The Effect of High-Speed Internet on Working from Home

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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 and positive effects on the likelihood of remote work, increasing the share of telecommuters to 4.5 percentage points each year on average over the period. 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

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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 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, with an increasing need for teleworking management.

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. Based on Butts (2021) and Butts (2023), these results are robust to a spatial contamination effect of the treatment on the untreated. Our contribution is threefold.

First, we find a significant increase in the share of teleworking in cities that have invested in the high-speed internet. This result is found for almost all kinds of cities (dense and less dense cities) and for all types of skilled workers/households. This has important implications, implying that with the improvement in what can be done through the Internet (in particular, the increasing use of AI), firms will have to manage more workers remotely regardless of their location. It is not a phenomenon limited to dense and large cities. Furthermore, the disparity in access to remote job opportunities can cause feelings of discontent and dissatisfaction among unskilled workers, which can represent a serious managerial challenge for companies.

[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.

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 effects 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 (pecuniary externalities). In contrast, the growth of one city thanks to FFTH can spur on untreated surrounding cities, attracting businesses and jobs from further afield. We find none of these effects for teleworkers, neighborhood cities are unaffected by the treatment. The HSI investment may have been too small to generate these large spatial effects. This may come as good news for urban policy makers that aim to internalize the effect of their investments. There is, however, 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.

Third, to better understand what is happening at the firm level, we examine how the high-speed Internet has affected establishment births. As for teleworkers, we observe a significant increase in firm creation when HSI is implemented, but we also detect negative spillovers: the implementation of HSI seems to attract firms from intermediate-dense and rural areas.

With regard to the literature, the impact of HSI on firms has generated a large literature (Hjort and Poulsen, 2019; Duvivier et al., 2021; Duvivier and Bussiere, 2022; Deller et al., 2021; Cambini and Sabatino, 2023). Nevertheless, to our knowledge, no studies have been carried out on working from home.

The choice of location of telecommuters has also been investigated in many articles (Duranton and Handbury, 2023; Gokan et al., 2022; Delventhal et al., 2022; Ramani and Bloom, 2021; Brueckner et al., 2023 and Behrens et al., 2024, to name a few). However, the role of HSI has never been analyzed.

The remainder of the paper is structured as follows. Section 2 briefly reviews the background of ultra-fast broadband in France and presents a quantified model to discuss the mechanisms as well as the literature on HSI, firm location and remote jobs. Section 3 presents the data used and the empirical strategy adopted. Section 4 shows the main results on the impact of FTTH on telework. Section 5 performs some extensions by questioning the heterogeneous effect of FTTH depending on several factors (type of city, type of household). Section 6 examines the mechanisms related to the effect of FTTH on business creation. Finally, Section 7 concludes the paper.

2 Background

2.1 The Very High-Speed Broadband Plan

Historically, the introduction of the Internet in France began with the use of dial-up modems in the early 1990s, which allowed connection 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. Fiber optic technology (FTTH - Fiber to the Home) started to be deployed in 2003 in some avant-garde cities, such as the small peripheral city of Pau with the objective of attracting IT firms.[3]

But the main transition to FTTH began in 2013 with the launch of the *Very High-Speed Broadband Plan* (in French "Plan France Très Haut Débit"), a national initiative aimed at providing ultrafast broadband ($>$ 100 Mbps) to at least 80% of the population by 2025 for a budget of 13.3 billion euros over the period.[4]

Under this program, the French government has separated the country into territories called "private initiative zones" and "public initiative zones". In private initiative zones, which encompass densely populated urban areas, the deployment of fiber networks has been driven by competition between private infrastructure providers. Due to their density, these zones are profitable for operators. In contrast, 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.

All this background explains why France has a vast network enabling FTTH, including in rural areas (Duvivier et al., 2024; Duvivier and Bussiere, 2022).

By 2023, the number of fiber optic subscribers in France surpassed 21 million, and the number of equipped homes should reach 43 million in 2025-26.

According to the OECD Broadband Database,[5] the growth rate of investment

[3]See the Wall Street Journal.

[4]See European Commission.

[5]See also Dozias, 2023

in fiber optic implementation in France has been one of the strongest in the OECD countries (40% between 2009 and 2018 while Germany was at 26%). Only the United States has a similar growth rate of 41% in the period.

2.2 Empirical findings on the effect of HSI on firms

Considering french 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. 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.

These works echo several other researches around the world. Taking advantage of the gradual arrival of submarine internet cables on the African coast, Hjort and Poulsen (2019) shows large positive effects on employment rates without 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) finds 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.

2.3 Mecanism 1: Impact of HSI on the location of firms

To illustrate the most simple mechanism explaining the impact of FTTH on remote jobs, we use the standard quantitative model of the new economic geography (see Redding and Sturm, 2008; Redding, 2016; Redding and Rossi-Hansberg, 2017). Since this model is described in various publications and because we do not introduce any substantial extensions, we do not present here the equations and only briefly present its main assumptions.

Consumers have a utility function linking goods and housing consumption with a Cobb-Douglas form. Goods are horizontally differentiated, and consumers have a constant elasticity of substitution over these varieties that are all consumed. Since our aim is to present a framework in which HSI by affecting the productivity of firms can shape the economy geography of remote jobs, we do not introduce other forms of heterogeneity across space, and then we consider that the utility of consumers is not a function of urban amenities (our utility function is thus equivalent to Redding, 2016 with $b_n(\omega) = 1$). Expenditure on land in each location is redistributed in a lump sum to the workers residing in that location.

The different varieties of goods are produced under monopolistic competition and increasing returns to scale. Labor is the only factor of production, and a firm incurs a fixed cost of F units of labor and a variable cost that depends on the productivity of the location A_i. Productivity is drawn independently across locations from a logarithmic normal distribution with A_i as the scale parameter of this distribution. The amount of labor in i for a firm j, $l_i(j)$, that produced $x_i(j)$ is given by:

$$l_i(j) = F + \frac{x_i(j)}{A_i}. \tag{1}$$

Workers live and work in the same city and do not have any benefits or costs to work at home. WFH does not imply lower productivity for firms (in our framework, this would lead to simply reducing the effect of HSI on firms' productivity). We simply assume that an exogenous share θ of the labor force in each city works at home. Thus, only the endogenous location of firms and workers defines the number of telecommuters in each city. We then discuss how the literature that has relaxed these assumptions finds new results. Trade is balanced at each location. Mobility implies an equalization of the indirect utility in space. Trade costs are symmetric and identical between each pair of cities. Finally, we impose the parameter condition that guarantees a unique equilibrium (depending on the share of land expenditure α and the substitution elasticity σ, such as $\sigma * (1 - \alpha) > 1$).

2.4 Illustrative results

We consider an economy on a 30×30 latitude and longitude grid as in Redding and Rossi-Hansberg (2017). However, contrary to these authors, we do not divide this grid in two countries/regions. Each cell represents a city, and hence we work with a spatial economy of 900 cities. Labor is perfectly mobile in all locations. As in Donaldson (2016), the effective distance of the lowest-cost route is calculated, minimizing the cumulative cost of traveling between each origin and destination (Donaldson, 2018). Under these assumptions and by setting values to parameters that are identical to those chosen in the literature (see the next footnote for details), we resolve the system of market clearing equations. Figure 1 shows the initial distribution of productivity.

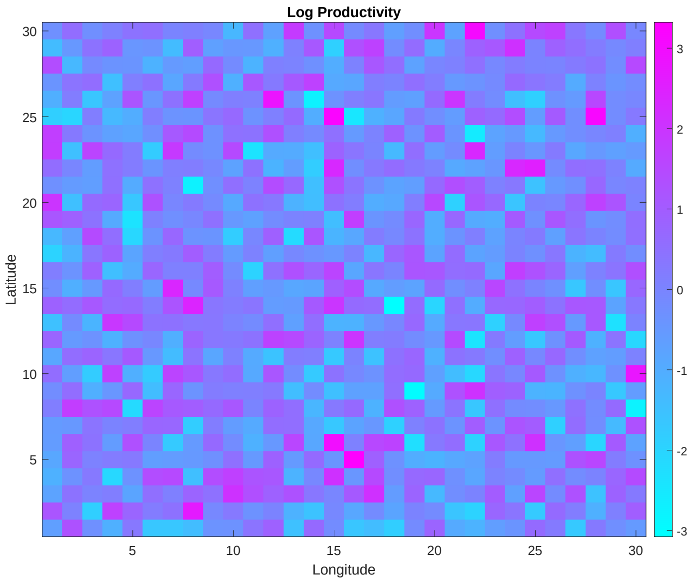

Figure 1: Initial Productivity

Under these conditions, as reported in Figure 2, we observed two conurbations and several sub-centers that agglomerate more labor due to the higher productivity of firms in these locations. As a consequence, these cities also host more telecommuters.

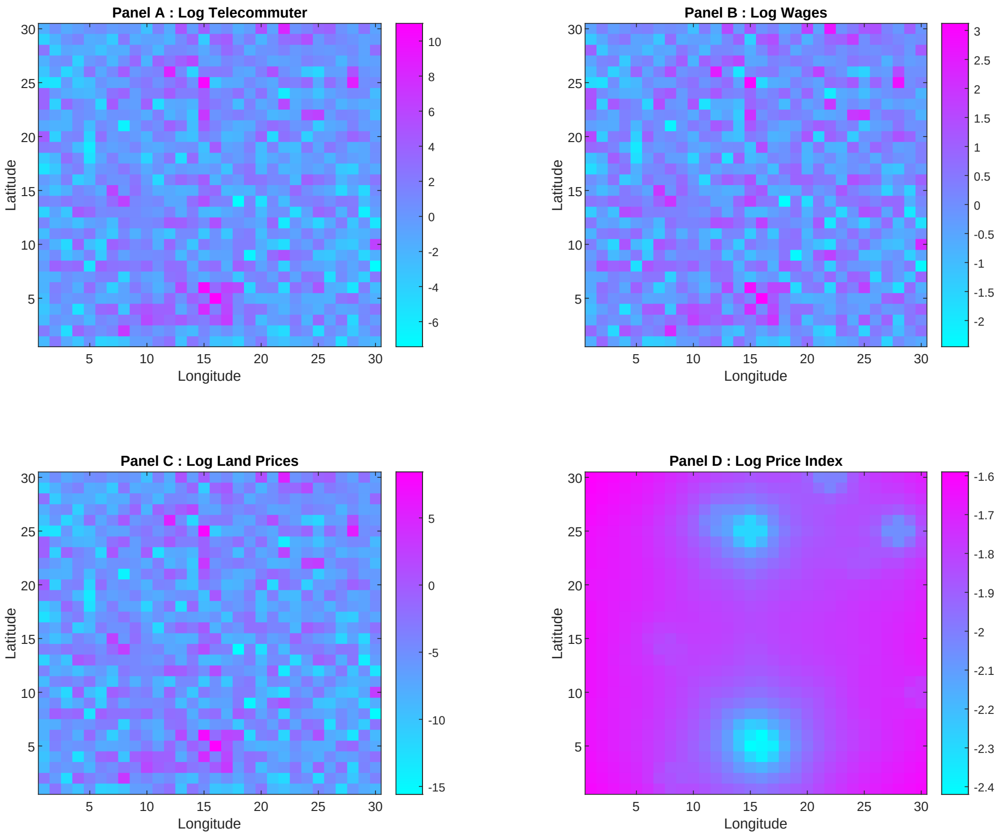

Figure 2: Initial Equilibrium

These locations are also characterized by higher wages and higher land prices. In contrast, price index are smaller there because more goods are produced in these locations and then the burden of trade costs in the consumption basket is smaller. What happens now if the HSI internet is only installed in some cities? We model this in a very simple form, we assume that HSI improves the productivity parameter A_i of workers in the city i where it is installed. One may think that several tasks are done faster thanks to fast connection (downloading data, working on the cloud, coordinating the supply chain, improving skills via online training, etc.). This assumption that a good internet connection fosters the productivity of firms is confirmed by a large literature across very different economic geography. Such as Bartel et al. (2007) for the U.S., Czernich et al. (2011) for OECD countries, Aboal and Tacsir (2017) for Uruguay, Zhang et al. (2021) for China, and Gbandi et al. (2024) for Togo.

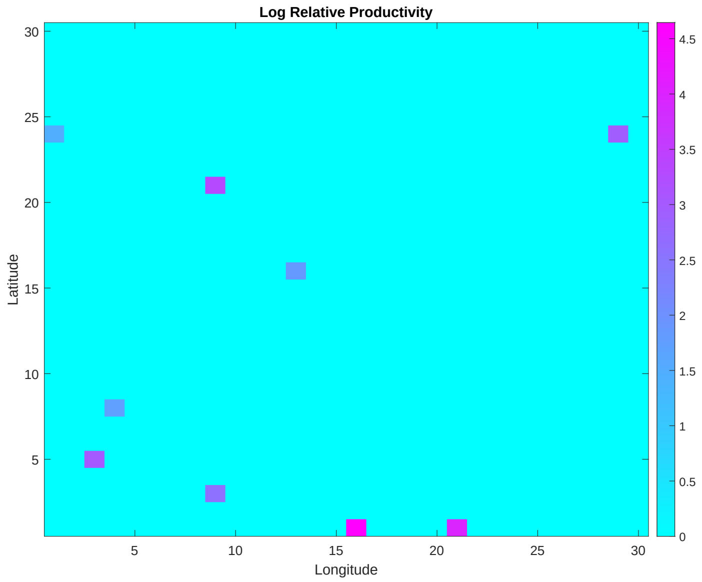

Figure 3: High Speed Internet Productivity Shock

Although in reality HSI may have been installed in an endogenous way, here we can implement an exogenous treatment. We use our model as a laboratory and set an improvement of productivity λ in a random way on our spatial economy (a number z of cells/cities randomly receive an additional productivity such as firms there benefits of $A_i + \lambda$ while other cells remain with their initial draw). Figure 3 shows the locations that receive this additional increase in productivity by presenting the ratio λ / A_i (to get a clear picture, we set a low value for z: only 1% of the cities receive HSI).[6] Relative change due to this implementation is reported in Figure 4.

[6]More precisely parameters used are: $F = 1$, $\alpha = 0.75$, $z = 0.01$, $\theta = 0.1$. The effect of HSI on productivity is set to $\lambda = 20$, which represents a strong productivity shock. With a smaller impact of HSI on productivity (e.g $\lambda = 0.5$), results are less strong and less visible in maps; in particular there are no spillovers effects around treated units. For the total population, we use $L = 153889$ which is the number taken by Redding (2016) (US labor force in 2010). Finally the housing supply in each city is set to $H = 100$.

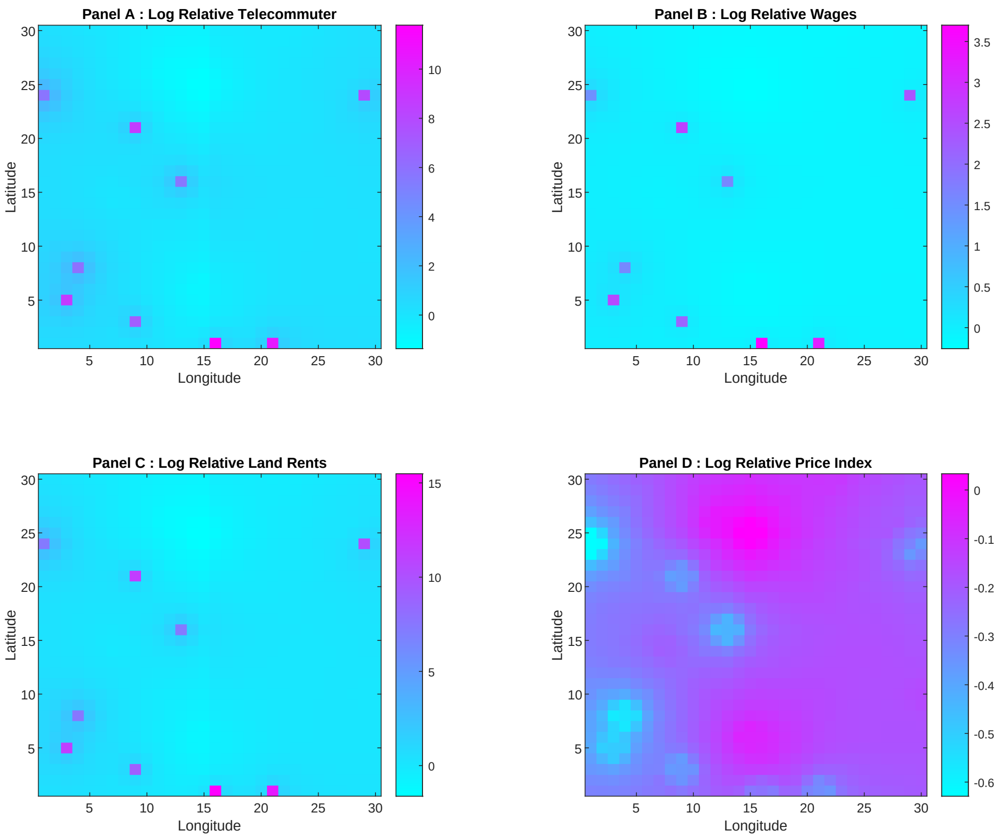

Figure 4: Spatial Change due to High Speed Internet

We observe three results that are testable:

1. Cities with HSI gain telecommuters
2. Untreated and large agglomeration are negatively affected and lose telecommuters.
3. Distance to the treatment matter: untreated cities near the treated one gain firms and then telecommuters.

Several additional assumptions can amplify or reduce the results presented here.

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).

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). Increasing competition for resources (e.g., labor) can also generate this urban attrition around attractive cities (Cuberes et al., 2021). Bjerke et al. (2024) find a result that supports this mechanism and assert that ”shadow effects are magnified by the work-from-home revolution”.

Finally, if telecommuters are less productive at home than at the office, the productivity shock of HSI may be mitigated if the share of remote jobs is too high (Behrens et al., 2024).

2.5 Mechanism 2: the teleworking choice

In the previous model, several assumptions attach the results of firms/workers location to those of remote jobs. The objective was to isolate the effect due to firm creation and relocation from the choice to work at home or at the office. This serves as a useful starting point to introduce the literature that has relaxed the spatial dependence among firms, workers, and teleworkers.

Considering that teleworkers use part of their home for office without an increase in utility (an implicit ”home office tax”), Duranton and Handbury (2023) presents a spatial sorting of the individual based on skills and incomes. Remote skilled workers chose to live in the outer suburbs to satisfy their higher demand of housing at a lower price, while unskilled (and in-person skilled workers) remain close to the center. Gokan et al. (2022) show that teleworking also leads to a reallocation of jobs for unskilled workers that fuels wage inequality. Using a similar quantitative model to that presented previously, but with telecommuting choice, Delventhal et al. (2022) report a decline in real estate prices in the core locations of the Los Angeles metropolitan area, coupled with an increase in the peripheral areas. This flattening of the bid-rent curve due to the suburbanization of telecommuters has been referred to as the ”donut effect” (Ramani and Bloom, 2021).

Brueckner et al. (2023) also highlight the growing separation between work and residential locations. They observed that while population and housing prices may decline, employment can increase in cities with a productivity advantage; however, these cities export remote jobs possibly toward cities with high amenities. Although they do not find support for this last point in their data, they observe that prices and rent decrease in high-productivity cities after the pandemic.

Still working on the COVID-19 period (from February 2020 to January 2021), Ramani and Bloom (2021) find that the most densely populated zip codes experienced a population loss of approximately 15%, while the least dense areas gained approximately 2%.

3 Data

3.1 Ultra-fast broadband

We analyze the impact of the deployment of FTTH in France at the level of units that are connected or eligible for fiber optic. The period studied is between 2006 and 2022 and the data is aggregated at the level of the municipality.[7] We analyze the impact of the arrival of HSI in each municipality on the date when the completion deadline for fiber connection begins. This is the date when telecommunication operators commit to install the optical fiber network in a location. [8]

3.2 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.

[7]These data comes from the Regulatory Authority for Electronic Communications, Postal Services, and Press Distribution, known under the acronym ARCEP in French.

[8]For convenience we are going to speak of implementation, but a better term may be the "eligibility" of FTTH in a city. 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 time to generalize the urban network.

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.

3.3 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.

3.4 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".

4 Empirical Strategy

4.1 Dynamic difference-in-differences

The main challenge with spatial spillovers is to determine where they no longer exist and where we can begin to consider an area as completely untreated and then chosen as a valid control. In the following analysis, we ignore this problem and make the strong assumption that there are no spatial spillovers. This analysis thus represents a first approach using standard DiD estimators, that we improve in the next subsection.

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):

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

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.

4.1.1 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, as already discussed, it is entirely possible that the impact of the treatment extends beyond the treated municipalities.

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 this 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 (2) as previously but with a new term Γ_{it}, such as:

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

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.

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 $\sum_{\ell} \beta_{\ell} 1 \{t - E_i = \ell\} + \Gamma_{it}$.

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 (See Appendix B).

This ad-hoc robustness check is motivated by the use of a nonparametric estimation[9] presented in Figure (5). This graph reports the impact of the treatment on the control group based on the distance from the treated municipality for the teleworkers. The first interesting result is that most controls are not affected. The second interesting result is that cities between 12 and 20 km are negatively affected.

[9]The nonparametric method partitions the sample based on the distance from the treated municipality. First, we select a threshold distance d_t such that only municipalities within d_t are expected to experience the treatment effect. Next, we choose a maximum distance d_c beyond which the effect is assumed to vanish; municipalities with distances between d_t and d_c serve as the control group. Municipalities within d_t are then grouped into bins, and a regression is performed for each bin to estimate the treatment effect by comparing outcomes in the treated group (municipalities within d_t) with those in the control group (municipalities between d_t and d_c).

Finally the effect of treatment beyond 20 km (and even more after 30 km) is not significantly different to zero. This leads us to verify our results with a $\bar{d}$ of 25 km in Appendix B, since no spillovers seem significant after that distance.

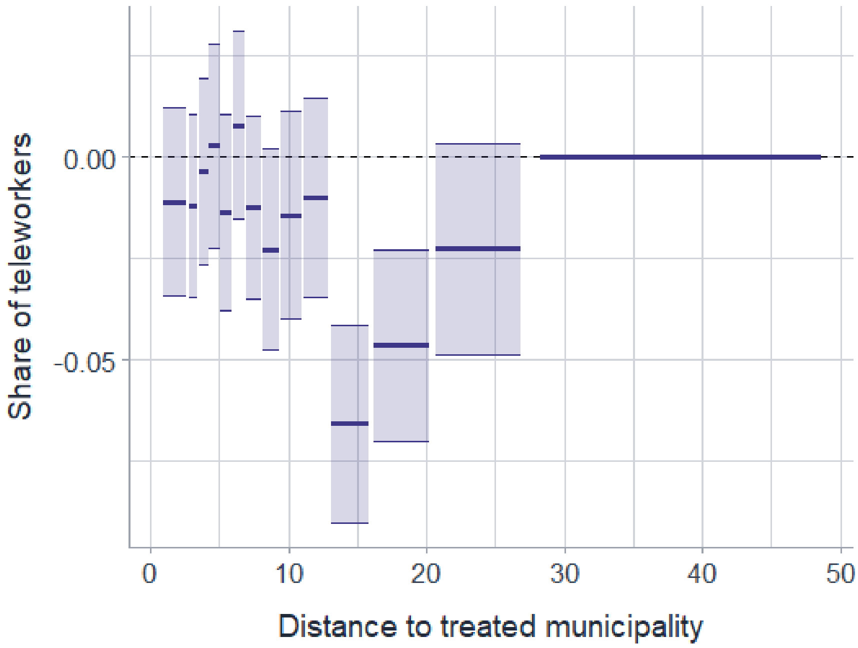

Figure 5: The distance of spillovers for teleworkers

5 FTTH a New Factor of Attractiveness?

5.1 Main Result: the Rise of Telework

In Figure (6) 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 (2), 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 6), 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.

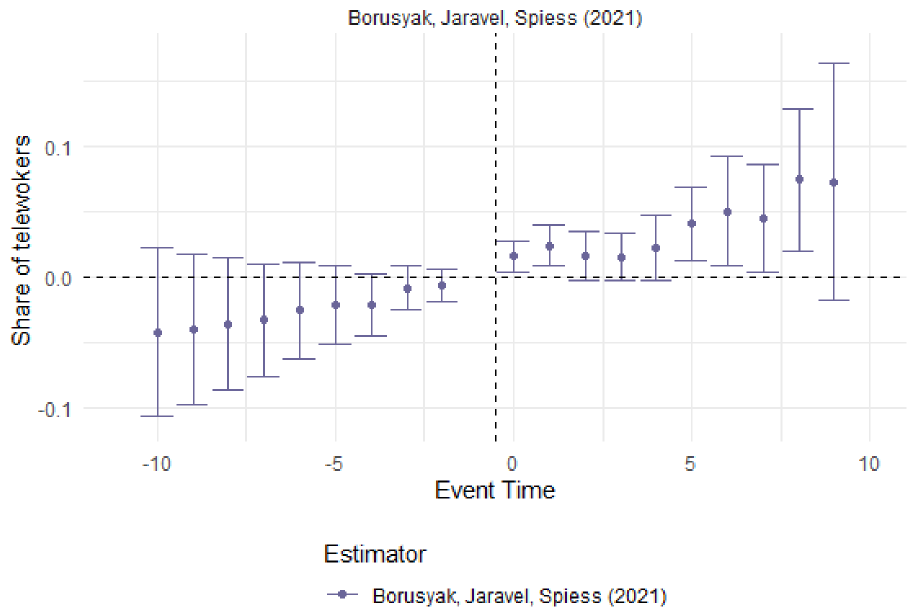

Figure 6: High Speed Internet and Working from Home

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 (7) 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.

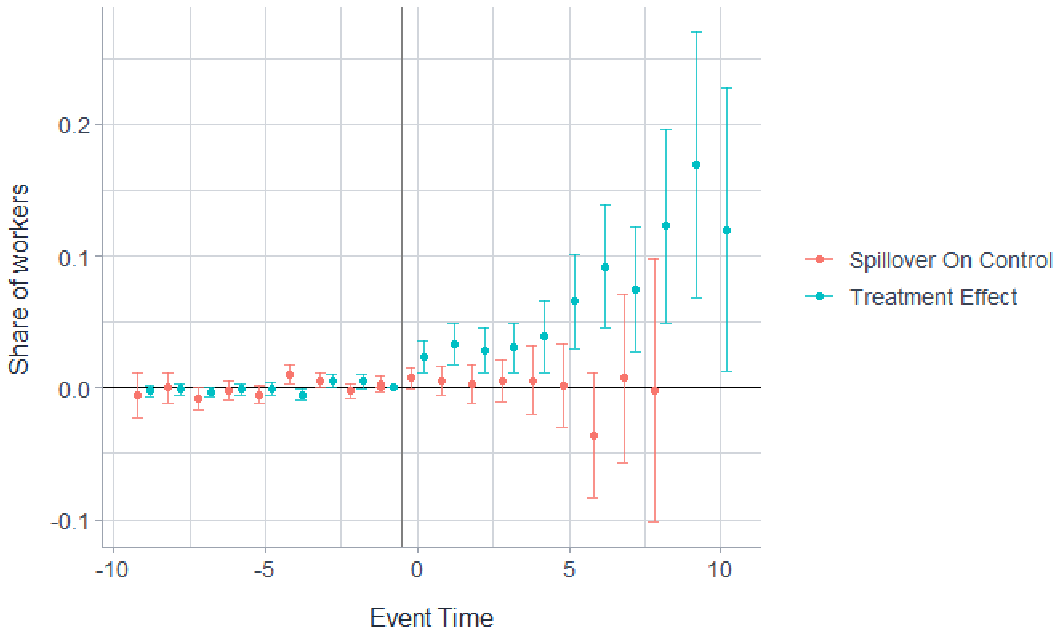

Figure 7: High-Speed Internet, Working From Home and Spillovers

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.

5.2 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 8, 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.

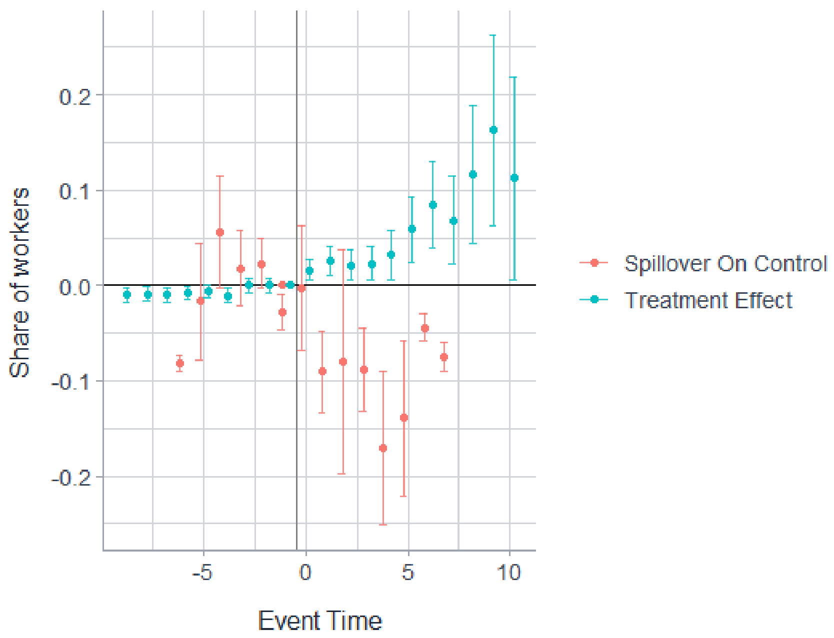

Figure 8: Cities with IC sector (5% IC firms)

6 Extensions

6.1 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 trains 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. The 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, 7).

Dep var: share of teleworkers	Dense urban	Interm dense	Rural areas
Treatment (by density)	0.049 ***	0.045 ***	0.033
	(0.011)	(0.013)	(0.02)
R^2	0.379	0.375	0.379
Observations	23,794	23,794	23,794

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, as found in Figure (7). Not reported here, the ATT is always significant (a coefficient of 0.045 significant at 1%) as already found in Figure (7).

Dep var : share of teleworkers	Dense urban	Interm dense	Rural area
Spillover (by density)	-0.0002	-0.001	-0.0025
	(0.0016)	(0.0017)	(0.0016)
R^2	0.378	0.378	0.378
Observations	26,447	26,447	26,447

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)

6.2 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".

6.3 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.

7 Testing the Simplest Mechanism: the effect of HSI on firms

The impact of FTTH on teleworking can be categorized into two main effects: its direct influence on the location choice of teleworkers and an indirect effect related to the creation of new firms. This dual impact introduces some ambiguity in predicting its overall spatial impact, as discussed in the literature section. We use again the model based on Redding (2016) presented in Section 2 to put in perspective the results obtained on teleworkers and to link them to firms.

The predictions of this model are a) teleworking in treated areas is possible only if there are an increase in the number of firms in the treated areas, b) the absence of spillovers in remote work is explained by the lack of spillovers for firms (we obtain this result with a small shock of HSI on productivity, $\lambda = 0.5$), and c) the presence of negative spillovers for teleworking in the IC cities is explained by the negative spillovers on firms in these cities.

As we will see in this section, while the prediction of this model concerning the treatment effect on the treated is verified for firms and teleworkers, its predictions concerning spillovers are invalidated.

7.1 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 (9) shows that the eligibility of 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.

These symmetrical results between the impact of the HSI on the growth of telework and business creation, that confirm predictions a) and b) 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 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, but only in a limited way, offering new outlets inside the city that encourage the creation of new businesses there.

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. However, 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[10]) and then teleworking can often occur close to its place of work.

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

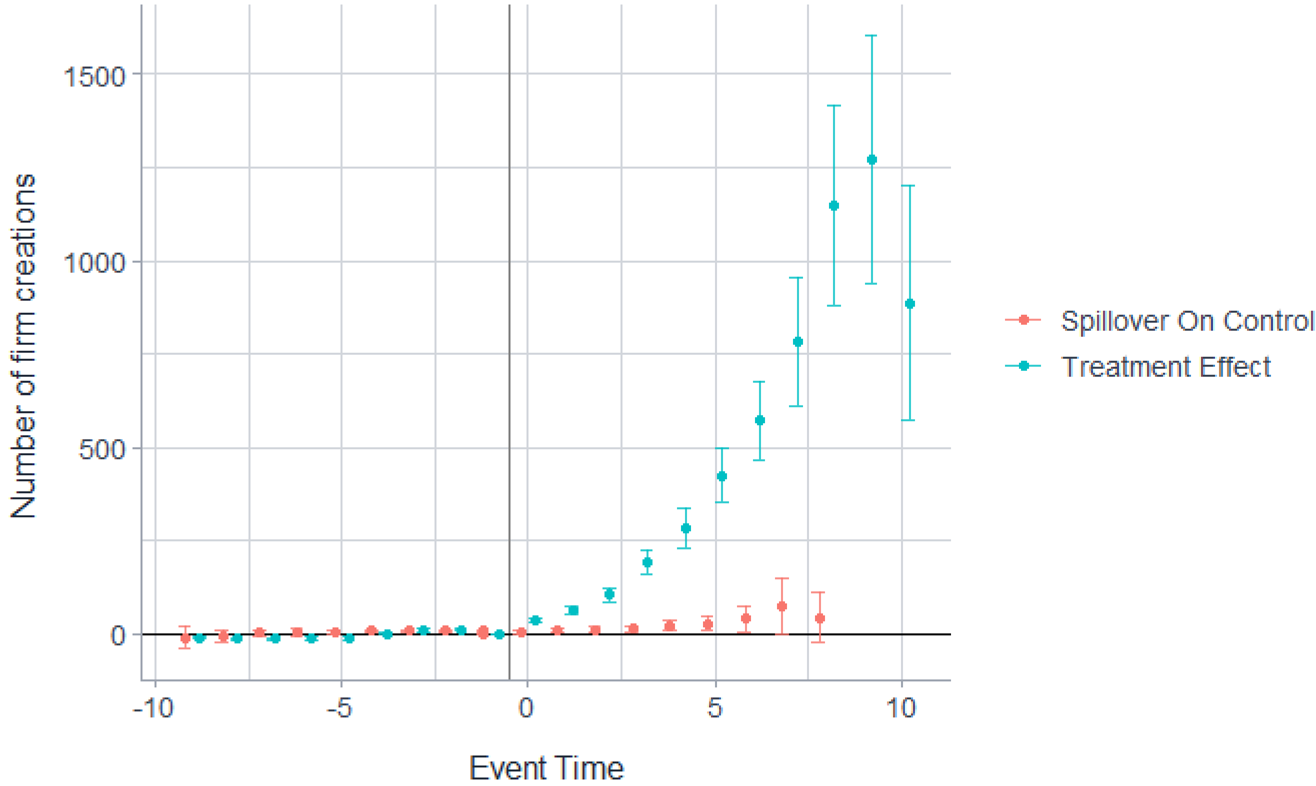

Figure 9: High Speed Internet, Firm births and Spillovers

7.2 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 (10), 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. We thus verify here the prediction a). However, with regard to spillovers, we find a very different picture, obtaining significant positive spillovers in cities around the treated. This result may come from pecuniary externalities generating positive effects around the treated, as represented in the theoretical model (see Figure 4 where the untreated cities around the treated are also affected). However, this result invalidates the mechanism behind our previous empirical result, the negative spillovers of FTTH on teleworking in IC cities (obtained in share of teleworkers, but also the number of teleworkers, see Appendix F,21) do not appear to come from a reduction in firm creation (falsification of prediction c).

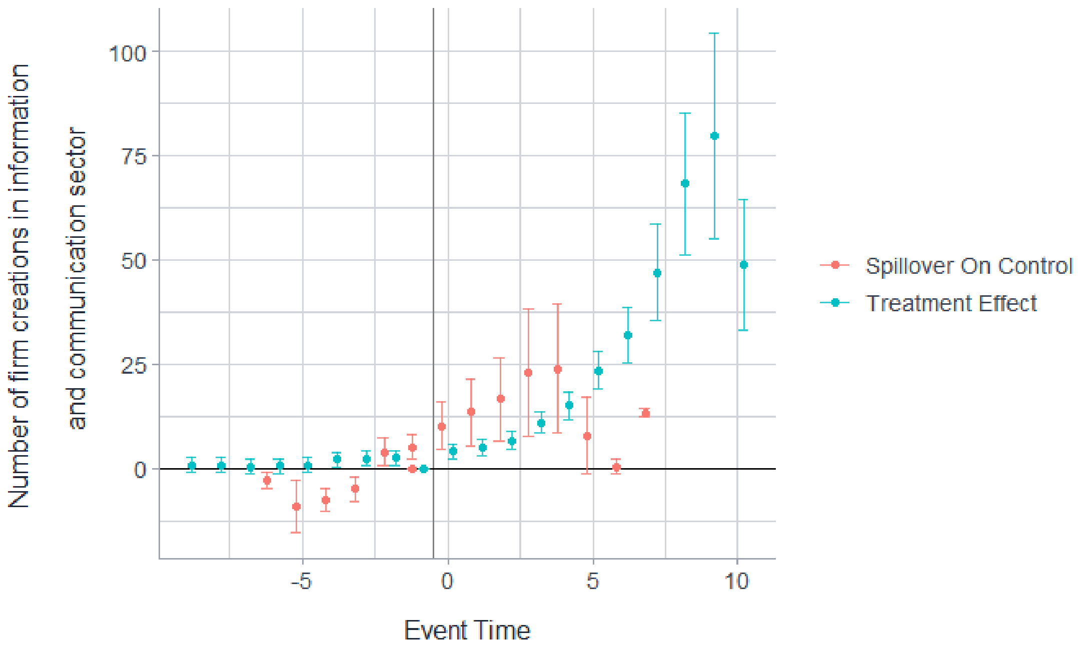

Figure 10: High Speed Internet, Firm births and Spillovers in IC cities

7.3 Type of City

The table 3 presents the impact of the development of FTTH considering the different types of cities that can host externalities in terms of firm creation.

Dep var : Firm creations	Dense urban	Interm dense	Rural area
Treatment (by density)	301.84 ***	41.94 ***	-1.15
	(32.5)	(5.78)	(3.15)
R^2	0.89	0.89	0.89
Observations	22,788	22,788	22,788

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 number of firm creation. Our control variables are: 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 3: Heterogeneous treatment effect (15 km radius)

We observe no significant effect for rural areas and significant positive effect in dense urban and intermediate dense cities. These findings are similar to those obtained for teleworkers in Table 1. We thus verify prediction a).

However, we again find divergent results for spillovers in Table 4. We observe negative spillovers in rural and intermediate cities for firms, while the spillover impact of HSI was not significant for teleworkers in these types of cities.

Dep var : Firm creations	Dense urban	Interm dense	Rural area
Spillover (by density)	0.22	-13.32 ***	-13.54 ***
	(0.87)	(2.48)	(2.58)
R^2	0.89	0.89	0.89
Observations	24,218	24,064	23,840

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 number of firm creation. Our control variables are: 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 4: Heterogenous spillovers according to density (15 km radius)

These results seem to go in the direction of the literature on telework showing a separation between the location choices of firms and of remote jobs. For example, Brueckner et al. (2023) present a model in which productive cities attract firms but send teleworkers to cities with amenities. A possible extension to the current work could be to analyze how the impact of HSI differs depending on these definitions of cities.

8 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 find that ultra-broadband internet connections also cause a spatial unbundling of labor with a significant increase in working from home.

This result has several implications. The advancement of Internet capabilities, especially with the growing application of AI, suggests notable consequences for organizational practices, indicating that companies may increasingly need to supervise employees operating remotely. In addition, in regions where the high-speed Internet (HSI) is newly implemented, businesses are likely to anticipate a growing demand for effective management of teleworking personnel.

We also find that, in general, there are no significant spillover effects for teleworkers, indicating that the benefit to a city of investing in this technology is internalized within the city fabric, at least at the time of HSI deployment. 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. Our analysis also shows that the attraction of firms due to HSI has negative consequences (spillovers) in neighboring intermediate-size cities and in rural areas.

In this study, we just pick the low hanging fruits of the analysis linking HSI and teleworking. The benefit of HSI may be magnified in the coming years with increasing access to innovative solutions and services located in the cloud. Many works also remain to be done to better understand how HSI affect the spatial separation between firms agglomeration in productive cities and the attraction of teleworkers in amenity-cities.

9 Reference

References

Aboal, Diego and Ezequiel Tacsir (2017). “Innovation and productivity in services and manufacturing: the role of ICT”. In: *Industrial and Corporate Change* 27.2, pp. 221–241. ISSN: 1464-3650. DOI: 10.1093/icc/dtx030.

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

Bartel, A., C. Ichniowski, and K. Shaw (2007). “How Does Information Technology Affect Productivity? Plant-Level Comparisons of Product Innovation, Process Improvement, and Worker Skills”. In: *The Quarterly Journal of Economics* 122.4, pp. 1721–1758. ISSN: 1531-4650. DOI: 10.1162/qjec.2007.122.4.1721.

Behrens, Kristian, Sergei Kichko, and Jacques-Francois Thisse (2024). “Working from home: Too much of a good thing?” In: *Regional Science and Urban Economics* 105, p. 103990. ISSN: 0166-0462. DOI: 10.1016/j.regsciurbeco.2024.103990.

Behrens, Kristian and Frédéric Robert-Nicoud (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 (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, Ángela Muñoz-Acevedo, and Sylvain Dejean (2022). “Impact of Fiber on Firm Creation: Evidence from France”. In.

Brueckner, Jan K., Matthew E. Kahn, and Gary C. Lin (2023). “A New Spatial Hedonic Equilibrium in the Emerging Work-from-Home Economy?” In: *American Economic Journal: Applied Economics* 15.2, pp. 285–319. ISSN: 1945-7790. DOI: 10.1257/app.20210190.

Butts, Kyle (2021). *Difference-in-Differences Estimation with Spatial Spillovers*. DOI: 10.48550/ARXIV.2105.03737.

— (2023). “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 (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 (2023). "Digital highways and firm turnover". In: *Journal of Economics and Management Strategy* 32.4, pp. 673–713. ISSN: 1530-9134. DOI: 10.1111/jems.12522.

Chaisemartin, Clément de and Xavier D'Haultfœuille (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 (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 (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 (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 (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.

Donaldson, Dave (2018). "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure". In: *American Economic Review* 108.4–5, pp. 899–934. ISSN: 0002-8282. DOI: 10.1257/aer.20101199.

Dozias, A (2023). "Competition in the French Electronic Communications Market". In: *Tresor Economics*.

Duranton, Gilles and Jessie Handbury (2023). *Covid and Cities, Thus Far*. DOI: 10.3386/w31158.

Duvivier, C, L Berge, and F Leon (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 (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 (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.

Gaspar, Jess and Edward Glaeser (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.

Gbandi, Tchapo, Mawuli K. Couchoro, Komivi Afawubo, Yawo Agbenyegan Noglo, and Afissou Djibril (2024). "In the Technological Age: The Internet and the Performance of Micro-Enterprises in Togo". In: *The Journal of Development Studies* 61.3, pp. 459–484. ISSN: 1743-9140. DOI: 10.1080/00220388.2024.2413084.

Glaeser, Edward (1998). "Are Cities Dying?" In: *Journal of Economic Perspectives* 12.2, pp. 139–160. ISSN: 0895-3309. DOI: 10.1257/jep.12.2.139.

— (2020). *Infrastructure and Urban Form*. DOI: 10.3386/w28287.

Gokan, Toshitaka, Sergei Kichko, Jesse A. Matheson, and Jacques-Francois Thisse (2022). *How the Rise of Teleworking Will Reshape Labor Markets and Cities*. eng. CESifo Working Paper 9952. Munich. URL: https://hdl.handle.net/10419/265987.

Goodman-Bacon, Andrew (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.

Hjort, Jonas and Jonas Poulsen (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 and A. J. Venables (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 (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.

Ramani, Arjun and Nicholas Bloom (2021). *The Donut Effect of Covid-19 on Cities*. DOI: 10.3386/w28876.

Redding, Stephen (2016). "Goods trade, factor mobility and welfare". In: *Journal of International Economics* 101, pp. 148–167. ISSN: 0022-1996. DOI: 10.1016/j.jinteco.2016.04.003.

Redding, Stephen and Esteban Rossi-Hansberg (2017). "Quantitative Spatial Economics". In: *Annual Review of Economics* 9.1, pp. 21–58. ISSN: 1941-1391. DOI: 10.1146/annurev-economics-063016-103713.

Redding, Stephen and Daniel Sturm (2008). "The Costs of Remoteness: Evidence from German Division and Reunification". In: *American Economic Review* 98.5, pp. 1766–1797. ISSN: 0002-8282. DOI: 10.1257/aer.98.5.1766.

Sun, Liyang and Sarah Abraham (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.
Zhang, Wei, Siqi Zhao, Xiaoyu Wan, and Yuan Yao (2021). “Study on the effect of digital economy on high-quality economic development in China”. In: *PLOS ONE* 16.9. Ed. by László Vasa, e0257365. ISSN: 1932-6203. DOI: 10.1371/journal.pone.0257365.

Appendix A: Many Estimators with Diverging Views

We present here estimation of Equation (2) 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 (11) presents results with the share of telecommuters on the right hand side of the estimation, while in Figure (12) 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.

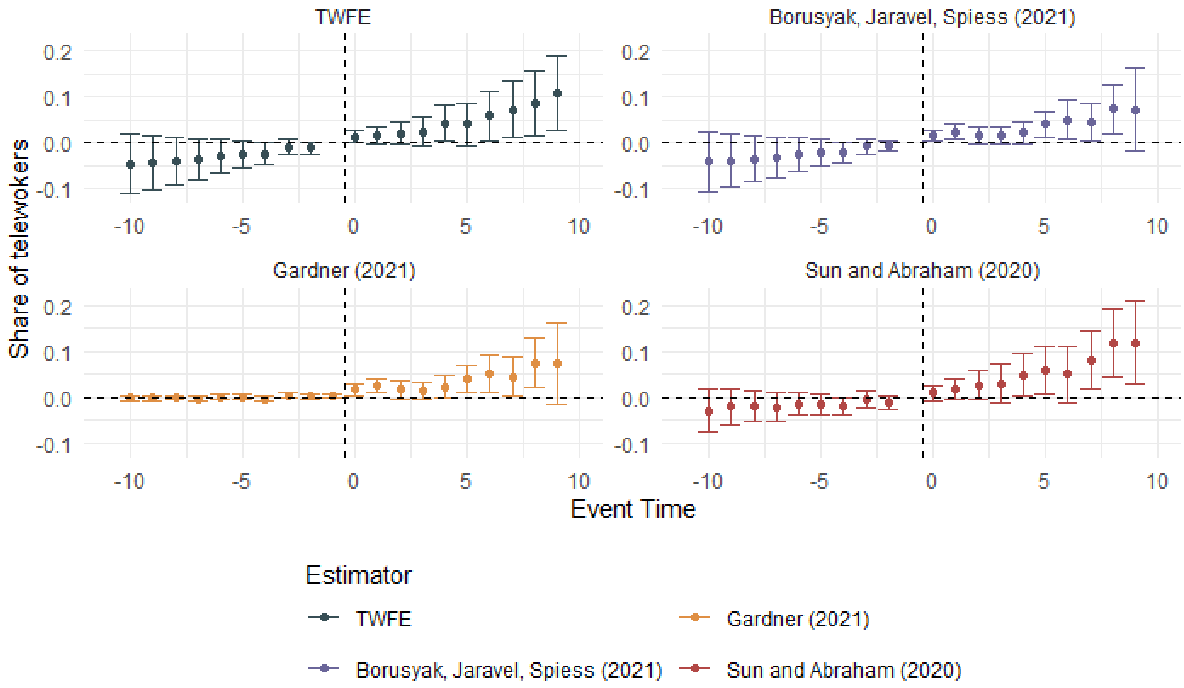

Figure 11: High Speed Internet and Working from Home

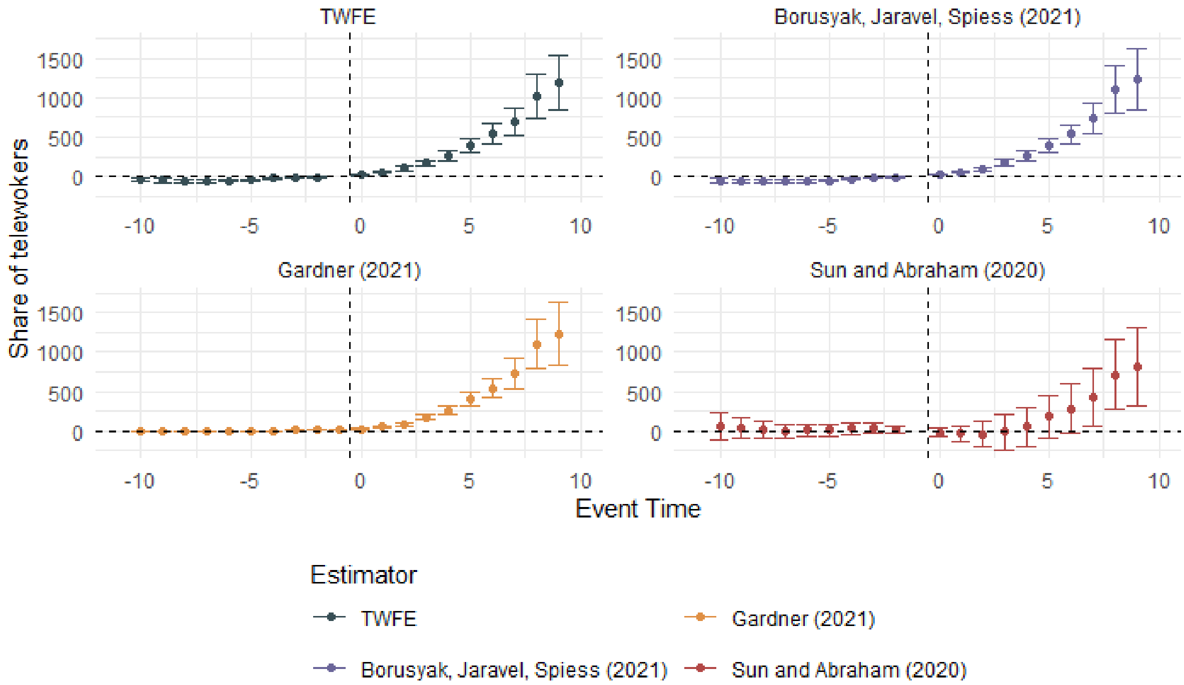

Figure 12: High Speed Internet and Working from Home

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.

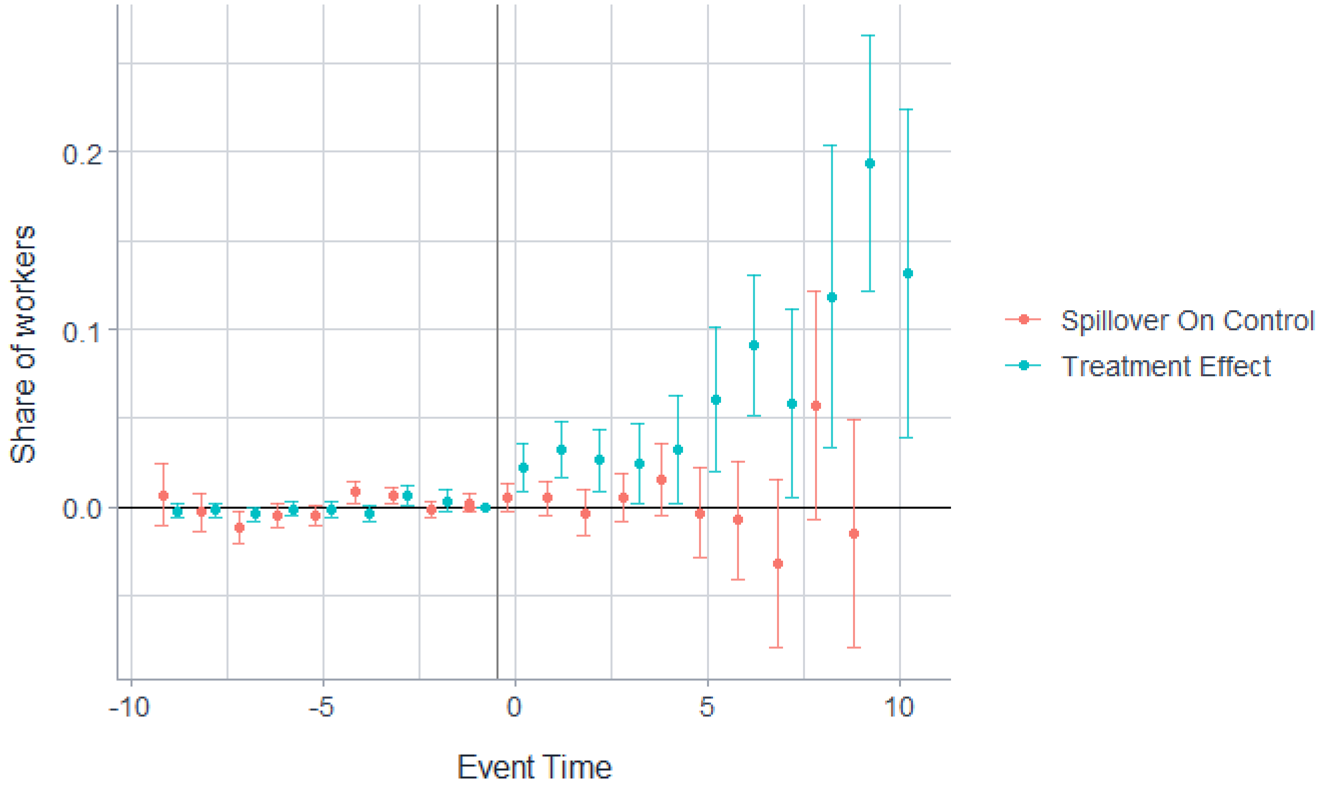

Figure 13: No spillover at 25 km for telecommuters

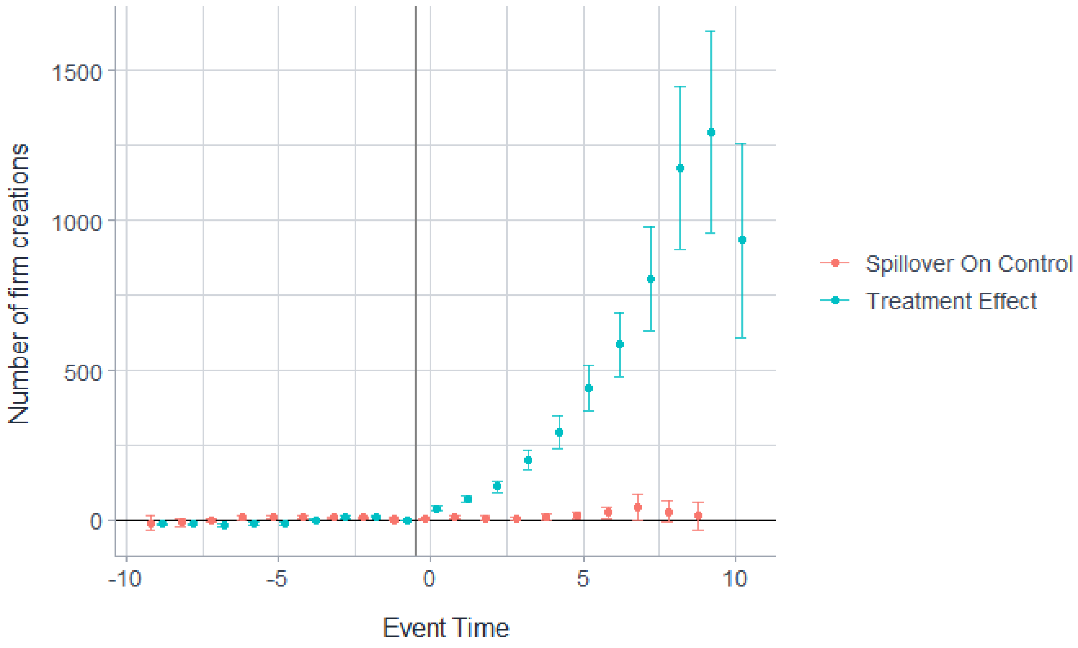

Figure 14: No spillover at 25 km for firms

Appendix C: Skilled Telecommuters

As discussed in many papers, remote work concern mainly high-skilled workers, thus in Figure (15) we select a particular category of skilled workers that are ”executives and higher intellectual professions”. We find a similar pattern to that presented in the text. The coefficients are less significant, but this comes from a lack of power due to the reduced number of observations in that case.

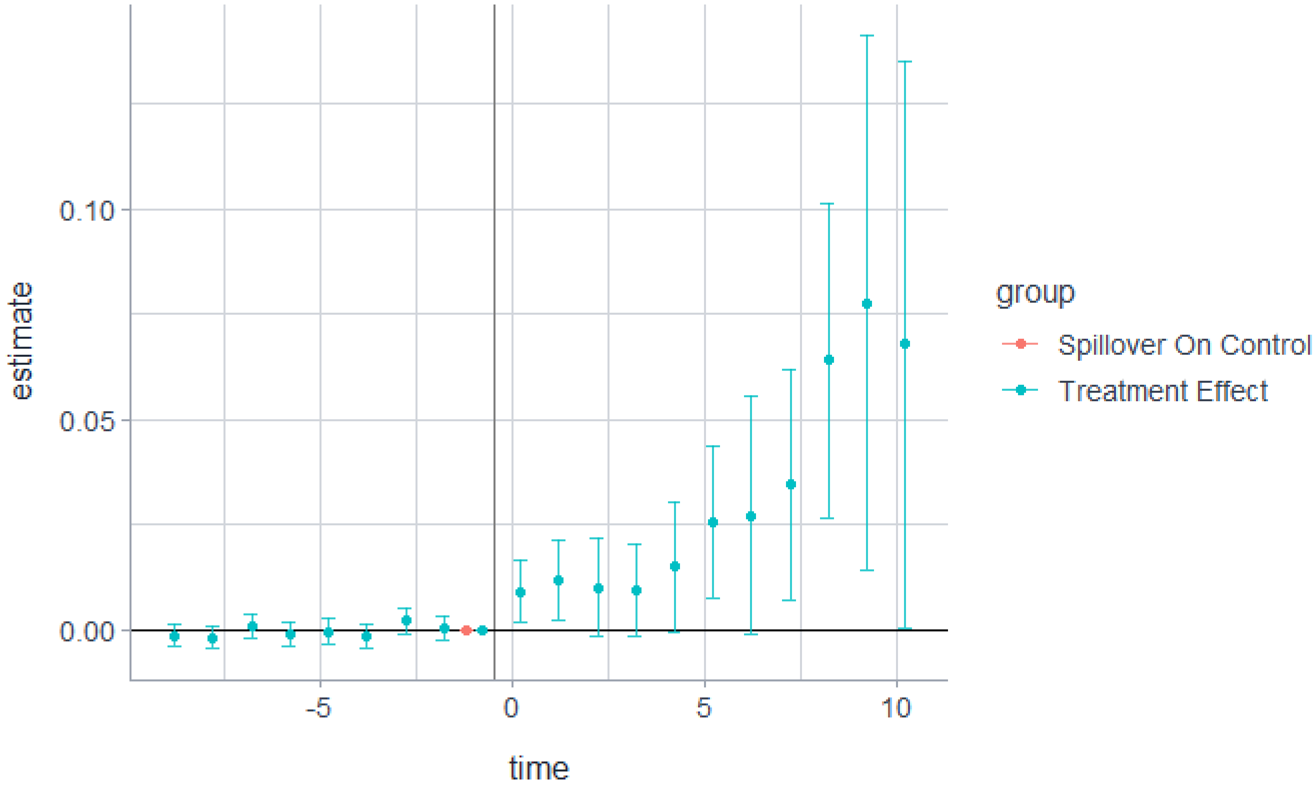

Figure 15: Impact of the arrival of fiber optics on the proportion of teleworkers in executives and higher intellectual professions

We also 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 in Figure (16) for professionals with children than in the general case.

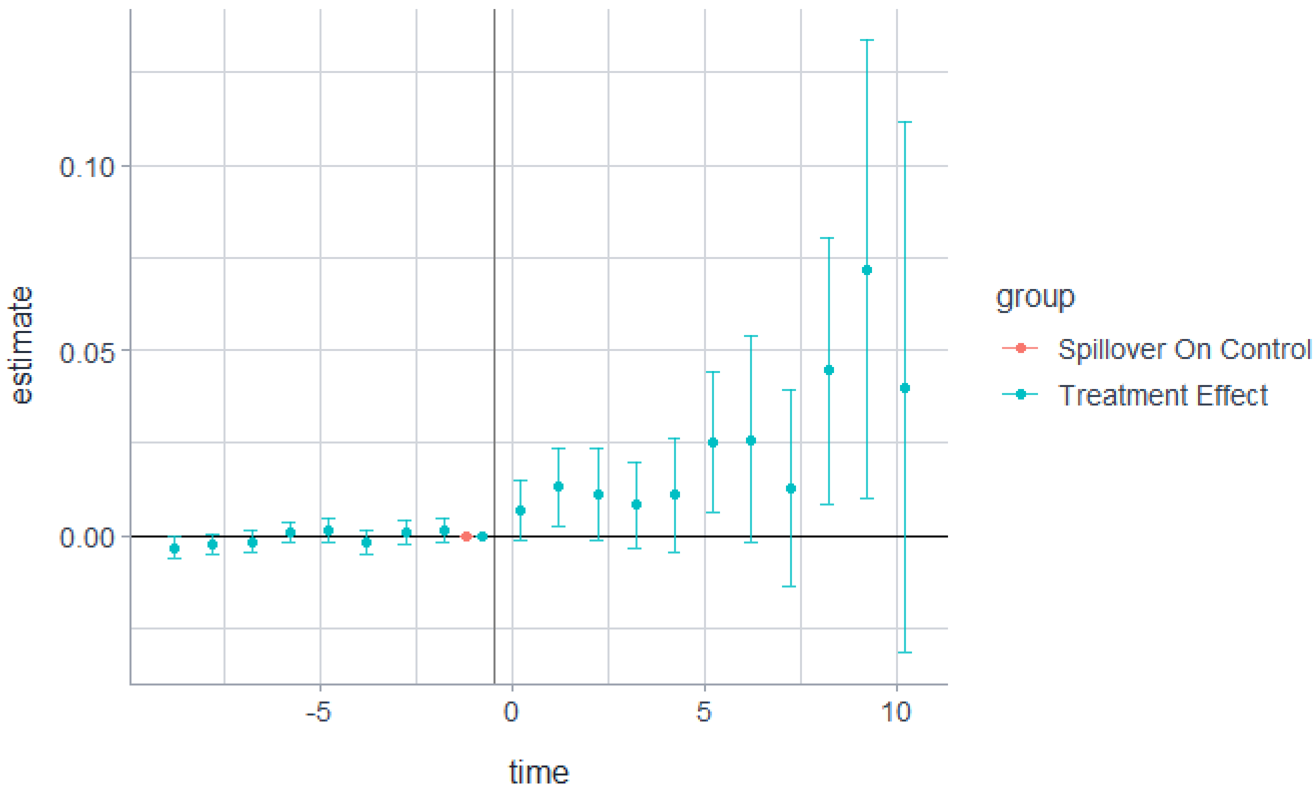

Figure 16: Impact of the arrival of fiber optics on the proportion of teleworkers with children

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. And we estimate for each category the impact of the FTTH arrival on share of teleworker and firm creations (we use). 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).

We find the following results presented in Table 5. 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.

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	0.041 *** (0.01)	0.047 ** (0.014)	0.038 ** (0.015)	0.045 *** (0.013)	114.73 *** (21.46)	135.06 *** (28.2)	178.57 *** (50.1)	505.5 *** (75.9)
R^2	0.378	0.378	0.378	0.379	0.894	0.893	0.893	0.899
Observations	23,794	23,794	23,794	23,794	23,794	23,794	23,794	23,794

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 5: 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

Table 6 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 for all municipalities. The magnitude of the impact is very high and strong for the first and the last categories.

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	0.044 *** (0.014)	0.033 ** (0.013)	0.039 ** (0.016)	0.05 *** (0.013)	111.24 *** (12.14)	235.97 *** (43.51)	496.34 *** (157.77)	493.1 *** (78.66)
R^2	0.378	0.378	0.378	0.379	0.896	0.893	0.896	0.897
Observations	23,794	23,974	23,974	23,974	23,974	23,974	23,974	23,974

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 6: 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

Appendix E : Descriptive Statistics and Parallel trend verification

9.1 Evolution of the treatment

Year	Untreated units	Treated units
2006	1726	1
2007	1724	1
2008	1718	3
2009	2035	6
2010	2444	12
2011	2420	36
2012	1893	63
2013	1138	156
2014	1071	223
2015	997	279
2016	853	454
2017	723	587
2018	535	756
2019	427	920
2020	245	878
2021	116	1035
2022	46	1108

Table 7: Number of Treated and Untreated Units per Year

9.2 Summary of Descriptive Statistics

Characteristic	Mean	SD	Median	Min	Max
Share of telew	0.2	0.2	0.2	0.0	1.0
Share telew Executive	0.1	0.1	0.0	0.0	1.0
Share telew IC	0.0	0.1	0.0	0.0	1.0
Firm Creation	256.4	801.4	54.0	0.0	21 276.0
Firm creation in Infocom	10.1	36.8	1.0	0.0	884.0
Total Firms (per 1000 inhab.)	0.4	1.1	0.1	0.0	17.3
Teleworkers	12 821.6	18 560.6	7628.8	0.0	387 546.3
Household with Teleworkers	7101.4	10 867.1	3680.9	0.0	179 346.0
Executive Teleworkers	6847.6	12 312.4	3310.7	0.0	327 100.6
Infocom Teleworkers	1541.4	3583.7	0.0	0.0	73 699.4
Blue-collar Employment	18 074.4	25 514.1	8634.4	0.0	577 773.4
Population	13 767.5	30 262.1	4019.0	17.0	498 003.0
Households	5939.9	14 513.1	1511.7	3.8	229 697.2
Employed	60 557.3	62 229.5	45 045.6	238.8	1 273 376.1
Commercial Act	5446.1	12 058.5	1624.0	4.8	220 655.7

Table 8: Descriptive Statistics (N = 26,629)

9.3 Trend Parallel Verification

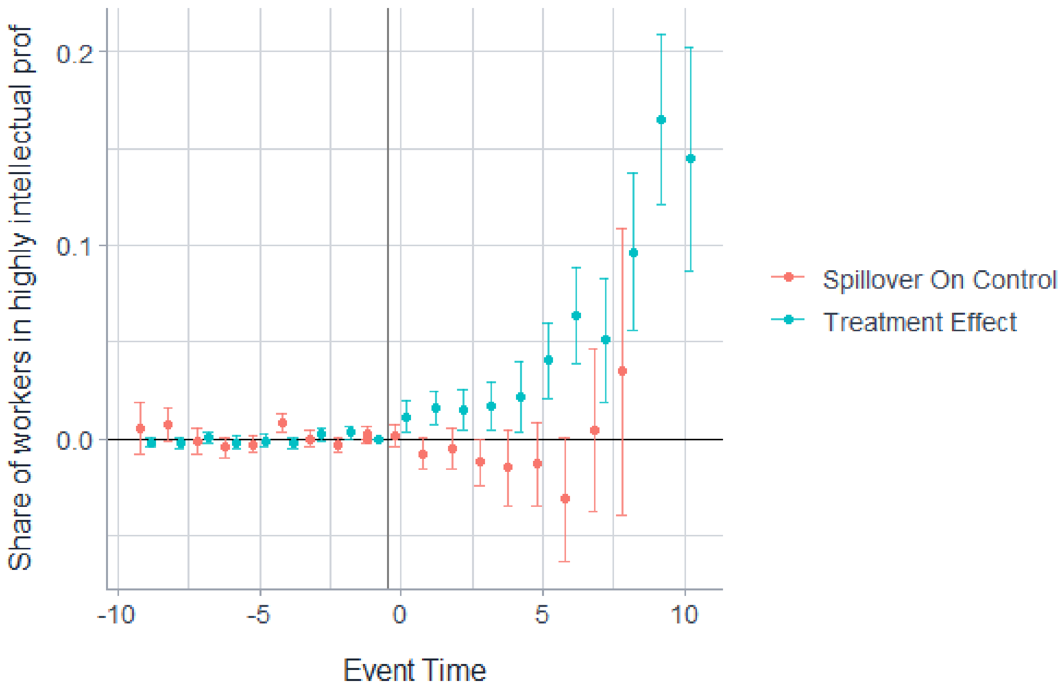

Figure 17: Estimation with the share of workers in high intellectual professions

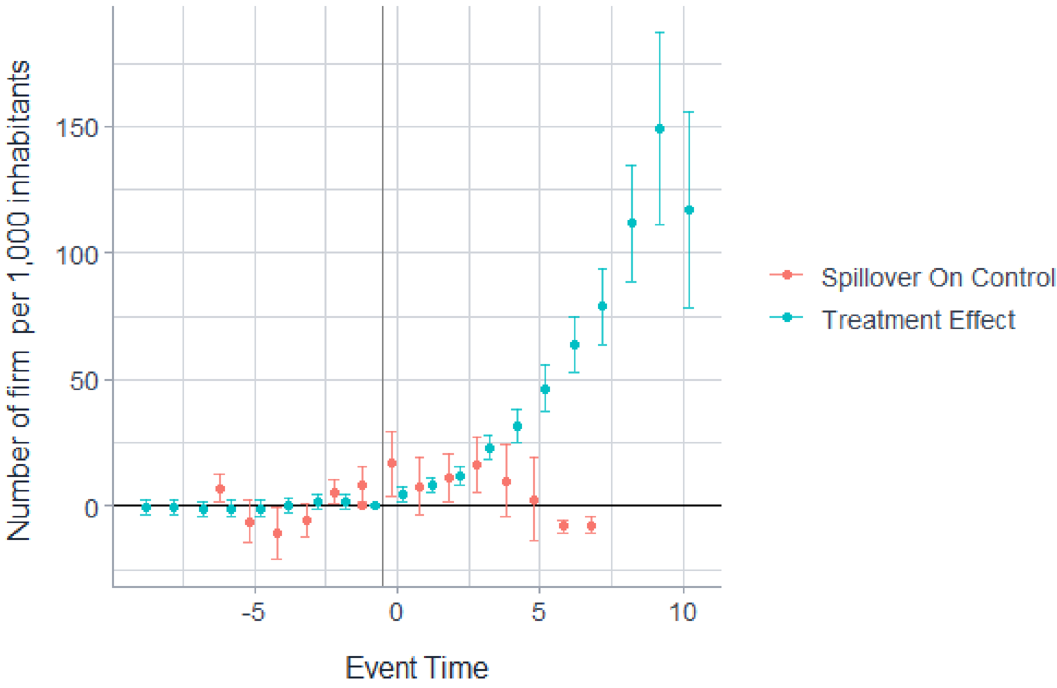

Figure 18: Estimation with the number of firms per 1,000 inhabitants

Appendix F : Estimation with number of teleworkers

In all the text, we use the share of teleworkers, which is the most convenient way to build the panel and merge with controls. However, this makes it difficult to distinguish effects coming from the numerator, the number of workers, from the effects coming from the total numbers of workers. Here we then directly use the number of teleworkers and find similar results.

9.4 Without Spillovers

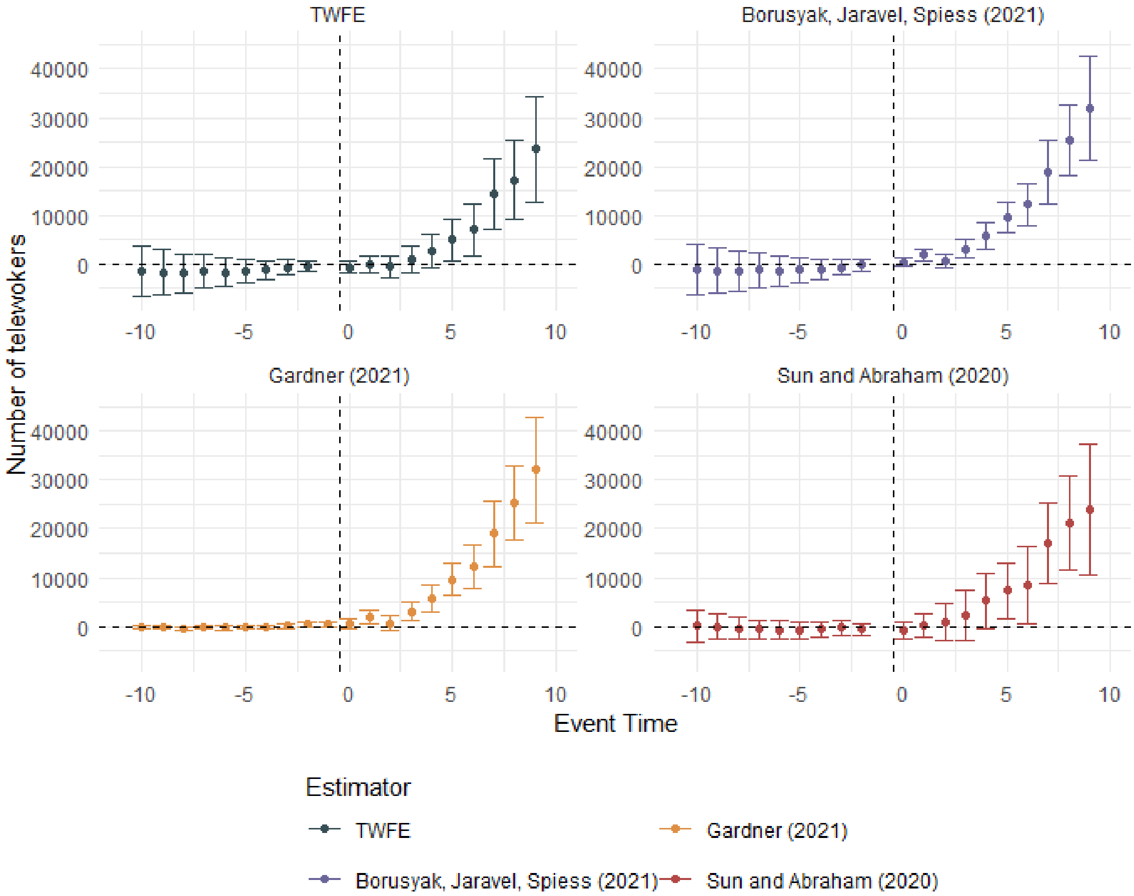

Figure 19: Estimation with number of teleworkers

9.5 With Spillovers

9.5.1 All sample

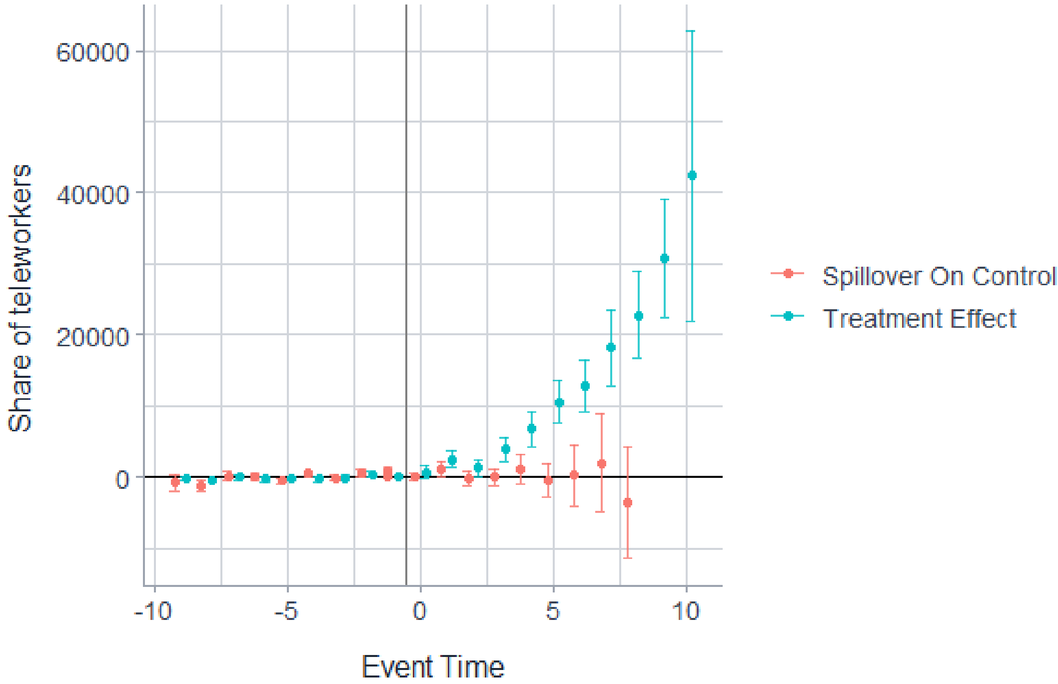

Figure 20: Estimation with number of teleworkers

9.5.2 IC sector

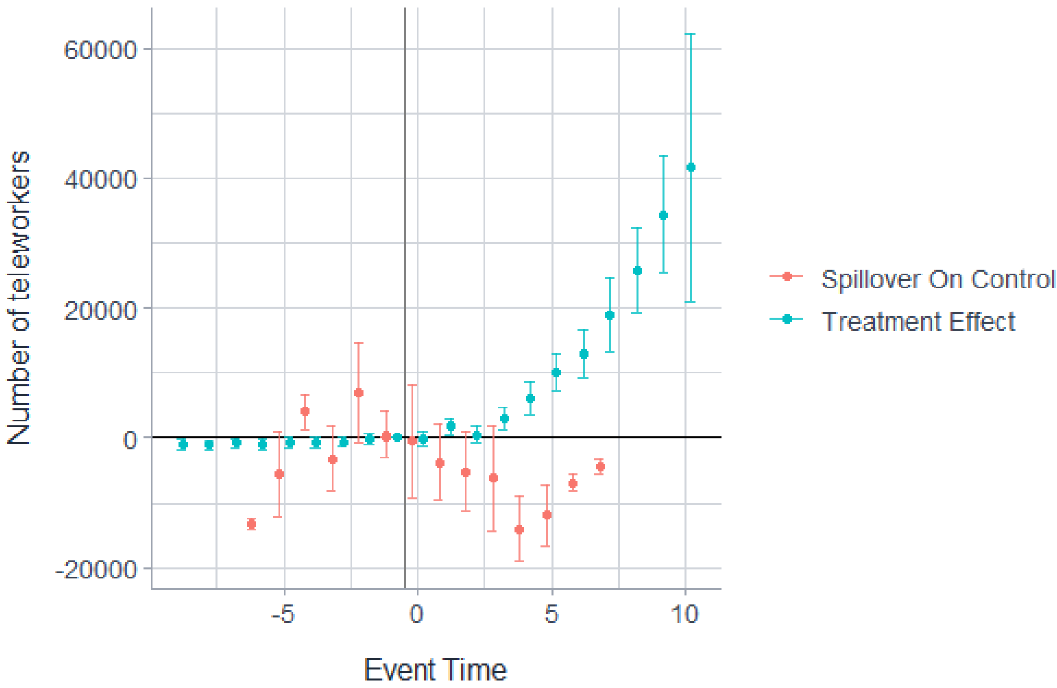

Figure 21: Estimation with number of teleworkers

9.5.3 Type of cities

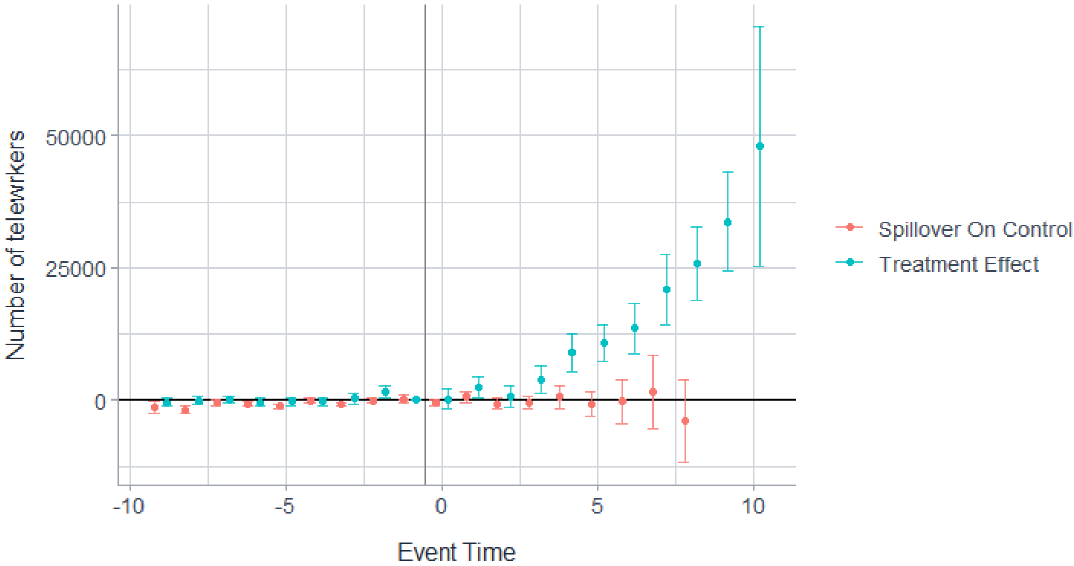

Figure 22: Estimation with number of teleworkers : Urban Dense Cities

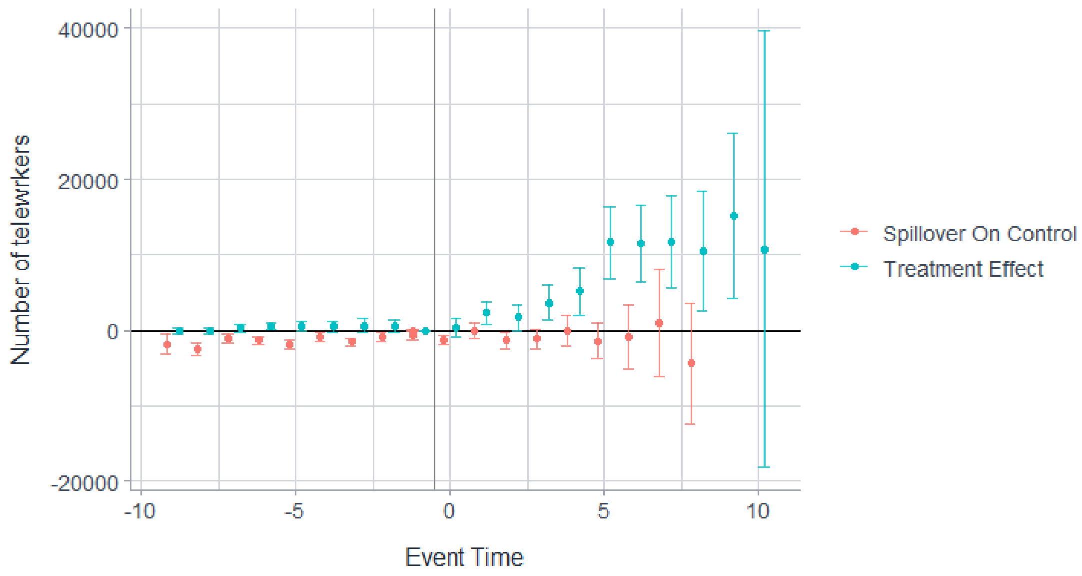

Figure 23: Estimation with number of teleworkers : Interm Dense Cities

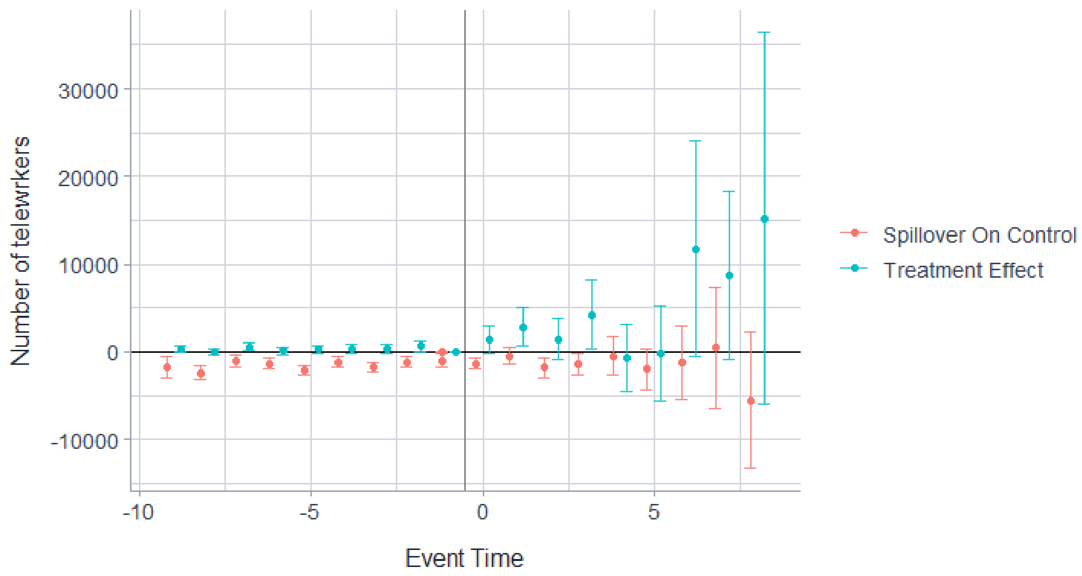

Figure 24: Estimation with number of teleworkers : Rural Cities