The Effect of High-Speed Internet on Working from Home

L. Belloy[*] F. Candau[‡] Y. Abdoulhazis-Oumarou[§]

February 17, 2025

Abstract

We estimate the effects of the deployment of high-speed internet on working from home in France from 2006 to 2022. We find that the investment at the city level of fiber optic technology (hereafter FTTH for Fiber To The Home) has significant, positive, and strong effects on the likelihood of remote work, increasing the share of telecommuters to 10 percentage points after several years of deployment. We observe no significant spillover effects in the general case: cities without high-speed Internet are not affected, even when they are in the close proximity of other cities that have invested in this infrastructure. However, in some specialized cities in the information and communication sector, we find negative spillovers, namely a significant decrease in the share of teleworkers in cities that do not install FTTH when their neighborhood does.

1 Introduction

Although the Internet has been praised as "the greatest invention of our time", doubts remain about its impact on productivity and growth (Gordon, 2017), about its substituability with real face-to-face interactions (Gaspar and Glaeser, 1998) or about its effects on the future of cities (Glaeser, 1998; Glaeser, 2020). Technological

[*]UPPA, CNRS, TREE, France.

[†]UPPA, CNRS, TREE, France. fabien.candau@univ-pau.fr

[‡]We acknowledge financial support from the ANR grant "Numerique en Transition et Transformations Urbaines". We are particularly grateful to Sylvain Dejean, Raphael Suire, Calum Robertson, Camille Massie, and Florian Lafferrere for their comments and to the participants of the workshop NETURB at Nantes.

[§]UPPA, CNRS, TREE, France.

advances in information and communication technologies periodically revive this debate. The replacement of traditional telephone cables with optical fibers and, most recently, advancements in artificial intelligence have all underscored the critical role of internet access. Here, we examine whether very High-Speed Internet (HSI) serves as an effective substitute for real face-to-face interaction and analyze its impact on the growing trend of Working From Home (WFH) in France.

In the media, the main determinant of remote work has been the 2020 pandemic shock, with Forbes considering WFH as "the legacy of COVID-19", or the Financial Times arguing that the coronavirus will create "long-lasting workplace change".[1] What is often overlooked is that the pandemic comes after a period of intense investment in fiber infrastructure[2], which may have been a critical enabler of the teleworking revolution. The causal effect of high-speed internet on teleworking is important to analyze in order to better understand future changes in the workplace. If teleworking is only due to the pandemic, with the hysteresis effect leading people who worked from home during the crisis to maintain their habit, then we can expect a decline in this type of work in the coming years. If, on the other hand, the reason for WFH is technological rather than cultural, we can expect it to increase in all places in the world where FTTH is being installed.

We used a unique database in France, surveying people who work remotely from 2006 to 2022, aggregating these data at city level and linking them to the deployment of high-speed networks in each location. We develop a staggered difference-in-difference for each city that acquires FTTH technology to analyze its causal impact on teleworking. Our contribution is threefold.

First, we find a significant increase in the share of teleworking in cities that invest in high-speed internet. This result is found for almost all types of cities, namely high-density cities and rural areas, with, however, no effect on teleworking in rural areas. Based on Butts (2021) and Butts (2023), these results are robust to a spatial contamination effect of the treatment on the untreated. We also find that FTTH attract mainly remote work from skilled workers with no difference between households with and without children.

Second, we examine the spatial externalities that investment in high-speed Internet in one city can generate in its neighborhood, and in particular spillovers in municipalities that have not invested in HSI. Theoretically, both positive and negative externalities are possible. The growth of a treated city can cannibalize its untreated periphery through its technological advantage (technological spillovers) or through price competition or wage advantages for teleworkers (pecuniary ex-

[1] Respectively available at Forbes and FT.

[2] To avoid repetition, we use terms such as Fiber to the Home (FTTH) and High Speed Internet (HSI) interchangeably.

ternalities).[3] On the contrary, the growth of one city thanks to FFTH can spur on untreated surrounding cities, attracting businesses and jobs from further afield. Our contribution is to show the absence of these spillover effects, suggesting that the benefits to a city of investing in this technology are internalized within the city. There is an exception to this general result in cities with a relatively high specialization in the information and communication (IC) sector, where we find negative spillovers: a decrease in the share of remote work for cities without high-speed internet from cities with access to it. This result is a kind of cannibalization effect that leads to a reduction in the share of teleworkers, either due to the relocation of teleworkers or to a differential dynamic of firms offering teleworking between treated and untreated cities.

Third, to better understand what is happening at the firm level, we examine how high-speed Internet has affected establishment births. As for teleworkers, we observe a significant increase in firm creation and no spillover for the whole sample. We find only weak evidence of negative spillovers in the IC cities for firm creation.

With regard to the literature,[4] to the best of our knowledge, no studies have been carried out on the impact of HSI on working from home. Furthermore, spillovers and/or pecuniary externalities due to FTTH have often been neglected in the analysis of the consequences of HSI. In many articles, the Average Treatment effect on the treated is estimated under the assumption that cities without high-speed internet, even located at a close proximity, are untreated. This is a strong assumption regarding the theoretical background that explains the economic geography of cities. Upward linkages (firms purchasing inputs from suppliers) and downward linkages (firms selling outputs to customers), create a self-reinforcing cycle of cost reduction and productivity gains that can affect the control group (Krugman and Venables, 1995). Similarly, workers in firms that benefit from the HSI increase the market size of places that are close to this demand (Krugman, 1991), potentially in the control group. Going in the opposite direction, the agglomeration of firms in the treated group can create an "urban shadow" due to tougher competition that reduces opportunities in the control group (Behrens and Robert-Nicoud, 2014).

While these externalities are often central to the analysis of remote working,

[3] We use the terminology of Butts (2021) by talking about "spillovers", a term which should be understood here as covering both technological spillovers and pecuniary externalities.

[4] We do not review here the literature on the impact of high-speed internet on economic growth, which is only indirectly related to our analysis and uses different methodologies than ours. For example, Roller and Waverman (2001) and Czernich et al. (2011) find that investment in telecommunications and broadband infrastructure has boosted economic growth in OECD countries. See also Forman et al. (2012) for the US.

for example concerning the 'donut effect' of teleworking,[5] they have not been fully included in the analysis of the causal impact of the high-speed Internet on teleworking and firms. Only some recent papers have started to analyze these effects. For instance, by exploiting the gradual arrival of submarine internet cables on the African coast, Hjort and Poulsen (2019) show large positive effects on employment rates with no job displacement across space. This indicates the absence of negative externalities in Africa. Analyzing non-metropolitan US counties, Deller et al. (2021) show that download speeds of up to 50 Mbps contribute to increasing rural start-up activity in a variety of industries. Working on the dynamics of entry and exit of Italian firms, Cambini and Sabatino (2023) shows that HSI increases the exit of small firms but fosters the entry of new firms, mainly in digitally intensive sectors and in developed geographical areas. In France, considering cities where HSI has not been (or not yet) deployed as a control, Bourreau et al. (2022) find that the rollout of fiber optic networks had a positive effect on firm creation in large municipalities, increasing the number of firms by 7.3% relative to the average. Still on French data, Duvivier et al., 2021 finds that an increase of 1% of broadband coverage increases the rate of firm births by 1.03. Finally, Duvivier and Bussiere (2022) presents positive broadband effects on the creation of firms in rural areas, which are, however, limited to municipalities with local economic dynamics and natural amenities. We complement these analyses by showing that the spillover effects of HSI are spread over a short distance, often limited to the boundaries of cities. Neighboring cities 15 km and 25 km away are not affected. But our main contribution is obviously regarding the impact of HSI on remote work which has not been studied in this literature.

Finally, our paper is related to several articles that analyze remote work or the internet separately. For example, on the one hand, Akerman et al. (2015) have shown that the Internet is skill-biased, benefiting high-skilled workers the most. However, remote work has been found to be predominantly performed in high-skilled jobs (Dingel and Neiman, 2020; Bartik et al., 2020). Thus, we fill the gap between these studies by showing that the high-speed Internet and teleworking are linked by a causal relationship, particularly for skilled workers.

The remainder of the paper is structured as follows. Section 2 briefly reviews the background of ultrafast broadband in France, followed by the data used and the empirical strategy adopted. Section 3 presents the main results on the im-

[5]The finding that the increase in remote employment after COVID has led to a decrease in activity in the urban Central Business District (CBD) to the benefit of the periphery has been called the 'donut' effect (Ramani and Bloom, 2021). Many articles have been written on this topic, such as Delventhal et al. (2022), Parkhomenko and Delventhal (2022) and Althoff et al. (2022). Interestingly, Bjerke et al. (2024) find a result that supports our finding by considering "shadow effects magnified by the work-from-home revolution".

pact of FTTH on telework. Section 4 performs some extensions by questioning the heterogeneous effect of FTTH depending on several factors (type of city, type of household). Section 5 examines the mechanisms related to the effect of FTTH on business creation. Finally, Section 6 concludes the paper.

2 Background, Data and Empirical Strategy

2.1 Background and stylized facts

In the early 1990s, the introduction of the Internet in France began with the use of dial-up modems, which allowed the connexion via traditional telephone lines. This period marked the initial phase of Internet democratization, characterized by slow and unstable connections.

By the late 1990s, France saw the introduction of DSL (Digital Subscriber Line), a technology that significantly improved Internet access by offering faster and more reliable connections. The early 2000s witnessed a gradual increase in DSL speeds, enabling more bandwidth-intensive applications such as video streaming and online gaming. The transition towards fiber optic technology (FTTH - Fiber to the Home) began in 2013 with the launch of the Plan France Très Haut Débit, a national initiative aimed at developing a fiber optic infrastructure across the country.[6]

By 2023, the number of fiber optic subscribers in France surpassed 21 million, marking a significant shift in the broadband market toward faster and more reliable connections.

According to the OECD Telecommunications Database,[7] the growth rate of investment in fiber optic implementation in France has been one of the strongest in the OECD countries (40% between 2009 and 2018 while Germany was 26% and only the United States has a similar growth rate of 41%).

[6] Under this program, the French government has designated areas into two main categories: private initiative zones and public initiative zones. In private initiative zones, which encompass densely populated urban areas, the deployment of fiber networks is primarily driven by competition between private infrastructure providers. Public initiative zones cover rural and sparsely populated areas where private companies do not see sufficient financial return to justify the deployment of fiber networks. In these zones, local authorities can leverage financial support from both the French government and the European Union to develop the necessary infrastructure. The French government has, for instance, financed the Reseaux d'Initiative Publique (RIP), which enable local governments to form partnerships with private operators to build and operate fiber networks. See Duvivier et al. (2024) for a review.

[7] See Dozias (2023)

2.2 Data

2.2.1 Broadband Network Data

The data used come from the Regulatory Authority for Electronic Communications, Postal Services, and Press Distribution.[8] This authority provides data on the deployment of very high-speed networks in France at the level of housing that are connected or eligible for fiber optic. The period of our analysis is over 2006-2022 and data are aggregated at the level of the municipality.

The variable selected to analyze the impact of fiber optic arrival in each municipality is the date when the completion deadline for fiber connection starts, that is, the date when telecommunication operators commit to installing fiber in a location. For convenience we are going to speak of implementation, sometimes to the "eligibility" of FTTH in a city, but we should mention that the timing of the treatment we use is not for sure the year when the FTTH is fully implemented; some delays are possible. Moreover, the fact that FTTH starts to be installed in one district of the city does not mean that the whole city will be equipped soon; it takes sometimes years to generalize the network.

2.2.2 Data on teleworkers

Data on the proportion of teleworkers in each municipality come from the Continuous Employment Survey (INSEE). This quarterly survey tracks employment, unemployment, and inactivity in France and corresponds to the French part of the European Labor Force Survey. Each individual is interviewed for six consecutive quarters. The data are aggregated at the municipal level and are representative of the French population. Data on teleworking are given in proportion due to weighted values. Not all communes are available for all years, due to the fact that the survey is representative of the French population for each of the 13 regions but alternates communes within each region. The communes taken into account are drawn randomly each year, which reduces the bias that could result from missing data. Telecommuters are defined as those who reported working from home during the reference week indicated at the beginning of the survey. Before 2013, the question about working from home was asked in each initial interview. From 2013 onward, this question is more specific and is asked in the first and last interviews. The question is no longer general but focuses on whether or not the individual worked from home in the four weeks preceding the reference week.

[8] Autorite de Régulation des Communications Electroniques, des Postes et de la distribution de la presse (ARCEP)

2.2.3 Firm creation

For business startup, we use the number of firms and establishments created (INSEE, Sirene), on a year basis, and disaggregated by industry (NAF rev.2 in 88 divisions). We use establishment births, because as argued by the literature (McCoy et al., 2018; Duvivier et al., 2021) the bias of reverse causality is less severe with this variable than for other ones (e.g. the growth of already established firms which may lobby to get the FTTH).

Part of the current paper discusses the results at the disaggregated level for a) information and communication, b) scientific and technical activities, and c) catering activities. The first two categories (Information-communication and scientific and technical activities) are particularly likely to have a significant need for optical fiber because they rely heavily on high-speed data transmission for their operations. In these sectors, reliable and fast Internet connectivity is essential for exchanging services, conducting research, collaborating across distances, and producing goods efficiently. For example, information-communication businesses might require optical fiber to support activities such as data processing, cloud computing, and maintaining digital communications, while scientific and technical fields could use it for data analysis, research development, and accessing large databases remotely. The catering sector, in contrast, is likely to benefit from ultrafast broadband more indirectly through pecuniary externalities. For example, as the growth of other sectors accelerates due to enhanced internet infrastructure, it will offer advantages through economic spillover effects by attracting more workers to the area, ultimately increasing the number of potential customers for catering establishments.

2.2.4 Other variables

Other data on industry sectors and the socio-professional category of workers (share of workers in executives and higher intellectual professions, share of workers in the information communication sector) also come from the French Statistic Institute (INSEE) regarding the survey called *Enquête Emploi en Continu*. The proportion of active workers employed outside their city of residence and the population data come from the INSEE population census.

We also lead our analysis by distinguishing cities according to their size measure in terms of density as defined by INSEE. Because French cities vary greatly on a geographical scale, some may appear to be sparsely populated or, on the contrary, densely populated, even though their populations are of comparable size. In order to take into account the population of the municipality and its distribution in space, a density grid is used based on the distribution of the population within the municipality by dividing the territory into 1 kilometer squares. After identifying built-up areas, it is the size of these built-up areas within a municipality that is used to characterize density (and not the usual municipal density). From this work four types of cities are considered: a) dense cities, b) intermediate dense cities, c) sparsely populated municipalities, and d) very sparsely populated municipalities. These categorizations are built from population data derived from demographic files (database Fideli).

We cluster the last two categories under the name ”rural areas”, the two others are respectively called ”dense urban” and ”intermediate dense”.

2.3 Empirical Strategy

2.3.1 Dynamic difference-in-differences

Let's denote t the different periods considered here ($t = 1, ..., T$) and i the municipality that can be treated (deployment of the infrastructure) or not, at any time. Spatial units are categorized into different cohorts based on their initial treatment. The binary treatment is denoted D_{it}, the earliest period of treatment is given by $E_i = \min \{t : D_{it} = 1\}$. The time defined relative to the timing treatment is $\ell = t - E_i$. With these notations at hand, we estimate the following dynamic Two-Way Fixed Effects (TWFE):

$$N_{i,t} = \sum_{\ell} \beta_{\ell} 1 \{t - E_i = \ell\} + Z_{i,t} + f_i + f_t + \varepsilon_{it}, \tag{1}$$

with $N_{i,t}$ the dependent variable representing either the creation of firms, or the share of remote workers in the municipality i at time t. $Z_{i,t}$ is a vector of control variables including the number of inhabitants, the number of businesses, public facilities, and the proportion of executives. Time and individual fixed effects are introduced *via* f_i and f_t. β_{ℓ} are the coefficients associated with indicators for being ℓ periods relative to the treatment. $\epsilon_{i,t}$ is the error term.

This dynamic TWFE is estimated by using the ”not-yet-treated” as a control group because ”never treated” units may have very particular characteristics, in particular geographical characteristics (mountain areas) that render them inadequate as controls. We also use different treatment effect estimators robust to heterogeneous and dynamic treatment effect presented in Callaway and Sant'Anna (2021), Borusyak et al. (2024), Butts and Gardner (2021) and Sun and Abraham (2021). In the text, we present the results with the methods of Borusyak et al. (2024); other estimators are presented in Appendix A.

The estimator Borusyak et al. (2024) is relevant for our analysis, which can suffer from the possibility of heterogeneous dynamic treatment effects between cities in the implementation of FTTH. Indeed, it is likely that the average treatment effect in the first year after adoption will be different for cities that adopted the HSI at the beginning of the period than for those that adopted it several years later, for technological reasons or because the internet content has changed significantly (e.g., widespread use of streaming video by the end of the period). Cultural changes may also trigger heterogeneous dynamic treatment effects since, for early adopters, the initial impact could be limited by factors such as lower initial awareness or lack of remote work culture at that time.

Finally, according to Chaisemartin and D'Haultfœuille (2022), the Borusyak et al. (2024) estimator offers precision gains compared to other estimators.

2.3.2 Taking into account spillovers

The previous analysis aims to estimate the average treatment effect on the treated, assuming no contamination effects on the control group. However, it is entirely possible that the impact of the treatment extends beyond the treated municipalities. Pecuniary externalities, such as those generated by the creation of firms that benefit from fiber deployment, can play an significant role. As shown by a vast literature on economic geography (Helpman, 1998, Krugman and Venables, 1995, Redding and Rossi-Hansberg, 2017 and Allen and Arkolakis, 2024), these spillover effects are circular. For instance, if companies producing intermediate goods and services used by high-tech firms are located in nearby municipalities, then a cluster of these firms can generate more competition and a reduction in the price of these intermediate inputs which, in turn, increase the competitiveness of the downstream sector in the treated area and then favor the entry of new firms there. Similarly, the development of an urban center due to a better connection to online markets may hinder the development of nearby urban centers due to tougher competition in the production of final goods, which casts an agglomeration shadow (Behrens and Robert-Nicoud, 2014). The increase in the competition for resources (e.g., labor) can also generate this urban shadow (Cuberes et al., 2021).

To take into account these spillover effects, we follow the two-step analysis of Butts (2021) and Butts (2023) as described below.

In the first step, the fixed effects of the municipality and time are estimated to explain the dependent variable only for the untreated or not yet treated municipalities. This first step helps limit bias that could be generated by spillover effects on neighboring municipalities and also reduces differences in characteristics between municipalities. The predictions of the dependent variable are then extended to the entire dataset (untreated, not yet treated, and treated). In the second step, the dependent variable represents the residuals of the first-step estimation, with the treatment and spillovers as explanatory variables. Using a two-step structure, the method clearly separates the group-specific and time-specific effects, allowing for a more precise estimate of the treatment effects by isolating other potentially confounding factors. This two-step method helps isolate the effect of treatment by adjusting for the baseline differences between the treated and untreated groups, eliminating biases that could result from these disparities.

More precisely, we estimate exactly the same Equation (1) as previously but with a new term Γ_{it}, such as:

$$N_{it} = \sum_{\ell} \beta_\ell 1\{t - E_i = \ell\} + Z_{it} + \Gamma_{it} + f_i + f_t + \varepsilon_{it}, \tag{2}$$

with Γ_{it} given by:

$$\Gamma_{it} = \beta^c S_{it}(1 - \sum_{\ell} 1\{t - E_i = \ell\}) + \beta^t S_{it} 1\{t - E_i = \ell\},$$

where S_{it} is a dummy capturing spatial spillovers. Since these spillover are local, S_{it} is defined by a distance $\bar{d}$ from the treated, on which these externalities play a significant effect on the control group. Hence, within a $\bar{d}$ radius, control units are influenced by spillovers and S_{it} takes one, while taking zero beyond that distance. The selection of $\bar{d}$ is data-driven, and consists in an estimation that nonparametrically identifies the treatment effect curve using partitioning based least squares estimation (Butts, 2023). This procedure provides a $\bar{d}$ of 15 km, but we also lead analysis by using ad-hoc distance of 25 km and we find similar results.

As mentioned above, the estimation is done in two stages. The first stage consists of estimating f_i and f_t, hereafter denoted with a "hat", using observations that are not yet treated/affected by spillovers ($D_{it} = 0$, $S_{it} = 0$). Then subtract off $\hat{f}_i$ and $\hat{f}_t$ to get $\tilde{N}_{it}$ such as $\tilde{N}_{it} = N_{it} - \hat{f}_i - \hat{f}_t$ which finally regressed on $\sum_\ell \beta_\ell 1\{t - E_i = \ell\} + \Gamma_{it}$.

3 FTTH a New Factor of Attractiveness?

3.1 Main Result: the Rise of Telework

In Figure (1) we present the effect of the treatment at different points in time relative to the policy intervention, namely the dynamic estimation of DID from Equation (1), using Borusyak et al. (2024) estimator.

First, one can observe that there is no significant difference between the treated and control groups prior to treatment. This is a necessary condition (certainly not sufficient) to ensure that results are due to the treatment itself and not influenced by other pre-existing differences. Second, there is a strong increase in the coefficient β over time representing the increase in the share of remote workers in cities where HSI has been installed. We find similar results regardless of the estimators used in Appendix A, namely the standard dynamic TWFE, and estimators developed by Callaway and Sant'Anna (2021) and Butts and Gardner (2021). However, there are some discrepancies; in particular, it is unclear from this analysis when investment in FTTH finally has an impact on working from home. While our preferred estimator (presented below in Figure 1), shows a significant effect in the year after the FTTH eligibility; other estimators, such as the Sun and Abraham (2021), present a significant impact only 5 years later. The results using the Callaway and Sant'Anna (2021) method (see Appendix A) even show an unsignificant effect for almost all periods.

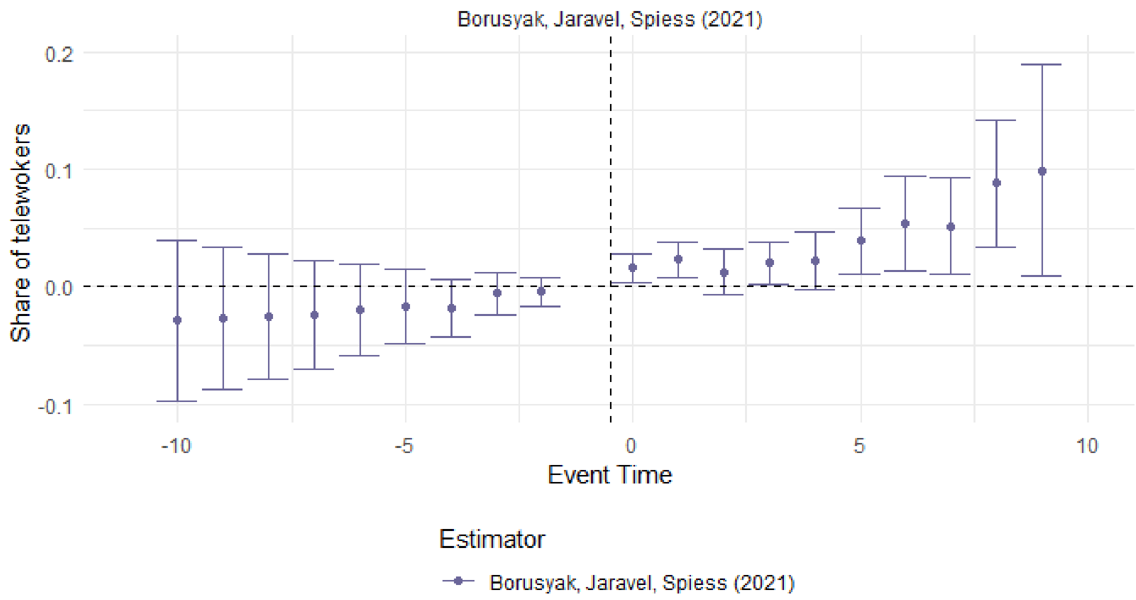

Figure 1: High Speed Internet and Working from Home

However, as noted above, an unresolved issue with these estimates is the potential spillover effects that HSI may have on teleworking in the control group.

Figure (2) shows how accounting for these externalities affects the significance of the timing of the treatment. Indeed, such a two-step analysis shows that FTTH has a rapid impact on telecommuters, starting just one year after telecom operators commit to installing high-speed internet fiber in the city. This clear increase in the number of remote workers in cities with FTTH lasts for nine years.

In this analysis, we take into account spillover effects on cities that are not treated but are less than 15 km from these cities where fiber optic technology has been installed. See Appendix B for a distance of 25 km given by the nonparametric method that identifies the treatment effect curve using partitioning-based least squares estimation. We find similar results.

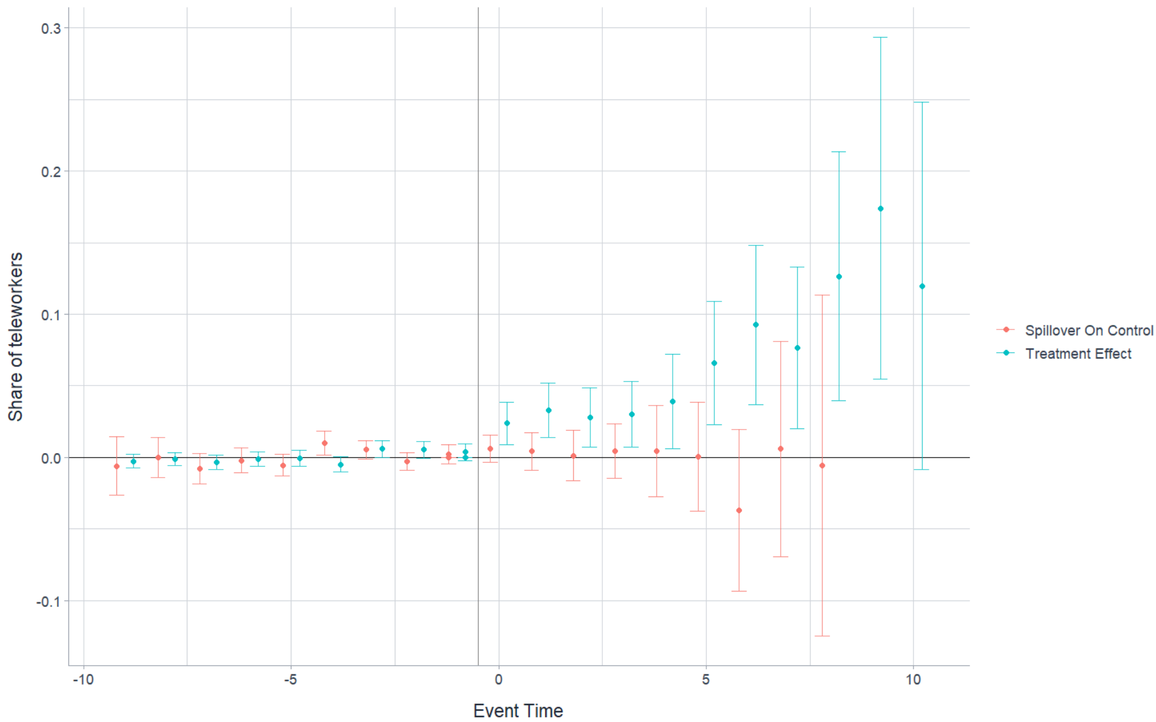

Figure 2: High-Speed Internet, Working From Home and Spillovers

This finding on the absence of spillover effects for remote work is robust in different sectors. To confirm this, we replicated our estimates by disaggregating the data by sector (including, for example, hotels and restaurants and scientific activities). The results remained consistent, showing no significant spillover effects in most sectors. We do not report the results here, but it was an unexpected result not to observe externalities in scientific and technical activities. This implies that if spillovers exist, they are internalized within the boundaries of the cities considered. However, there is one notable exception for cities that host a significant share of firms in the information and communication sector.

3.2 Telework in the Information and Communication Sectors

To analyze the specific sector of the information and communication which is obviously more concerned by a good access to the Internet, we specifically examined cities that are particularly specialized in this sector, which we refer to as the "IC cities".

These cities, defined as municipalities whose establishments in this sector represent more than 5% of the total number of firms, demonstrated a unique pattern of negative spillovers.

We find in Figure 3, that the proportion of teleworkers decreases in untreated municipalities located within a 15 km radius of IC cities, which, on the other hand, become even more attractive for teleworking as time goes by.

One should notice that these effects may not be due to the IC sector itself but to other firms that rely on teleworking and that are also overrepresented in these IC cities.

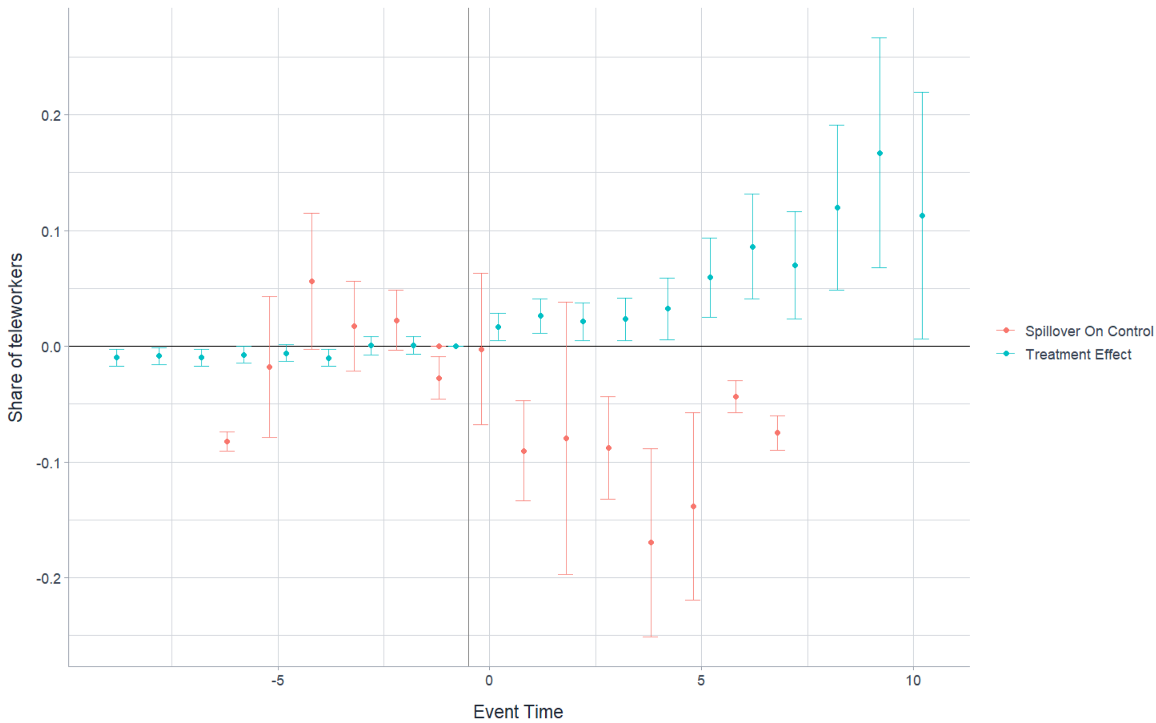

Figure 3: Cities with IC sector (5% IC firms)

4 Extensions

4.1 Type of City

In this section, we are going to successively revisit our result by analyzing what happens when we consider a) different types of *treated* cities b) different types of *untreated* cities that are closed to the treated one. As defined in the data section, cities are differentiated according to their density and geographic type. We consider dense and intermediate dense cities, as well as rural areas. We are interested in testing whether the Average Treatment on the Treated (ATT) found in the previous section is affected by the heterogeneity of cities, or more precisely how the different choice of workers to work remotely, which certainly depend on the type of cities, may have changed over time. We are agnostic about the sign of this heterogeneous time-varying treatment bias within the treated groups over time, that can be negative or positive.

On the one hand, it is possible that skilled workers (who are often the ones most concerned about remote work) have been more and more attracted to live in dense cities to benefit from social and cultural amenities. This is even more likely that other shocks may have facilitated the mobility of these workers, for instance, high-speed train have connected some dense urban areas during our time span.

On the other hand, the COVID crisis has also shown a new preference for workers to work in less dense cities and sometimes rural areas to benefit of environmental amenities. Regarding point b) our main result is that there is no spillover effect (at the exception of some particular IC cities), but this aggregated effect may hide positive and negative effects depending on the types of cities.

In Table 1 where the ATT in different cities is tested (we aggregate municipalities classified as dispersed rural and dense rural into a single category, rural areas, due to the limited number of observations in the dispersed rural category), we verify the significant treatment effect for urban areas. In contrast, rural areas are not more attractive once FTTH is implemented. High speed internet does not seem to be a magic bullet to attract teleworkers in these areas. Not reported in this table, spillover effects are never significant (as presented in the general case depicted in Figure, 2).

Dep var: share of teleworkers	Dense urban	Interm dense	Rural areas
Treatment (by density)	0.031 ***	0.022 **	0.012
	(0.003)	(0.01)	(0.016)
R^2	0.379	0.375	0.379
Observations	23,232	23,232	23,232

Notes: Standard errors are clustered at the municipality level in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Results are obtained from a spillover regression using the OLS estimator. Individual fixed effects and time effects are included in all estimations. The dependent variable is the share of teleworkers. Our control variables are: the number of firms per 1,000 inhabitants, the share of workers in the information and telecommunications sector, and the share of workers in highly intellectual professions; they are all significant, not reported to save space. Columns present results for municipalities types according to INSEE.

Table 1: Heterogeneous treatment effect (15 km radius)

In Table (2), we consider the different types of city near the treated one that may have benefited or suffered from spillover effects; we also verify the previous results: no spillover effect is detected for the vast majority of cities. However, we detect negative spillovers in cities with an intermediate level of density. These towns with negative spillovers could be weakened by the arrival of fiber in neighboring towns, which would prevent workers in sectors using the Internet for their work from being able to work from home, preferring to move to the nearest town with HSI. Not reported here, the ATT is always significant (a coefficient of 0.045 significant at 1%) as already found in Figure (2).

Dep var : share of teleworkers	Dense urban	Interm dense	Rural area
Spillover (by density)	-0.01	-0.019 **	0.009
	(0.006)	(0.0087)	(0.006)
R^2	0.378	0.378	0.378
Observations	24,746	24,746	24,746

Notes: Standard errors are clustered at the municipality level in parentheses, *** p< 0.01, ** p< 0.05, * p< 0.1. Results are obtained from a spillover regression using the OLS estimator. Individual fixed effects and time effects are introduced in all estimations. The dependent variable is the share of teleworkers. Our control variables are: the number of firms per 1,000 inhabitants, the share of workers in the information and telecommunications sector, and the share of workers in highly intellectual professions; they are all significant, not reported to save space. Columns present results for municipalities types according to INSEE.

Table 2: Heterogenous spillovers according to density (15 km radius)

4.2 Type of household

We have led several other investigations based on the characteristics of the household. More precisely we investigate who are the telecommuters attracted by the deployment of FTTH. As expected, we find in Appendix C that teleworkers affected by the policy are skilled workers belonging to the social category "executives and higher intellectual professions". We also test whether having a child affects the choice to work from home after the deployment of ultra-fast broadband. We do not find noticeable results, both kinds of household positively react to HSI, with or without children.

4.3 Type of Speed

What about the initial condition of the Internet? Internet may be a good substitute for face-to-face interaction only when the speed to exchange bits is high enough. In this regard, FTTH represents a substantial improvement. However, depending on the investment of cities in past technologies such as DSL, it is possible that FTTH has represented only a small improvement in some places. Or, to put this in a different way, the effect of the treatment may vary depending on the quality of the initial access to Internet. In Appendix D, we study this question and find that, in most cases, FTTH stimulates an increase in teleworking indiscriminately.

5 Mechanism

The ways in which FTTH affects telework can be divided between the direct impact on teleworkers' location choices and an indirect effect influenced by firms. So far, we have focused on telecommuters, but we lack data to explore further, such as determining whether good internet access influences their housing choices, whether they relocate to gain better access, or if it only new employees that choose job with teleworking and their location accordingly. However, there may be a second channel, from a composition effect due to the creation of firm, which we are able to discuss.

To simplify, consider a model where teleworkers always work in the city where firms are located, and assume that firms produce goods with heterogeneous teleworking content. If establishment birth increases in locations with FTTH for firms that employ the most teleworkers, but not in other similar locations, then we have an explanation for our previous main result. If this channel is correct, we should observe business startups in cities with FTTH, and not in other cities, even if they are nearby.

More formally, under these assumptions we have the following predictions a) teleworking in treated areas is possible only if there are firms creation in the treated areas, b) the absence of spillovers in remote work is explained by the lack of spillovers for the creation of firms, and c) the presence of negative spillovers for teleworking in the IC cities is explained by the negative spillovers on business start-up in these cities.

5.1 General case

We reproduce here our analysis to study how the implementation of HSI has affected the number of new firms. We test here the predictions a) and b).

Figure (4) shows that the eligibility of the fiber in cities has a significant positive impact on the creation of firms that increase over time. We find very similar results to what has been obtained for teleworkers. There are no significant pre-trend before the deployment and a positive effect since the first event-time. This confirms what has been shown in the literature (Bourreau et al. (2022), Duvivier et al. (2021)) with the two-step analysis of Butts (2023) and thus with the additional result that there is no spillover in firm creations.

This symmetrical result between the impact of the HSI on the growth of telework and business creation are worth discussing. One plausible explanation is that the entry of new firms has created employment opportunities that facilitate teleworking inside the same city where the FTTH has been installed. This explanation, already presented, is obviously speculative since we have no data on the companies that employ teleworkers. The explanation may in fact be the opposite: the moving of teleworkers may have expanded the market, offering new outlets that encourage the creation of new businesses.

Finally, there is perhaps no causal link between these two relationships; it may be a common unobserved factor that simultaneously increases business start-up and teleworking. In fact, even this simple correlation between the increase in teleworking and firm creations is an interesting result, in particular because this correlation is observed at the city level without spillover. This shows that these two positive effects of HSI are internalized within the city. This result may be explained by the short distance covered by French commuters. To give a number, the median distance between work and home for workers in France is approximately 12.5 km (in 2019[9]) and then teleworking can often occur close to its place of work.

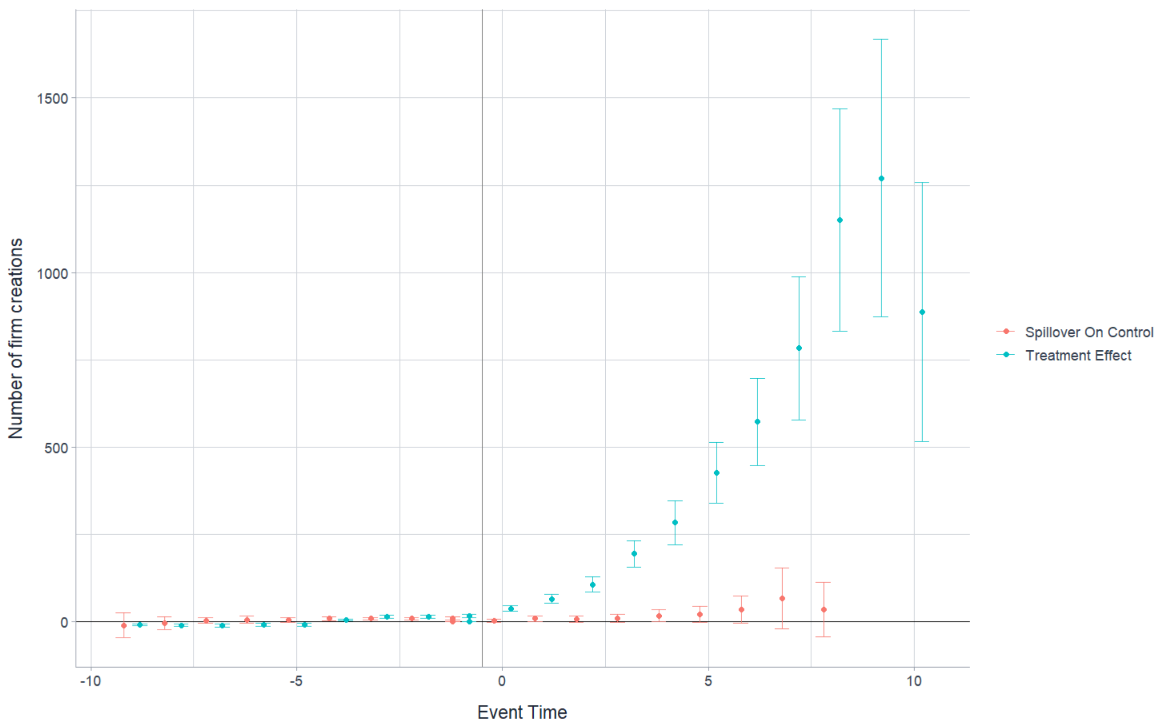

Figure 4: High Speed Internet, Firm births and Spillovers

[9]https://www.insee.fr/fr/statistiques/7622203

5.2 IC cities

Let us start by focusing our analysis on information and communication (IC) cities as previously done for teleworkers. Here we aim to test the predictions a) and c).

In Figure (5), we observe results similar to those obtained until now. Positive effects over a four-year period are significant, indicating a higher creation of firms in locations with HSI in IC cities. With regard to spillovers, a particular type of cannibalization may be at work, with fewer firms being created in neighboring areas. However, such an effect is hard to capture, and even if we observe a decrease in the coefficient of business start-up, this result is only significant five years after the treatment, which makes the conclusion hard to reach in that particular case. In other terms, the mechanism explaining the negative spillovers of FTTH on teleworking in IC cities does not appear to come from a reduction in firm creation (falsification of prediction c).

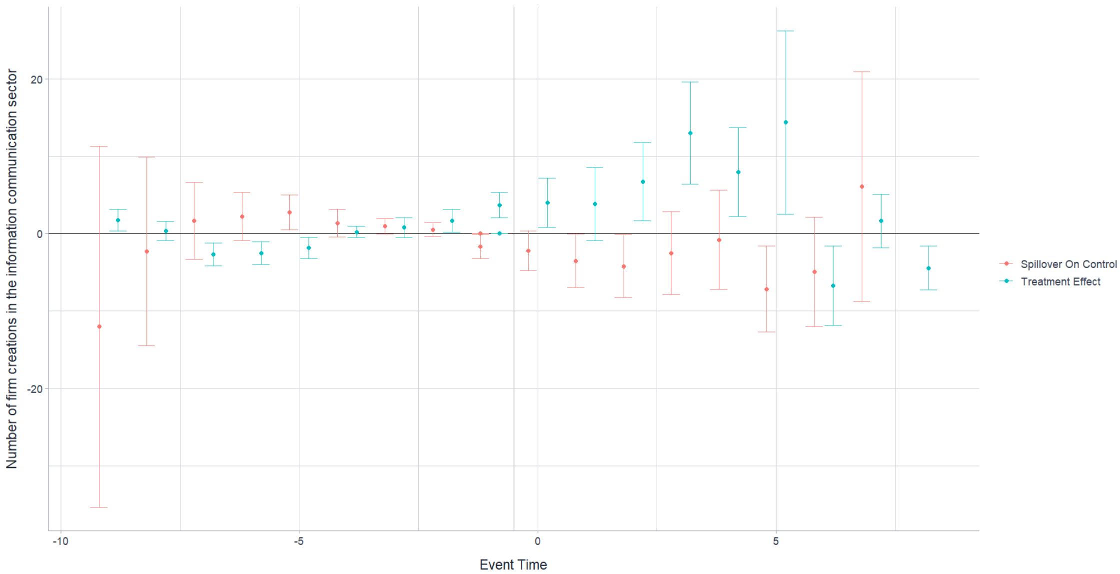

Figure 5: High Speed Internet, Firm births and Spillovers in IC cities

6 Conclusion

High speed Internet enables, in the words of Baldwin (2006), to a 'great unbundling' process by which production and services are increasingly separated into distinct segments that can be managed and delivered independently. In this study we wonder whether this unbundling of the firm is not a new 'bundling' for workers concerning the place where they work and the place where they live.

This is at least verified by our finding that ultra-broadband internet connections cause a significant increase in working from home. We also find that, in general, there are no significant spillover effects, indicating that the benefit to a city of investing in this technology is internalized within the city fabric. This result could be important for policy makers elsewhere in the world who wish to invest in this infrastructure, obviously to attract businesses, but also to attract a new population that will live, consume and pay taxes in the city and not in its neighborhood.

In this study, we just pick the low hanging fruits of the analysis linking HSI and teleworking. First of all, the benefit of HSI may be magnified in the coming years, with an increasing access to innovative solutions and services located on the cloud. We thus just analyze here a short run relationship that will deserve to be revisited in the future. This seems all the more necessary, that WFH is a recent phenomenon that represents a small share of the workplace over a significant part of our period.

Finally, to go beyond our analysis, which deals separately with teleworking and firms' location choice, it would be necessary that statistical offices provide data on teleworkers *at the firm level* for the whole French territory.

7 Reference

References

Akerman, Anders, Ingvil Gaarder, and Magne Mogstad (July 2015). "The Skill Complementarity of Broadband Internet *". In: *The Quarterly Journal of Economics* 130.4, pp. 1781–1824. ISSN: 1531-4650. DOI: 10.1093/qje/qjv028.

Allen, Treb and Costas Arkolakis (2024). "Quantitative Economic Geography". In.

Althoff, Lukas, Fabian Eckert, Sharat Ganapati, and Conor Walsh (Mar. 2022). "The Geography of Remote Work". In: *Regional Science and Urban Economics* 93, p. 103770. ISSN: 0166-0462. DOI: 10.1016/j.regsciurbeco.2022.103770.

Baldwin, Richard E (2006). "Globalisation: the great unbundling (s)". In.

Bartik, Alexander, Zoe Cullen, Edward Glaeser, Michael Luca, and Christopher Stanton (June 2020). *What Jobs are Being Done at Home During the Covid-19 Crisis? Evidence from Firm-Level Surveys*. DOI: 10.3386/w27422.

Behrens, Kristian and Frédéric Robert-Nicoud (Mar. 2014). "Survival of the Fittest in Cities: Urbanisation and Inequality". In: *The Economic Journal* 124.581, pp. 1371–1400. ISSN: 0013-0133. DOI: 10.1111/ecoj.12099.

Bjerke, Lina, Steven Bond-Smith, Philip McCann, and Charlotta Mellander (2024). *Work-from-home, relocation, and shadow effects: Evidence from Sweden*. Tech. rep.
Borusyak, Kirill, Xavier Jaravel, and Jann Spiess (Feb. 2024). "Revisiting Event-Study Designs: Robust and Efficient Estimation". In: *Review of Economic Studies*. ISSN: 1467-937X. DOI: 10.1093/restud/rdae007.
Bourreau, Marc, Lukasz Grzybowski, Angela Munoz Acevedo, and Sylvain Dejean (2022). "Impact of Fiber on Firm Creation: Evidence from France". In: *WP*.
Butts, Kyle (2021). *Difference-in-Differences Estimation with Spatial Spillovers*. DOI: 10.48550/ARXIV.2105.03737.
— (Jan. 2023). "JUE Insight: Difference-in-differences with geocoded microdata". In: *Journal of Urban Economics* 133, p. 103493. ISSN: 0094-1190. DOI: 10.1016/j.jue.2022.103493.
Butts, Kyle and John Gardner (2021). "did2s: Two-Stage Difference-in-Differences". In: DOI: 10.48550/ARXIV.2109.05913.
Callaway, Brantly and Pedro H.C. Sant'Anna (Dec. 2021). "Difference-in-Differences with multiple time periods". In: *Journal of Econometrics* 225.2, pp. 200–230. DOI: 10.1016/j.jeconom.2020.12.001.
Cambini, Carlo and Lorien Sabatino (Apr. 2023). "Digital highways and firm turnover". In: *Journal of Economics amp; Management Strategy* 32.4, pp. 673–713. ISSN: 1530-9134. DOI: 10.1111/jems.12522.
Chaisemartin, Clément de and Xavier D'Haultfœuille (June 2022). "Two-way fixed effects and differences-in-differences with heterogeneous treatment effects: a survey". In: *The Econometrics Journal* 26.3, pp. C1–C30. ISSN: 1368-423X. DOI: 10.1093/ectj/utac017.
Cuberes, David, Klaus Desmet, and Jordan Rappaport (May 2021). "Urban growth shadows". In: *Journal of Urban Economics* 123, p. 103334. ISSN: 0094-1190. DOI: 10.1016/j.jue.2021.103334.
Czernich, Nina, Oliver Falck, Tobias Kretschmer, and Ludger Woessmann (May 2011). "Broadband Infrastructure and Economic Growth". In: *The Economic Journal* 121.552, pp. 505–532. ISSN: 1468-0297. DOI: 10.1111/j.1468-0297.2011.02420.x.
Deller, Steven, Brian Whitacre, and Tessa Conroy (Sept. 2021). "Rural broadband speeds and business startup rates". In: *American Journal of Agricultural Economics* 104.3, pp. 999–1025. ISSN: 1467-8276. DOI: 10.1111/ajae.12259.
Delventhal, Matthew, Eunjee Kwon, and Andrii Parkhomenko (Jan. 2022). "JUE Insight: How do cities change when we work from home?" In: *Journal of Urban Economics* 127, p. 103331. ISSN: 0094-1190. DOI: 10.1016/j.jue.2021.103331.
Dingel, Jonathan I. and Brent Neiman (Sept. 2020). "How many jobs can be done at home?" In: *Journal of Public Economics* 189, p. 104235. ISSN: 0047-2727. DOI: 10.1016/j.jpubeco.2020.104235.

Dozias, A (2023). "Competition in the French Electronic Communications Market". In: *Tresor Economics*.
Duvivier, C, L Berge, and F Leon (Apr. 2024). "Le déploiement du très haut débit a-t-il favorisé la numérisation des entreprises ? Une évaluation du plan France Très Haut Débit". In: *Revue économique* Vol. 75.2, pp. 301–352. ISSN: 0035-2764. DOI: 10.3917/reco.752.0301.
Duvivier, C and C Bussiere (June 2022). "The contingent nature of broadband as an engine for business startups in rural areas". In: *Journal of Regional Science* 62.5, pp. 1329–1357. ISSN: 1467-9787. DOI: 10.1111/jors.12605.
Duvivier, C, E Cazou, S Truchet, C Brunelle, and J Dube (Dec. 2021). "When, where, and for what industries does broadband foster establishment births?" In: *Papers in Regional Science* 100.6, pp. 1377–1402. ISSN: 1056-8190. DOI: 10.1111/pirs.12626.
Forman, Chris, Avi Goldfarb, and Shane Greenstein (Feb. 2012). "The Internet and Local Wages: A Puzzle". In: *American Economic Review* 102.1, pp. 556–575. ISSN: 0002-8282. DOI: 10.1257/aer.102.1.556.
Gaspar, Jess and Edward Glaeser (Jan. 1998). "Information Technology and the Future of Cities". In: *Journal of Urban Economics* 43.1, pp. 136–156. ISSN: 0094-1190. DOI: 10.1006/juec.1996.2031.
Glaeser, Edward (May 1998). "Are Cities Dying?" In: *Journal of Economic Perspectives* 12.2, pp. 139–160. ISSN: 0895-3309. DOI: 10.1257/jep.12.2.139.
— (Dec. 2020). *Infrastructure and Urban Form*. DOI: 10.3386/w28287.
Goodman-Bacon, Andrew (Dec. 2021). "Difference-in-differences with variation in treatment timing". In: *Journal of Econometrics* 225.2, pp. 254–277. DOI: 10.1016/j.jeconom.2021.03.014.
Gordon, Robert (2017). *The rise and fall of American growth: The US standard of living since the civil war*. Princeton university press.
Helpman, E (1998). *The size of regions*. Ed. by Zilcha I Pines S Sadka P. Cambridge University Press, Cambridge.
Hjort, Jonas and Jonas Poulsen (Mar. 2019). "The Arrival of Fast Internet and Employment in Africa". In: *American Economic Review* 109.3, pp. 1032–1079. ISSN: 0002-8282. DOI: 10.1257/aer.20161385.
Krugman, Paul (June 1991). "Increasing Returns and Economic Geography". In: *Journal of Political Economy* 99.3, pp. 483–499. ISSN: 1537-534X. DOI: 10.1086/261763.
Krugman, Paul and A. J. Venables (Nov. 1995). "Globalization and the Inequality of Nations". In: *The Quarterly Journal of Economics* 110.4, pp. 857–880. ISSN: 1531-4650. DOI: 10.2307/2946642.
McCoy, Daire, Sean Lyons, Edgar Morgenroth, Donal Palcic, and Leonie Allen (Jan. 2018). "The impact of broadband and other infrastructure on the location of

new business establishments". In: *Journal of Regional Science* 58.3, pp. 509–534. ISSN: 1467-9787. DOI: 10.1111/jors.12376.
Parkhomenko, Andrii and Matthew Delventhal (2022). "Spatial Implications of Telecommuting in the United States". In: DOI: 10.7922/G2GB22D2.
Ramani, Arjun and Nicholas Bloom (May 2021). *The Donut Effect of Covid-19 on Cities*. DOI: 10.3386/w28876.
Redding, Stephen J. and Esteban Rossi-Hansberg (Aug. 2017). "Quantitative Spatial Economics". In: *Annual Review of Economics* 9.1, pp. 21–58. ISSN: 1941-1391. DOI: 10.1146/annurev-economics-063016-103713.
Roller, Lars-Hendrik and Leonard Waverman (Sept. 2001). "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach". In: *American Economic Review* 91.4, pp. 909–923. ISSN: 0002-8282. DOI: 10.1257/aer.91.4.909.
Sun, Liyang and Sarah Abraham (Dec. 2021). "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects". In: *Journal of Econometrics* 225.2, pp. 175–199. ISSN: 0304-4076. DOI: 10.1016/j.jeconom.2020.09.006.

Appendix A: Many Estimators with Diverging Views

We present here estimation of Equation (1) with the different methods, namely the dynamic TWFE using the 'not yet treated' as a control group (to avoid forbidden comparisons, see Goodman-Bacon, 2021) as well as the methods of Callaway and Sant'Anna (2021), and Butts and Gardner (2021). We also add the results with the estimators of Sun and Abraham (2021) and Borusyak et al. (2024) already presented in the text to ease comparison. Figure (6) presents results with the share of telecommuters on the right hand side of the estimation, while in Figure (7) it is the number of firm creation. As already discussed in the text, overall these indicators seem to show a significant positive effect of the HSI on teleworking and establishment births, but it is difficult to be fully convinced as some estimators cast doubt on the pre-trend, while others show a significant effect only for a few and late periods. The fact that some towns in the control group may be affected by the treatment seems to obscure the result of these estimates, which are obviously based on the assumption of no contamination.

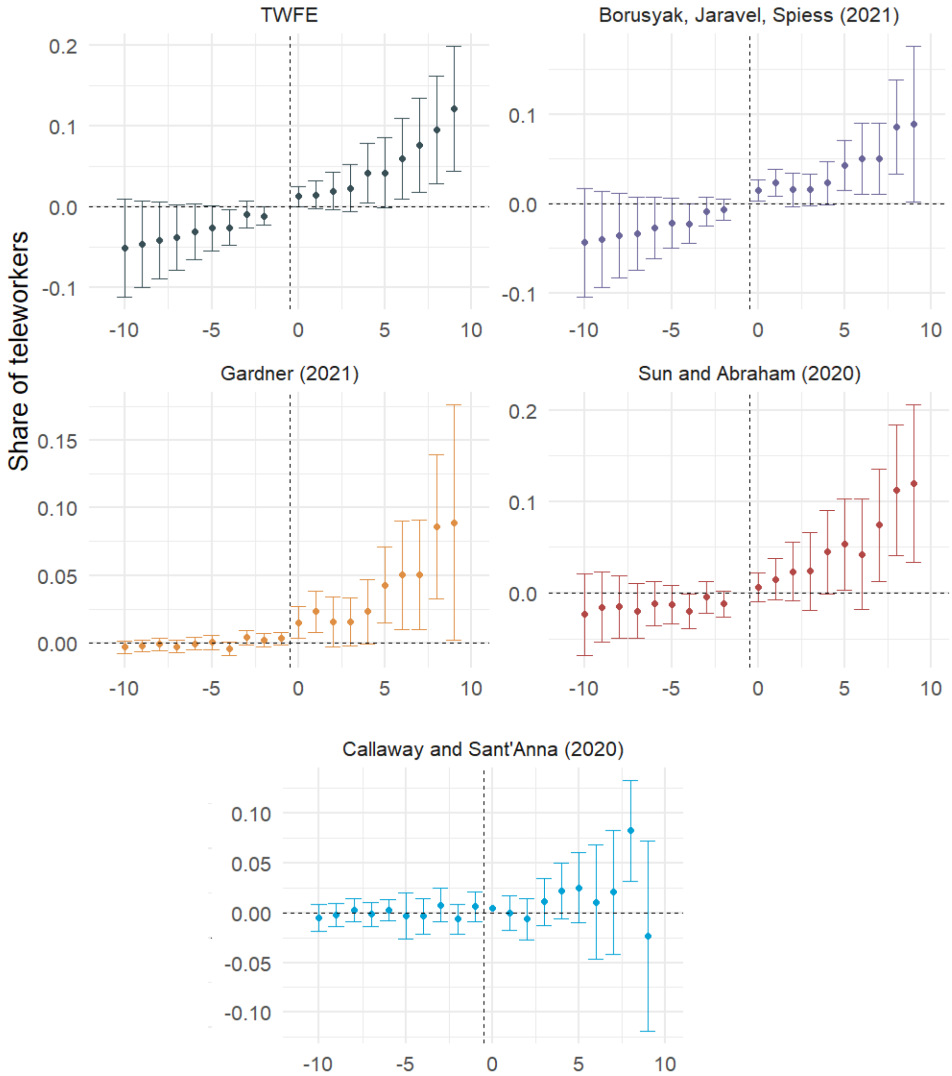

Figure 6: High Speed Internet and Working from Home

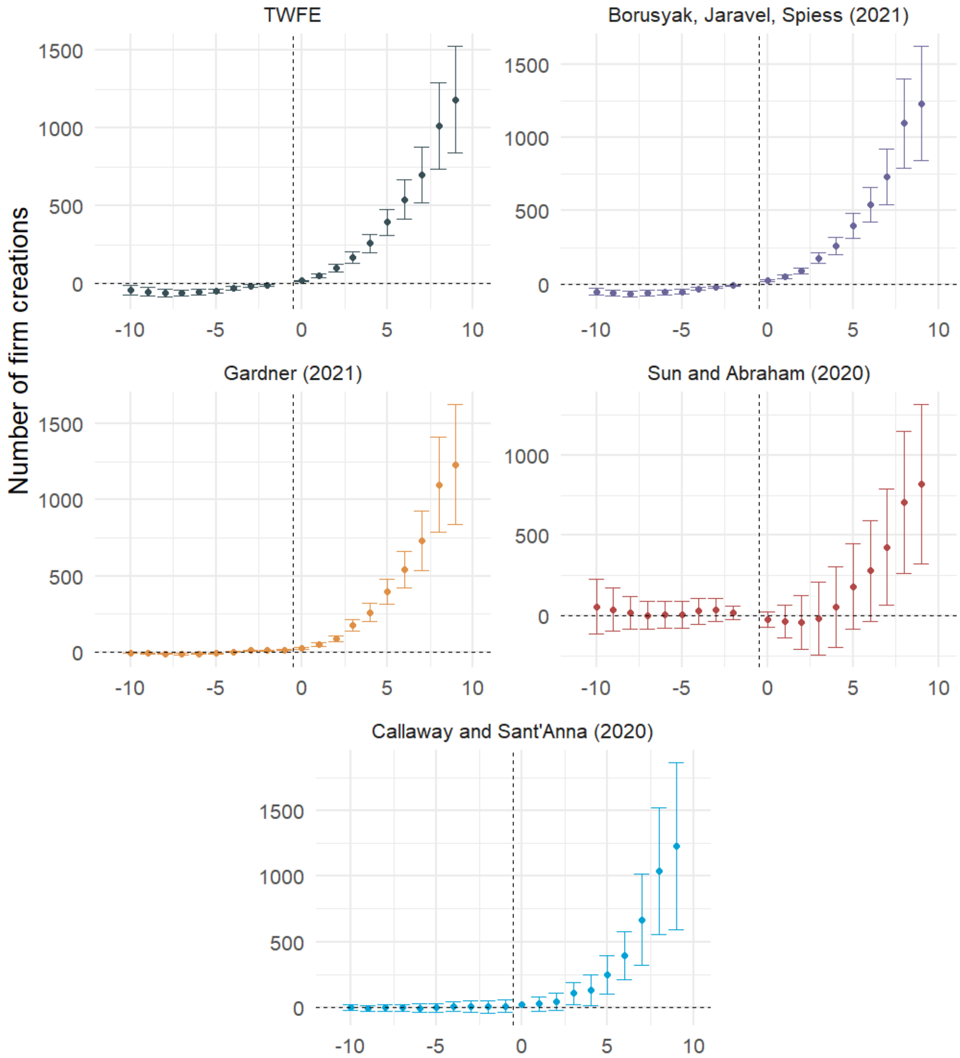

Figure 7: High Speed Internet and Working from Home

Appendix B: Spillovers at 25 km

Throughout the text, we use a distance of 15 km from the treated area to account for spillover effects. Here, we test the robustness of our result by using a threshold of 25 km. We find similar results.

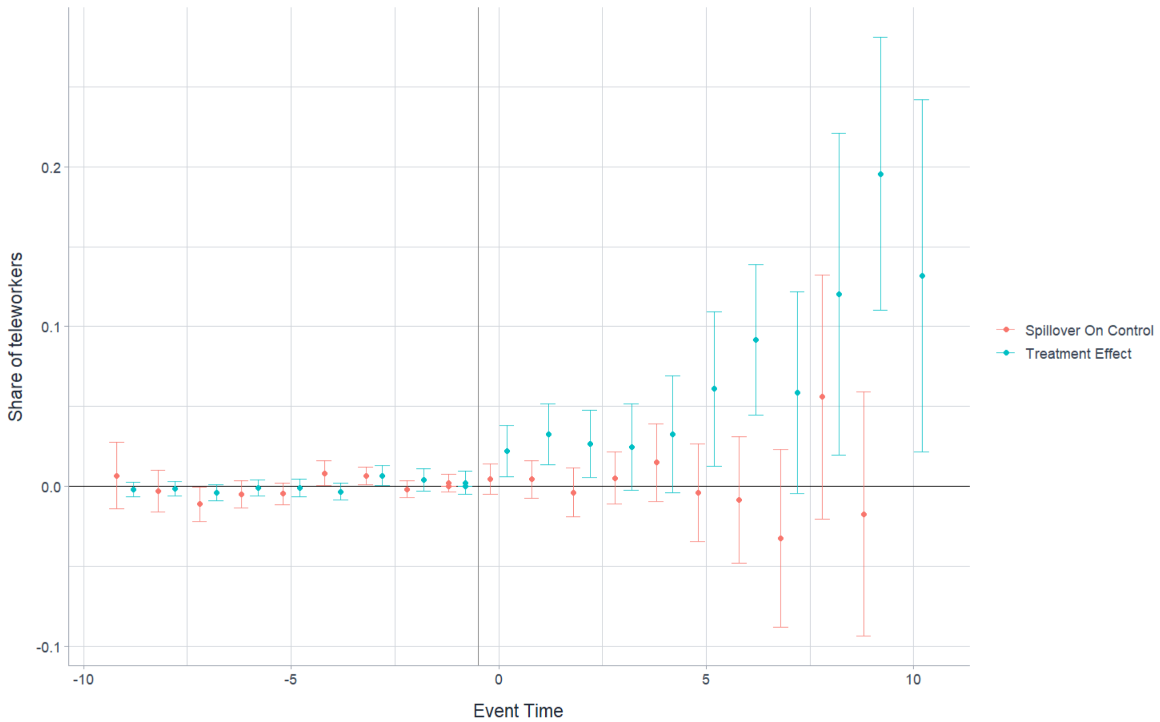

Figure 8: No spillover at 25 km for telecommuters

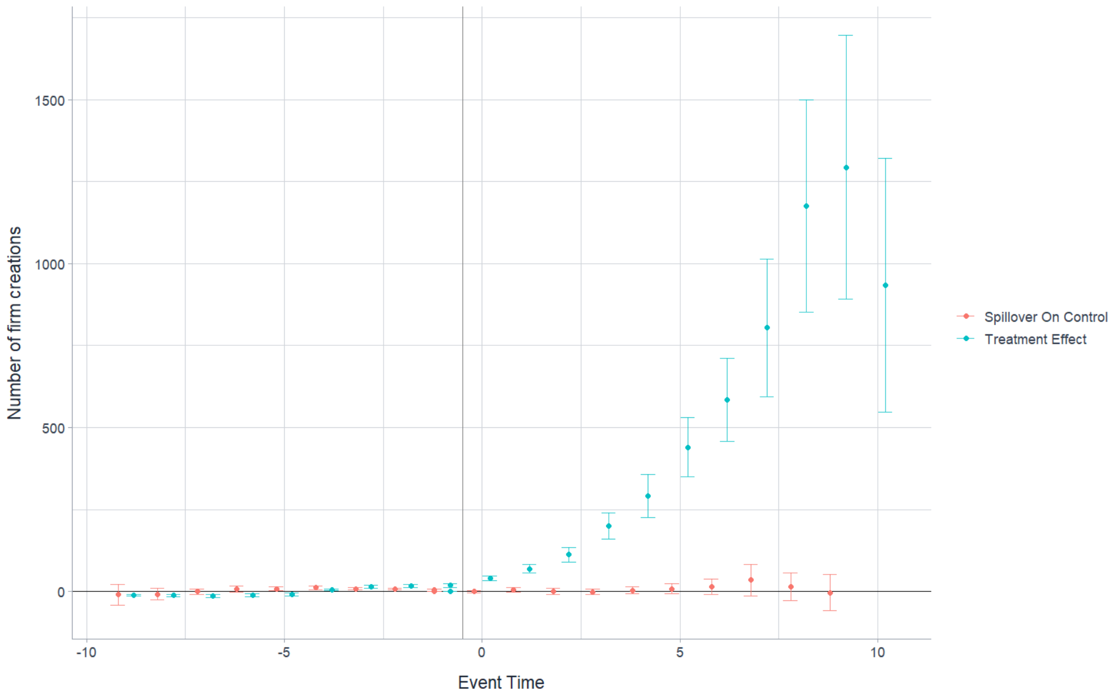

Figure 9: No spillover at 25 km for firms

Appendix C: Skilled Telecommuters

As discussed in many papers, remote work concern mainly high-skilled workers and the results obtained in the text are driven by this category. In Figure (10) we report our results for teleworkers in executives and higher intellectual professions, and clearly see a similar pattern of the one presented in the text.

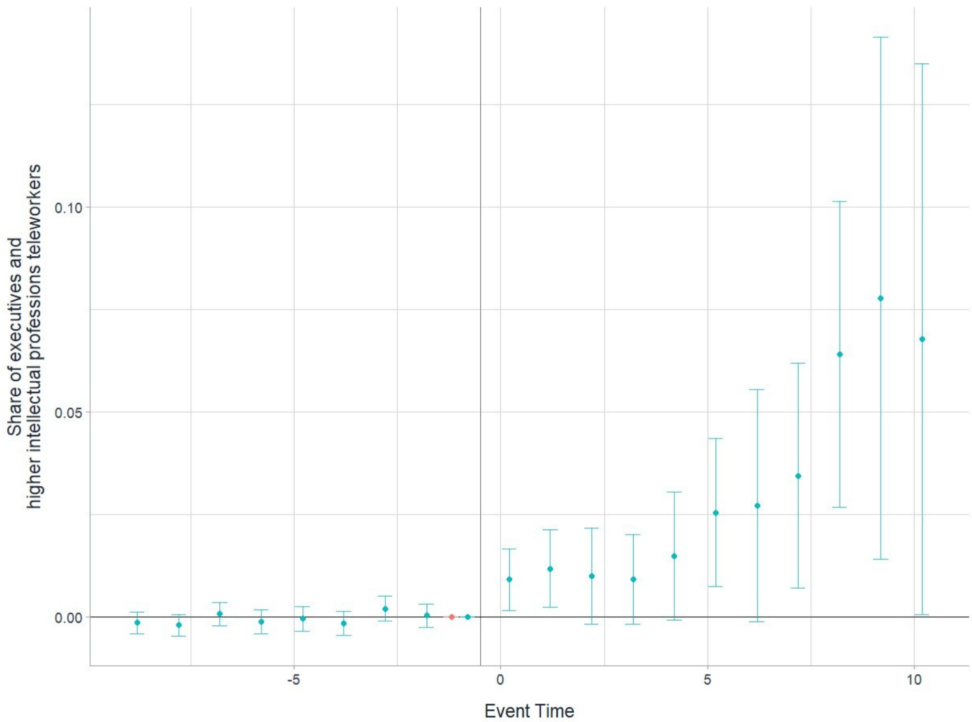

Figure 10: Impact of the arrival of fiber optics on the proportion of teleworkers in executives and higher intellectual professions

We wonder whether the fact of having a child influences the decision to work at home or, in contrast, acts as a brake. In fact, we find similar results for professionals with or without children. Figure (11) shows the result for teleworkers with children.

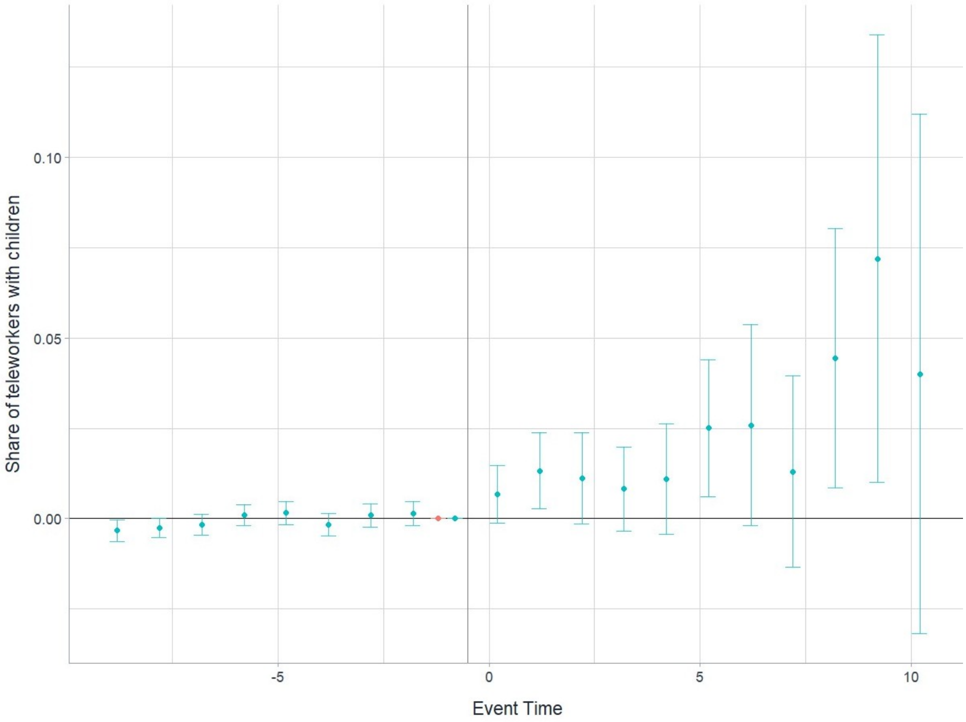

Figure 11: Impact of the arrival of fiber optics on the proportion of teleworkers with children

Appendix D: Internet Speed

In this section, we analyze the impact of FTTH on both the share of teleworkers and the number of firm creations considering the pre-existing quality of Internet access in different municipalities in 2015. More precisely, we have data on the share of housing in each municipality that had access to Internet speeds of at least 100 Mbps and at least 30 Mbps in both 2015 and 2020.

We reproduce our estimations in this section by distinguishing municipalities by the share of housing which have access at least to 30 Mbps in 2015. Technically, we create a set of dummy variables based on the share of housing units with access to at least 30 Mbps in 2015. These dummy variables are then interacted with the treatment variable (FTTH) to capture potential heterogeneous effects across municipalities with different initial levels of Internet accessibility. For instance, for the first category, if a municipality had between 0% and 25% of households eligible for at least 30 Mbps in 2015, the variable C1 (Category 1) takes the value 1, and 0 otherwise. We follow the same approach for the other categories (C2, C3 and C4).

The equations that we have estimated are the following ones :
For C1 :

$$N_{it} = \sum_{\ell} \beta_{\ell} C1 * 1\left\{t - E_i = \ell\right\} + Z_{it} + \Gamma_{it} + f_i + f_t + \varepsilon_{it}, \tag{3}$$

For C2 :

$$N_{it} = \sum_{\ell} \beta_{\ell} C2 * 1\left\{t - E_i = \ell\right\} + Z_{it} + \Gamma_{it} + f_i + f_t + \varepsilon_{it}, \tag{4}$$

For C3 :

$$N_{it} = \sum_{\ell} \beta_{\ell} C3 * 1\left\{t - E_i = \ell\right\} + Z_{it} + \Gamma_{it} + f_i + f_t + \varepsilon_{it}, \tag{5}$$

And for C4 :

$$N_{it} = \sum_{\ell} \beta_{\ell} C4 * 1\left\{t - E_i = \ell\right\} + Z_{it} + \Gamma_{it} + f_i + f_t + \varepsilon_{it}, \tag{6}$$

We find the following results presented in Table 3. In general, the impact of FTTH is positive on the share of teleworkers and firm creations. We also observed that the higher the share of housing units with access to at least 30 Mbps in 2015, the greater the impact of FTTH on both the share of teleworkers and the creation of firms.

Table 4 we use the share of home which have access to at least 100 megabits in 2015 to categorize municipalities and analyze the FTTH effect on treated and untreated municipalities according their category. As before, we find positive and significant effect on firm creation for all our categories. For the share of teleworkers, we find positive and significant effect except for the municipalities which have between 25% and 75% home eligible to 100Mbps in 2015.

Dep Var	Share of teleworkers				Firm creation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SHE >30 MB	[0;25[	[25;50[	[50;75[	[75;100]	[0;25[	[25;50[	[50;75[	[75;100]
Treatment	0.022 ** (0.01)	0.023 ** (0.011)	0.017 (0.013)	0.027 *** (0.01)	52.04 *** (14.17)	79.13 *** (19.63)	110.1 *** (31.15)	515.2 *** (61.7)
R^2	0.378	0.378	0.378	0.379	0.894	0.893	0.893	0.899
Observations	23,217	23,217	23,217	23,217	23,217	23,217	23,217	23,217

Notes: Standard errors are clustered at the municipality level (in parentheses), *** p< 0.01, ** p< 0.05, * p< 0.1. Results are obtained from a spillover regression using the OLS estimator. Individual fixed effects and time effects are included in all estimations. Our control variables for the share of teleworkers are: the number of firms per 1,000 inhabitants, the share of workers in the information and telecommunications sector, and the share of workers in highly intellectual professions. These variables are all significant, not reported to save space. Furthermore, for firm creation, we do not control by the number of firms per 1,000 inhabitants. Columns represent percentage points in the proportion of homes eligible for 30 megabits or more of Internet access in 2015. SHE : Share of homes eligible for 30 megabits or more in 2015.

Table 3: Impact of fiber on the share of teleworkers and firm creation on treated according to the share of homes eligible for 30 megabits or more in 2015

Dep var	Share of teleworkers				Firm creation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SHE >100 MB	[0;25[	[25;50[	[50;75[	[75;100]	[0;25[	[25;50[	[50;75[	[75;100]
Treatment	0.022 ** (0.011)	0.011 (0.011)	0.011 (0.016)	0.036 ** (0.01)	58.84 *** (12.14)	206.78 *** (43.51)	694.82 *** (256.81)	529.47 *** (89.98)
R^2	0.378	0.378	0.378	0.379	0.896	0.893	0.896	0.897
Observations	23,217	23,217	23,217	23,217	23,217	23,217	23,217	23,217

Notes: Standard errors are clustered at the municipality level in parentheses, *** p< 0.01, ** p< 0.05, * p< 0.1. Results are obtained from a spillover regression using the OLS estimator. Individual fixed effects and time effects are introduced in all estimations. Our control variables for the share of teleworkers are: the number of firms per 1,000 inhabitants, the share of workers in the information and telecommunications sector, and the share of workers in highly intellectual professions. These variables are all significant, not reported to save space. Furthermore, for firm creation, we do not control by the number of firms per 1,000 inhabitants. Columns represent percentage points in the proportion of homes eligible for 100 megabits or more of Internet access in 2015. SHE : Share of homes eligible for 100 megabits or more in 2015.

Table 4: Impact of fiber on the share of teleworkers and firm creation on treated according to the share of homes eligible for 100 megabits or more in 2015