

[21] Due to the size of the dataset, it was not possible to run the propensity score matching estimator on the full database. Therefore a sub-sample has been build by selecting the four closest municipalities within the control group. For comparison purposes between the two matching estimators, Model 2 has also been run on the sub-sample.

broadband network deployed, and control municipalities, where there is none. The ATE is weighted by the propensity score distribution of treated municipalities across specific intervals. Then, by comparing treated and untreated municipalities with similar propensity score, it is possible to estimate the ATT.

I find that the deployment of superfast broadband networks favors local economic development by increasing the number of establishments operating locally. Model 1 of Table 4 shows that the number of establishments increases by an average of 20% with the presence of a superfast broadband network. It also highlights that superfast broadband has a higher effect on the treated municipalities, i.e. in which a superfast broadband network has been deployed, as the number of establishments there increases by an average of 24%. Model 2 and Model 3 also confirm these positive effects.

To better capture the average effect of superfast broadband on the local economy, the establishments are disaggregated into the three main categories of the non-farm market sector: the industrial sector, the construction or building sector and the tertiary sector.

As expected, municipalities benefit from the spill over of the local presence of superfast broadband networks, helping them to maintain and develop a healthy economic sector. Superfast broadband networks tend to have on average a positive impact on all types of establishments of the non-farm market sector. The amplitude of its positive impact tends to be higher for establishments belonging to the tertiary sector, which rely more on ICT to conduct their business. The tertiary sector encompasses a vast field of activities ranging from commerce to administration, via transport, financial and real estate activities, services to business, personal services, education, health and social services.

On the contrary, the impact seems to be lower for establishments from the industrial sector, which are also implicated in the network deployment but to a lower extent than establishments from the construction sector. The industrial sector regroups all activities combining factors of production (facilities, supplies, work, knowledge) to produce material goods intended for the market. Therefore, unlike the establishments from the construction sector which in the short-term encounter an increase in their workload, establishments from the industrial sector have a more stable production pace. The construction sector is essentially an activity of deployment,

installation or maintenance on the customer's work-site.

Model 1 of Table 4 highlights a positive impact of superfast broadband on the number of establishments from the industrial sector, which increases by an average of 24%. The positive average effect of superfast broadband networks is slightly higher in the treated municipalities. On average, their number increases by an average of 25% in these municipalities. Model 2 and model 3 confirm this positive average impact and its higher amplitude within the treated municipalities.

I also show a positive impact of superfast broadband networks on the number of establishments from the construction sector, which increases by an average of 30%. This positive ATE is confirmed by model 3. However, the average effect of superfast broadband networks tends to be lower for treated municipalities with an average of 22%.

Table 4 also shows that the presence of superfast broadband networks has a positive impact on the number of establishments from the tertiary sector, which increases by an average of 20% and by an average of 25% in treated municipalities.

The increase in the number of establishments from the construction sector, especially as regards treated municipalities in which a superfast broadband network has been deployed, could be the result of the construction of the infrastructure itself. Investment plans in infrastructures have been a tool of economic recovery in the short-term. The roll-out of a network requires the creation of direct jobs, such as technicians, manual workers as civil engineering represents the major part of the work. Then, to a lower extent, direct jobs are also created in the industrial sector to manufacture the in-site telecommunication equipments and also all related devices or receptors such as the set-up boxes. Finally, indirect jobs are created in businesses that use ICT to operate, those ones are mostly present in the tertiary sector. This sector has been predicted to benefit the most from superfast broadband networks, which seems to be confirmed by the estimation results.

The average effects measured in Table 4 are based on the net number of establishments resulting from the creation of new companies and the disappearance of those having ceased their activities. To get a better understanding of how the presence of superfast broadband networks can enhance municipality attractiveness to incentivize new establishments to settle

down, Table 5 estimates the average treatment effect of the presence of superfast broadband networks on the number of new local establishments.

Only model 3 confirms a positive and significant average effect of the presence of superfast broadband networks on establishments creation for the whole population. This effect is strengthened in treated municipalities. Though coefficients are higher than for model 1, due to the difference of estimators. Model 1 shows a positive and significant impact of the presence of superfast networks in treated municipalities, where the number of establishments creation increases by an average of 3%. More specifically, the number of establishments from the tertiary sector increases the most with an average of 6%, whereas the number of establishments from the construction sector decreases by an average of 13%. This negative effect is also confirmed by model 2. Both models infirm that superfast broadband networks enhance municipality attractiveness for establishments from the construction sector. Model 3 also shows an average positive effect on the number of establishments from the tertiary sector and to a lower extent of establishments from the industrial sector, both with a higher impact in treated municipalities.

Estimation results from Table 4 and Table 5 tend to confirm the findings of Mccoy et al. (2016), which highlight that on average areas covered by broadband are more attractive for firms.

I also find that on average superfast broadband networks have a positive impact on the household income, which increased by an average of 1,700 euros per year, i.e. by 7% in the whole population and by an average of 3,000 euros per year, i.e. by 10% in treated municipalities. All models display positive and significant coefficients of similar amplitude, which reflect the quality of the models to evaluate the impact of superfast broadband networks on this measure of local economic development that is income.

The presence of superfast broadband networks also has an average positive impact on unemployment reduction, which decreases by an average of 6 to 13 percentage points depending on the model and by an average of 4 to 7 percentage points in treated municipalities. All models display quite similar coefficients, reflecting the quality of the models to evaluate the impact of the presence of superfast broadband networks on local economic health, which could be approximated by the unemployment rate.

These latter estimation results from Table 6 are in line with the empirical literature, especially the study from Gruber (2014), which finds that economic benefits from the achievement of the 2020 Digital Agenda for Europe mostly spill over to users and to the national economy. They are also confirmed by the study of Whitacre et al. (2014) which also finds a positive impact of broadband adoption on unemployment reduction and median household income.

5.2 Impacts of Public Initiative Networks

Public initiatives broadband plans are based on different types of public-private partnerships to ensure and trigger the roll-out of broadband networks. To achieve the coverage objectives of the broadband plans, local governments rely on a mix of technologies (VDSL, upgraded cable, fiber or wireless networks). Public initiative networks could play a role in enhancing their positive impacts locally. Therefore, local governments are eager to bring the benefits of these electronic communication technologies to their electorate.

However, considering the high investment costs of deploying broadband and superfast broadband networks, I am particularly interested in assessing whether these benefits are revealed by a thorough economic analysis. In a first subsection, the analysis of the potential average effect of the presence of public initiative networks on local economic growth is realized at the national level. In a second subsection, the analysis is performed on a specific region, Auvergne. Auvergne is a good candidate for the analysis as the local government adopted a rather ambitious broadband plan relatively early compared to other French regions.

5.2.1 Impact of Public Initiative Networks on the French Economy

I use the same estimation models as in the analysis of the impact of superfast broadband networks, deployed by private operators, on local economic growth. However, I withdraw from the full dataset and the sub-samples municipalities in which a private network, either optical fiber, upgraded cable or upgraded copper network has been deployed. Besides, the departement Hauts-de-Seine (92) has been withdrawn from the database to ensure that the estimation results are not biased. Although Hauts-de-Seine is the French richest department, a public initiative

network has been deployed.[22] As previously, model 1 is the preferred model.

Table 7 shows that public investment in electronic communication networks positively benefits local economies by increasing the number of establishments operating locally. Model 1 highlights that the number of establishments increases by an average of 2% for the whole population and by an average of 7% in treated municipalities. Models 2 and 3 confirm this positive impact.

A more fine-tuned analysis of the impact of publicly funded broadband networks reveals that they have an average positive impact on all non-farm market sectors of the economy. Similarly, as the effect of superfast broadband networks, the presence of public initiative broadband networks has a higher impact on the number of establishments from the tertiary sector, to which most businesses using ICT belong. In addition, the average positive impact on the number of establishments from the construction sector is higher than for those from the industrial sector for the same reasons as mentioned previously.

Model 2 predicts an average increase in the number of establishments from the industrial sector by 5%. Model 1 and model 2 predict a similar increase also by an average of 5% in the treated municipalities. Model 3 confirms both positive effects for the whole population and on the treated municipalities. As regards the establishments from the construction sector, only model 3 shows significant and positive impact of the presence of public initiative network, which is strengthened in treated municipalities. Finally, model 1 predicts an average positive impact of public initiative network on the number of establishments from the tertiary sector, which increases by an average of 3%, and by an average of 8% in treated municipalities. Model 2 confirms the amplitude of this average treatment effect on the treated municipalities. Model 3 also confirms the positive impact of both average treatment effects.

To get a better insight on how a public initiative broadband network enhances the attractiveness of a municipality so as to encourage new establishments to enter the local market, I estimate whether the presence of this particular type of networks has a positive impact on establishments creation. Table 8 shows the estimation results. Similarly to the effect of superfast

[22]The roll-out of a public initiative network in Hauts-de-Seine has led to fierce debates and has been challenged to Court by private operators. It has been cleared by the Competition Authority and the European Commission. However due to delays in the network deployments, the contract has been annulled by the department.

broadband networks, I observe an average positive impact of public initiative networks on the number of new establishments settling down their business in the municipality. Based on model 1, on average 2% more new business have been created. According to models 1 and 2, treated municipalities have experienced an average growth of around 3% of new establishments. Model 3 confirms both positive effects.

Likewise, the average impact of superfast broadband on establishment creation in the different sectors of the economy, the models show that the impact of public initiative network is positive and higher for establishments operating in the tertiary sector, which increase by approximately 3% to 4%, than for those operating in the industrial sector. The impact is higher in treated municipalities. Besides, the average impact for establishments operating in the construction sector is also negative. There are on average around 7% to 10% less establishments created from the construction sector in the whole population and around 8% less in treated municipalities. The same reasons as for private broadband networks may apply.

As regards the benefits of public broadband initiative networks for households, Table 9 show somehow mitigated results for the evolution of income. Model 1 predicts an average negative effect on income, whereas models 2 and 3 predict an average positive effect with a similar amplitude. Based on model 2 and model 3, with the presence of public initiative networks, the aggregated household income slightly increases by an average ranging between 77 to 150 euros per year, i.e. by 0.3% to 0.4% for the whole population and by an average ranging between 193 to 313 euros per year, i.e. by 0.8% to 1.3% for treated municipalities.

The average impact of publicly funded broadband networks is surprisingly negative as regards unemployment reduction, but the amplitude of these impacts is marginal. Both model 2 and model 3 show average effect of a similar amplitude. With the deployment of this networks, the unemployment rate increases by an average of 0.3 to 0.4 percentage points in the whole population, and by an average of 0.7 to 0.8 percentage points in the treated municipalities.

A comparison with superfast broadband effects on local economic growth, highlights that regardless of the type of network ownership, either private or public, or the existence of subsidy in its deployment, the average effects of broadband and superfast broadband networks on the local economic growth follow the same trends, in terms of signs. However, we observe that

the average effects of publicly funded broadband networks are much lower both globally and for treated municipalities, for any types of socio-economic measures. Especially, the average effect of these public initiative network are mitigated as regards the evolution of households income. As mentioned previously, the average effects of public initiative broadband networks on the local economic growth were expected to be lower than for those of superfast broadband networks deployed by private operators. One of the reason lies in the inherent socio-economic characteristics of the concerned municipalities. Besides, I cannot distinguish which technology has been deployed in those municipalities.

5.2.2 Impact of Public Initiative Networks: Example of a Precursor Region

Auvergne has been a precursor in the definition and implementation of a regional broadband plan. Therefore, it may be expected that the local economic benefits, if any, stemming from the roll-out of a public initiative broadband network, should have materialized in a more visible and significant way than in any other French regions. As such, assessing whether the average impacts of this policy could provide more accurate insights on the extent to which public investments into broadband networks play a role in enhancing local economic development.

The dataset used for these estimations reduced to the Auvergne region. Model 1 is estimated using the nearest neighbor matching estimator, whereas model 2 is estimated using the propensity score matching estimator. As previously, model 1 is the preferred model.

Table 10 shows that on average, public initiative broadband networks have a positive impact on the number of establishments both from the construction and tertiary sectors. However, only model 2 highlights a significant impact on the number of establishments settled locally, which increases by an average of 30% for the whole population and 60% treated municipalities. These effects are higher than those predicted at the national level for public broadband networks, but lower than those stemming from superfast broadband networks (as measured by model 3 using the same estimator).

Having a more fined-grained look into the different non-farm market sectors of the economy, I observe that unlike for the previous estimations, the average effect of public initiative networks on the industrial sector is negative in treated municipalities. The number of establishments

decreases by an average of 23% and 24% respectively for the whole population and in treated municipalities. However, none of the models find significant results for both the ATE and ATT.

Similarly to the previous estimation results, model 1 shows that the presence of public initiative broadband networks benefits the construction sector, which experiences an increase by an average of 28% in treated municipalities. Model 2 highlights that the positive average effect is more pronounced as regards treated municipalities. Finally, model 2 shows that the average benefits stemming from the roll-out of public initiative networks is also higher as regards the tertiary sectors, especially in treated municipalities.

Table 11 provides an overview of the average effects of the presence of public initiative broadband networks on the municipality attractiveness for new companies. None of the models reveal a significant impact of these networks on establishments creation. However and unlike the previous estimations, when the analyze is performed onto the different sectors, then model 1 confirms the existence of a negative average effect on establishments creation from the industrial sector, which slightly decreases by an average of 23%, and by an average of 24% in treated municipalities. An explanation for such a negative average effect could come from the economic characteristics of the region itself. The fringe of industries in expansion due to the roll-out of broadband networks, those manufacturing the related equipments, may be settled in other more dynamic regions. Most of the manufacturers are indeed present in more urbanized areas. Thus, the deployment of broadband networks in Auvergne do not endeavor establishments from the industrial sector to settle their business within the region. Generally speaking, the roll-out of broadband networks, no matter of the type of ownership, has little if any impact on company creation in the industrial sector.

Besides and also unlike previous estimations, model 1 displays significant and positive impact, but only for the treated municipalities, which increases by an average of 11%, but the result is significant only at the 10% level. This result, may be explained by the fact that in the municipalities in which a publicly funded broadband network is being deployed, the number of establishments from the construction sector is rather low, or at least insufficient to keep up with the demand for infrastructure building, incentivizing establishments from this sector to settle down their business.

As far as the tertiary sector is concerned, both models display insignificant results, preventing us to conclude on the existence of any impact from public initiative broadband networks on establishments creation in this sector.

Table 12 provides us with more clear-cut results relatively to the average effect of public initiative networks on consumers surplus and economic health in the region. Both model 1 and 2 predict an average positive impact of the deployment of these networks on households income, which is expected to increase by an average ranging between 600 euros, i.e. by 3%, to 1,190 euros, i.e. by 10% per year. Though we might expect a higher average effect in treated municipalities, in which these networks are being deployed, the results are not significant. These effects are higher than those predicted at the national level for public broadband networks and similar than those stemming from superfast broadband networks (as measured by model 1 using the same estimator).

Both models also highlight a positive effect of public initiative broadband networks on unemployment reduction, which decreases by an average ranging between 5 to 9 percentage points for the whole population, and by an average of 5 to 10 percentage points in treated municipalities. As previously, both models estimate the impact of broadband networks on unemployment more accurately, with similar coefficients. These effects are higher than those predicted at the national level for public broadband networks and roughly similar than those stemming from superfast broadband networks (as measured by model 1 and model 3 using the same estimator).

6 Discussion

Very high speed broadband networks are considered by policy makers to be a significant factor of economic growth in many sectors of the economy. There is a large consensus among economists to support the benefits of infrastructure investment for the national economy. Many countries worldwide have adopted a national broadband plan, in which they set ambitious objectives for broadband availability.

Policy makers seek ways to promote broadband and especially superfast broadband investment, by providing operators with a secure and incentivizing regulatory framework. But also by providing financial support with the deployment of public initiative networks in areas where

private investment alone is unlikely to occur due to the socio-demographic characteristics of the concerned municipalities, low density of population and insufficient return on investment to justify the costs of deployment. Public investment in broadband network is also a tool to bring down the digital divide by providing higher bandwidth in more rural or less densely populated municipalities, enhancing their attractiveness for both companies and households.

As infrastructure investment produces spill overs, it affects all sectors of the national economy. However, the economic benefits vary significantly across sectors. Considering the evolution of the number of establishments, we observe that superfast broadband has a direct effect on the construction sector, as it leads to job creation to deploy the network. It also stimulates further investment in ICT systems or devices, which positively benefits the industrial sector. As foreseen by policy makers and economic analysts, superfast broadband networks have on average a higher positive impact for establishments operating in the tertiary sector, where indirect jobs requiring ICT skills are mostly found.

However, if we take into account the average impact of superfast broadband networks on company creation, the estimation results reveal a mixed picture. Though they confirm that the presence of superfast broadband networks enhances municipality attractiveness for new businesses operating in the tertiary sector, they infirm that superfast broadband networks have an average positive impact on establishment creation in the construction sector. Both results are not antinomic, as superfast broadband networks could have a positive effect on maintaining a healthy economy, by reducing the rate of establishment dissolution.

I also find that superfast broadband networks' benefits spill over to the local population, as household income increases. In addition, broadband networks have a positive impact on unemployment reduction. However, as regards the specific case of public initiative broadband networks at the national level, the estimation results do not confirm such a positive effect, but rather highlight a marginal increase in the unemployment rate. This result is not surprising considering the inherent characteristics of these municipalities. Besides, the effect of very high speed networks are deemed to take time to be reflected in the statistics.

Thus, this paper highlights the benefits of superfast broadband networks on local economic growth, providing further grounds for policy makers to stimulate investments from private op-

erators. Besides, it reveals the positive impacts of public initiative networks on municipality attractiveness for companies and on consumer surplus. Though the average effects of the presence of those networks are lower than the presence of superfast broadband deployed by private operators, they still appear as a factor of local economic development and may be part of a response to address the growing digital divide both between households and territories. By financially supporting the deployment of broadband networks in areas which are not attractive for private operators, local government may help to open up small or medium municipalities, contributing to their economic development.

References

Ahfeldt, G. M., Koutroumpnis, P. and T. Valletti "Speed 2.0: Evaluating Access to Universal Digital Highways," Working paper 2014.

Akerman, A., Gaarder, I. and M. Mogstad (2015) "The Skill Complementarity of Broadband Internet," *The Quarterly Journal of Economics*, 130, 1781–1824

Becker, S. and A. Ichino (2002) "Estimation of Average Treatment Effects Based on Propensity Scores," *The Stata Journal*, 2, 358–377

Bertschek, I., Cerquera, D. and G. J. Klein (2013). "More Bits- More Bucks? Measuring the Impact of Broadband Internet on Firm Performance," *Information Economics and Policy*, 25, 190–203.

Crandall, R. W. and Jackson, C. (2003) "The $500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet," in *Down the Wire: Studies n the Diffusion and Regulation of Telecommunications Technologies*, edited by Shampine, L. Nova Science Publisher.

Crandall, R. W., Litan, R. E. and W. Lehr (2007) "The Effects of Broadband Deployment on Output and Employment: A Cross-Sectional Analysis of U.S. Data" *Issues in Economic Policy*, The Brooklin Institution, Number 6.

Czernich, N., Falck, O., Kretschmer, T. and L. Wößmann (2011). "Broadband Infrastructure and Economic Growth," *Economic Journal*, 121, 505–532.

Czernich, N. (2014). "Does Broadband Internet Reduce the Unemployment Rate? Evidence for Germany," *Information Economics and Policy*, 29, 32–45.

Dimelis, S. P. and S. K. Papaionnou (2011). "ICT Growth Effect at the Industry Level: A comparison between the US and the EU," *Information Economics and Policy*, 23, 37–50.

Dutz, M. Orszag, J. and Robert, W. (2009). "The Substantial Consumer Benefit of Broadband Connectivity for us Households," Compass Lexecon *Internet Innovation Alliance*

Gillet, S.E., Lehr, W.H., Osario, C.A. and M.a; Sirbu (2006) "Measuring the Economic Impact of Broadband Deployment. Final Report," National Technical Assistance, Training, Research and Evaluation Project No. 99-07-13829.

Greenstein, S. and R. C. McDevitt (2011). "The Broadband Bonus: Estimating Broadband Internet's Economic Value," *Telecommunications Policy*, 35, 617–632.

Grimes, A., Ren, C. and P. Stevens (2012). "The Need for Speed: Impacts of Internet Connectivity on Firm Productivity," *Journal of Productivity Analysis*, 37, 187–201.

Gruber, H., Hätönen, J. and P. Koutroumpis (2014). "Broadband Access in the EU: An Assessment of Future Economic Benefits," *Telecommunications Policy*, 38, 1046–1058.

Hagén, H. O., Glantz, J. and M. Nilsson (2008). "ICT Use, Broadband and Productivity.," *Yearbook on Productivity*, (Statistics Sweden), 37–70.

Haller, A. H. and S. Lyons (2015). "Broadband Adoption and Firm Productivity: Evidence from Irish Manufacturing Firms," *Telecommunications Policy*, 39, 1–13.

Hitt, L. and P. Tambe (2007). "Broadband Adoption and Content Consumption," *Information Economics and Policy*, 19, 362–378.

Holt, L. and M. Jamison (2009). "Broadband and Contributions to Economic Growth: Lessons from the US Experience," *Telecommunications Policy*, 33, 575–581.

Imbens, G. (2004). "Nonparametric estimation of average treatment effects under exogeneity. A review," *Review of Economics and Statistics*, 86, 4-29.

Jayakar, K. and E.A. Park (2013) "Broadband Availability and Employment: An Analysis of County-Level Data from the National Broadband Map," *Journal of Information Policy*, 3, 183-200.

Kolko, J. (2012). "Broadband and Local Growth," *Journal of Urban Economics*, 71, 100–113.

Koutroumpis P. (2009). "The Economic Impact of Broadband on Growth: A Simultaneous Approach," *Telecommunications Policy*, 33, 471–485.

Kretschmer T. (2009). "Information and Communication Technologies and Productivity Growth: A Survey of the Literature," *OECD Digital Economy Papers*, 195, 471–485.

McCoy, D., Lyons, S., Morgenroth, E., Palcic, D. and L. Allen (2016). "The Impact of Local Infrastructure on New Business Establishments,"Mimeo.

Mack, A. E. (2014). "Businesses and the Need for Speed: The Impact of Broadband Speed on Business Presence," *Telematics and Informatics*, 31, 617–627.

Röller, L. H. and L. Waverman (2001). "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach," *American Economic Review*, 91(4), 909–923.s

Rosenbaum, P. R. and D. B. Rubin (1983). "The Central Role of the Propensity Score in Observational Studies for Causal Effects," *Biometrika*, 70, 41–45

Van Der Ie, M., Verbrugge, S, Driesse, M. and. and M. Pickavet (2015). "Identifying and Quantifying the Indirect Benefit of Broadband Networks for E-Government and E-Business: A Bottom-Up Approach," *Telecommunications Policy*, 39, 176–191.

Vu, K. M. (2011). "ICT as a Source of Economic Growth in the Information Age: Empirical Evidence from 1996-2005 Period," *Telecommunications Policy*, 35, 357–372.

Whitacre, B., Gallardo, R. and S. Strover (2014). "Broadband's Contribution to Economic Growth in Rural Areas: Moving Towards a Causal Relationship," *Telecommunications Policy*, 38, 1001–1023.

Appendix

Table 1: Descriptive statistics: Superfast Broadband Network

	ATE model 1	***ATE model 2 et 3***	***ATT***
Establishment	51	715	1131
	(0.93)	(26.34)	(46.76)
Industry	4	38	59
	(0.05)	(1.26)	(2.20)
Construction	5	51	80
	(0.07)	(1.93)	(3.45)
Tertiary	40	595	948
	(0.80)	(22.60)	(40.31)
New_establishment	15	175	28
	(0.21)	(5.78)	(10.19)
New_industry	1	7	11
	(0.00)	(0.22)	(0.39)
New_construction	2	23	34
	(0.03)	(0.79)	(1.39)
New_tertiary	10	128	206
	(0.16)	(4.24)	(7.49)
Income (in tsd)	23.9	28.7	29.7
	(0.02)	(0.12)	(0.19)
Unemployment	9.6	9.4	9.4
	(0.00)	(0.02)	(0.03)
Observations	180052	6047	3175

Standard errors in parenthesis

Table 2: Descriptive statistics: Public Initiative Network

	ATE model 1	***ATE model 2 et 3***	***ATT***
Establishment	47	111	128
	(0.90)	(2.48)	(4.50)
Industry	4	7	8
	(0.05)	(0.13)	(0.21)
Construction	4	9	10
	(0.06)	(0.18)	(0.34)
Tertiary	37	89	103
	(0.77)	(2.11)	(3.85)
New_establishment	13	28	32
	(0.20)	(0.55)	(0.99)
New_industry	1	2	2
	(0.00)	(0.22)	(0.04)
New_construction	2	4	4
	(0.03)	(0.08)	(0.14)
New_tertiary	9	20	23
	(0.14)	(0.39)	(0.72)
Income (in tsd)	23.8	24.5	24.5
	(0.02)	(0.02)	(0.03)
Unemployment	9.7	9.7	9.7
	(0.00)	(0.01)	(0.01)
Observations	178524	68644	34321

Standard errors in parenthesis

Table 3: Descriptive statistics: Auvergne

	ATE	***ATT***
Establishment	23	80
	(1.09)	(7.67)
Industry	3	8
	(0.10)	(0.63)
Construction	2	7
	(0.09)	(0.54)
Tertiary	17	61
	(0.90)	(6.45)
New_establishment	6	22
	(0.21)	(1.44)
New_industry	1	2
	(0.02)	(0.09)
New_construction	1	3
	(0.03)	(0.19)
New_tertiary	4	14
	(0.14)	(0.98)
Income (in tsd)	20.1	23.9
	(0.06)	(0.16)
Unemployment	8.5	8.6
	(0.02)	(0.06)
Observations	6444	813

Standard errors in parenthesis

DATAR Indexes

The two indexes provides informations on municipalities which do not belong to an urban unity of more than 10,000 employments.

First Index: Typological classification Three groups have been identified, leading to the creation of seven classes:

- Municipalities located around a town or city, around a coastline, and around an urbanized valley. This category is divided in three classes:
  - densely populated municipalities, in the suburb, with a high residential growth and a dynamic economy;
  - extended municipalities, in the suburb, with residential growth and a diversified economic dynamic;
  - densely populated municipalities, in the coastline or in the valley, with a high residential growth and a "in-place" economy.[23]
- Agricultural and industrial sector municipalities, under a low urban influence.
- "Aged-municipalities" with a low population density. This category is divided into three classes:
  - low-income municipalities, in-place and agricultural economy;
  - low-income municipalities, with residential growth, in-place and touristic economy;
  - low-income municipalities, with residential growth, dynamic in-place and touristic economy, distant from basic services.
- All municipalities belonging to an urban unity with more than 10,000 employments.

[23] French economic notion describing an economy based on the population being really present on a territory, which could vary and which both produce and consume.

Second Index: Economic Classification The second index is composed of four groups, leading to the creation of eight classes.

- Municipalities with economic growth, high rate of post-graduate diploma. This category is divided in two classes:
  - located in the suburb, low unemployment rate;
  - municipalities under the influence of an urban area with a diversified economy and a medium unemployment rate.
- Municipality with a dominant residential and touristic economy. This category is divided in three classes:
  - with a very low unemployment rate;
  - with a high unemployment rate;
  - with uncertainty relatively to the economic growth, a medium level of formation and a medium unemployment rate. This category is divided in three classes:
    - municipalities under the influence of an urban area, with a residential and industrial sector economy;
    - dominant industrial sector economy;
    - dominant agricultural economy.
- Municipalities with a labor market in difficulty, with a low growth rate, a high unemployment rate and a low rate of postgraduates.
- All municipalities belonging to an urban unity with more than 10,000 employments.

Table 4: Number of establishments

	Model 1			
	Establishment	Industry	Construction	Tertiary
ATE	10.305***	0.955***	1.365***	7.986***
	(1.784)	(0.215)	(0.338)	(1.460)
ATT	271.476***	14.841***	17.582***	239.053***
	(31.901)	(1.834)	(4.519)	(28.145)
	Model 2			
	Establishment	Industry	Construction	Tertiary
ATE	217.997***	12.871***	4.116	201.010***
	(19.260)	(1.471)	(3.340)	(17.208)
ATT	407.104***	21.664***	13.298**	372.141***
	(31.784)	(2.181)	(5.391)	(27.483)
	Model 3			
	Establishment	Industry	Construction	Tertiary
ATE	356.046***	18.183***	27.616***	310.247***
	(34.765)	(1.672)	(3.631)	(30.253)
ATT	682.194***	34.058***	58.491***	589.645 ***
	(52.587)	(2.528)	(6.034)	(45.350)

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5: Number of new establishments

	Model 1			
	New_establishment	New_industry	New_construction	New_Tertiary
ATE	-0.946	-0.151	-0.116	-0.679
	(1.603)	(0.173)	(0.288)	(1.333)
ATT	8.592*	0.254	-4.409***	12.747***
	(4.654)	(0.239)	(1.193)	(3.694)
	Model 2			
	New_establishment	New_industry	New_construction	New_Tertiary
ATE	-2.980	-0.117	-7.541***	4.678**
	(2.763)	(0.214)	(0.789)	(2.282)
ATT	-4.797	-0.274	-13.094***	8.571**
	(3.938)	(0.297)	(1.291)	(3.183)
	Model 3			
	New_establishment	New_industry	New_construction	New_Tertiary
ATE	57.986***	2.055***	2.350	53.581***
	(12.934)	(0.459)	(2.466)	(10.214)
ATT	100.355***	3.772***	4.514	92.069***
	(21.441)	(0.731)	(4.356)	(16.644)

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6: Evolution of income and unemployment rate

	Model 1		***Model 2***		***Model 3***	
	Income	Unemployment	Income	Unemployment	Income	Unemployment
ATE	1.701**	-1.201***	1.235***	-0.551***	1.856***	-0.727**
	(0.816)	(0.150)	(0.296)	(0.078)	(0.359)	(0.231)
ATT	3.033***	-0.345***	2.605***	-0.256**	2.741***	-0.688
	(0.263)	(0.094)	(0.349)	(0.114)	(0.376)	(0.423)

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7: Number of establishments RIP France

	Model 1			
	Establishment	Industry	Construction	Tertiary
ATE	1.116**	0.0247	-0.102	1.193**
	(0.569)	(0.039)	(0.0931)	(0.502)
ATT	8.325**	0.392**	0.088	7.844***
	(2.811)	(0.173)	(0.453)	(2.481)
	Model 2			
	Establishment	Industry	Construction	Tertiary
ATE	6.546***	0.366***	-0.254	6.434***
	(1.418)	(0.092)	(0.203)	(1.251)
ATT	9.330***	0.395***	0.127	8.807***
	(1.942)	(0.095)	(0.234)	(1.723)
	Model 3			
	Establishment	Industry	Construction	Tertiary
ATE	21.419***	1.258***	2.018***	18.142***
	(3.357)	(0.198)	(0.402)	(2.914)
ATT	53.364***	3.026***	4.926***	45.411***
	(4.512)	(0.240)	(0.483)	(3.853)

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 8: Number of new establishments RIP France

	Model 1			
	New_establishment	New_industry	New_construction	New_Tertiary
ATE	0.224**	-0.001	-0.083***	0.316***
	(0.093)	(0.009)	(0.025)	(0.075)
ATT	0.837**	0.031	-0.349***	1.155***
	(0.397)	(0.026)	(0.101)	(0.319)
	Model 2			
	New_establishment	New_industry	New_construction	New_Tertiary
ATE	0.608**	0.027	-0.290***	0.871***
	(0.223)	(0.017)	(0.047)	(0.201)
ATT	0.771***	0.020	-0.334***	1.085***
	(0.147)	(0.017)	(0.053)	(0.140)
	Model 3			
	New_establishment	New_industry	New_construction	New_Tertiary
ATE	0.968**	0.035	-0.014	0.946**
	(0.471)	(0.033)	(0.114)	(0.387)
ATT	3.514***	0.182***	0.183	3.150***
	(0.722)	(0.051)	(0.155)	(0.561)

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 9: Evolution of income and unemployment rate RIP France

	Model 1		***Model 2***		***Model 3***	
	Income	Unemployment	Income	Unemployment	Income	Unemployment
ATE	-0.203***	-0.016	0.077**	0.038**	0.158***	0.031*
	(0.033)	(0.013)	(0.033)	(0.013)	(0.048)	(0.017)
ATT	-0.086*	-0.023	0.313***	0.075***	0.193***	0.064***
	(0.043)	(0.016)	(0.033)	(0.012)	(0.053)	(0.019)

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 10: Number of establishments Auvergne

	Model 1			
	Establishment	Industry	Construction	Tertiary
ATE	1.492	-0.204	0.395**	1.3
	(0.998)	(0.160)	(0.158)	(0.813)
ATT	1.521	-1.212**	1.993***	0.740
	(4.739)	(0.452)	(0.448)	(4.158)
	Model 2			
	Establishment	Industry	Construction	Tertiary
ATE	6.510**	0.134	0.645**	5.731**
	(3.223)	(0.397)	(0.301)	(2.591)
ATT	42.683*	3.299	4.975*	34.408*
	(23.2)	(2.782)	(2.07)	(18.564)

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 11: Number of new establishments Auvergne

	Model 1			
	New_establishment	New_industry	New_construction	New_Tertiary
ATE	-0.213	-0.161**	0.035	-0.087
	(0.210)	(0.067)	(0.052)	(0.173)
ATT	-0.275	-0.416**	0.341*	-0.199
	(0.690)	(0.138)	(0.131)	(0.584)
	Model 2			
	New_establishment	New_industry	New_construction	New_Tertiary
ATE	0.883	-0.074	0.131	0.826
	(1.018)	(0.087)	(0.153)	(0.811)
ATT	8.079	0.277	1.263	6.539
	(8.223)	(0.496)	(1.206)	(6.548)

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 12: Evolution of income and unemployment rate Auvergne

	Model 1		***Model 2***	
	Income	Unemployment	Income	Unemployment
ATE	0.637**	-0.762***	1.978***	-0.396***
	(0.217)	(0.084)	(0.277)	(0.093)
ATT	0.419	-0.452***	0.441	-0.848***
	(0.347)	(0.130)	(0.435)	(0.159)

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 13: Percentage change with superfast broadband networks

	Establishment	Industry	Construction	Tertiary
	Model 1			
ATE	20%	24%	30%	20%
ATT	24%	25%	22%	25%
	Model 2			
ATE	30%	33%		33%
ATT	36%	37%	17%	40%
	Model 3			
ATE	50%	48%	33%	52%
ATT	60%	58%	73%	62%

Percentage changes are only shown for significant results

Table 14: Percentage change with superfast broadband networks

	New_establishment	New_industry	New_construction	New_tertiary
	Model 1			
ATE				
ATT	3%		-13%	6%
	Model 2			
ATE			-34%	4%
ATT			-38%	4%
	Model 3			
ATE	33%	29%		42%
ATT	36%	34%		45%

Percentage changes are only shown for significant results

Table 15: Percentage change with superfast broadband networks

	Model 1		***Model 2***		***Model 3***	
	Income	Unemployment	Income	Unemployment	Income	Unemployment
ATE	7%	-13%	4%	-6%	6%	-8%
ATT	10%	-4%	9%	-3%	9%	-7%

Percentage changes are only shown for significant results

Table 16: Percentage change with public initiative broadband networks

	Establishment	Industry	Construction	Tertiary
	Model 1			
ATE	2%			3%
ATT	7%	5%		8%
	Model 2			
ATE	6%	5%		7%
ATT	7%	5%		9%
	Model 3			
ATE	19%	17%	22%	21%
ATT	42%	37%	49%	44%

Percentage changes are only shown for significant results

Table 17: Percentage change with public initiative broadband networks

	New_establishment	New_industry	New_construction	New_tertiary
	Model 1			
ATE	2%		-10%	3%
ATT	3%		-8%	5%
	Model 2			
ATE	2%		-7%	4%
ATT	2%		-8%	5%
	Model 3			
ATE	11%			
ATT	11%			14%

Percentage changes are only shown for significant results

Table 18: Percentage change with public initiative broadband networks

	Model 1		***Model 2***		***Model 3***	
	Income	Unemployment	Income	Unemployment	Income	Unemployment
ATE	-1%		0.3%	0.4%	0.6%	0.3%
ATT	-0.4%		1.3%	0.8%	0.8%	0.7%

Percentage changes are only shown for significant results

Table 19: Percentage change with public initiative broadband networks in Auvergne

	Establishment	Industry	Construction	Comm-adm
	Model 1			
ATE				
ATT		-16%	28%	
	Model 2			
ATE	30%		28%	35%
ATT	53%		69%	56%

Percentage changes are only shown for significant results

Table 20: Percentage change with public initiative broadband networks in Auvergne

	New_establishment	New_industry	New_construction	New_comm_adm
	Model 1			
ATE		-23%		
ATT		-24%	11%	
	Model 2			
ATE				
ATT				

Percentage changes are only shown for significant results

Table 21: Percentage change with public initiative broadband networks in Auvergne

	Model 1		***Model 2***	
	Income	Unemployment	Income	Unemployment
ATE	3%	-9%	10%	-5%
ATT		-5%		-10%

Percentage changes are only shown for significant results