Impact of Fiber on Firm Creation: Evidence from France*

Marc Bourreau† Lukasz Grzybowski‡ Ángela Muñoz-Acevedo§
Sylvain Dejean¶

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Abstract

In this paper, we estimate staggered difference-in-difference models to assess the impact of high-speed broadband roll-out on the creation of firms in three categories of municipalities in France. We find that the roll-out of fiber significantly impacted the creation of firms in 'greater municipalities.' The number of firms in this category increased on average by 11.41 (7.3% relative to the mean number of firms). We also find that within four years since fiber deployment, on average 45.70 firms were created. In the case of 'commuter municipalities,' the average treatment effect is 0.41, which corresponds to an increase of 5.3% relative to the mean number of firms in this category. There is also a significant dynamic effect, with an increase by 15% within three years after fiber deployment. For the third category of 'rural municipalities,' we do not find that the deployment of high-speed broadband impacted the creation of firms.

Keywords: High-Speed Broadband; Economic Impact; Firm Creation.

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†Telecom Paris, Institut Polytechnique de Paris, Department of Economics and Social Sciences, 19 Place Marguerite Perey, 91120 Palaiseau, France. E-mail: marc.bourreau@telecom-paris.fr

‡Telecom Paris, Institut Polytechnique de Paris, Department of Economics and Social Sciences, 19 Place Marguerite Perey, 91120 Palaiseau, France. E-mail: lukasz.grzybowski@telecom-paris.fr

§Telecom Paris, Institut Polytechnique de Paris, Department of Economics and Social Sciences, 19 Place Marguerite Perey, 91120 Palaiseau, France. E-mail: angela.munozacevedo@telecom-paris.fr and Deloitte France

¶La Rochelle Universite, CEREGE, F-17000 La Rochelle, France. E-mail: sylvain.dejean@univ-lr.fr

1 Introduction

The deployment of high-speed broadband is strategically important for creating a digital single EU market and for the economic and social development. Innovative online services, such as immersive technologies, tele-health, e-government and many others, depend on universal access to high-speed broadband.

In 2013, the French government launched the *Plan France Très Haut Débit* (hereafter, the "French Broadband Plan") to stimulate universal broadband deployment. This plan sets out the rules for deploying fiber-to-the-home (FTTH) broadband infrastructure in France, dividing the country into private and public initiative zones. Private initiative zones are densely populated and policy makers expect that firms will commercially deploy fiber infrastructure without need for public funding. Public initiative zones are typically rural or suburban and policy makers expect that fiber will not be deployed here commercially by private investors. Thus, with financial support from the State and the European Union, local authorities in these areas can form partnerships with private operators to deploy fiber.

Public authorities estimated that a total investment of 21 billion Euros over ten years from public and private sources is needed to achieve the objectives set by the "French Broadband Plan". This funding scheme should enable access to high-speed broadband to people living in less attractive and less densely populated areas, stimulating economic development and reducing the digital divide.

There is a growing body of literature on the impact of broadband on economic development, which we will review in the next section. For earlier empirical evidence on the positive impact of telecommunications and broadband infrastructure on economic growth, see Röller and Waverman (2001) and Czernich et al. (2011). In general, high-speed broadband infrastructure should contribute to economic development and job creation through increased productivity and innovation in products and services. In this paper, we study how the deployment of high-speed broadband impacts economic growth via firm creations at the municipality level in France. We use panel data from about 34,000 municipalities in France in the years 2014-2019. We estimate different models using the staggered difference-in-difference approach, considering that the impact of high-speed broadband may differ depending on the nature and economic role of the municipalities in their area, which are divided into three groups which we call 'greater municipalities', 'commuter municipalities' and 'rural municipalities'.

We find that the roll-out of fiber significantly impacted the creation of firms in 'greater municipalities.' The number of firms in this category increased by 11.41 (i.e., 7.3% more relative to the mean number of firms). We also find that within four years since fiber deployment, on average, 45.70 firms were created. In the case of 'commuter municipalities,' the simple average treatment effect is 0.41, which corresponds to an increase of 5.3% relative to the mean number of firms in this category. There is also a significant dynamic effect, with an increase of 15% within three years after fiber deployment. For the third category of 'rural municipalities,' we do not find that the deployment of high-speed broadband (positively) impacted the creation of firms.

The remainder of the paper is organized as follows. In Section 2, we review the related literature. In Section 3, we remind the objectives of the Digital Agenda for Europe, provide an overview of the EU State aid scheme, and describe the main features of the French Broadband Plan. In Section 4 we present our data sets. In Section 5, we introduce the econometric framework, and in Section 6 we discuss the estimation results. Finally, Section 7 concludes.

2 Literature Review

Our paper contributes to the growing literature on the impact of broadband infrastructure on economic growth and firm creation. In a related paper, Hasbi (2020) uses a sample of 5,000 French municipalities from 2010-2015, which corresponds to the early stage of the French Broadband Plan. She finds that the deployment of fiber positively impacted the creation of firms. In another paper, Duvivier et al. (2018) study the impact of public deployment of broadband on firm creation in the rural areas of the Auvergne region in France, using a difference-in-differences propensity score matching estimator. They find that broadband deployment increased the number of firms in three sectors: (i) food and accommodation services; (ii) public administration, education, human health, and social work activities; and (iii) other services. Similarly, Lapointe (2015) finds a positive impact of fiber roll-out on employment and the number of firms at the county level using data from the National Broadband Map in the U.S.

There is also a growing body of research on the impact of Internet access on labor markets. The evidence shows that the Internet has made labor markets more efficient as information about job openings can reach a broader audience while reducing search costs (see Autor (2001)). However, empirical evidence also suggests that access to the Internet and digitization benefits educated and skilled workers more than unskilled ones. In particular, Atasoy (2013) uses U.S.

county-level panel data from 1999 to 2007 and finds that increased broadband penetration led to a 1.8 percentage point increase in employment. He suggests that broadband adoption complements skilled labor as counties with a more significant proportion of college-educated individuals had higher employment rates. In addition, broadband access increases employment in industries with higher share of college-educated individuals, but has the opposite effect in lower-skilled industries. In another paper, Akerman et al. (2014) use rich Norwegian firm-level data and estimate production functions, where firms can change their technology by adopting broadband Internet. They conclude that broadband Internet complements skilled workers in executing non-routine abstract tasks and substitutes for unskilled workers in performing routine tasks.

There is also a small body of literature on the impact of State aid on the deployment of broadband networks. This literature focuses mainly on case studies of European Union member states. Matteucci (2019) discusses the effect of the Italian State aid plan for deploying the first generation of broadband. He argues that State aid stimulated the expansion of broadband coverage in rural areas, but with a delay compared to other areas. Briglauer et al. (2019) assess the impact of a State aid program introduced by the German State of Bavaria in 2010 and 2011 to improve broadband availability in rural areas. The authors find that aided municipalities have higher broadband coverage at a higher speed than non-aided municipalities. Duso et al. (2021) study the impact of State aid broadband plans implemented in Germany between 2011 and 2013 on broadband availability and competition. They find that State aid has improved broadband coverage in the targeted areas without distorting local competition. Briglauer and Grajek (2021) use cross-country data to study the effectiveness of State aid programs for the deployment of new fiber broadband networks. Using data from 32 OECD countries for 2002-2019, they find that State aid significantly increased broadband coverage. Finally, Wilson (2021) studies the impact of public investment in broadband infrastructure on private investment using nationwide U.S. data. He estimates the demand for internet access and a dynamic oligopoly model where private and public firms make entry and investment decisions. He finds that public investment crowds out private investment to some extent. However, this effect is dominated by a dynamic preemption effect, whereby the threat of public provision of broadband induces private firms to invest preemptively.

3 State Aid for Broadband and the French Broadband Plan

3.1 EU Digital Agenda and State Aid for Broadband

In May 2010, the European Union (EU) announced its Digital Agenda to boost Europe's economy and consolidate the EU Digital Single Market. At the time, Europe was lagging behind other regions in terms of fast and reliable digital networks.[1] Moreover, coverage with very-high capacity fiber networks capable of delivering high-speed broadband[2] was much smaller in rural areas than in urban areas, revealing a persistent digital divide. In 2011, 10% of households were covered with very-high capacity networks in the EU but only 2% in rural areas.[3]

Several factors can explain the slow transition from basic to high-speed broadband. First, on the supply side, the roll-out of very-high capacity networks requires large fixed and sunk costs. Operators may also face an opportunity cost when deploying next-generation networks due to their revenues from the legacy copper network (the so-called "replacement effect"). Finally, operators deploying fiber face competition from Internet service providers using other technologies (e.g., DSL and cable). On the demand side, switching costs may refrain basic broadband users from subscribing to new high-speed broadband offers. Moreover, their willingness to pay for higher speeds might be low, at least at the early stages of the diffusion of the new technology.

Most importantly, in rural and less densely populated areas, there may be a market failure for the provision of high-speed broadband. While deployment costs are higher than in dense urban areas, the potential demand might be low and/or uncertain. Thus, private operators may have no incentive to deploy high-speed broadband networks in these areas. However, it may be socially desirable to cover these areas due to high economic and social benefits not internalized by market players.

As demand for fast and reliable connectivity increases and the digital divide becomes visible, the need for widespread deployment of very-high capacity networks has become a primary objective. The 2010 Digital Agenda for Europe defined the objective of providing at least 50% of European households with access to high-speed broadband by 2020. In 2016, the EU updated its target, with the objective that by 2025, all EU households have access to high-speed broadband.[4]

[1] See: European Commission, "The EU explained: Digital Agenda for Europe," November 2014.

[2] Very-high capacity networks (VHCN) correspond to "any network providing a fixed-line connection with fiber roll out at least up to the multi-dwelling building" or any network providing the same quality of service (BEREC, 2020). High-speed broadband, allowing connection speeds of 100Mbps or more, requires VHCNs.

[3] Source: European Commission, "Digital Economy and Society Index (DESI)," 2020, p. 10-11.

[4] See: European Commission, "Connectivity for a Competitive Digital Single Market - Towards a European

To foster the deployment of very-high capacity networks, the European Commission issued recommendations on next-generation access networks and revised its State aid guidelines for broadband deployments. State aid is an important policy tool for the deployment of networks in rural and low-density areas, where it is not financially viable for private operators to deploy on their own.[5]

State aid control is intended to ensure that the positive effects of the aid outweigh possible distortions of competition. For broadband specifically, State aid schemes must achieve a higher level of coverage and penetration in areas where a market failure exists. State aid should also not be granted in areas where market operators have already invested or would normally choose to invest. Otherwise, they would crowd out private investment and distort competition.

3.2 The French Broadband Plan

In 2013, the French government launched the *Plan France Très Haut Débit*. This plan supports the design and funding of broadband infrastructure in France, mainly based on fiber-to-the-home (FTTH) networks.

Under this program, the French territory is divided into private and public initiative zones. Private initiative zones are areas where fiber deployment does not require public funding. In very densely populated areas, the deployment of fiber networks is expected to be driven by infrastructure-based competition.[6] In some less densely populated areas, major telecommunications operators have also expressed their intention to deploy very-high capacity networks without public support.

Public initiative zones are areas (typically rural) where no private investment is planned for the deployment of fiber networks. With the support of the State and the EU, local authorities can cover these areas by forming partnerships with private operators. Access to the subsidized network must be open and non-discriminatory, with oversight by the French regulator, ARCEP.

Figure 1 shows the distribution of private and public initiative zones in the fourth quarter of 2020. Public authorities estimated that a total investment of 21 billion euros over 10 years,

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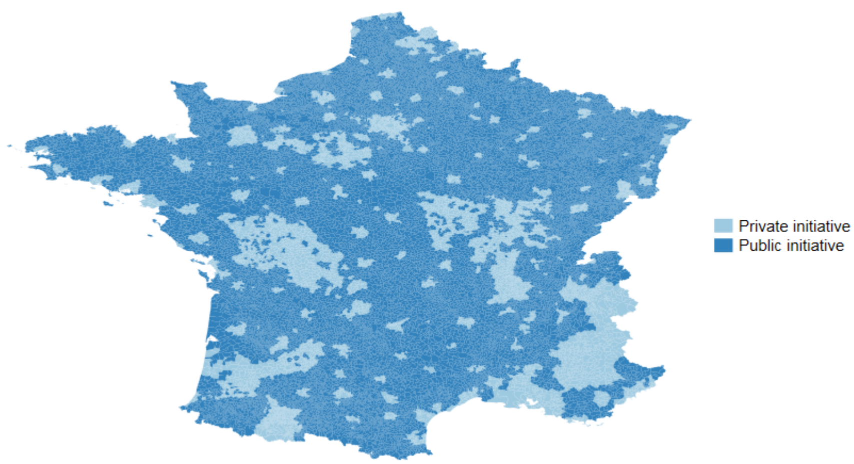
Gigabit Society," COM(2016) 587 final.

[5] Article 107(1) of the Treaty on the Functioning of the European Union (TFEU) defines State aid as "any State resources granted by a Member State which distorts or threatens to distort competition by favoring certain undertakings or the production of certain goods."

[6] Very dense areas were defined by ARCEP in 2009 as a list of 148 municipalities. In 2013, ARCEP revised the list, reducing the number of municipalities to 106 due to the absence of deployment or infrastructure-based competition in some municipalities.

from both public and private sources, would be necessary to achieve the objectives set by the French Broadband Plan.[7] Within this total investment, the program consolidates a State budget of around 3 billion euros to support the deployment of public initiative networks (*"Reseaux d'initiative publique"* or "RIP" by its French acronym). Eligibility for State funding is subject to examination by the ANCT (*"Agence Nationale de la Cohésion des Territoires"*, previously *"Agence du Numerique"*).[8]

Figure 1: Public and private initiative zones for fiber coverage in France as of the fourth quarter of 2020.



Source: own elaboration based on data from AVICCA.
Note: 27,566 municipalities are categorized as public initiative zones and 6,792 as private initiative zones. 85 municipalities are mixed initiative zones (they have both private and public initiative networks). They are depicted here as part of the private initiative zone.

State subsidies are paid in several installments, spread over several years, at the rate of the construction of the network and after proof that the network has been built in accordance with current regulations and technical specifications. Projects are designed at the department or

[7] See: France Strategie (2020), *"Déploiement du très haut débit et Plan France très haut débit : évaluation socioéconomique"*, Technical report.

[8] State aid concerns only certain parts of the network, namely passive elements of the network, civil engineering works, reception equipment for satellite technologies and terrestrial wireless networks - exceptionally and in a limited manner – and studies directly related to the project.

supra-department level, and applications are under the responsibility of local authorities.[9]

In 2016, the European Commission approved the French Broadband Plan. As of January 2021, 82 projects were eligible to State aid (74 in Mainland France). Table 7 in the Appendix presents the list of projects with the departments or regions concerned.

4 Data

Our sample is composed of 34,436 municipalities in France over the period 2014-2019. We combine two types of data for each municipality: (i) data on the deployment of fiber infrastructure, and (ii) data on firm creations.

Data on fiber infrastructure We received data from ARCEP on the geographic location, deployment status, and the identity of the fiber infrastructure operator for more than 16 million buildings in France as of June 2020. We aggregate this data at the municipality level using the geographic location of each building. The data contains information about the date of availability of the mutualization point (MP) of each building. We adopt this date as the date of fiber deployment, as it indicates that the costliest part of the fiber network has been deployed.[10]

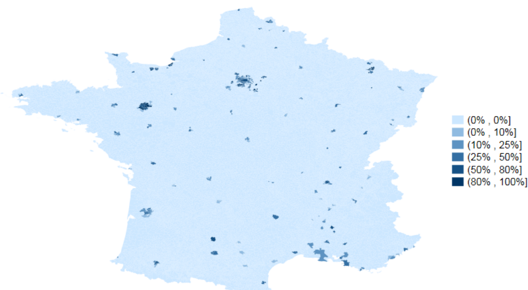
For each quarter between 2014-2019, we thus observe the number of fiber operators and the number of fober lines deployed in each municipality of Mainland France. We consider that a municipality is covered once the first fiber line has been deployed. It is a reasonable assumption for two reasons. First, once fiber deployment has started in a municipality, a significant part of the investment effort has already been realized. Second, once the fiber infrastructure is available somewhere in the municipality, the opportunity exists for a company to locate in a place covered by the high-speed broadband network.

Panels (a) and (b) of Figure 2 show the geographic location of fiber deployments in the first period (2014Q1) and the last period (2019Q4) covered by our data. The first deployments occurred in the main urban areas, and then tend to expand as clusters around the municipalities initially covered.

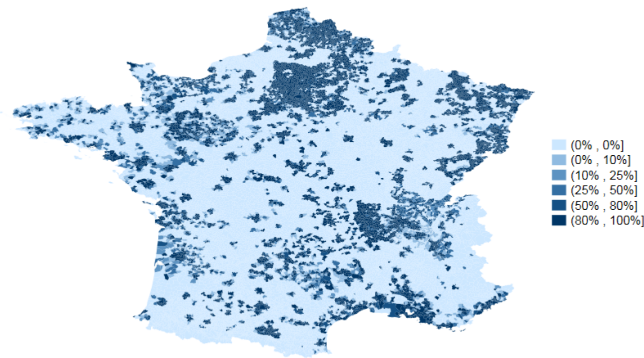
[9] Local authorities are French administrative structures, distinct from the State administration, which are in charge of the interests of the population of a specific territory (municipalities, departments, regions, etc.). Local authorities can join forces to exercise their powers by creating public cooperation bodies.

[10] For some buildings, the MP availability date is missing. In this case, we replace the missing information by the availability date of the first optical connection point (*Point de branchement optique* in French) deployed in the building.

Figure 2: fiber coverage in Mainland France municipalities, 2014Q1 and 2019Q4.



(a) 2014Q1



(b) 2019Q4

Firm creation: We use the repertory of firms and establishments (REE) provided by the French National Institute for Statistics and Economic Studies (INSEE). For each municipality and each year, we have data on the stock of firms and establishments, and the number of newly created entities. This information is also available at the sector level in 9 categories: industry; construction; retail, lodging and catering; information and communication; financial and insurance activities; housing activities; specialized science and technical activities; public administration; health and education; other services (including arts, entertainment and associative services).

Other data on characteristics of municipalities: We obtained socio-economic information at the municipality level from INSEE. In particular, we have municipal-level data on the population size (defined as the number of households). This information is published with a two-year delay and is available until 2017. In addition, we have information on the share of population with a college degree.

Finally, we use information on the quality of the legacy copper network in each municipality. We obtained this data set from the French incumbent operator Orange. In general, broadband signals traveling along a copper line from an exchange point to a customer's location suffer attenuation. This is called copper loss and translates into a reduction of speed on DSL access. The further a customer is from the exchange, the more copper loss they can experience. We use this information as a proxy for the opportunity cost operators may face when deploying next-generation networks due to their revenues from the legacy copper network (the so-called "replacement effect"). In our data, municipalities are assigned to the following categories based on the average quality of copper lines measured in decibels (dB): 20dB and below (outstanding); 20-30dB (excellent); 30-40dB (very good); 40-50dB (good); 50-60dB (poor and may experience connectivity issues); and 60dB or above (bad, will experience connectivity issues).

We merged the different data sets using the unique INSEE code for each municipality. After merging, we have information on 34,443 municipalities in Mainland France for the years 2014-2019.[11]

Categorization of municipalities: There is a lot of heterogeneity across municipalities in terms of economic attractiveness and density of population. Thus, an important challenge for our difference-in-difference empirical strategy is to ensure that municipalities in the control and treatment groups are comparable. To create the control group, we use a propensity score matching approach using the following set of municipality characteristics: (i) the size of the city (in number of households); (ii) the share of population with a college degree; (iii) the average copper loss; and (iv) the stock of firms in 2014.

Besides, to analyze the impact of fiber deployment on firm creation, we divide municipalities into the following three INSEE categories: (i) Greater City, (iii) Functional Urban Area (FUA), and (iii) Rural Area. A Greater City corresponds to the urban center and its expansion beyond the administrative city boundaries. A Functional Urban Area consists of the Greater City and of a surrounding area (commuting zone) whose labour market is highly integrated with the city. The Functional Urban Areas gather 95% of the population in France. The remaining 5% of the population and 25% of the municipalities are Rural Areas. We respectively divide municipalities in France into these three categories and call them: (i) 'greater municipalities'; (ii) 'commuter municipalities'; and (iii) 'rural municipalities'. Table 1 provides descriptive statistics for these three categories. We expect that the roll-out of high-speed broadband has a different impact on the creation of firms in each category of municipalities.

[11]There were 34,479 municipalities in Mainland France in the year 2020. Due to administrative changes in the years 2014-2019 (some municipalities split and others merged) and lack of information for some small municipalities in the different data sources, we removed from the data 36 small municipalities.

Table 1: Statistics for the three categories of municipalities

		Mean				
	Obs.	Population	Density	Firms	fiber 2014 (%)	fiber 2019 (%)
Greater	1,700	16,916	16.5	150.1	0.23	0.75
Commuter	23,942	1,124	1.0	7.6	0.01	0.36
Rural	8,794	494	0.4	3.2	0.00	0.20
Total	34,436	1,743	1.6	13.5	0.02	0.34

Finally, Table 2 shows the timing of the treatment for these three types of municipalities. For the 'greater municipalities', the ratio between treated and untreated is balanced. This is less the case for the 'commuter municipalities', where the deployment of fiber accelerated in 2018. By the end of 2019, 64% of municipalities in this category were still non-treated. Yet, we have a relatively large number (8,000) of treated municipalities. For the 'rural municipalities', the deployment of the high-speed broadband is slower and few municipalities were treated during the period of our data.

Table 2: Timing of the treatment

	Never	2014	2015	2016	2017	2018	2019	Total
Greater	431	394	71	258	213	147	186	1,700
(%)	25.4	23.2	4.2	15.2	12.5	8.7	10.9	100
Commuter	15,357	211	332	751	1,057	2,410	3,824	23,942
(%)	64.1	0.9	1.4	3.1	4.4	10.1	16.0	100
Rural	7,056	8	20	124	163	376	1,047	8,794
(%)	80.2	0.1	0.2	1.4	1.9	4.3	11.9	100
Total	22,844	613	423	1,133	1,433	2,933	5,057	34,436
(%)	66.3	1.8	1.2	3.3	4.2	8.5	14.7	100

5 Empirical Strategy

As discussed in the previous section, there are differences in the timing of fiber roll-out across municipalities in France. The earlier literature, based on panel data and the difference-in-difference (DiD) approach, estimated models including period and group fixed effects (see Lapointe (2015), Hasbi (2020) and Aldashev and Batkeyev (2021)). However, in a recent paper de Chaisemartin and D'Haultfoeuille (2020) demonstrate that when the treatment varies both across groups and over time, what is estimated are weighted sums of the average treatment effects (ATE) in each group and period, with weights that may be negative. Due to the negative weights, the linear regression coefficient may be negative, while all the ATEs are positive. They propose an estimator that solves this issue. Goodman-Bacon (2021) also shows that the two-way fixed effects estimator equals a weighted average of all possible two-group/two-period DiD estimators in the data. A causal interpretation of two-way fixed effects DiD estimates requires a parallel trends assumption and treatment effects constant over time. He shows how to decompose the difference between two specifications and provides a new analysis of models that include time-varying controls. Callaway and Sant'Anna (2021) show that a family of causal effect parameters are identified in staggered DiD setups, even if differences in observed characteristics create non-parallel outcome dynamics between groups. Their methodology deals with the issues of (i) multiple time periods, (ii) variation in treatment timing, and (iii) when the "parallel trends assumption" holds potentially only after conditioning on observed covariates.

We follow the approach proposed by Callaway and Sant'Anna (2021), where in our case the deployment of high-speed broadband varies over time and the effect on the local economy may come with a delay. We define G as the time period when a unit first becomes treated. Thus, for all units that eventually participate in the treatment, G defines which 'group' they belong to. Next, G_g denotes a binary variable that is equal to one if a unit is first treated in period g (i.e., $G_{i,g} = 1\{G_i = g\}$). We use the average treatment effect for units who are members of a particular group g at a particular time period t, denoted by:

$$ATT(g,t) = E[Y_t(g) - Y_t(0)|G_g = 1] \text{ with } t \geq g \tag{1}$$

This causal parameter is called the group-time average treatment effect, where $Y_t(g)$ is the potential outcomes at time t when the treatment begins in period g and $Y_t(0)$ is the potential outcome without treatment. A separate parameter is estimated for each 'group' or 'cohort' of municipalities, which have been connected to the fiber network at a particular period. This specification allows to account for the dynamic effects of the treatment, where parameters can be estimated at different points in time for a given first period treatment.[12]

The following conditions need to be satisfied for the identification of the effect of fiber deployment. The first condition is the irreversibility of the treatment, which is the case because the high-speed broadband network cannot be removed after deployment. The second condition

[12] See the discussion on the contribution of Callaway and Sant'Anna, (2021) in the blogpost of Scott Cunningham https://causalinf.substack.com/p/callaway-and-santanna-dd-estimator?s=r

is the non-anticipation of the treatment. In our case, a firm may decide to locate in a municipality anticipating that high-speed broadband will be deployed there in the future. However, this is unlikely if the firm needs a high-speed broadband connection immediately and with certainty. Third, as in all DiD models, the parallel trend condition is probably the most difficult to satisfy. The non-randomization of the treatment requires that statistical methods are used to match treated and non-treated units with similar characteristics. This is especially the case in our context because the decision to roll out high-speed broadband in a municipality is driven by its characteristics. Thus, we use propensity score matching methods in the first stage to form treated and non-treated groups, which include municipalities with similar characteristics.

In general, in the panel data framework, the control group may include 'never-treated' or 'not-yet-treated' units. Callaway and Sant'Anna (2021) suggest using 'never-treated' units as long as their number is sufficient in comparison to the size of treated group. Following their suggestion, we use 'never-treated' municipalities in the control group. In particular, Callaway and Sant'Anna (2021) propose the following propensity score matching approach:

$$P_{g,t}(X) = P(G_g = 1|X, G_g + (1 - D_t)(1 - G_g) = 1) \tag{2}$$

where $P_{(g,t)}(X)$ is the probability of being in the treatment group at time g conditional on the covariates denoted by X and on either being a member of group g (in this case, $G_g = 1$) or a member of the 'not-yet-treated' group by time t (in this case, $(1 - D_s)(1 - G_g) = 1$). Because the treatment takes place in different periods, the covariates used for the propensity score should be from the pre-treatment period.

Callaway and Sant'Anna (2021) propose an unbiased and consistent estimator of equation (2) based on the procedure developed by Sant'Anna and Zhao (2020). We use this approach which is implemented in Stata by Rios-Avila et al. (2022).[13] Next, different parameters which are estimated for the group-time average treatment effects are aggregated following the approach proposed by Callaway and Sant'Anna (2021). The computed effect represents in our case a total effect of being a municipality connected to the fiber network. This approach allows us to account for different dimensions of fiber roll-out, such as time and cohort-specific effects and dynamic effects.

[13] In particular, the logit model is used to estimate the propensity score.

6 Estimation Results

The methodology proposed by Callaway and Sant'Anna (2021), which we use in this paper, allows estimating aggregated ATT by cohort, time, and the dynamic effect which is measured within a certain time after treatment. The results for our three categories of municipalities: (i) greater, (ii) commuter, and (iii) rural, are shown in Tables 3, 4 and 5, respectively. Below, we discuss the estimation results for each category.

In the case of 'greater municipalities', the ATT suggests that the roll-out of fiber increased the number of firms by 11.41 (7.3% more relative to the mean number of firms in this category). There are substantial differences depending on the year of treatment. The most significant effect is observed for the cohorts of municipalities treated in 2015-2017, with no effect at all for municipalities treated in 2019. Finally, our results suggest a significant dynamic effect that can be observed within a certain time after broadband deployment. In Table 3, the length of exposure in years after treatment is denoted by e. In the first year after fiber roll-out, $e = 1$, on average 8.29 firms were created. This effect increases over time, and after 4 years from treatment, 45.70 firms were created (30% more relative to the mean number of firms).

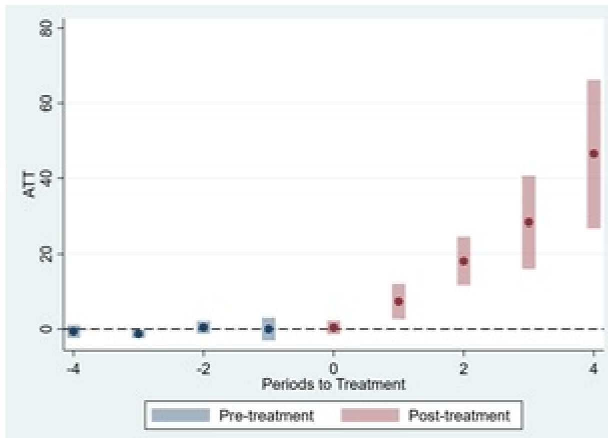
Table 3: Aggregated treatment effect estimates under conditional trends assumption: greater municipalities

	Partially aggregated parameters					Single par.
Simple average of ATT						11.41***
						(2.52)
Group effects	$g = 2015$	$g = 2016$	$g = 2017$	$g = 2018$	$g = 2019$	
	18.65***	10.80**	15.53***	2.95*	0.17	9.01***
	(4.513)	(4.51)	(5.06)	(3.29)	(1.74)	(1.95)
Time effects	$t = 2015$	$t = 2016$	$t = 2017$	$t = 2018$	$t = 2019$	
	3.85	-6.72	9.20***	13.78***	18.34***	7.69***
	(2.47)	(3.26)	(3.30)	(3.02)	(3.47)	(1.83)
Dynamic effect	$e = 0$	$e = 1$	$e = 2$	$e = 3$	$e = 4$	
	0.36	8.29***	18.32***	28.53***	45.70***	20.24***
	(1.07)	(2.45)	(3.64)	(6.98)	(9.99)	(3.62)

Figure 3 shows the dynamic effect with 95% confidence interval. There is no difference between the control and treatment groups before treatment, which supports the parallel trend assumption. We should note that the category of 'greater municipalities' includes municipalities that are more densely populated and economically developed, where fiber was deployed early on.

As shown in Table 2, 75% of municipalities in this category belong to the treatment group, and 23% of them were treated in 2014. Thus, it is statistically easier to estimate the dynamic effect for these municipalities due to the longer period of exposure to treatment.

Figure 3: Dynamic effect for the greater municipalities

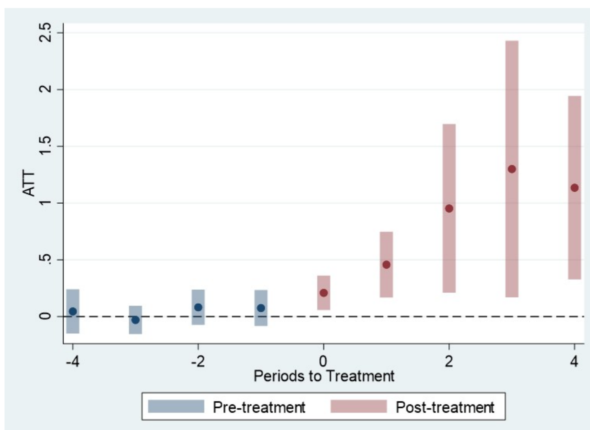


The second category of 'commuter municipalities' corresponds to municipalities where people reside rather than work. The average number of 7.6 firms in these municipalities is much smaller than 150.1 in 'greater municipalities.' Also, the effect of broadband deployment on the creation of firms is expected to be smaller. The simple average ATT is 0.41, which corresponds to an increase of 5.3% relative to the mean number of firms in this category. In percentage terms, this effect is however comparable to the impact of broadband deployment in 'greater municipalities.' There is also a significant dynamic effect with an increase of 15% relative to the mean number of firms within 3 years after fiber deployment. But as shown in Figure 4, the 95% confidence interval for these estimates is large. This may be explained by a smaller number of 5.4% of 'commuter municipalities' in which fiber was rolled out in the first three years 2014-2016, as shown in Table 2. At the cohort level, more than 70% of 'commuter municipalities' in the treated group had broadband deployed in 2018 and 2019. Thus, the dynamic effect of broadband deployment on the local economy in 'commuter municipalities' may occur in the years which are not covered by our data. Figure 4 also suggests that the parallel trends assumption holds for 'commuter municipalities' before the treatment.

Table 4: Aggregated treatment effect estimates under conditional trends assumption: commuter municipalities

	Partially aggregated parameters					Single par.
Simple average of ATT						0.41***
						(0.15)
Group effects	$g = 2015$	$g = 2016$	$g = 2017$	$g = 2018$	$g = 2019$	
	0.35	1.05*	0.32	0.27**	0.21*	0.32***
	(0.27)	(0.54)	(0.29)	(0.12)	(0.11)	(0.11)
Time effects	$t = 2015$	$t = 2016$	$t = 2017$	$t = 2018$	$t = 2019$	
	0.08	0.26	0.38	0.42**	0.46***	0.32**
	(0.34)	(0.35)	(0.25)	(0.19)	(0.16)	(0.16)
Dynamic effect	$e = 0$	$e = 1$	$e = 2$	$e = 3$	$e = 4$	
	0.19**	0.40***	0.84**	1.20**	1.01**	0.73***
	(0.08)	(0.15)	(0.38)	(0.58)	(0.42)	(0.26)

Figure 4: Dynamic effect for the commuter municipalities

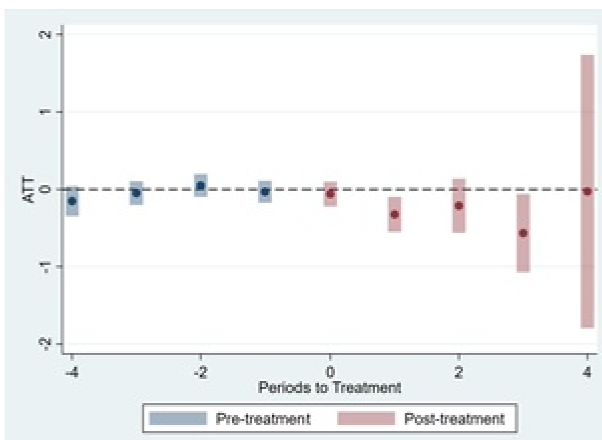


For our third category of 'rural cities,' our results do not show that the deployment of high-speed broadband had a positive impact on the creation of firms. But as shown in Table 2, 80% of these municipalities were never treated, and more than half of those which belong to the treated group had fiber deployed in 2019. Thus, the treatment effect in this category may not be visible in the data yet.

Table 5: Aggregated treatment effect estimates under conditional trends assumption: rural municipalities

	Partially aggregated parameters					Single par.
Simple average of ATT						-0.18**
						(0.08)
Group effects	$g = 2015$	$g = 2016$	$g = 2017$	$g = 2018$	$g = 2019$	
	0.23	-0.33	-0.48**	-0.18	-0.01	-0.11
	(0.45)	(0.22)	(0.19)	(0.13)	(0.12)	(0.08)
Time effects	$t = 2015$	$t = 2016$	$t = 2017$	$t = 2018$	$t = 2019$	
	0.72*	-0.10	-0.46***	-0.10	-0.18**	-0.03
	0.39	0.25	0.16	0.12	0.09	(0.12)
Dynamic effect	$e = 0$	$e = 1$	$e = 2$	$e = 3$	$e = 4$	
	-0.07	-0.35***	-0.26	-0.62**	-0.06	-0.27
	0.08	0.12	0.18	0.26	0.90	(0.22)

Figure 5: Dynamic effect for the rural cities



6.1 Sectoral effects

The deployment of high-speed broadband may differently impact sectors of the economy. Thus, we estimate the model separately for the creation of firms in nine sectors including: (i) industrial production; (ii) construction; (iii) retail, transport, lodging and catering; (iv) information and communication; (v) financial services and insurance; (vi) housing activities; (vii) specialized science and technical activities; (viii) administration, health and education.

Table 6 summarizes the results and reports the average treatment effects, which differ by sector and category of municipalities. We find that in the case of 'greater municipalities,' there is a positive impact on the creation of firms in all sectors except: (i) industrial production; (v) financial services and insurance; (vi) housing activities. The greatest number of firms were created in (iii) retail, transport lodging and catering, which may be driven by the overall impact of broadband on the local economy. In the case of 'commuter municipalities,' there is a positive impact on two sectors: (iv) information and communication and (vii) specialized science and technical activities. These sectors may be impacted directly by the deployment of fiber because they rely on high quality of Internet, while a more central geographic location is less important. Employees in these two sectors may also be able to work remotely. In the case of 'rural municipalities,' we do find a significant impact on any of the sector.

Table 6: Sectorial effects for different industries

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
Greater	ns	0.83***	6.86***	0.85***	ns	ns	3.42***	1.64***
Commuter	ns	ns	ns	0.04***	ns	ns	0.16***	ns
Rural	ns	ns	ns	ns	ns	ns	ns	ns

(i) industrial production; (ii) construction; (iii) retail, transport, lodging and catering; (iv) information and communication; (v) financial services and insurance; (vi) housing activities; (vii) specialized science and technical activities; (viii) administration, health and education

7 Conclusion

In this paper, we adopt the methodology proposed by Callaway and Sant'Anna (2021) and estimate a staggered difference-in-difference model to assess the impact of high-speed broadband roll-out on the creation of firms in municipalities in France. We divide the municipalities into three categories based on the methodology used by INSEE in France, which are: (i) greater municipalities; (ii) commuter municipalities; (iii) rural municipalities. We estimate separate models for each category. In addition, for each category we estimate separate models for the creation of firms in nine different sectors of the economy.

We find that fiber roll-out had a significant impact on the creation of firms in 'greater municipalities.' The number of firms in this category increased by 11.41 (7.3% more relative to the mean number of firms). There are substantial differences depending on the time of fiber deployment, which was greatest for the cohorts of municipalities treated in years 2015-2017, while there was no effect in 2019. Moreover, the positive effect of high-speed broadband on firm creation occurs between 2017 and 2019. Our results also suggest a significant dynamic effect that can be observed some time after broadband deployment. In particular, within 4 years since treatment, 45.70 firms were created (30% more relative to the mean number of firms).

In the case of 'commuter municipalities,' the simple average treatment (ATT) is 0.41, corresponding to an increase of 5.3% relative to the mean number of firms in this category. In percentage terms, this effect is comparable to the impact of broadband deployment in 'greater municipalities.' There is also a significant dynamic effect with an increase of 15% within 3 years after fiber deployment relative to the mean number of firms. For the third category of 'rural cities,' we do not find that the deployment of high-speed broadband positively impacted the creation of firms. However, 80% of these municipalities were never treated, and more than half of those which belong to the treated group had fiber deployed in 2019. Thus, the treatment effect in this category may not be visible in the data yet.

Concerning the impact of fiber roll-out on the creation of firms in different sectors of the economy, we find that the effect is significant in six sectors of 'greater municipalities.' The greatest number of firms were created in retail, transport lodging and catering, which may be indirectly driven by the overall impact on local economy. In the case of 'commuter municipalities', there is a significant impact in two sectors only and no impact at all on the sectors in the case of 'rural municipalities.'

References

Akerman, A., Gaarder, I. & Mogstad, M. 2015. "The skill complementarity of broadband Internet." *The Quarterly Journal of Economics*, 130(4):1781-1824.

Aldashev, A. and B. Batkeyev (2021). "Broadband Infrastructure and Economic Growth in Rural Areas." Information Economics and Policy, 57.

Atasoy, H. 2013. "The effects of broadband Internet expansion on labor market outcomes." *ILR Review*. 66(2):315-345.

Autor, D.H. 2001. "Wiring the labor market." *Journal of Economic Perspectives*. 15(1):25-40.

Bourreau, M., Feasey, R., and Nicolle, A. (2020). "Assessing fifteen years of State Aid for broadband in the European Union: A quantitative analysis." *Telecommunications Policy*, 44(7).

Briglauer, W., Duerr, N.S., Falck, O. and K. Hueschelrath (2019). "Does state aid for broadband deployment in rural areas close the digital and economic divide?" *Information Economics and Policy*, 46, 68-85.

Briglauer, W. and M. Grajek (2021). "Effectiveness and efficiency of state aid for new broadband networks: Evidence from OECD member states.", Mimeo.

Callaway, B., Sant'Anna, P.H.C., (2021). "Difference-in-Differences with multiple time periods." Journal of Econometrics, Themed Issue: Treatment Effect 1 225, 200–230.

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

de Chaisemartin, C., D'Haultfeuille, X., (2020). "Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects." American Economic Review 110, 2964–2996.

Dijkstra, L., H. Poelman and P. Veneri (2019), "The EU-OECD definition of a functional urban area", OECD Regional Development Working Papers, No. 2019/11, OECD Publishing, Paris.

Duso, T., Nardotto, M. and J. Seldeslachts (2021). "A Retrospective Study of State Aid Control in the German Broadband Market," mimeo.

Duvivier, C., Truchet, S., Mauhe, N., Mbarek, M., (2018). Deploiement du tres haut debit et creation d'entreprises dans les zones rurales: une evaluation du programme Auvergne Tres Haut Debit. Economie prevision, 214, 97–139.

European Commission, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society, COM(2016) 587 final.

European Commission, Digital Economy and Society Index (DESI) 2020

European Commission, EU Guidelines for the application of State aid rules in relation to the rapid deployment of broadband networks, 2013/C 25/01.

European Commission, The EU explained: Digital agenda for Europe, November 2014

Fabritz, N. and O. Falck (2013). "Investment in Broadband Infrastructure Under Local Deregulation: Evidence from the UK Broadband Market," CESifo Working Paper No. 4277.

France Stratégie (2020), *Déploiement du très haut débit et Plan France très haut débit. Évaluation socioéconomique*, Technical report.

Goodman-Bacon, A., (2021). "Difference-in-differences with variation in treatment timing." Journal of Econometrics, Themed Issue: Treatment Effect 1 225, 254–277.

Hasbi, M., (2020). "Impact of very high-speed broadband on company creation and entrepreneurship: Empirical Evidence." Telecommunications Policy 44, 101873.

Investissements d'Avenir – Développement de l'Économie Numérique France Très Haut Débit, Réseaux d'initiative publique, mars 2017.

Lapointe, P., (2015). "Does Speed Matter?: The Employment Impact of Increasing Access to fiber Internet." Journal of the Washington Academy of Sciences 101, 9–28.

Matteucci, N. (2019). "The EU State aid policy for broadband: An evaluation of the Italian experience with first generation networks," *Telecommunications Policy*, 43, 101830.

Rios-Avila, F., Sant'Anna, P., Callaway, B., (2022). CSDID: Stata module for the estimation of Difference-in-Difference models with multiple time periods, Statistical Software Components.

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

Sant'Anna, P.H.C., Zhao, J., (2020). Doubly robust difference-in-differences estimators. *Journal of Econometrics*, 219, 101–122.

Wilson, K. (2021). "Does Public Competition Crowd Out Private Investment? Evidence from Municipal Provision of Internet Access," NET Institute Working Paper 16-16.

Appendix: Tables and Figures

Table 7: List of projects eligible to State aid in the framework of the French Broadband Program as of January 2021

Project code	Departments/region	Project code	Departments/region
CD01	Ain	CD40	Landes
CD02	Aisne	LIMO	Limousin
PACA	Alpes-de-Haute-Provence & Hautes-Alpes	CD42	Loire
CD06	Alpes-Maritimes	CD44	Loire-Atlantique
ALSA	Alsace	CD45	Loiret
ARDR	Ardèche & Drôme	CD41	Loir-et-Cher
CD09	Ariège	CD46	Lot
CD10	Aube	CD47	Lot-et-Garonne
CD11	Aude	CD48	Lozère
AUVE	Auvergne	CD49	Maine-et-Loire
CD12	Aveyron	CD50	Manche
CD13	Bouches-du-Rhône	C972	Martinique
BRET	Bretagne	CD53	Mayenne
CD14	Calvados	C976	Mayotte
CD16	Charente	CD57	Moselle
CD17	Charente-Maritime	CD58	Nièvre
CD18	Cher	NPDC	Nord-Pas-de-Calais
CORS	Corse	CD60	Oise
CD21	Côte-d'or	CD61	Orne
CD79	Deux-Sèvres	CD64	Pyrénées-Atlantiques
CD24	Dordogne	CD66	Pyrénées-Orientales
CD25	Doubs	C974	Réunion
CD91	Essonne	C977	Saint-Barthélémy
CD27	Eure	C975	Saint-Pierre-et-Miquelon
CD28	Eure-et-Loir	CD71	Saône-et-Loire
CD30	Gard	CD72	Sarthe
CD32	Gers	CD73	Savoie
CD33	Gironde	CD77	Seine-et-Marne
GDES	Grand Est	CD76	Seine-Maritime
C971	Guadeloupe	CD80	Somme
C973	Guyane	CD81	Tarn
CD31	Haute-Garonne	CD82	Tarn-et-Garonne
CD52	Haute-Marne	CD94	Val-de-Marne
CD70	Haute-Saône	CD95	Val-d'oise
CD74	Haute-Savoie	CD83	Var
CD65	Hautes-Pyrénées	CD84	Vaucluse
CD34	Hérault	CD85	Vendée
CD36	Indre	CD86	Vienne
CD37	Indre-et-Loire	CD88	Vosges
CD38	Isère	CD89	Yonne
CD39	Jura	CD78	Yvelines