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 on average after adoption. 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

A long-standing debate in urban and regional economics concerns the extent to which improvements in information and communication technologies (ICT) substitute for face-to-face interaction and, in turn, alter where work and economic

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activity take place (Gaspar and Glaeser, 1998; Glaeser, 1998;Glaeser, 2020). A concrete and policy-relevant manifestation of this debate is the diffusion of Working From Home (WFH): if better internet quality relaxes the need for physical proximity, then investments in digital infrastructure may change local labor-market outcomes and the geography of firm activity.

This paper estimates the effect of high-speed internet on WFH in France, using the staggered rollout of Fiber-to-the-Home (FTTH) across municipalities. While the COVID-19 shock accelerated the adoption of remote work, France experienced a substantial expansion of high speed internet during the preceding decade. Identifying the role of infrastructure quality—separately from short-run shocks—matters for forecasting how remote work persist and spread as networks expand, and for evaluating the local returns to broadband policies.

We combine repeated survey data on remote work over 2006–2022 with municipality - level information on the timing of high-speed internet deployment. We aggregate the survey outcomes to the municipality-year level and define treatment as the first year a municipality becomes covered by (or eligible for) deployment according to the national rollout schedule. To estimate causal effects, we implement a staggered difference-in-differences design with municipality and time fixed effects and event-study dynamics.

A key challenge in this setting is spatial contamination: outcomes in a municipality that has not yet received the fiber infrastructure may nevertheless either attract teleworkers in nearby municipalities through local labor-market interactions, commuting ties, and firm location decisions or lose these teleworkers that may choose to live in cities with high-speed internet. For example, the literature has identified a ”donuts effect” in American cities, due to the increasing attractiveness of the suburbs for remote workers to the detriment of the center (Ramani and Bloom, 2021). Ignoring these exposures can bias conventional difference-in-differences estimates. Consequently, our baseline approach uses spillover-robust estimators in the spirit of Butts (2021) and Butts (2023), which allow nearby untreated municipalities to be affected by treatment and separate direct effects from exposure effects. As an additional robustness check, we also report complementary instrumental variables (IV) estimates based on predetermined network conditions and engineering costs that predict FTTH deployment intensity.

Our results can be summarized as follows. First, FTTH deployment increases the share of workers who work from home in treated municipalities. The effect is not confined to large urban cores: we estimate positive effects across dense and less dense municipalities and across skill groups. Second, we find limited evidence of average spillovers in WFH in neighboring untreated municipalities, suggesting that the local effect of deployment largely accrues where infrastructure investment has been made and has no negative or positive impact beyond the treated city boundary. However, around municipalities relatively specialized in information and communication (IC) activities, we estimate negative spillovers on WFH in nearby non-treated municipalities. Third, on the production side, FTTH deployment is associated with higher establishment births in treated municipalities, and we detect negative spillovers in firm creation consistent with a reallocation of new establishments away from nearby intermediate-density and rural areas.

Regarding the literature, the impact of HSI on firms has generated many research and findings (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.[1] The location choice 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 in these studies. Our main contribution is then to connect these two strands of literature to better understand the impact of high speed internet on remote work. In addition, to our knowledge, no empirical study has used observed data on home-based workers, the existing literature relies principally on estimates of the teleworking potential of jobs. This study differs in that it uses individual worker declarations.

The remainder of the paper is organized as follows. Section 2 describes the institutional context of FTTH deployment in France and the mechanisms motivating our empirical tests. Section 3 presents the data and empirical strategy, including the spillover-robust identification approach. Section 4 reports the main results on WFH and their heterogeneity across municipalities and workers. We also analyze the potentially heterogeneous effects of HSI by analyzing IC-specialized municipalities, dense and less dense cities. Section 5 studies establishment births and their spatial spillovers. Section 6 presents the IV strategy and results. Section 7 concludes.

[1] 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. 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. 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.

2 Background

2.1 The Very High-Speed Broadband Plan

Our empirical strategy exploits variation in the timing of Fiber-to-the-Home (FTTH) deployment across French municipalities. FTTH installations began in the early 2000s on a limited scale and in a small number of early-adopting municipalities. For example, the first city to adopt FTTH is Pau, a middle town in the south-western France, which started deploying fiber in 2003 as part of a local strategy to attract information-technology activity.[2] These early initiatives, although not insignificant,[3] remained geographically narrow. The large-scale diffusion of FTTH occurred later, with the launch in 2013 of the *Plan France Très Haut Débit*, a national program intended to accelerate very high-speed broadband access (commonly defined as speeds above 100 Mbps) through coordinated action by the State, local authorities and private operators.[4]

A practical feature of the national plan was that the deployment responsibilities differed across territories. In areas where rollout was commercially viable (typically denser municipalities) deployment has largely been led by private operators. In less profitable areas—often rural or sparsely populated municipalities—local authorities have played a larger role, relying on public support mechanisms and partnerships with operators (notably through *Réseaux d'Initiative Publique*, RIP) to finance, build, and operate fiber networks. This institutional organization helps explain why FTTH expanded beyond the largest metropolitan areas and progressively reached a wide range of municipality types, including low-density places (see, e.g., Duvivier and Bussiere, 2022; Duvivier et al., 2024).

For the purposes of this paper, the institutional background mainly matters because it generated a gradual, multi-year expansion of FTTH availability, with substantial temporal variation across municipalities.

2.2 Mechanism 1: firm productivity and local WFH

To motivate the empirical focus on both direct effects and spatial spillovers of FTTH, as well as to briefly survey the literature, we rely on quantitative spatial models of the New Economy geography as a starting point (based on Redding and

[2] See this article of the Wall Street Journal.

[3] In Appendix A we present the number of cities where optical fiber has been deployed (treated cities) by years. Before 2013, more than 100 cities have started to install FTTH.

[4] For the program's objectives and the associated public support framework, see the European Commission state-aid documents related to French broadband deployment (e.g., European Commission).

Sturm, 2008; Redding, 2016; Redding and Rossi-Hansberg, 2017). In this class of models, locations differ in fundamentals (consumer amenities, firm productivity), firms operate under monopolistic competition with increasing returns, and trade is subject to iceberg costs. In these models, if we consider high-speed internet as a location-specific improvement in productivity, this implies that treated locations become more attractive for production, which tends to increase local wages and employment. Under the simplifying assumption that a fixed share of jobs is performed remotely,[5] the number of teleworkers then moves with the local labor force, providing a direct rationale for a positive local effect of FTTH on teleworking. This simple framework also predicts spillover effects[6]: untreated cities that are at the proximity of treated cities, benefit of an increasing market size, of higher nominal wages, and of cheaper goods,[7] which attract other workers/teleworkers (until the rise of housing prices clears the spatial equilibrium).

Several additional assumptions can amplify or reduce these results. 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).

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).

2.3 Mechanism 2: the teleworking choice

In the previous discussion, several assumptions attach the results of firms/workers location to those of remote jobs, we survey here the literature that has relaxed this spatial dependence between firms, workers, and teleworkers.

Considering that teleworkers use part of their home for office without an in-

[5]See our Online Appendix where we model this and use numerical simulations to analyze the results

[6]Which are called "pecuniary" effects in the economic geography literature, in reference to Scitovsky (1954), because they transit via market prices and quantities

[7]Indeed, trade costs are reduced by the agglomeration of new firms that now produce locally

crease 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 telecommuting 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 option, 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 highlights 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 are aggregated at the level of the municipality.[8] 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. [9]

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

[9] 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.

3.2 Data on teleworkers

Data on the proportion of teleworkers in each municipality come from the Continuous Employment Survey (*Enquête Emploi en Continu*, 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 cities 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 municipalities within each region. The municipalities taken into account are drawn randomly each year, reducing 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. Although the employment survey's telework question changes in 2013, our staggered DiD identification comes from within-municipality changes relative to contemporaneous not-yet-treated municipalities with the same year fixed effects, so any nationwide shift in measurement is absorbed by time effects rather than mechanically generating differential post-treatment dynamics. Furthermore, we are the first to exploit a survey on the declaration of remote work in France (many studies, for instance, use an approximation of remote work based on jobs that can be done *potentially* remotely).

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). This desegregation enables not only a firm analysis but also a sectorial analysis (we present results for the classification of Information and Communication activities). 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).

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 survey *Enquête Emploi en Continu* from the French Statistic Institute (INSEE). 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 Spillover-robust staggered difference-in-differences

We estimate here a dynamic treatment effects while allowing outcomes in not-yet-treated municipalities to respond to nearby treatment.[10] We follow the two-step procedure of Butts (2021) and Butts (2023), which estimates municipality and year components using only observations that are neither treated nor exposed, and then estimates direct and exposure effects on the residualized outcome.

Let i index municipalities and $t \in \{1, \ldots, T\}$ index years. The outcome N_{it} is either the share of remote workers or the number of establishment births in municipality i at year t. The variable D_{it} equals one if municipality i has FTTH by

[10]We also report in Appendix B several estimations with standard staggered DiD estimators, without controlling for spillovers. We find less precise results statistically, which motivates the current methodology.

year t and equals zero otherwise. The first treatment year is $E_i = \min\{t : D_{it} = 1\}$ for treated municipalities; for municipalities never treated in the sample we set $E_i = +\infty$. Event time is defined as $\ell = t - E_i$ for treated municipalities, so that $\ell = 0$ is the first treated year, $\ell < 0$ are leads, and $\ell > 0$ are lags. We estimate a set of event-time coefficients $\{\beta_\ell\}_{\ell \in \mathcal{L}}$, omitting one pre-treatment period (typically $\ell = -1$) for normalization. The event-time indicators are included only for treated municipalities; for never-treated municipalities (with $E_i = +\infty$) they are identically zero. We also include a vector of time-varying municipality controls Z_{it} (population, number of establishments, public facilities, share of executives, etc.).

Spatial exposure is captured by an indicator $S_{it}(\bar{d})$ defined from the set of treated municipalities at time t. Let $d(i,j)$ denote the distance (in km) between municipalities i and j (measured between centroids). For a radius $\bar{d}$, we define

$$S_{it}(\bar{d}) = \mathbf{1}\left\{ \min_{j \neq i:\, D_{jt}=1} d(i,j) \leq \bar{d} \right\}, \tag{1}$$

and set $S_{it}(\bar{d}) = 0$ when there is no treated municipality $j \neq i$ at time t. This definition makes exposure time-varying as more municipalities become treated.

The procedure is implemented in two steps. In the first step, we estimate municipality and year fixed effects (and the coefficients on controls) using only municipality-years that are neither treated nor exposed. Concretely, we estimate

$$N_{it} = f_i + f_t + Z_{it}'\gamma + u_{it}, \tag{2}$$

restricting the sample to observations such that $D_{it} = 0$ and $S_{it}(\bar{d}) = 0$. Denote the resulting estimates by $\widehat{f}_i$, $\widehat{f}_t$, and $\widehat{\gamma}$.

In the second step, we remove these estimated components from the outcome and regress the residualized outcome on the same dynamic event-time indicators and on exposure terms. The residualized outcome is $\widetilde{N}_{it} = N_{it} - \widehat{f}_i - \widehat{f}_t - Z_{it}'\widehat{\gamma}$. Using this new variable, we then estimate:

$$\widetilde{N}_{it} = \sum_{\ell \in \mathcal{L}} \beta_\ell \mathbf{1}\{t - E_i = \ell\} \; + \; \beta^c S_{it}(\bar{d})\,(1 - D_{it}) \; + \; \beta^t S_{it}(\bar{d})\, D_{it} \; + \; \eta_{it}. \tag{3}$$

Equation 3 contains the event-time leads and lags that define the dynamic treatment profile. The coefficient β_ℓ measures the direct effect at event time ℓ relative to the omitted pre-treatment period. The parameter β^c captures exposure effects among municipalities that are not yet treated, since it loads on $S_{it}(\bar{d})$ only when $D_{it} = 0$. The parameter β^t allows outcomes in treated municipalities to be affected by proximity to other treated municipalities; including this term avoids imposing that exposure effects must be zero once a municipality is treated.

The radius $\bar{d}$ is selected using the data-driven procedure in Butts (2023). For transparency, Appendix B reports the corresponding distance-profile diagnostic for the telework outcome and shows that estimated exposure effects are concentrated at short distances, motivating our baseline choice $\bar{d} = 15$ km and a robustness check with $\bar{d} = 25$ km.

5 FTTH a New Factor of Attractiveness?

5.1 Main Result: the Rise of Telework

Figure 1 reports the event-study estimates of the dynamic effect of FTTH on the share of remote workers using the spillover-robust two-step procedure described in the previous section.

Two features of Figure 1 are important for identification. First, the pre-treatment coefficients are small and statistically indistinguishable from zero. This absence of differential pre-trends is consistent with the identifying assumption that, conditional on fixed effects and controls, treated municipalities would have followed similar paths as the appropriate comparison group in the absence of FTTH. While parallel trends is not directly testable, the lack of systematic pre-treatment movements makes it less likely that the estimated post-treatment increase is driven by pre-existing differential dynamics.

Second, the post-treatment coefficients show a clear and persistent increase in remote work following FTTH deployment. The effect becomes statistically significant shortly after treatment and remains positive for several years. The dynamic profile is consistent with a rapid adjustment of work arrangements once high-speed connections become available, followed by persistence rather than transitory effects.

Obviously, because the set of not-yet-treated municipalities becomes small in the later years of the sample, the long-lag event-time coefficients rely on comparatively limited remaining comparison variation and should therefore be interpreted with appropriate caution.

The figure also reports the estimated exposure effect for non-treated municipalities within the radius $\bar{d}$ (captured by the parameter β^c in Equation 3). This term is central because it determines whether municipalities used as comparisons are themselves affected by nearby deployment. In our baseline specification with $\bar{d} = 15$ km, the estimated spillover effect on non-treated municipalities is small and not robustly different from zero on average. This implies that the main post-treatment increase is primarily driven by changes within treated municipalities rather than by systematic changes among neighboring not-yet-treated municipalities. Indeed our two-step design ensures that fixed effects and baseline components are estimated using observations that are neither treated nor exposed.

A potential concern in this setting is that the estimated increase could reflect compositional changes in the survey sample or differential measurement rather than changes in behavior. Two points mitigate this concern in the present design. The outcome is constructed at the municipality-year level and the estimation includes municipality fixed effects, which absorb time-invariant differences in sampling and baseline levels of telework across municipalities, and year fixed effects, which absorb national shocks to measurement and common changes in telework prevalence. In addition, the event-study leads provide a direct check that treated municipalities do not exhibit differential pre-treatment dynamics relative to the clean comparison group.

Finally, the choice of $\bar{d}$ could matter if exposure effects decay slowly with distance. Appendix B reports robustness checks using $\bar{d} = 25$ km, motivated by the distance-profile diagnostic borrowed to Butts (2023). The estimated dynamic treatment effects on treated municipalities are very similar (see Appendix C), indicating that the main result is not sensitive to this change in the exposure radius.

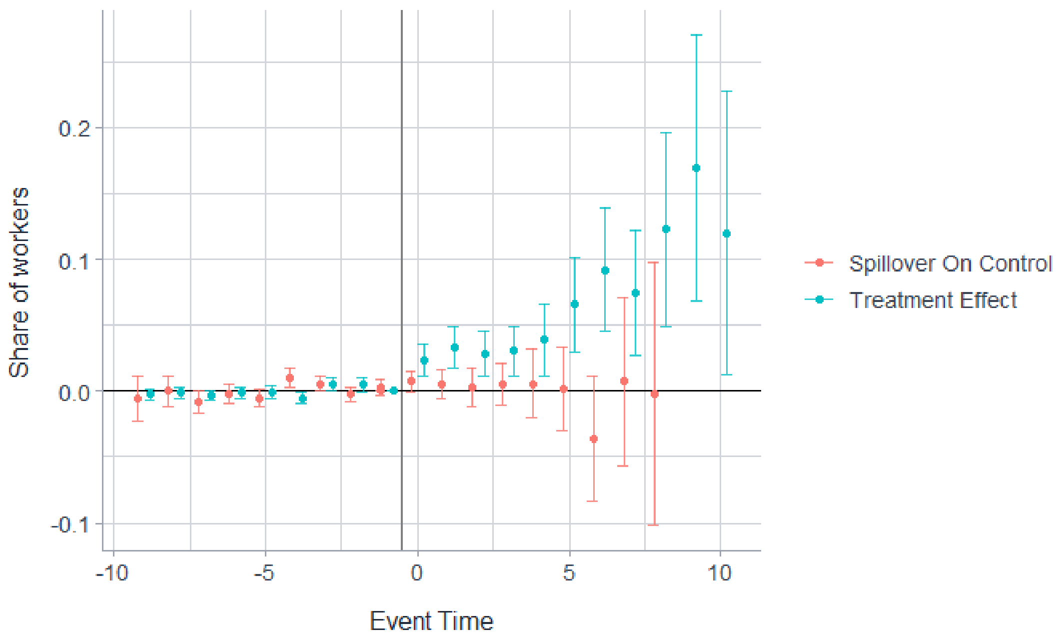

Figure 1: High-Speed Internet, Working From Home and Spillovers

Not reported here, we find that the absence of spillover effects for remote work is robust in different sectors (including, for example, hotels and restaurants and scientific activities). We, however, find one exception that we present in the next subsection.

5.2 Heterogeneous effects

5.2.1 Telework in the Information and Communication Sectors

To analyze cities that are particularly concerned by a good access to the Internet, we examined cities ”specialized” in Information and Communication,[11] 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 2, 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.

[11] This sector is particularly likely to have a significant need for optical fiber because it relies heavily on high-speed data transmission. It require optical fiber to support activities such as data processing, cloud computing and maintenance of digital communications.

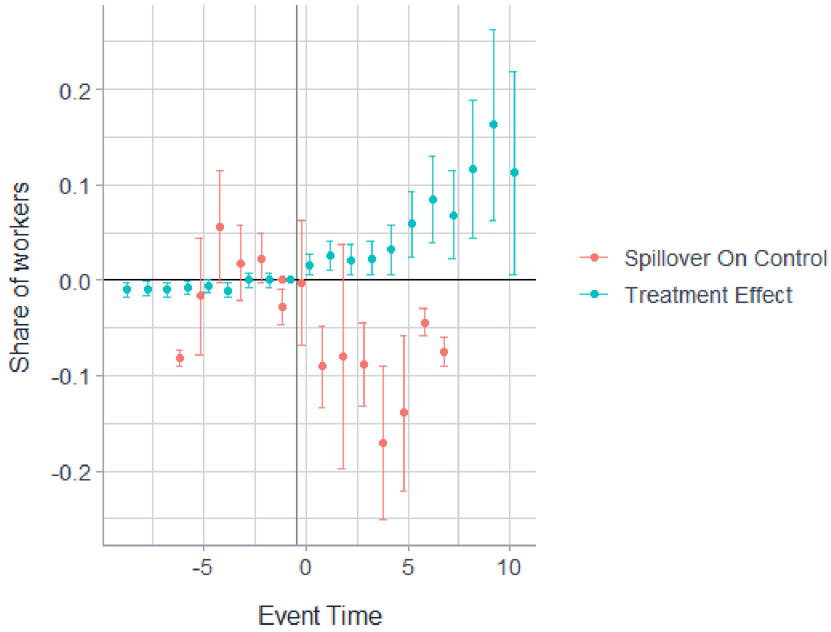

Figure 2: Cities with IC sector (5% IC firms)

5.2.2 Urban and rural areas

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. 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, 1).

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

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

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: Spillovers according to density

5.2.3 Telecommuters are Skilled Workers

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 D that teleworkers affected by the policy are skilled workers belonging to the social category ”executives and higher intellectual professions”. The arrival of FTTH in the residential municipality was associated with an increase in long-distance commuting (over 65 km) and a decrease in local commuting (less than 65 km), which may be linked to the greater flexibility offered by teleworking (Appendix E).

6 About the simplest Mechanism: the Effect of HSI on Firms

This section studies how FTTH deployment affects establishment births and whether these effects extend to nearby, not-yet-treated municipalities. The motivation is that the new infrastructure can raise the productivity of digitally intensive tasks and reduce coordination frictions, potentially making treated municipalities more attractive for firm entry (as emphasized in our ”mechanism 1” section). The results below therefore complement the previous estimates by documenting how the production side responds to FTTH and whether these responses are internalized within municipal boundaries.

6.1 General case

Figure 3 reports the dynamic estimates for establishment births using the spillover-robust two-step approach. Two elements are worth emphasizing.

First, the pre-treatment coefficients are not statistically different from zero. This absence of differential pre-trends is consistent with the identifying assumption that, conditional on fixed effects and controls estimated on the clean subsample, treated municipalities would have followed similar entry dynamics as comparable municipalities in the absence of FTTH. This point matters in particular for firm creation, where anticipation (e.g., investment planning) could generate early movements.

Second, the post-treatment coefficients indicate a clear positive effect of FTTH on establishment births in treated municipalities, with an effect that tends to increase over time. This pattern is consistent with existing evidence that broadband infrastructure can stimulate entrepreneurship and firm dynamics, including in the French context (Bourreau et al. (2022); Duvivier et al. (2021)).

The spillover component in Figure 3 is small and not robustly different from zero on average. This suggests that, in the aggregate, the entry gains associated with FTTH are largely internalized within treated municipalities rather than systematically shifting entry to their immediate neighbors. This finding also aligns with the telework results, where average exposure effects are limited outside the IC specialization case, and it helps rule out an interpretation in which the main treated effect is mechanically driven by nearby reallocation at very short distances.

These parallel positive responses of telework and firm creation in treated municipalities should nevertheless be interpreted with caution. The data do not match teleworkers to their employers, so the results do not identify whether increased entry causes more telework opportunities, whether telework expands local demand and encourages entry, or whether both outcomes respond to the same infrastructure-driven shock. What the estimates establish is the joint reduced-form pattern: FTTH is followed by higher telework and higher establishment births within treated municipalities, with limited average spillovers at the municipal border.

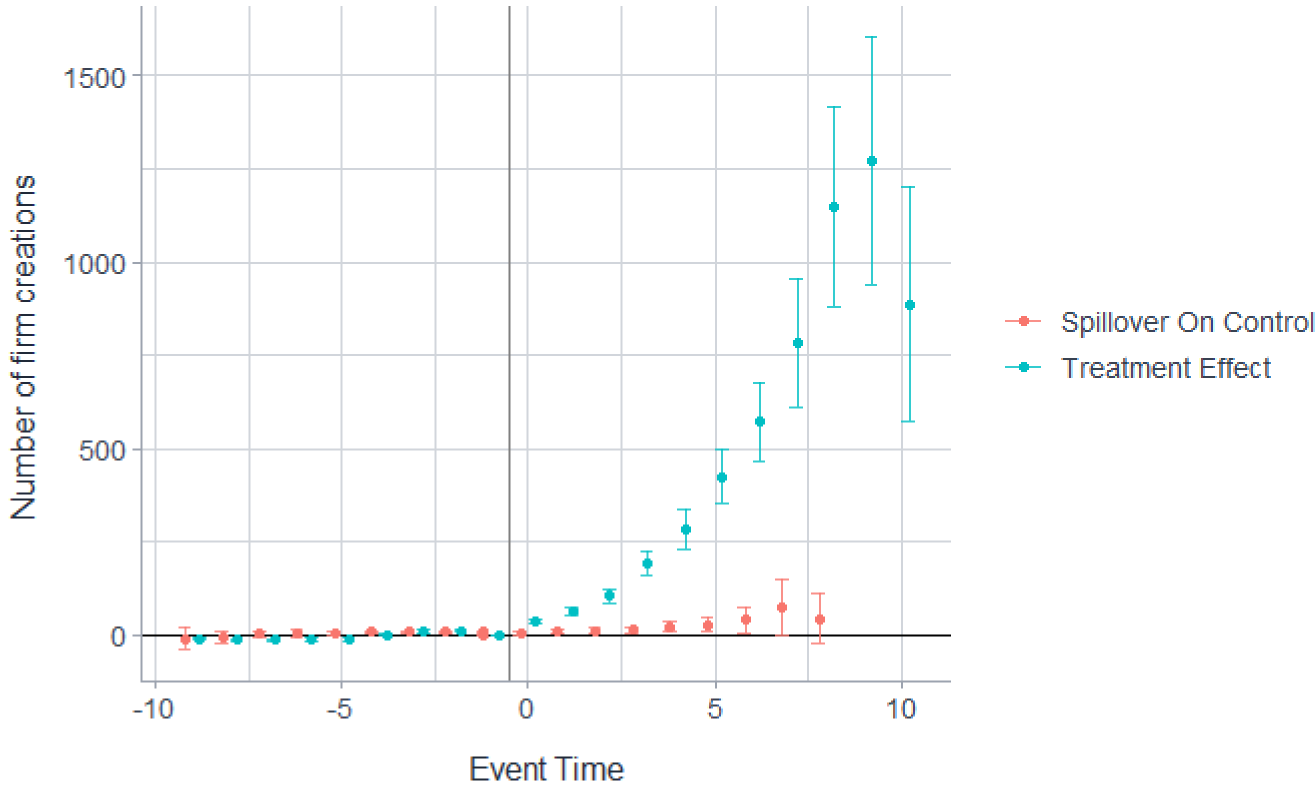

Figure 3: High Speed Internet, Firm births and Spillovers

6.2 Cities with information and communication activities

Figure 4 focuses on municipalities relatively specialized in information and communication (IC) activities, the same subset for which the telework analysis revealed negative spillovers on nearby not-yet-treated municipalities. The treated effect on establishment births remains positive and statistically significant for several post-treatment years, indicating that FTTH is associated with increased entry even in these IC-specialized places.

The spillover pattern for firm births, however, differs from the telework spillover pattern in IC cities. In Figure 4, exposure effects on firm births are positive for nearby not-yet-treated municipalities. This contrast is informative because it implies that the negative telework spillovers around treated IC municipalities do not appear to be driven by a contraction of entrepreneurial activity in neighboring places. In other words, the mechanism behind negative telework spillovers in IC contexts is unlikely to be a simple reduction in nearby firm creation.

A plausible interpretation is that, in IC environments, FTTH primarily reshapes the geography of remote work through worker sorting, job composition, or firm–worker matching rather than through a contraction in neighboring entry. This interpretation is consistent with the broader telework literature emphasizing that the geography of production and the geography of residence can decouple when remote work expands. For example, Brueckner et al. (2023) develop a framework in which productive cities attract firms while workers (including teleworkers) may locate in amenity-rich places. Our results speak to this separation in a reduced-form way: firm creation responds positively in treated IC municipalities and also exhibits positive exposure effects nearby, while telework shares can still display negative exposure effects in the same IC setting.

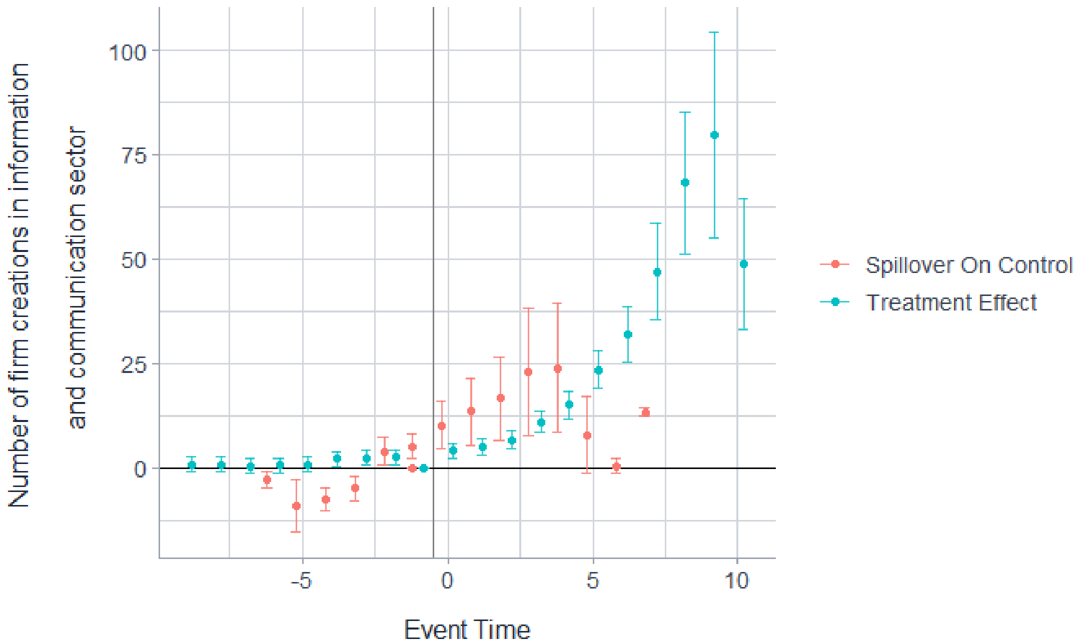

Figure 4: High Speed Internet, Firm births and Spillovers in IC cities

6.3 Urban and rural areas

Tables 3 and 4 report heterogeneity by municipality density. Table 3 shows a large and significant treated effect on establishment births in dense urban municipalities and a smaller but still significant effect in intermediate-density municipalities, while the effect is not statistically different from zero in rural areas. This gradient is consistent with the idea that improved connectivity interacts with local market size and complementary inputs, so that entry responses are strongest where these complements are abundant.

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)

Table 4 reveals a different pattern for spillovers: exposure effects are negative and statistically significant for intermediate-density and rural municipalities, while they are not significant for dense urban municipalities. This suggests displacement of entry away from nearby intermediate and rural areas when FTTH is deployed elsewhere. Unlike the main telework results (which show limited average spillovers outside IC specialization), establishment births display a clearer reallocation margin across nearby municipalities.

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)

Taken together, these heterogeneous exposure patterns reinforce the view that firm location responses and remote-work outcomes need not move one-for-one. The IC-city results even suggest that telework spillovers can differ in sign from firm-entry spillovers. This is in line with recent telework models in which productive places attract firms while remote-capable workers' residential choices respond to housing costs and amenities (e.g., Brueckner et al. (2023)). A natural extension would be to explore how FTTH effects vary across place characteristics that proxy for productivity versus amenity advantages, although we leave such an analysis for future work.

7 Instrumental Variables (IV)

The timing and intensity of FTTH deployment may correlate with time-varying local factors that are imperfectly observed (e.g., local economic dynamism, or operators' expectations about future demand). While our baseline staggered DiD design absorbs time-invariant municipal heterogeneity and common national shocks, remaining endogeneity concerns could bias the estimated effects if such factors co-move with both FTTH rollout and telework. Reverse causality, for instance due to the fact that mayors want to attract telecommuters in their municipalities by implementing FTTH, is also a concern. However, concerning this last problem, one may note that during a long period of time telecommuters represented only a small share of the population (around 0.2% depending on the period, see our descriptive data) and thus they may not have been a central strategic target for local public policies.[12]

Consistent with this perspective, we observe that French press coverage initially discussed fiber deployment largely independently from teleworking. The explicit media links between the two topics emerged later and became recurrent only during and after the COVID crisis (see Appendix G). Obviously, media discourse does not provide evidence of causality in any case, but this pattern does not suggest reverse causality, namely that telecommuting demand was an obvious driver of early fiber deployment.

In this section, we instrument municipal FTTH coverage using a predetermined source of variation: the distance from the municipality centroid to the fiber connection node (denoted $Dist_i$), which proxies engineering and deployment costs. This instrument has been used in comparable empirical settings (e.g., Cambini et al. (2023), Campante et al. (2017), Miner (2015)).

The identifying assumption is that, conditional on municipality fixed effects, year fixed effects, and time-varying controls, $Dist_i$ affects telework and firm creation only through its effect on FTTH coverage. A concern is that distance to the FTTH connection node could correlate with geographic or settlement patterns. Two points mitigate this issue in our setting. First, distance to the assigned node is essentially time-invariant, so any level differences associated with remoteness, urban form, or local geography are absorbed by municipality fixed effects. Second, in the French FTTH architecture, the access network is deployed between the "Nœud de Raccordement Optique" (NRO) and downstream network elements (notably a cluster point called "mutualisation"), so distance to the node primarily acts as a predetermined engineering cost shifter that influences the pace of deployment rather than directly affecting telework or firm creation conditional on coverage. We therefore interpret this instrument as capturing rollout frictions rooted in legacy network topology and deployment costs, while maintaining the standard caveat that the exclusion restriction remains a maintained assumption. The exclusion restriction is always debatable, and we treat this IV strategy as an additional analysis that yields results from a different perspective.

7.1 Empirical specification

Let Cov_{it} denote FTTH coverage in municipality i at year t (as defined in the data section). Let N_{it} denote the outcome of interest (either the share of teleworkers

[12] Another issue is that we have no data on the previous technology, related to the deployment of the DSL, and one may argue that it is an omitted variable that drive our results. However, the DSL technology was not fast enough, depending on the location on the line, to enable remote work. If we have no data on a long period, we have data on the DSL that starts in 2020 and we show in Appendix H that there is no correlation between the speed of DSL and working from home.

or the number of establishment births), and let X_{it} denote the same set of time-varying controls used in the main specifications. Municipality fixed effects are denoted f_i and year fixed effects are denoted f_t.

Because $Dist_i$ is time-invariant, it is absorbed by municipality fixed effects. Identification therefore comes from allowing its predictive content for Cov_{it} to vary over time by interacting it with year indicators. The first stage is

$$Cov_{it} = f_i + f_t + X_{it}'\delta + \sum_{t=1}^{T} \pi_t \left(Dist_i \times \mathbf{1}\{year = t\}\right) + \nu_{it}. \tag{4}$$

We then estimate the second stage by 2SLS:

$$N_{it} = f_i + f_t + X_{it}'\gamma + \beta\, Cov_{it} + \varepsilon_{it}, \tag{5}$$

where Cov_{it} is instrumented by the set of excluded instruments $\{Dist_i \times \mathbf{1}\{year = t\}\}_{t=1}^{T}$. Standard errors are clustered at the municipality level.

Under the standard IV conditions (relevance, exclusion, and monotonicity), the coefficient β can be interpreted as a local average effect of an increase in FTTH coverage induced by the instrument.

7.2 Results

Table 5 reports the IV estimates using distance to the FTTH node ($Dist_i$) as the instrument. The first-stage diagnostics indicate strong relevance, with excluded-instrument F-statistics well above conventional thresholds. Across both outcomes, the second-stage estimates imply that higher FTTH coverage increases the share of teleworkers and increases establishment births. The sign and statistical significance of these IV estimates are consistent with the baseline results, providing reassurance that the positive treated effects documented in the main text are not driven solely by endogenous rollout correlated with unobserved local shocks.

Dep. Var.	Share of teleworkers	Firm creation
Instrument	Dist. to FTTH node	Dist. to FTTH node
FTTH coverage (Cov_{it})	0.0044***	27.356***
	(0.00017)	(0.81762)
First-stage F-stat (excluded instruments)	630.034	1119.44
Observations	5,259	5,259
R^2	0.0524	0.0781

Notes: 2SLS estimates of Equation 5 where FTTH coverage is instrumented using the interactions $\{Dist_i \times \mathbf{1}\{year = t\}\}_{t=1}^{T}$ in Equation 4. Municipality and year fixed effects are included in both stages, and standard errors are clustered at the municipality level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Impact of FTTH Coverage, IV Estimates Results

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.

We analyze high-speed internet and telework at a time when the remote-work margin remains far from exhausted. The benefits of high-speed internet may be amplified in the coming years as a growing share of work relies on cloud-based tools, data, and services. Many research 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.

Butts, Kyle (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, Elena Grinza, and Lorien Sabatino (2023). "Ultra-fast broadband access and productivity: Evidence from Italian firms". In: *International Journal of Industrial Organization* 86, p. 102901. ISSN: 0167-7187. DOI: 10.1016/j.ijindorg.2022.102901.
Cambini, Carlo and Lorien Sabatino (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.
Campante, Filipe, Ruben Durante, and Francesco Sobbrio (2017). "Politics 2.0: The Multifaceted Effect of Broadband Internet on Political Participation". In: *Journal of the European Economic Association* 16.4, pp. 1094–1136. ISSN: 1542-4774. DOI: 10.1093/jeea/jvx044.
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.
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.
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.
Miner, Luke (2015). "The unintended consequences of internet diffusion: Evidence from Malaysia". In: *Journal of Public Economics* 132, pp. 66–78. ISSN: 0047-2727. DOI: 10.1016/j.jpubeco.2015.10.002.

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.
Scitovsky, Tibor (1954). "Two concepts of external economies". In: *Journal of political Economy* 62.2, pp. 143–151.
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.

Online Appendix (not for publication): Illustrative quantitative spatial model and simulation

This appendix provides a stylized quantitative illustration of how improvements in FTTH can affect the spatial allocation of activity and, mechanically, the local number of teleworkers. The exercise, based on an existing model of the new economic geography literature (see Redding and Sturm, 2008; Redding, 2016; Redding and Rossi-Hansberg, 2017), is intended to clarify intuition and generate qualitative comparative statics only.

There is a set of locations $i \in \mathcal{I}$. Workers are perfectly mobile across locations and choose where to live; in equilibrium, mobility equalizes indirect utility. We abstract from location-specific amenities to keep the mechanism simple.[13]

Preferences are Cobb–Douglas between a composite consumption good and housing/land. The composite good is CES over a continuum of horizontally differentiated varieties produced under monopolistic competition. Housing expenditure is redistributed lump-sum to local residents. Goods trade is subject to iceberg

[13] Formally, this corresponds to setting the amenity shifter to one, as in Redding, 2016.

trade costs $\tau_{ni} \geq 1$ between origin i and destination n.

Firms produce varieties with increasing returns to scale. Labor is the only factor of production. A firm located in i incurs a fixed cost F (in units of labor) and a variable labor requirement inversely proportional to location productivity A_i. Producing quantity $x_i(j)$ of variety j requires

$$l_i(j) = F + \frac{x_i(j)}{A_i}. \tag{6}$$

To connect the spatial allocation of activity to remote work in the simplest possible way, we assume an exogenous fraction θ of each location's workforce performs its job remotely (i.e., there is no endogenous WFH choice and no productivity penalty from WFH). Under this assumption, the number of teleworkers in location i is proportional to employment, $\text{Teleworkers}_i = \theta L_i$.

This simplification isolates the spatial-allocation channel: only the endogenous location of firms and workers defines the number of telecommuters in each city. We then discuss in the text how the literature that has relaxed these assumptions finds new results.

Simulation setup

We consider an economy on a $30 * 30$ grid as in Redding and Rossi-Hansberg (2017), yielding 900 locations.[14] Each cell represents a city. Trade costs between locations are computed using least-cost paths on the grid following the logic in Donaldson (2018): the effective distance between an origin and a destination is the minimum cumulative travel cost over available routes.

We solve for the spatial equilibrium (allocation of labor, wages, prices, and housing costs) given a baseline productivity distribution. Figure 5 displays the initial productivity draws. Figure 6 reports the corresponding equilibrium allocation (employment, teleworkers, wages, and land prices). 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. 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?

[14] Contrary to these authors, we do not divide this grid in two countries/regions.

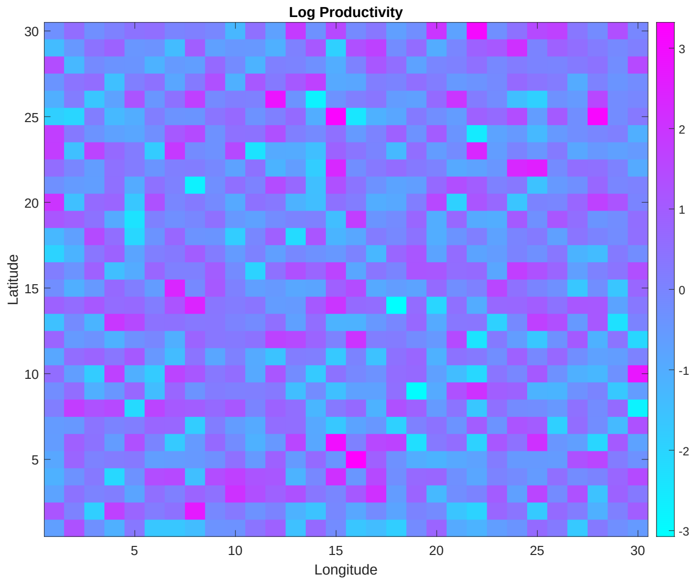

Figure 5: Initial productivity

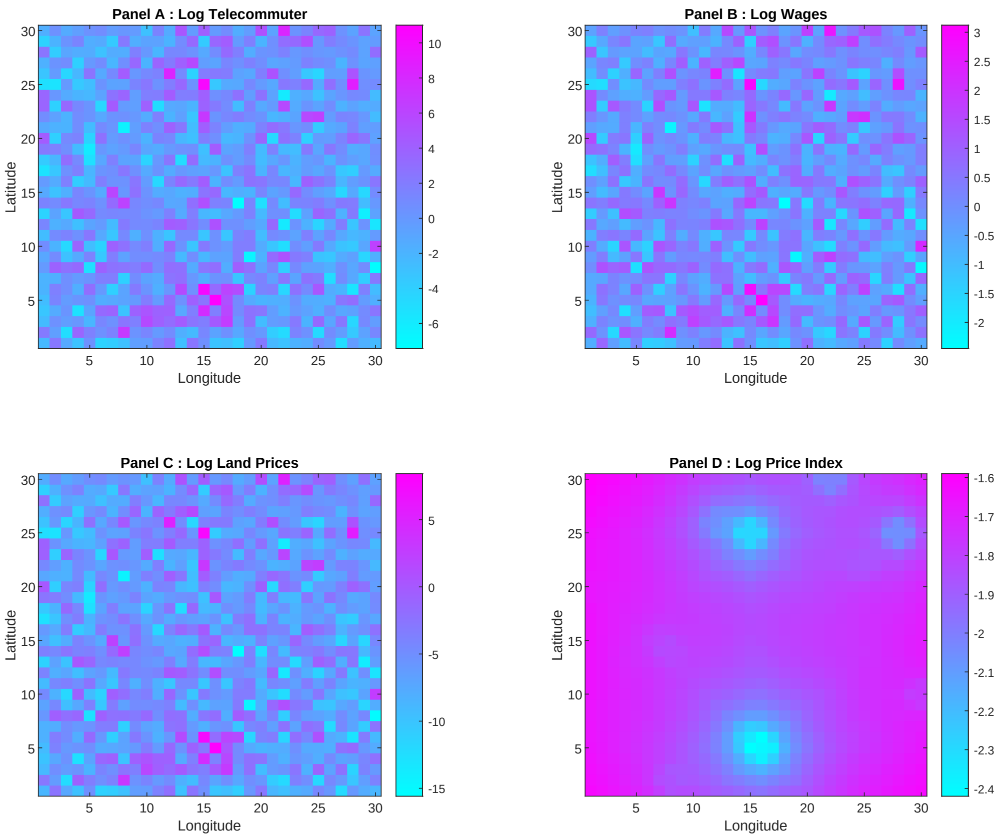

Figure 6: Initial equilibrium

We model FTTH in a very simple form, by assuming that it 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 has been found 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.

Specifically, we 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 7 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).[15] We then resolve the equilibrium with these new values and report relative changes compared to the initial equilibrium in Figure 8.

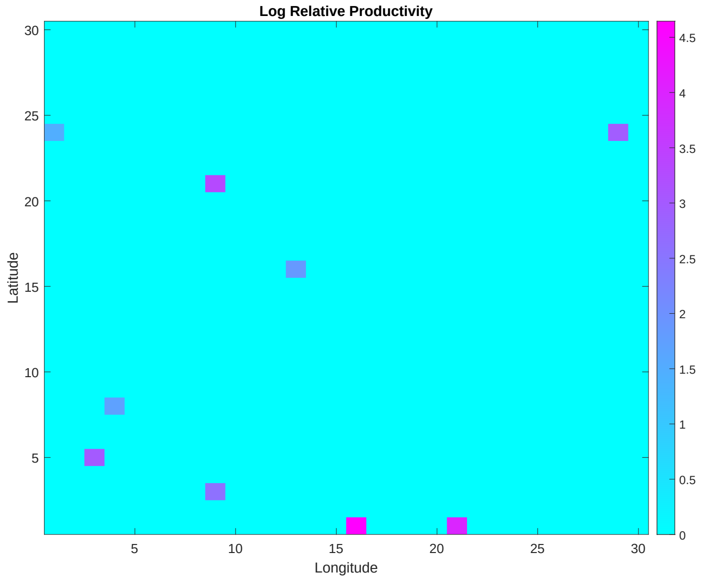

Figure 7: High-speed internet productivity shock

[15]The simulation uses parameter values standard in the quantitative spatial literature. Specifically, we set: $F = 1$, $\alpha = 0.75$, $z = 0.01$, $\theta = 0.1$, and $\lambda = 20$ (a strong productivity shock used for visual clarity). With smaller shocks (e.g., $\lambda = 0.5$), equilibrium changes are attenuated and spatial patterns are less visible in maps. Total population is set to $L = 153{,}889$ (as in Redding, 2016, corresponding to the U.S. labor force in 2010), and housing supply is set to $H = 100$ in each location.

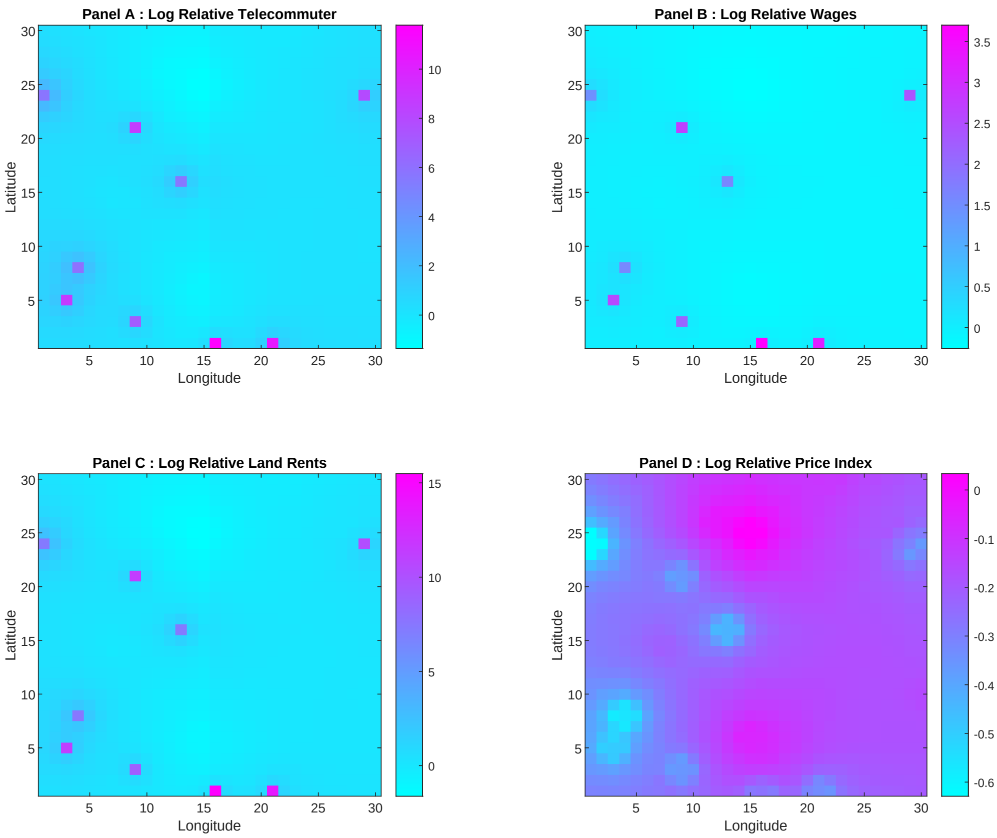

Figure 8: Spatial change due to the productivity shock

We observe three results that are relevant for the empirical design:

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.

A Descriptive Statistics

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 6: Number of Treated and Untreated Units per Year

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 7: Descriptive Statistics (N = 26,629)

B Standard Staggered DiD

We present here the results of standard staggered DiD estimations, without considering spillovers. We use the different estimators presented in the literature, 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).

The estimator Borusyak et al. (2024) is particularly 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.

Figure (9) presents results with the share of telecommuters on the right hand side of the estimation, while in Figure (10) it is the number of firm creation. 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 biased the results, which only hold under the strong assumption of no spatial contamination.

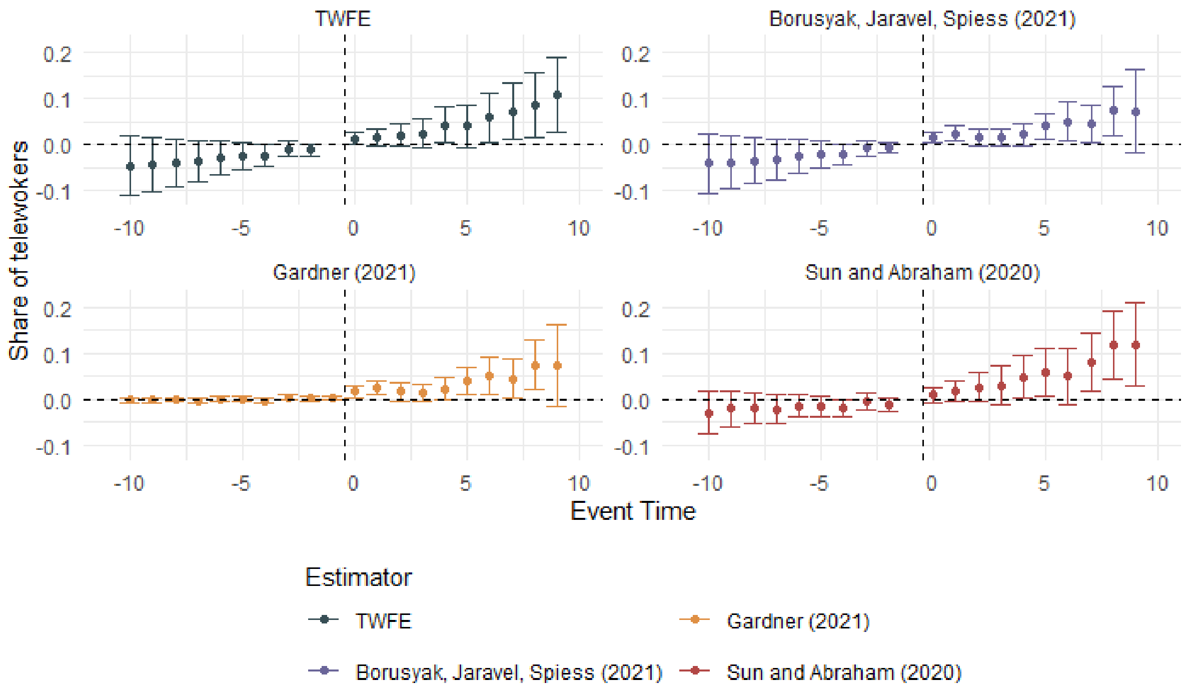

Figure 9: High Speed Internet and Working from Home

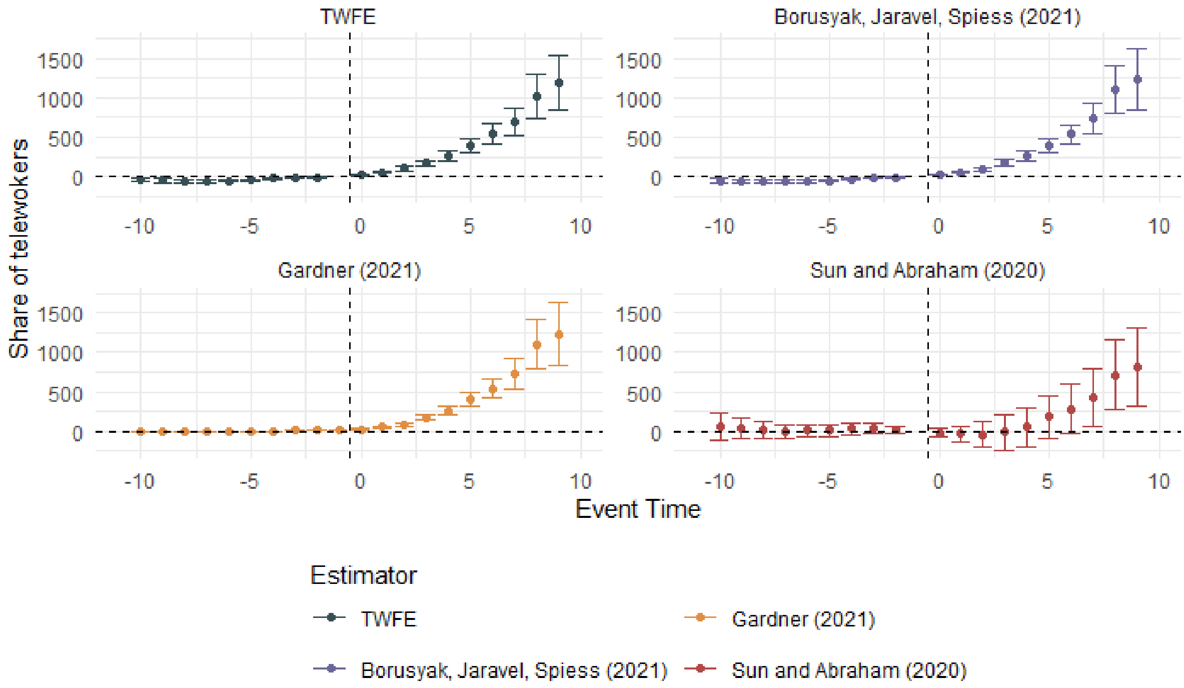

Figure 10: High Speed Internet and Working from Home

C Spillovers at 25 km

The radius $\bar{d}$ is selected using the data-driven partitioning least-squares procedure of Butts (2023), which estimates how outcomes for not-yet-treated municipalities vary with distance to treated municipalities and identifies a distance beyond which exposure effects are not statistically distinguishable from zero. In our application, this procedure yields $\bar{d} = 15$ km and then we use this threshold in the text. However, by leading further investigations, we observe that spillovers can affect cities beyond 15km. In particular, in Figure 11 which reports the estimated distance profile for the telework outcome, spillovers does not seem to vanish fully before 20 km. This figure also confirms that exposure effects are concentrated at relatively short distances and are not statistically different from zero beyond roughly 20–30 km.

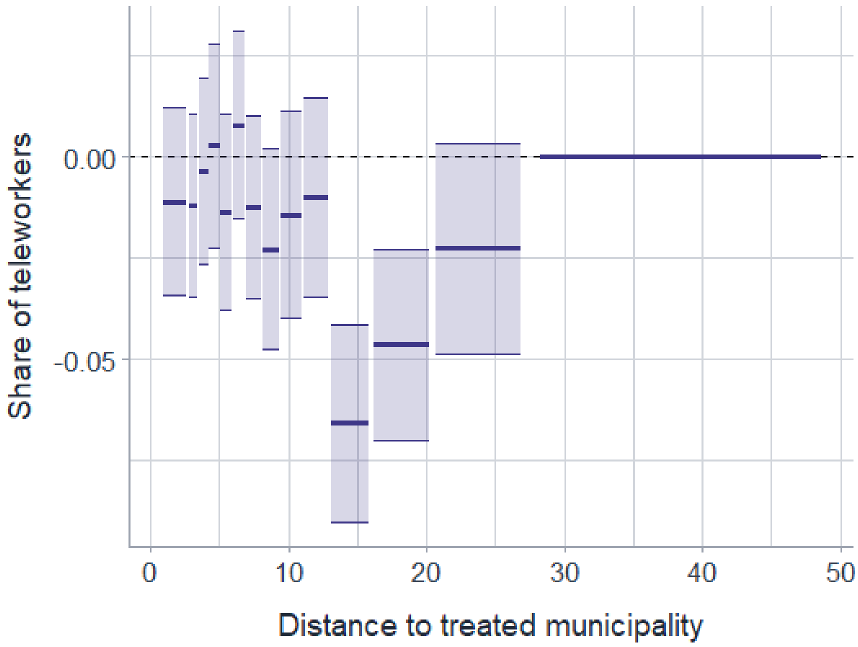

Figure 11: Estimated exposure effects by distance (telework outcome)

Then, we test the robustness of our result by using a threshold of 25 km on the share of teleworkers and number of firms respectively in Figure 12 and 13. We find similar results.

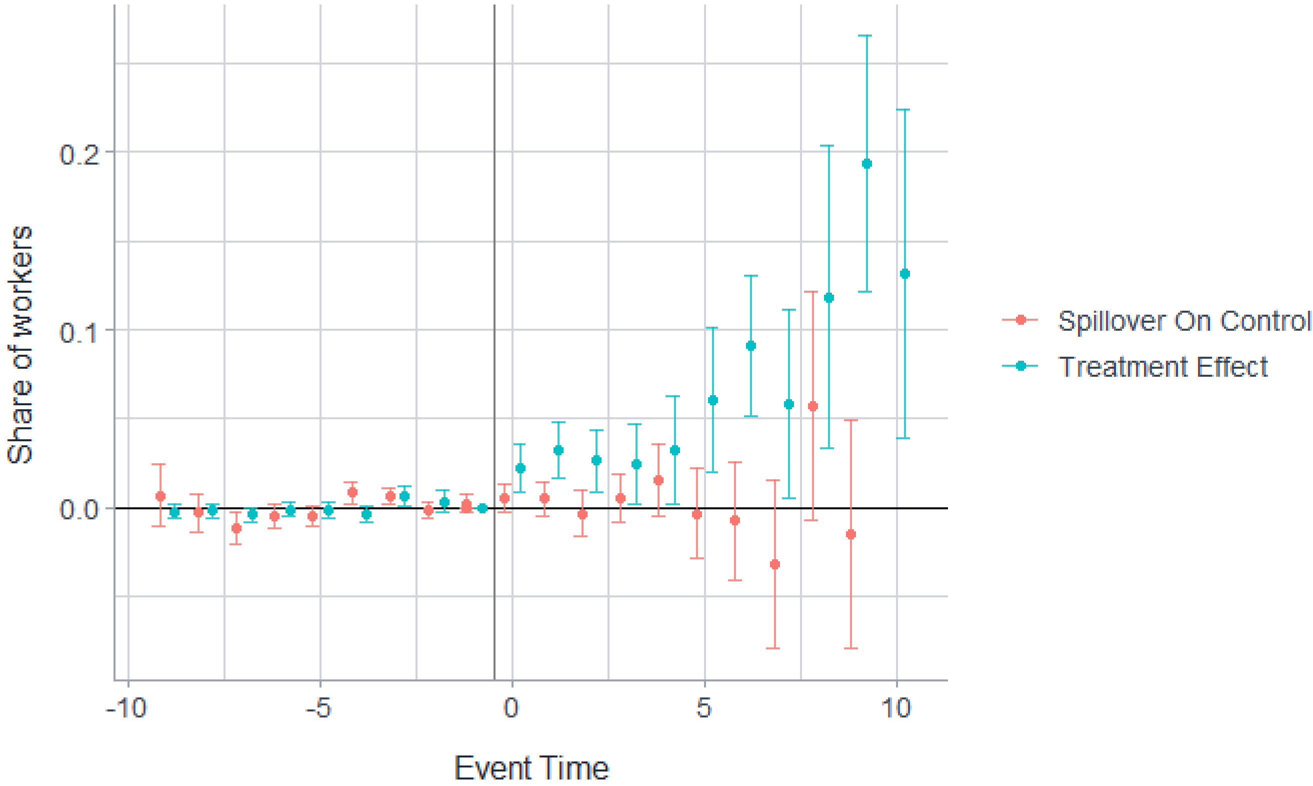

Figure 12: No spillover at 25 km for telecommuters

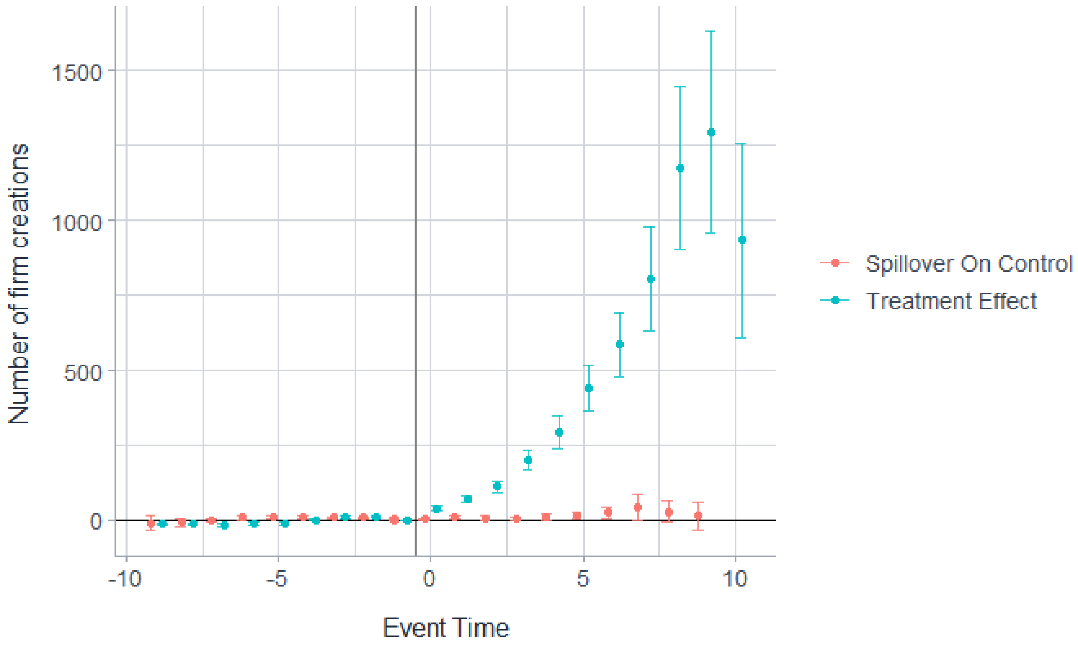

Figure 13: No spillover at 25 km for firms

D Skilled Telecommuters

As discussed in many papers, remote work concern mainly high-skilled workers, thus in Figure (14) 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.

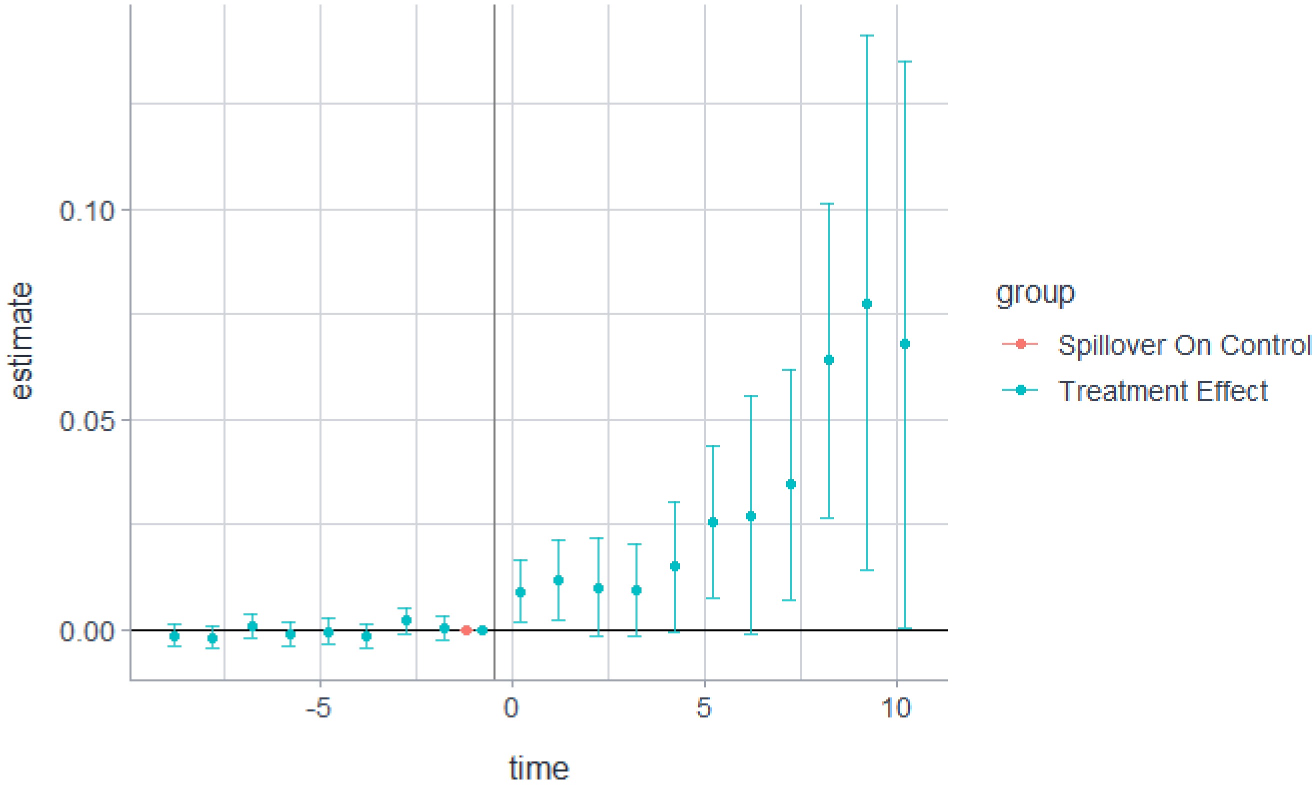

Figure 14: Impact of the arrival of fiber optics on the proportion of teleworkers in executives and higher intellectual professions

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 (15) for professionals with children than in the general case.

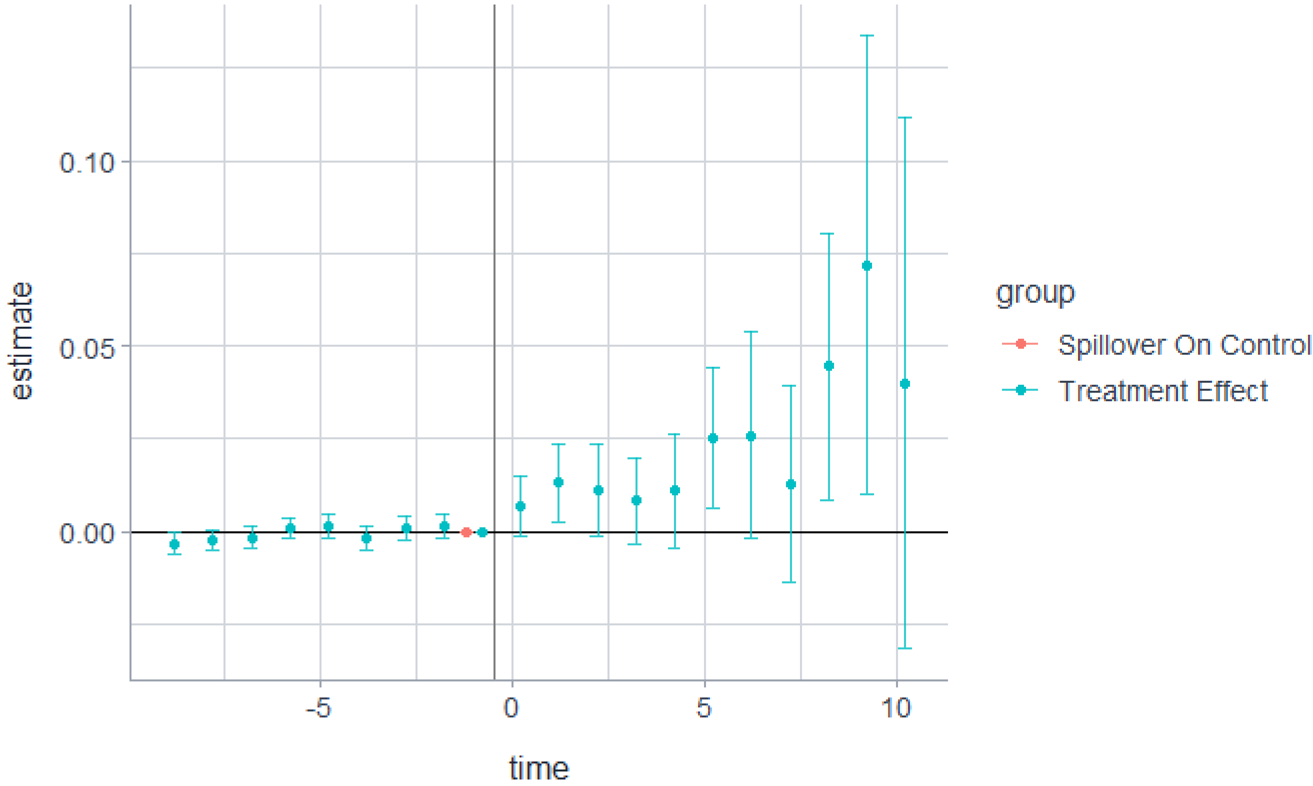

Figure 15: Impact of the arrival of fiber optics on the proportion of teleworkers with children

E FTTH and commuting arrival

To complete the analysis of the impact of FTTH on teleworking, we analysed the impact of the arrival of FTTH on commuting, particularly long, medium and short commutes. This allows analysis of the relationship with the potential residential locations of workers and whether FTTH encourages longer commutes. The results show that the effect of FTTH varies according to the distance between home and work. Very short commute distances of less than 5 km increase (Figure 16), which may reflect an increased concentration of local commutes. This phenomenon is consistent with the adoption of partial teleworking, as individuals can limit their travel while maintaining a regular connection with their job, favouring residential choices close to the workplace. However, the results should be treated with caution, as the effects emerge quite some time after FTTH arrives in the municipality.

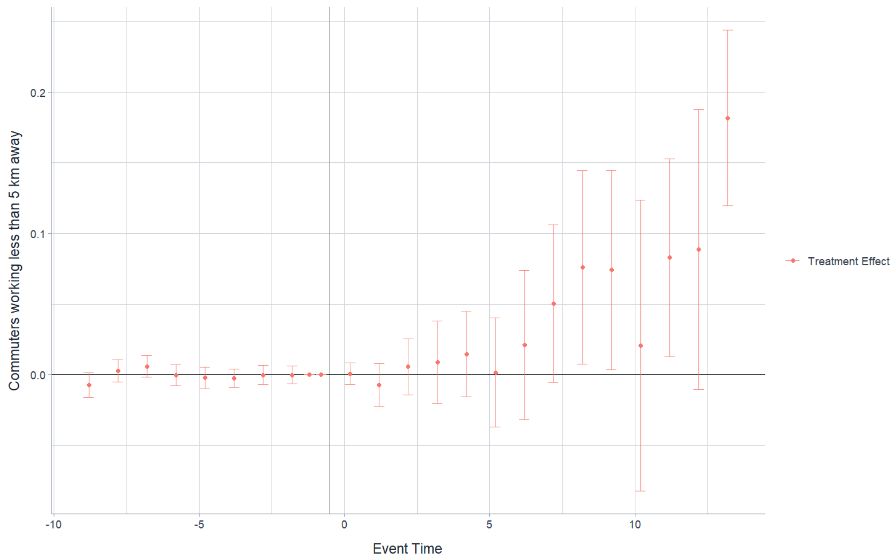

Figure 16: Number of commuters working less than 5 km away

In contrast, intermediate commutes of less than 65 km decreased (Figure 17) after the arrival of FTTH. This decline may reflect a direct substitution effect linked to teleworking: employees reduced the frequency of their commutes, favoured remote working, or adjusted their schedules and places of residence to limit their average commuting distances. This result highlights the impact of FTTH on the spatial organisation of work and may suggest that digital infrastructure can help reduce the constraints of regular commuting.

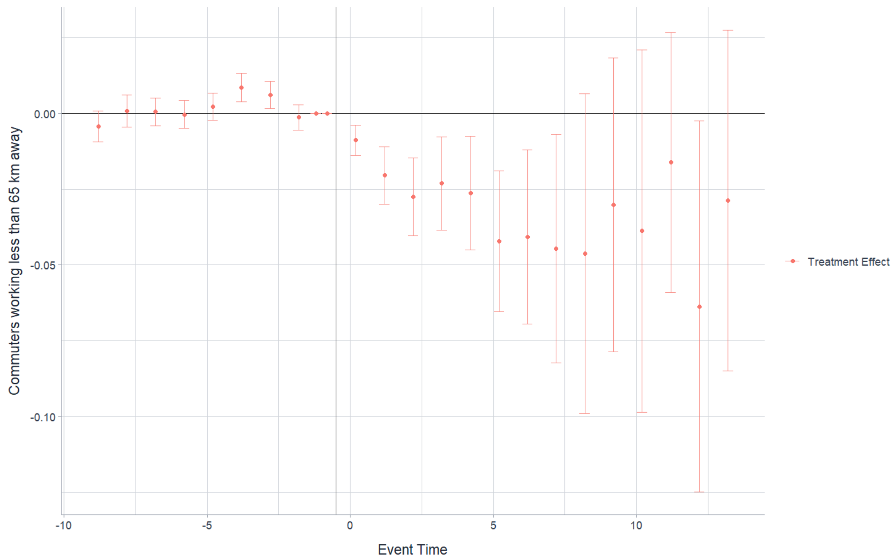

Figure 17: Number of commuters working less than 65 km away

For very long commutes, exceeding 65 km, an increase can be observed approximately three years after the implementation of FTTH (Figure 18). The delayed effect suggests that the flexibility provided by teleworking gradually allows households to relocate further away from their place of work while maintaining a stable professional connection. This temporal dynamic highlights that residential and professional adaptation requires a period of several years, which may reflect the adjustments made by businesses and individuals in response to the new opportunities offered by FTTH, but also the date taken into account for the implementation of FTTH, which may not be implemented immediately.

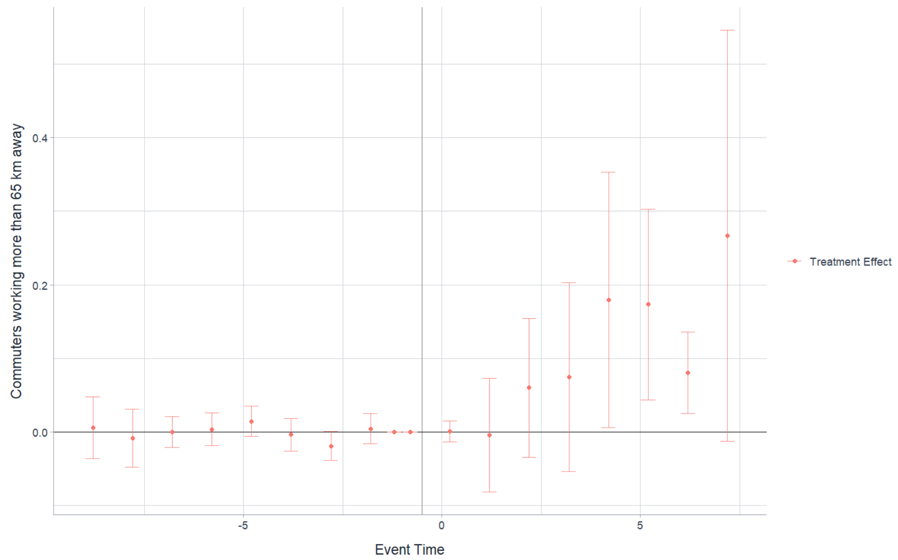

Figure 18: Number of commuters working less than 65 km away

These results show a polarisation in commuting behaviour that could be linked to teleworking: a concentration of very short commutes, a reduction in medium-length commutes and a delayed increase in very long commutes. FTTH can therefore have an impact on the spatial organisation of work and housing, facilitating more flexible residential and professional choices that are adapted to new remote working practices.

F Estimation with the 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.

Without Spillovers

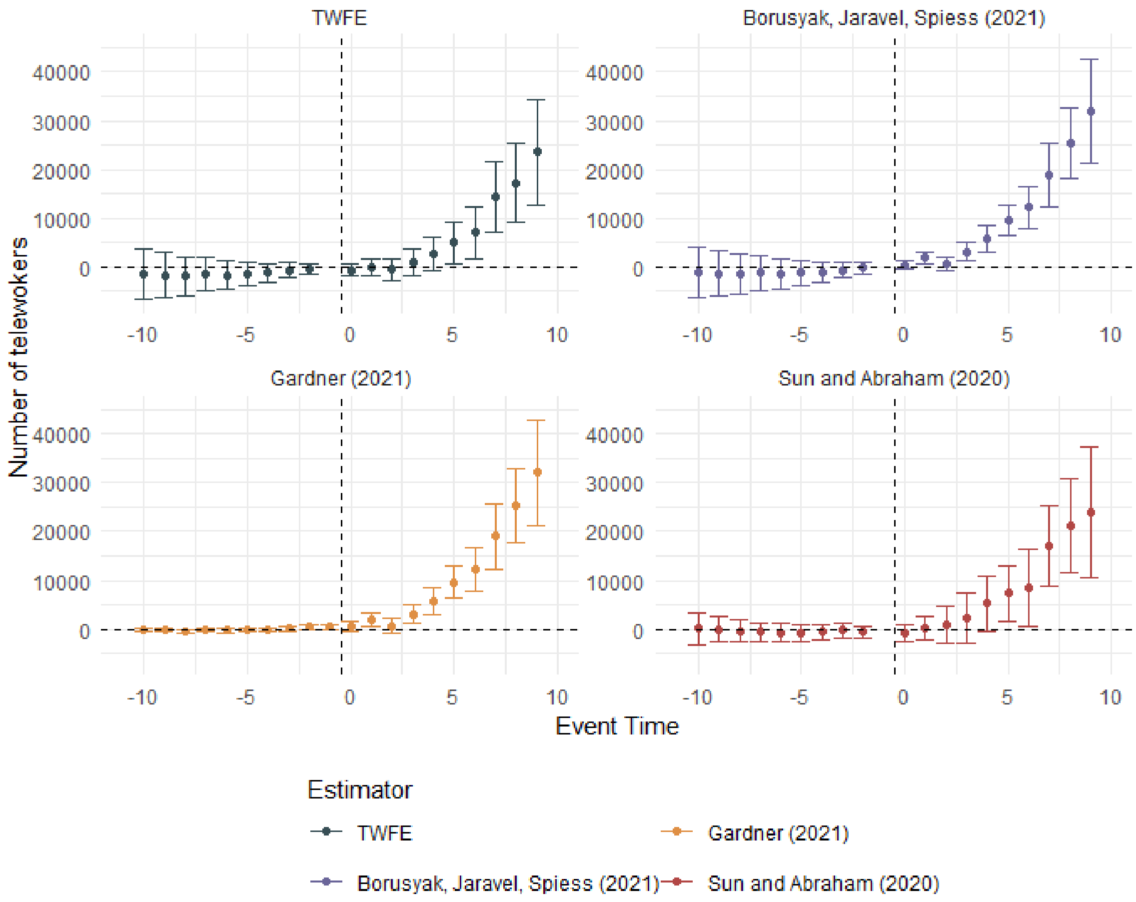

Figure 19: Estimation with number of teleworkers

With Spillovers

All sample

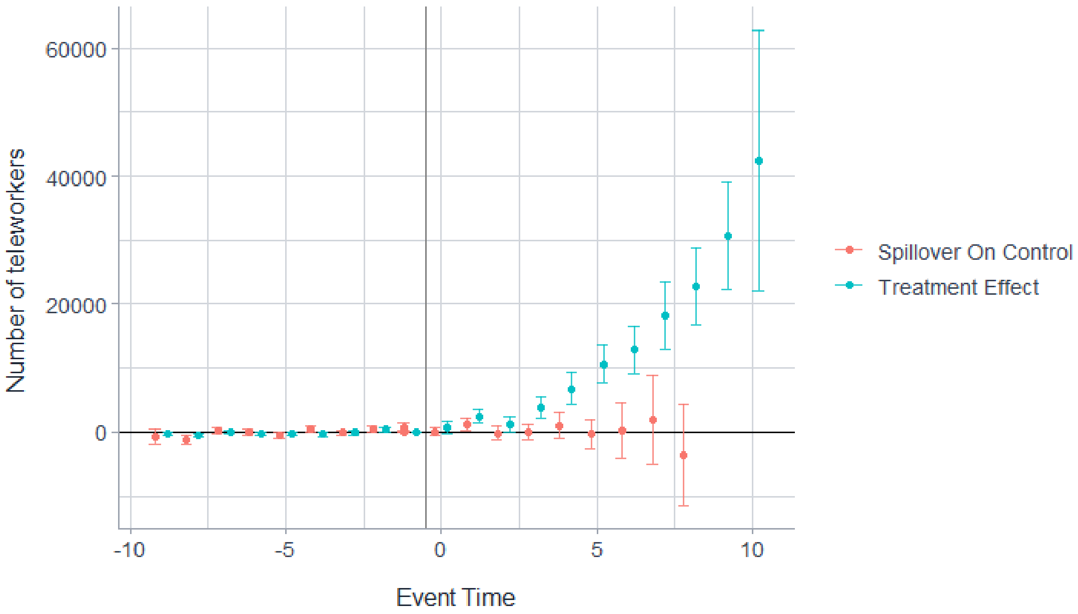

Figure 20: Estimation with number of teleworkers

IC sector

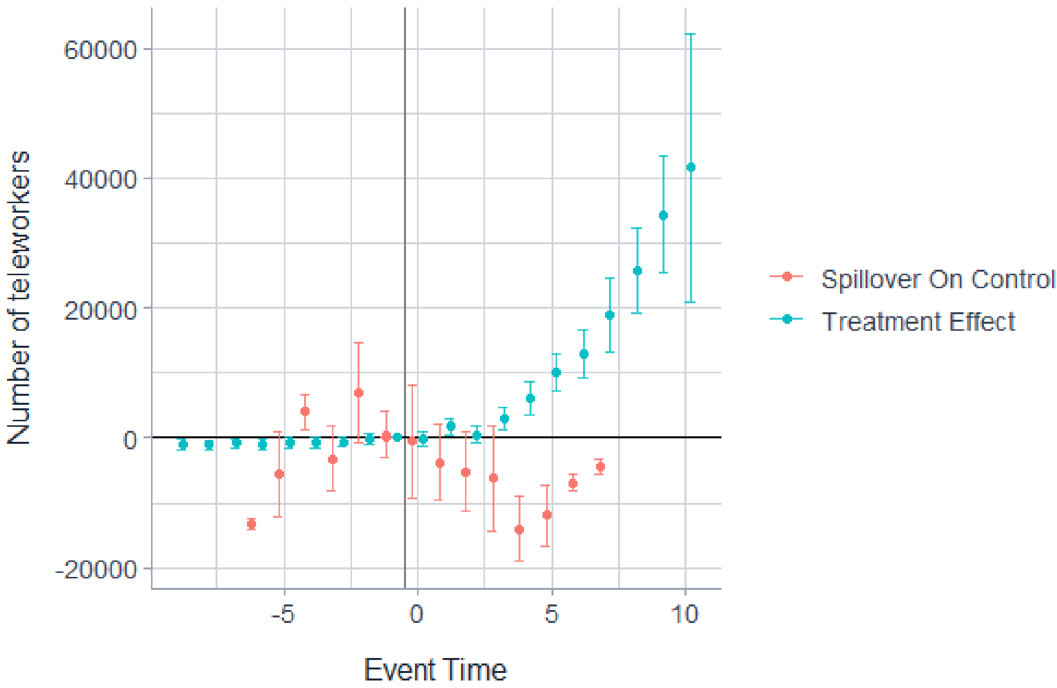

Figure 21: Estimation with number of teleworkers

Dense and less dense cities

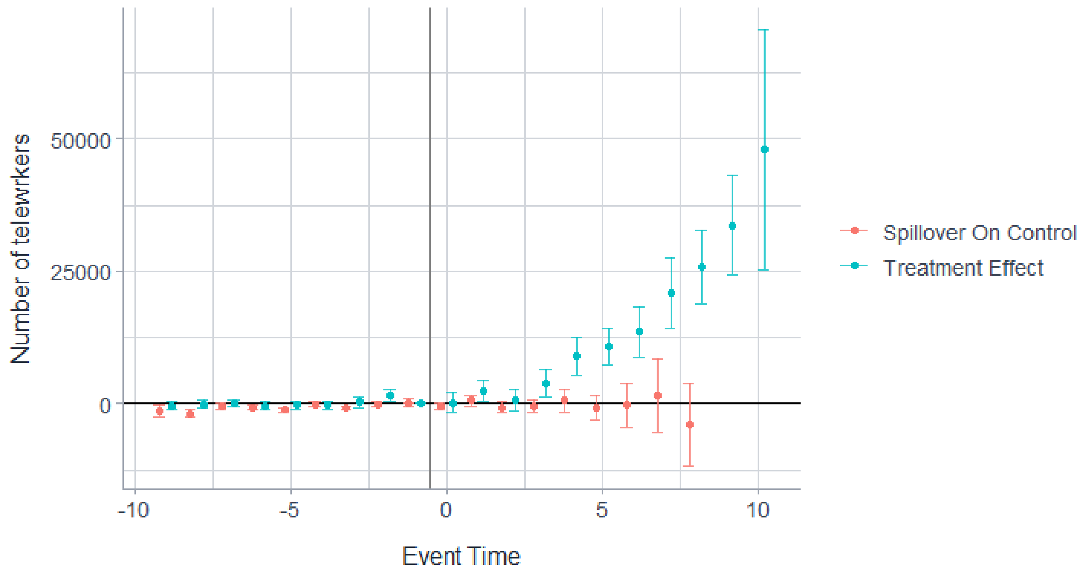

Figure 22: Estimation with number of teleworkers : Urban Dense Cities

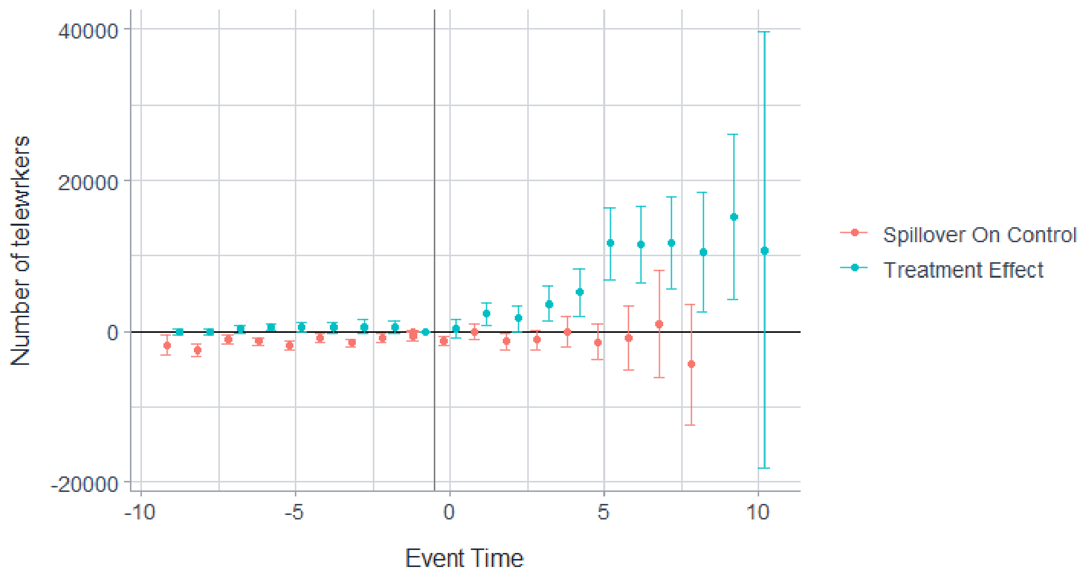

Figure 23: Estimation with number of teleworkers : Interm Dense Cities

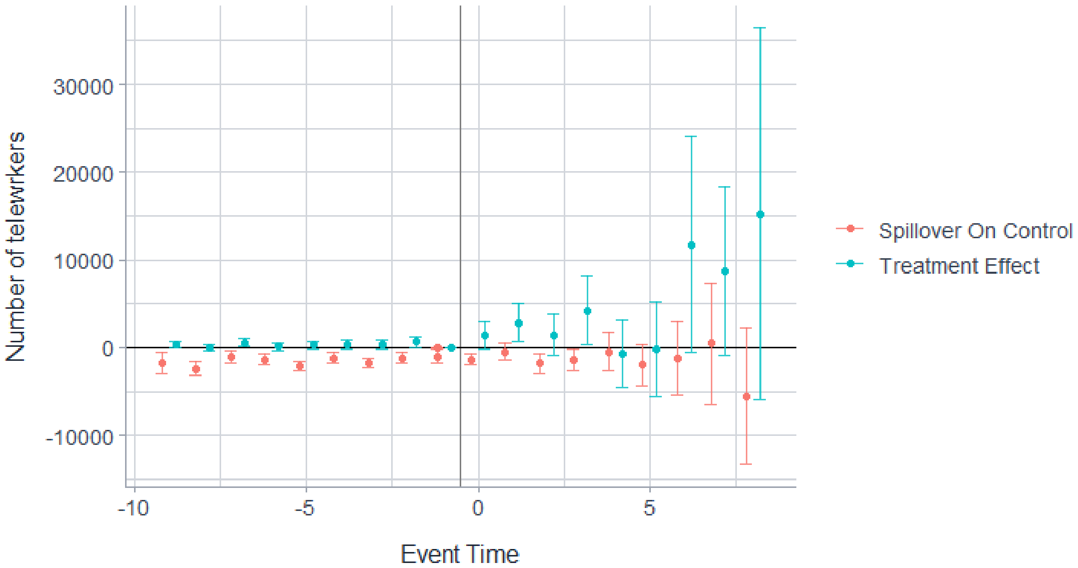

Figure 24: Estimation with number of teleworkers : Rural Cities

G Press coverage of telework and fiber

This appendix provides descriptive evidence on the timing and intensity of French media coverage that jointly discusses teleworking and optical fiber. The objective is not to identify causal effects, but to document how public discourse connecting these two topics evolved during the period studied in the paper.

We use the Europresse database and count press articles that contain the terms "Télétravail" (teleworking) and "Fibre optique" (optical fiber). The first series counts co-occurrences, defined as articles that mention both terms in the same document. The second series separates annual counts into mutually exclusive categories depending on whether an article mentions only telework, only fiber, or both.

Figure 25 shows that co-occurrences are essentially absent prior to the mid-2000s and remain rare until the early 2010s. Co-occurrences increase after 2013, the year in which the national Plan France Très Haut Débit is launched, and become more frequent toward the end of the 2010s.

Figure 26 provides additional context. Articles mentioning optical fiber display a clear upward trend over the full period, with a marked acceleration in the early 2010s. In contrast, articles mentioning telework are scarce in the early years and increase later. Articles that explicitly mention both telework and fiber appear after the launch of the national plan and grow thereafter.

These patterns are consistent with an interpretation in which fiber deployment and the associated policy debate became salient in the press before telework emerged as a widely discussed application, and before the surge in attention observed around the end of the 2010s. At the same time, several limitations imply that these figures should not be interpreted as evidence about causality. First, media attention is endogenous and may reflect many forces (editorial choices, policy announcements, major events such as COVID-19, or changes in the composition of outlets covered by the database). Second, the counts are not normalized by the total number of articles published, so changes in overall media volume may contribute to the observed trends. Third, co-occurrence in the press does not measure the timing of actual adoption of telework or the timing of infrastructure deployment; it measures the timing of discourse linking the two topics.

For these reasons, we treat this appendix as contextual evidence that complements our previous analysis.

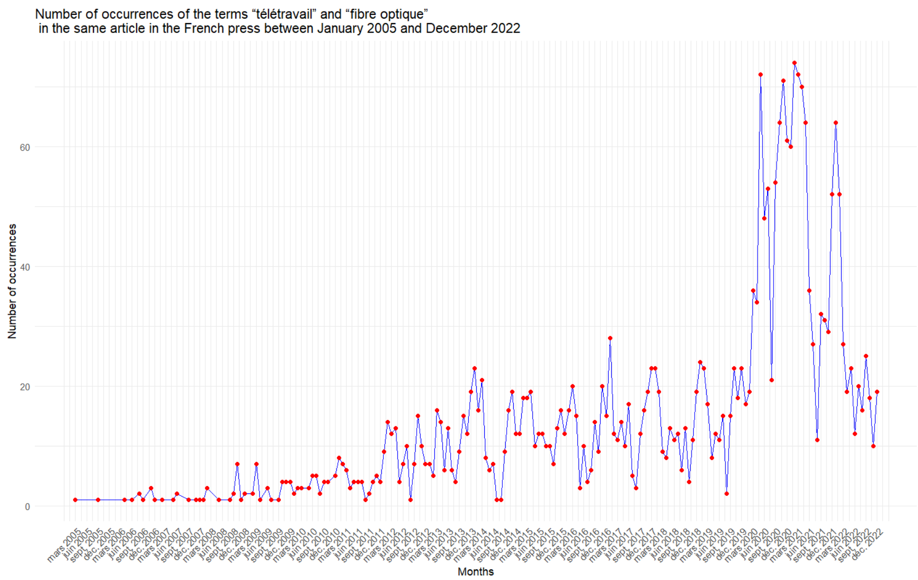

Figure 25: Number of press articles that mention both "Télétravail" and "Fibre optique" (Europresse), January 2005–December 2022

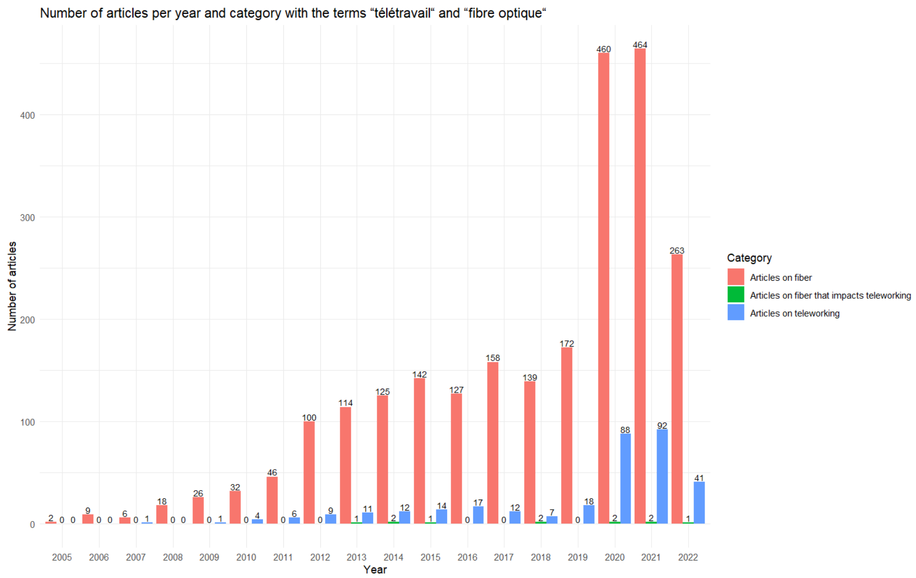

Figure 26: Number of press articles per year by category: "Télétravail" only, "Fibre optique" only, and both terms (Europresse)

H Effect of the DSL technology on working from home

This section examines whether variation in copper-based broadband quality (DSL) is associated with teleworking intensity, with the goal of assessing whether work-from-home arrangements can be supported by DSL alone. We use municipality-level measures of DSL eligibility at three speed thresholds ($\geq$ 30 Mbps, $\geq$ 8 Mbps, and $\geq$ 3 Mbps), available for 2020–2022. To align this exercise with the identification logic of the main analysis, we restrict the sample to municipalities that remain untreated in the baseline specification and estimate panel regressions of the municipal share of teleworkers on the share of dwellings eligible for each threshold. All specifications include municipality and year fixed effects, and standard errors are clustered at the municipality level.

Table 8 shows that DSL eligibility is not significantly associated with the municipal share of teleworkers at any of the considered thresholds. The point estimates are imprecise and do not display a clear gradient with the speed threshold, suggesting that, within this late-period sample of untreated municipalities, differences in DSL quality are not a primary driver of differences in teleworking intensity.

These results are consistent with the broader interpretation of the paper: the large increase in telework documented around FTTH deployment is unlikely to be explained solely by pre-existing copper-based broadband. Instead, they support the view that the transition to very high-capacity networks is the relevant margin for enabling telework at scale, at least in the period for which we observe comparable municipality-level measures of DSL eligibility.

	(1)	(2)	(3)
Dependent variable:	Share of teleworkers		
Share of dwellings eligible to DSL $\geq$ 30 Mbps	0.975		
	(1.730)		
Share of dwellings eligible to DSL $\geq$ 8 Mbps		0.432	
		(0.960)	
Share of dwellings eligible to DSL $\geq$ 3 Mbps			4.134
			(3.238)
Observations	188	188	188
Adjusted R^2	0.493	0.490	0.514
Within R^2	0.039	0.035	0.079

Notes: The dependent variable is the municipal share of teleworkers. Each specification includes municipality and year fixed effects. Standard errors clustered at the municipality level are reported in parentheses. The main explanatory variables measure the share of dwellings eligible to a given DSL speed threshold: at least 30 Mbps (column 1), 8 Mbps (column 2), and 3 Mbps (column 3). The sample is restricted to municipalities that remain untreated in the baseline specification.

Table 8: Impact of DSL internet quality on working from home