The Impact of Ultra-Broadband on Labor Income: An Event Study Approach

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Abstract

We study the impact of ultra-broadband (UBB) connections on labor income and employment of employed and self-employed workers. We use micro-level panel data for the Italian municipalities over the period 2012–2019, and we exploit the staggered roll-out of UBB started in 2015. Through an event study approach, we find evidence of endogeneity between UBB roll-out and labor market outcomes. To identify causal relationships, we use income from pensions to implement the estimator developed by Freyaldenhoven et al. (2019). We find that access to UBB connections significantly increases income from self-employed workers through the increase of their number. Such an effect is mostly driven by a rise in self-employed workers, which is concentrated in urban areas, and in municipalities at the top and bottom quartiles of labor income.

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1 Introduction

High-speed internet access via broadband infrastructures is widely recognized as a driver of economic growth. Owing to its nature of general-purpose technology (Bresnahan and Trajtenberg, 1995; Clarke et al., 2015), last-generation broadband networks can spur positive externalities on economic sectors, thus affecting aggregate productivity. Understanding the potential of these effects is therefore increasingly important to ensure economic growth and improve welfare. In this paper, we study the impact of fiber-based ultra-broadband (UBB) infrastructure on the income and employment of employed and self-employed labor using municipality-level panel data in Italy.

Fiber-based connections constitute a significant technology change relative to standard copper-based (DSL), with implications for business creation (Cambini and Sabatino, 2023) and firm productivity (Cambini et al., 2023). From a technological point of view, the performance of fiber-optic connections is far superior to DSL in terms of bandwidth, security, speed, reliability, signal strength, and cloud access. These features make it not susceptible to slowdowns or interruptions caused by unfavorable conditions, such as high demand for internet access, adverse weather (Gavazza et al., 2018), and distance from the switch (Campante et al., 2017). These benefits may translate into significant productivity gains for firms, by allowing more efficient business processes such as marketing, inventory optimization, and streamlining of supply chains, and by allowing new –remote– forms of organizations of labor, associated with important operational savings (Van der Wee et al., 2015). Moreover, fast internet connections can also favor the start of home-based business (European Commission, 2015).

Due to the potential economic benefits, the development of adequate broadband infrastructure has long been at the center of the attention of European policymakers. In the spirit of creating a new European "Gigabit society" with very high-speed connection, in September 2016 the European Commission identified, as strategic objectives for 2025, that all European households will be able to access internet connections with speeds of at least 100 Mbit/sec, and that connectivity at 1Gbit/sec will be guaranteed for key socio-economic development sites (such as schools, railways, subways, public service providers, etc.). The importance of such investments has called for direct public intervention, at least in those areas where private investments are not profitable (Gruber et al., 2014).[1] From a policymaking perspective, it is thus crucial to understand and quantify the impact of the investment in ultra-broadband (UBB) networks in sensitive economic outcomes such as employment and labor income.

To explore the impact of last-generation broadband internet connections on the labor market, we exploit the staggered roll-out of UBB in Italy, which started in 2015. These connections are based on optical fiber cables enabling a significantly higher performance compared to traditional copper-wire connections. We gather information on the availability of UBB in all Italian municipalities matched with publicly available data on local labor income from the Italian Ministry of Economy and Finance (MEF). The data distinguish between income generated by employed and self-employed workers, allowing us to investigate whether high-speed connections affect disproportionally self-employment (Denderski

[1] Indeed, starting in 2018, the Italian government has increased the financial resources from 0.5 to 7 billion Euros for UBB. In 2021, the Italian Government has decided to use part of the Next Generation EU funds to finalize the deployment of UBB infrastructure throughout the country, with around 3.6 billion Euros of public expenditure.

and Sniekers, 2019), for example by allowing more flexible working conditions.[2]

Our empirical strategy is based on an event study design that exploits the staggered roll-out of UBB. Estimating the economic impact of broadband technologies is challenging, mainly due to the presence of unobservable economic factors contributing to the diffusion of such infrastructures (Cambini et al., 2023; Campante et al., 2017; Falck et al., 2014; Gavazza et al., 2018). Consistently with the endogenous relation between UBB roll-out and economic outcomes, we observe significant pre-trends before treatment. To identify causal effects, we propose a novel approach that exploits the Freyaldenhoven et al. (2019) (FHS) estimator, which is based on the existence of a variable that is correlated with the unobserved confounders of labor income, but uncorrelated with UBB roll-out. In this framework, we use municipality retirement income (i.e., pensions), for two main reasons. First, it is strongly correlated with local labor income, as it derives from past income realizations. Second, it is unrelated to UBB roll-out, since the retirement system in Italy is highly centralized, allowing little flexibility to the current retirement choice of the workers. We show that, when estimating the labor income *via* the FHS estimator, event study estimates show parallel trends before treatment, thus validating the research design.

Our results show that UBB has a negligible effect on aggregate labor income. We show that fixed effect estimates suffer from a positive bias from omitted variables, thus overestimating the true effect. However, we find a significant positive effect on the income from self-employed workers. When performing the FHS estimator, the average impact implies a

[2] In a companion paper, Abrardi and Sabatino (2023) study the effect of UBB on economic resilience by restricting the analysis on the period of the Covid-19 pandemic (see also Section 2). Another difference with the present work is that they look at aggregated variations of employment and GDP, without studying heterogeneous effects on employed and self-employed labor.

1.3% increase in income from self-employment, with a long-term impact that amounts to 5%. The positive effect of UBB on self-employment income is due to the increase in the number of self-employed workers, rather than their average per capita income. Moreover, it is concentrated in urban areas, in municipalities where the population has a higher level of education, in those at the top and bottom quartile of the labor income distribution, and in the Southern and Northern-West regions of Italy. Overall, these results suggest that two different drivers into self-employment are at work, based on opportunity or necessity (Simoes et al., 2016). In regions where unemployment is more severe and employment alternatives are limited, like the Southern regions, UBB can spur necessity entrepreneurship, thus increasing the number of self-employed workers. Conversely, in the North, UBB can leverage on higher levels of education and create new opportunities for self-employment, thus increasing the productivity of self-employed workers and their per capita income (Forman et al., 2012; Simoes et al., 2016).

We then assess the presence of potential spatial spillovers that may confound our results. In particular, since both the number and earned income derive from tax returns, which in turn are based on the residence of the worker population, variations in labor income in the residence location may be affected by the presence of UBB at the workplace, thus biasing overall results. We test the severity of this issue by (i) estimating the spatial lag of the independent variable model, and (ii) by aggregating the data at the local labor market level. In both cases, we find that the impact of UBB concentrates on income from self-employed workers.

The rest of the paper is organized as follows. Section 2 provides the theoretical background for our analysis and reviews the recent literature. Section 3 provides information on the deployment of the broadband infrastructure in Italy and introduces the data. Section 4 describes the empirical model and the identification strategy. Section 5 discusses the results. Section 6 investigates potential spatial spillovers. Finally, Section 7 concludes.

2 Theoretical Background

The literature studying the economic impact of advanced digital technologies suggests that they may have disruptive effects in the labor market (see, e.g., Abrardi et al., 2022 for a review). While they could be associated with productivity gains, they may also cause a decrease in the labor share (Acemoglu and Restrepo, 2020; Cette et al., 2022). Autor et al. (2020) argue that the decline in the labor share could be due to the growth of firms with less labor-intensive technologies, especially in the digital economy. Looking specifically at broadband technologies, most of the available studies on their effects in the labor market focusing on basic broadband, and finding a positive impact on wages and employment, but only for specific types of workers or areas (Forman et al., 2012; Akerman et al., 2015; Czernich et al., 2011). In particular, Forman et al. (2012) find that the adoption of advanced Internet applications increases wages and employment in counties in the top quartile of income, education, and fraction of firms in IT-intensive industries. The presence of complementarities with broadband technologies is confirmed also at a worker level. Akerman et al. (2015) show that the adoption of basic broadband technologies enhances labor productivity and increases wages of skilled workers while worsening labor market outcomes for unskilled workers.

The economic literature on the impact of high-speed broadband is scant, and mostly based on aggregated data at a country or regional level (Briglauer and Gugler, 2019; Briglauer et al., 2021; see also the survey by Abrardi and Cambini, 2019). A cross-country study (Denderski and Sniekers, 2019) finds that faster internet prompts more self-employment. At a micro-level, Hasbi and Bohlin (2022), exploiting data from measurement tests realized by Internet users in Sweden, find that broadband quality can reduce unemployment of low-skilled workers in larger cities. Abrardi and Sabatino (2023) study the effect of UBB on economic resilience using data on GDP and employment during the Covid-19 pandemic period (2019–2020) in Italy, finding that exposure to UBB mitigates the negative effect of the pandemic on employment, especially in those areas hit more severely by the pandemic. Other studies focus specifically on rural areas and find that broadband coverage has a significant positive effect only on highly-qualified jobs (Briglauer et al., 2019) and on business startups in areas with favorable economic, natural, and demographic conditions (Duvivier and Bussière, 2022). In New Zealand, Fabling and Grimes (2016) find a significant impact of ultra-broadband on employment only for companies that make complementary investments in organizational capital. Further research has analyzed the impact of UBB on business creation, finding that UBB increases firm entry only in large urban centers and digital intensive sectors with a high skilled workforce (Duvivier et al., 2021; Cambini and Sabatino, 2023), whereas it increases net exit in sectors with low digital skills, such as Hotels, Restaurants and Trade (Cambini and Sabatino, 2023).[3] On the supply side, recent studies based on self-reported population surveys also suggest that the adoption of high-speed broadband, by allowing for more flexible working conditions, increases the labor supply of people living in rural areas

[3]Higher broadband speed levels may also affect property prices (Ahlfeldt et al., 2017) and firms' location decisions (Canzian et al., 2019; Duvivier, 2019), although entrepreneurship and company creation seem to be affected by important complementarities with industry types and educational levels (Hasbi, 2020).

(Min and Rossotto, 2012) and of married women, and specifically their self-employment (Han, 2021) and labor force participation (Dettling, 2017). In particular, Han (2021) exploits American Community Survey self-reported broadband data and the Federal Communications Commission broadband data, aggregated at a county level, to study the effects of adoption and access to high-speed internet.

In sum, the recent literature on high-speed broadband supports the hypothesis that UBB may positively affect employment, but with heterogeneous effects depending on complementary factors, such as workers' skills or the flexibility of working conditions. Although our data do not provide information on skills at a worker level, we explore the impact of UBB infrastructure on self-employment, and whether this effect is due to an increase in the number of workers or rather their income.

Our contribution to the literature is twofold. First, we provide a more refined picture of the effects of advanced ICT technologies on labor market outcomes, disentangling the effects of last-generation broadband infrastructure between employed and self-employed labor. Second, we propose a new identification strategy, which exploits local retirement income within the FHS estimator.

3 Data

UBB are connections based on optical fiber cables that allow a significantly higher performance (up to 1 Gigabit/s) compared to traditional copper-wired (ADSL) connections. The roll-out of fiber-based UBB in the Italian municipalities started in 2015 as a result of the implementation of the Italian Strategy for High-Speed Broadband, which incorporates the main objectives of the 2020 Digital Agenda for Europe.[4] As shown in Figure 1, by the end of 2019 around 55% of Italian municipalities had access to UBB services with connection speed higher than 30 Mbps, amounting to about 90% of the Italian population. A small fraction of municipalities (6%), representing 37% of the Italian population, have access to the most advanced Fiber-to-the-Home connections, which allow a maximum speed of 1 Gigabit per second (Gbps). ADSL connections are in their mature phase, as almost the whole population has access to basic ADSL connections.

Three possible UBB configurations exist, depending on the portion of optical fiber deployed in the last mile. Fiber-to-the-Cabinet (FTTC) leverages on a first portion of optical fiber, up to a cabinet located nearby the customer building from which the copper line departs, allowing at least 30 Mbps speed. Fiber-to-the-Building (FTTB) connects cabinet and customer building basement via optical fiber, and is characterized by a minimum speed of 100 Mbps. Fiber-to-the-Home (FTTH), in which the last mile is full fiber-based, allows the highest speed of 1Gbps. In all these settings, the length of the fiber portion of the last mile does not affect much connection performance, as fiber optical lines have a very low dispersion rate. However, in FTTC settings the length of the second part of the last mile - that is the distance between the cabinet and the final consumer - dampens connection performance because it is made of copper wire. In Italy, the average length of the last mile is 1.5 Km, with an average distance between cabinet and consumer premises of 200 meters. The short length of the final portion of the last mile ensures a significantly higher performance with

[4]The Digital Agenda for Europe specifies the goals in terms of network coverage and service adoption for the whole European population. See https://www.europarl.europa.eu/factsheets/en/sheet/64/digital-agenda-for-europe for more.

respect to ADSL connections.[5]

The UBB deployment plan has been implemented through a combination of public and private investments. There are only two distinct networks that supply UBB services to final consumers. The first one is owned by the telecommunication incumbent *Telecom Italia Mobile* (TIM), which leverages on the pre-existing telecommunication facilities used for voice telephone and ADSL connections. As a consequence, TIM has been the first in investing in UBB infrastructures throughout Italy since 2015,[6] covering the vast majority of municipalities with a mix of full fiber (FTTH) and copper-fiber (FTTC) connections. The second one is owned by *Open Fiber*, a wholesale operator currently owned by *Cassa Depositi e Prestiti* – the investment branch of the Ministry of Treasury – and two international private investment funds. Open Fiber entered the market in 2017 by acquiring Metroweb, a private telecom company covering a few large cities (e.g. Milan, Bologna, and Turin). Since then, Open Fiber has invested in FTTH connections mainly in large cities, as well as in less than densely populated areas (the so-called "white areas"), after being the recipient of public resources awarded through competitive procedures run by the Italian Government. By the end of 2019, Open Fiber covers 392 municipalities, 261 of which are also (fully or partially) covered by TIM.[7]

Using data from Telecom Italia Mobile (TIM) and OpenFiber (OF), we observe which municipalities have access to the UBB provided by TIM or OF for each year of observation, from 2015 to 2019. We thus construct a novel dataset matching municipality-level infor-

[5] `https://www.agcom.it/documents/10179/1571667/Documento+generico+08-11-2014+1415441917492/d34cc914-c150-4fd7-a383-a0c39c9d7670?version=1.1`

[6] Before 2015 only a few large cities such as Milan and Bologna enjoyed fiber-based connections realized by the local telecommunication operator.

[7] Open Fiber deployment plan can be found here: https://openfiber.it/area-infratel/piano-copertura/.

mation on UBB access and local labor income for the period 2012-2019. From the Italian Ministry of Economy and Finance (MEF) we obtain municipality-level data on i) payroll income, ii) income from self-employed labor, and iii) income from retired workers. The sum of i) and ii) allows us to compute the total labor income in a municipality. Since it is obtained from current workers, it does not include the income from retired workers in iii). Data are based on tax declarations of Italian citizens and collect income measures together with the number of taxpayers. This allows us to infer information on the per capita income. Summary statistics are provided in Table 1.[8]

Finally, we obtain demographic information from the Italian statistical office (ISTAT), including municipality population, degree of urbanization, the share of the population with a university degree, the share of the population below 40 years old, together with topological characteristics such as municipality geo-localization, altitude (in meters) and surface (in squared kilometers). The final data set is composed of 61,520 municipality-year observations for a total of 7,690 municipalities observed over the period from 2012 to 2019.

4 Empirical strategy

To study the effect of UBB availability on labor income and employment at the municipal level, we perform an empirical strategy based on three different models.

[8]For privacy reasons, data are missing for municipalities with less than three taxpayers for a particular category of income. This explains the lower number of observations for self-employed income, as in small municipalities there may be less than three self-employed workers. For the calculation of total labor income, we treat missing values as zeroes.

Two-Way Fixed Effects. Our baseline empirical model takes the following form:

$$y_{m,t} = \beta_0 + \gamma UBB_{m,t} + \alpha_m + \tau_{p(m),t} + \varepsilon_{m,t} \tag{1}$$

where α_m are municipality fixed effects, $\tau_{p(m),t}$ are fixed effects of the interaction between province (of the municipality) and year, so as to control for differential trends of the dependent variable across Italian provinces. Finally, $\epsilon_{m,t}$ is the mean-zero error term. $UBB_{m,t}$ is our main variable of interest, and it is a dummy equal to one if municipality m has access to UBB at time t, and zero otherwise. In all regressions, we cluster standard errors at the province level to allow for correlated shocks among municipalities belonging to the same administrative province.[9]

Our main outcome of interest is (log-) labor income in municipality m and year t. We split the analysis on two sources of labor income, namely employment and self-employment income. In fact, heterogeneous effects between employed and self-employed labor may emerge due to market frictions. For example, faster internet may prompt more self-employment by allowing self-employed workers to find consumer demand more easily (Denderski and Sniekers, 2019). Moreover, since we observe the number of workers generating the specific amount of income, we can also compute per capita income, so as to explore both the intensive and extensive margins of UBB impact.

Event Study. Model (1) performs a two-way fixed effect difference-in-differences (DiD) model with variation in treatment timing, where treated units are those municipalities with

[9]Results are not affected by different clustering methods.

access to UBB services. The model identifies the causal impact of UBB on labor income if UBB roll-out is as-good-as random. We study the dynamics of the treatment effect through an event study design that includes leads and lags from the timing of UBB introduction. We define as treated units those municipalities m that have some access to UBB in year (t). Let T_{0m} be the time when municipality m initially receives UBB – i.e., the lowest t such that $UBB_{m,t} > 0$, and let $r = t - T_{0m}$ be the relative time from the treatment.[10] The event study equation takes the following form:

$$y_{m,t} = \beta_0 + \sum_r \gamma_r \mathbb{I}\{r = t - T_{0m}\} + \alpha_m + \tau_{p(m),t} + \epsilon_{m,t} \tag{2}$$

Because of the staggered design of the treatment assignment, we drop $r = \{-7, -1\}$ to exclude two indicator variables identifying relative time from the treatment (Borusyak et al., 2021).

The inclusion of leads and lags in equation (2) allows us to investigate the dynamic effect of UBB introduction as well as the presence of pre-trends, which would point to the endogeneity of UBB roll-out to local labor income.

FHS Approach. We deal with the potential endogeneity of UBB diffusion by exploiting a variable $x_{m,t}$ that is correlated with confounders of local income but directly uncorrelated with our shock of interest, i.e., UBB roll-out. Freyaldenhoven et al. (2019) show that if such a variable exists, then one can identify the causal impact of the treatment through a two-stage least squares (2SLS) estimation in which $x_{m,t}$ is instrumented with the first lead of $UBB_{m,t}$, i.e., $UBB_{m,t+1}$.

[10]Since our sample covers from 2012 to 2019, then $r = \{-7, -6, ..., 0, +1, .., +4\}$.

Our variable $x_{m,t}$ is the retirement income. There are three main reasons why such a variable is suitable for our identification strategy. First, the demand for high-speed broadband for old people is very low (ISTAT, 2019). Hence, variation in the number of retired workers is unlikely to influence operators' deployment decision. Second, pensions are strongly correlated with local income, as they derive from past income levels.[11] This implies that they should proxy very well unobserved confounders of local income, but also that they are uncorrelated with current economic shocks that might affect UBB roll-out. Third, in Italy they are computed at the national level through a centralized system managed by the Italian National Institute for Social Security (INPS). The system is uniform across the Italian territory and the retirement decision timing of the worker is defined by strict rules at the national level, thus it is not influenced by UBB deployment.[12]

To investigate whether the data is consistent with the exogeneity of local pensions to UBB diffusion, we examine the relationship between UBB roll-out and baseline municipality characteristics. In particular, following Akerman et al. (2015), we run the following linear regression model:

$$UBB_{m,t} = \beta_0 + [\theta_t \times z_m]\eta_t + \alpha_m + \tau_{p(m),t} + \epsilon_{m,t} \tag{3}$$

where θ_t are year fixed effects, and z_m is a vector of baseline municipality-level characteristics. We let z_m include the 2012 (log-) local labor income and (log-) pensions, together with

[11] In Italy, the pension benefit is indexed to the accumulated lifelong contributions valorised with the nominal GDP growth rate (as a five-year moving-average).

[12] The Italian government introduced some (limited) flexibility only after 2019, by allowing early retirement under specific age and contribution conditions (i.e. workers must be no less than 62 years old and have made qualifying contributions for not less than 38 years) (OECD, 2021).

demographics from the 2011 Italian Census such as degree of urbanization, (log-) population, share of the population below 40 years old, and share of the population with a university degree. If the level of local pension does not correlate with UBB expansion, we should observe no statistically significant coefficients for the interaction of year fixed effects with (log-) pensions.

Figure 2 shows the estimated coefficients from this experiment, together with the corresponding 95% confidence interval. First, we observe that UBB roll-out correlates with crucial municipality-level characteristics, thus highlighting a potential endogeneity issue, as these factors are likely to affect local labor income. For instance, UBB is first introduced in municipalities with high population, and with a large share of graduates. Moreover, UBB does correlates with total labor income, although non-monotonically. Second, UBB roll-out does not correlate with the pre-existing level of local pensions. In fact, the upper-left panel displays coefficients that are never statistically different from zero. This is consistent with the idea that retirement income does not affect UBB roll-out, thereby validating our identification strategy.

5 Results

Total Labor Income. Panel (a) of Figure 3 displays estimated event study ($\hat{\gamma}_r$) coefficients from equation (2), together with the corresponding 95% confidence interval when the dependent variable is (log) aggregate labor income in municipality m and year t. Estimated coefficients show a positive impact induced by UBB, but also strong pre-trends, suggesting that endogeneity poses a serious concern. Panel (b) shows the event study estimates when the dependent variable is the (log-) income from retired workers in municipality m and year t. We notice that the two event study estimates are very similar to each other, suggesting that pensions can effectively be used to pin down the causal impact of UBB on local labor income. Including directly income from retired workers in the regression (Panel c) does not solve the issue. Finally, Panel (d) shows event study estimates from the FHS estimator, in which pensions are instrumented with the first lead of UBB. We notice that pre-trends are flat and not statistically different from zero, implying a correction of the endogeneity bias. Moreover, post-treatment coefficients are much lower than before, suggesting a positive bias from time-varying confounders, as one would expect. They are also close to zero not-statistically significant, implying a null effect of UBB on total labor income.

Table 2 Columns 1-3 show the estimates from the static empirical model (1) for this case. Column 1 refers to the model without further controls apart from municipality and province-year fixed effects. The coefficient is positive and strongly significant, although we know from the top-left panel of Figure 3 that UBB does correlate with confounders of labor income. In column 2, we control in the regression for (log-) local income from retired workers. The coefficient remains positive and significant, but lower in magnitude. Finally, in Column 3 we estimate equation (1) *via* the FHS estimator. Consistently with the bottom-right panel of 3, the coefficient is close to zero and not statistically significant. When we disentangle the impact of UBB on labor income in terms of intensive and extensive margin (Table 3 Columns 1-3) we find no significant effects (and coefficients very close to zero) on both the number of workers and their average per capita labor income. Despite the literature shows that access to UBB increases the productivity of Italian firms (Cambini et al., 2023), our result suggests that this effect does not translate into an increase of overall employment, most likely because of wage rigidities in the labor market.[13]

Employed and Self-Employed Income. Figure 4 shows event study estimates when the dependent variable is the (log-) municipality income coming from employed (Panel a) and self-employed (Panel b) workers. Focusing on Panel (a), dark blue dots refer to fixed effect estimates of the γ_r coefficients of equation (2), showing the usual negative pre-trends and a positive, increasing post-treatment effect. The impact is very similar to the impact observed in the upper-left Panel of Figure 3, suggesting a long-term effect of about +2%. However, correcting for the endogeneity of UBB and labor income through the FHS estimator nullifies the post-treatment effects (light blue dots). This implies that UBB has negligible effects on employed workers, a result confirmed in Table 2 Column 6.

Fixed effect estimates (dark green dots) show strong pre-trends and a positive and increasing post-treatment effect also with self-employed income (Panel b of Figure 4). Post-treatment coefficients are much larger in magnitude compared to previous cases, implying a long-term positive effect of around 8%. However, using the FHS estimator significantly corrects the endogeneity bias. Pre-trends are not statistically different from zero, while post-treatment effects are significant, implying a long-run effect of UBB on self-employed income of about 5%. This result is confirmed in Table 2 Columns 7-9. When estimating the model through the FHS estimator, the impact is positive and significant, implying an average increase in self-employed income of 1.3% induced by the UBB roll-out. Although

[13] In most industrialized countries, the growth of wages in recent decades has been lower than that of labor productivity, resulting in a decline in the share of value added attributable to paid employment (Istat, 2018). The growth rate of payroll wages has been particularly low in Italy, where average wages declined by around 5% from 2006 to 2015 (Istat, 2018).

the magnitude of this effect is relatively large, self-employment income accounts only for 7% of total labor income, implying that the overall impact is limited.

A comparison between the two Panels of Figure 4 is also informative on the differential magnitude of the endogeneity bias among employed and self-employed income. The FHS estimator drastically moves UBB coefficients downward on employed income (Panel a), nullifying the positive effect suggested by fixed effect estimates. On the contrary, the correction for self-employed income is more limited (Panel b), with FHS estimated coefficients remaining positive and significant. Hence, unobservable factors affecting UBB roll-out may correlate more strongly with employed income. As employment is driven by the presence of economic activities, this is consistent with the idea that UBB is first introduced in more developed areas characterized by either larger firms, or a higher number of firms per capita, or both.

We then ask whether the rise in self-employed income included by UBB is driven by an increase in self-employed workers or in their average per capita income. Results from Table 3 Columns 7-8 suggest that UBB increase the number of self-employed workers by 1.4%, without affecting their average per capita income. Hence, UBB affects only the extensive margin of self-employment, with negligible effects on the intensive margin.[14]

A Focus on Self-Employment. Next, we explore the potential heterogeneous effects of UBB on self-employed workers based on baseline municipality characteristics by exploiting the high heterogeneity of the Italian territory. We exploit the distribution of the 2012

[14]To ease the comparison with the baseline model, we report fixed effect results in Appendix Table A1. As can be seen, results are qualitatively the same but generally larger in magnitude, consistent with the positive bias detected so far. Interestingly enough, OLS estimates suggest a positive impact on per capita self-employment income, which however is not confirmed by the FHS estimates.

labor income to allocate municipalities across the quartiles of that distribution, so as to understand whether relatively richer areas are disproportionally affected by last-generation broadband technologies (Forman et al., 2012). As shown by Table 4 Columns 1-3, the effect is concentrated in municipalities in the top and bottom quartile of 2012 labor income, suggesting that UBB can increase business opportunities for independent workers in rich areas, and at the same time allow for business creation in poorer areas (Reynolds et al., 2005). The education level also plays an important role, as UBB increases the number of self-employed workers in municipalities in the top quartile in terms of the percentage of the population with a university degree (Table 4 Columns 4-6), in line with the findings in Simoes et al. (2016).

Table 5 shows that there is significant geographical heterogeneity across Italian regions. UBB increases income from self-employment only in North-Western and Southern areas (Column 1), with an important difference. While in the South the positive impact of UBB is due to the increase in the number of workers (Column 2), in the North-West it is driven by a rise in their per capita income (Column 3). These results can be reconnected to the two determinants of self-employment entry highlighted by the literature, namely opportunity-based and necessity-based self-employment (Simoes et al., 2016; Reynolds et al., 2005). In Southern regions, where unemployment is structurally high, access to UBB can increase the number of self-employed workers by spurring necessity entrepreneurship, i.e. the creation of new businesses due to lack of alternatives.[15] Conversely, in the North, where workers with a higher level of education are concentrated[16], UBB can create new opportunities for self-

[15]According to Istat data, the unemployment rate in Southern regions in 2019 was 17.9%, versus 6.6% in the North-West. See `http://dati.istat.it`.

[16]The share of the population with tertiary education in 2020 in Italy is 21.3% in the North, 24.2% in the

employment, thus increasing their productivity and their per capita income (Forman et al., 2012; Simoes et al., 2016; Hagsten, 2016).

We also explore the role of the degree of urbanization. Column 4 of Table 5 suggests that the positive effect of UBB on self-employment is concentrated in urban areas, while it does not have a significant effect in rural municipalities. Once again, the effect can entirely be attributed to the increase in the number of self-employed workers, rather than their per capita income (Columns 5 and 6).[17]

6 Assessing Spatial Spillovers

So far, our results suggest that UBB has a negligible effect on the labor income of employed workers. On the contrary, UBB affects significantly self-employment, particularly in municipalities with high population density and high education levels.

Our identification strategy allows us to account for municipality-level time-varying confounding factors that might affect UBB roll-out and labor outcomes. However, spatial effects may also confound the results. In particular, if the presence of UBB in neighboring municipalities has some effect on local labor income, then the estimated UBB coefficient would be biased. This is especially relevant in our setting, where the number of workers and earned income are obtained from the tax returns, which in turn are based on the residence of the worker population (night population). However, the impact of UBB should occur in the workplace (day population). Hence, if workers' residence and workplace locations are not

Center, and 16.2% in the South. Data are available at `https://italiaindati.com/laureati-in-italia/`.

[17]We report fixed effect estimates of the heterogeneous effects in Appendix Tables A2 and A3. As can be seen, the results are again qualitatively similar and slightly larger in magnitude, thus increasing the confidence in our main results.

the same, variations in labor income in the residence location may be affected by the presence of UBB in the workplace, thus biasing overall results. This is likely to happen when workers commute to large cities, which in turn received UBB earlier than smaller towns.

One simple test to check the severity of this issue is to drop large municipalities from the estimation, as they are more likely the working destination for commuters. Table 6 shows FHS estimates when we exclude municipalities at the top 1% in terms of population from the estimation. As can be seen, results again suggest a rise in self-employment induced by UBB of about 1.4%.

Spatial Spillovers. We directly investigate spatial spillovers by estimating a spatial lag of the independent variable model, which includes explanatory variables and their spatially lagged variables to account for characteristics in neighboring municipalities (Briglauer et al., 2021; Duvivier et al., 2021). The equation to be estimated takes the following form:

$$y_{m,t} = \beta_0 + \gamma UBB_{m,t} + \theta\, W\, UBB_{m,t} + \alpha_m + \tau_{p(m),t} + \varepsilon_{m,t}, \tag{4}$$

where W is an inverse distance matrix. The coefficient θ allows to test whether UBB access in neighboring municipalities has spillover effects on local income. When including local pensions as a time-varying control, we also add its spatially-lagged variable. Similarly, when estimating the model *via* FHS, we instrument both local and spatially lagged pensions with the first lead of UBB, namely $UBB_{m,t+1}$, and its spatial lag.

Table 7 collects estimated coefficients of Equation (4). Focusing on total labor income (Columns 1-3), fixed effect estimates suggest a negligible (yet statistically significant) effect of UBB on aggregate local income. Although in Column 1 UBB access in neighboring municipalities seems to have a positive effect on local income, when including local pensions the coefficient associated with the spatial lag of UBB becomes very close to zero and not statistically significant, thus suggesting that spatial spillovers are less than a problem. This is confirmed in Column 3, where the model is estimated through the FHS estimator that accounts for unobservable confounders of local income. In this case, both spatially lagged variables for UBB and local pensions are not statistically significant, thus reinforcing the idea that spatial spillovers are not biasing the results. Moreover, as in Table 2, the coefficient associated to $UBB_{m,t}$ is close to zero and not statistically significant. Similar results arise when we focus on municipality income from employed workers (Columns 4-6). Adding further controls (Column 5) or estimating the model *via* FHS estimator (Column 6) nullify spatial spillover effects.

When we focus on local income from self-employed workers (Columns 7-9), we observe a significant, positive, and sizeable effect of UBB on self-employment income. Consistently with our main results, the effect is larger with fixed effect estimates (Columns 7-8), but survives when we account for the endogeneity of UBB through the FHS estimator. The estimates are also informative of the potential spillover effects deriving from the presence of UBB in neighboring municipalities. We find a positive but rather small spillover effect of UBB (Column 7) which however does not survive the inclusion of local pensions as additional time-varying control (Column 8). If anything, the coefficient associated with the spatial lag of UBB is negative when estimating the model *via* FHS. This suggests that the diffusion of UBB in neighboring areas affects negatively local self-employment.

All in all, our results show that spatial spillovers do not confound our main results, namely the positive impact of UBB on self-employment income and the null effect on employed income.

Aggregating Local Labor Markets. To test the severity of this issue, we also aggregate the data at Local Labor System (LLS) Level.[18] LLS are commuting areas designated by the Italian Statistical Office, grouping together contiguous municipalities that are statistically and geographically comparable, and in which the labor force moves and works.

We re-estimate Equation (1) with data aggregated at the LLS level to internalize potential displacement effects towards large cities. In doing this, we compute aggregate labor income variables as the sum of municipality income in each LLS and year. As a measure of the diffusion of UBB within an LLS, we calculate the weighted average of $UBB_{m,t}$ across municipalities that belong to the same LLS, weighted by the population of each municipality. As $UBB_{m,t}$ is a dummy identifying municipalities with UBB access at some point in time, the aggregated variable measures UBB coverage within LLS.

By aggregating at the LLS level, we lose a lot of variation in our variables of interest. This imposes further limitations to the estimation. First, we depart from the DiD research design, as all LLSs have some UBB coverage from 2015. Second, FHS estimation performs poorly because the aggregated $UBB_{m,t+1}$ has little power in the first stage.[19] We thus estimate the model *via* OLS, and therefore we refrain from any causal interpretation. However, we can still assess the severity of spillover effects by comparing the newly estimated coefficients with

[18] From a geographical perspective, Italy is partitioned into 610 LLS, 107 provinces, and 20 administrative regions.

[19] The first stage F-test is well below 10.

our main results. If displacement is a real issue, estimates should be remarkably different from our main results in Table 2.

Table 8 collects estimated coefficients from such an empirical exercise for total labor income (Columns 1-2), income from employed workers (Columns 3-4), and from self-employment (Columns 5-6). We observe that coefficients are significantly larger than those reported in Table 2. However, consistently with our main results, the impact of UBB on self-employment income is much larger (almost three times larger) than the one on employed income. Moreover, coefficients are reduced when we control for local pensions, thus suggesting an overestimation of the true effect from omitted variable bias. Hence, we can expect the true effect to be much lower in magnitude and, perhaps, not statistically significant on employed income.

7 Conclusions

In this paper, we provide evidence on the impact of ultra-broadband technologies on labor market outcomes. Our results show that UBB has a negligible effect on total labor market income. However, when we disentangle the effects between employed and self-employed workers, we find that the latter benefits from UBB access. In particular, we find an average increase of 1.3% of labor income for self-employed workers. The effect is mainly due to the increase in the number of self-employed workers, rather than their per capita income and is concentrated in areas in the top and bottom quartile of income, in urban municipalities, in areas with a high share of the population with a university degree, and in the Southern and Northern-West regions of Italy.

From a methodological point of view, we provide a novel approach to the identification of the impact of advanced broadband technologies on labor market outcomes. Our event study shows strong pre-trends before treatment, thus suggesting that endogeneity is a real issue. We implement the estimator proposed by Freyaldenhoven et al. (2019) exploiting local pensions to identify the causal relationship between UBB and labor income. Our estimates show a positive bias from omitted variables, implying that confounders of labor income are positively correlated with UBB roll-out.

From a policy perspective, this research contributes to the debate about the economic effects of last-generation broadband connections in the labor market. European Member States are making important progress toward achieving the connectivity objectives of the Gigabit society. Last-generation broadband networks are mainly, if not exclusively, fiber-based, and significant resources are being allocated to digital reforms and investments. It is therefore important to assess the potential disruptive effects of such technologies in the labor market, similarly to those highlighted by the literature on advanced ICT technologies for some categories of workers. Our results suggest that high-capacity networks can enhance knowledge-based employment and growth (Qiang and Rossotto, 2009; Briglauer and Gugler, 2019; Czernich et al., 2011) by enabling high-speed Internet access. We provide evidence of a complementary relationship between work flexibility and advanced broadband technologies, as self-employed workers are those mostly benefiting from ultra-broadband internet connections. Moreover, our results suggest that UBB affects self-employment both by creating new business opportunities (especially in areas where the economy is lagging behind) and by improving the productivity of existing ones in more economically developed areas. This result implies that advanced broadband infrastructure may constitute an important driver of employment also in economically disadvantaged areas. All in all, our results highlight that advanced technology is not a blessing or a curse in itself, and its effects are not necessarily disruptive. Rather, our findings reinforce the notion that broadband effects are more likely to materialize when labor and capital complement each other.

Although this study contributes to improving our understanding of the role of high-speed broadband in the labor market, it has two main limitations. First, we rely on information on the availability of broadband infrastructure, as we lack data on the adoption of broadband technologies. Second, additional complementarities with factors at an individual level, such as workers' skills, may be an important channel through which UBB may affect the labor market. Addressing such issues can be an important avenue of future research.

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Tables and Figures

Table 1: Summary statistics

VARIABLES	N	Mean	sd	p50	Min	Max
Total Labor Income (Million)	61,520	60.31	450.47	16.21	0.076	30,523.32
Employment Income (Million)	61,520	56.21	403.40	15.48	0.076	28,092.44
Self-Employment Income (Million)	61,520	4.11	48.06	0.687	0	3,035.35
Pensions (Million)	61,520	32.05	217.71	9.47	0.092	14,915.50
N Workers	61,520	2,816.6	16,459	870	5	1,127,960
N Employed Workers	61,520	2,715.5	15,505	847	5	1,081,648
N Self-employed Workers	61,520	101.06	993.79	21	0	74,902
Per capita Total Income	61,520	19,150	3,957.3	19,218	6,438.9	87,109
Per capita Employed Income	53,644	35,607	28,280	33,481	937.33	3,306,122
Per capita Self-employed Income	61,520	18,767	3,765.7	18,871	6,438.9	57,205
UBB	61,520	0.242	-	0	0	1
UBB_{t+1}	61,520	0.311	-	0	0	1

The Table provides summary statistics of the main variables used in the paper. Source: TIM, OpenFiber, and MEF data.

Table 2: Impact of Ultra-Broadband on labor income

	Total Labor Income			**Employment Income**			**Self-Employment Income**		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	FE	FE	FHS	FE	FE	FHS	FE	FE	FHS
UBB	0.010***	0.008***	-0.000	0.009***	0.007***	-0.000	0.029***	0.026***	0.013*
	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.006)	(0.006)	(0.007)
log-Pensions		0.142***	0.780***		0.131***	0.717***		0.337***	1.642**
		(0.036)	(0.134)		(0.041)	(0.134)		(0.096)	(0.706)
First Stage F-test			54.96			54.96			54.37
Observations	61,520	61,520	61,520	61,520	61,520	61,520	53,559	53,559	53,559

Presented are UBB estimated coefficients of equation (1). The dependent variable is the natural logarithm of municipality total labor income (Columns 1-3), employment (Columns 4-6) and self-employment income (Columns 7-9). Columns 1,2,4,5,7 and 8 present fixed effect estimates, while Columns 3,6, and 9 report the estimates from the method proposed by Freyaldenhoven et al. (2019). Robust standard errors clustered by administrative province in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Impact of Ultra-Broadband on n. of workers and per capita income

	Total Labor Income			Employment Income			Self-Employment Income		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Income	N workers	Per capita	Income	N workers	Per capita	Income	N workers	Per capita
UBB	-0.000	-0.000	0.000	-0.000	0.000	-0.001	0.013*	0.014***	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.007)	(0.004)	(0.007)
First Stage F-test	54.96	54.96	54.96	54.96	54.96	54.96	54.37	54.37	54.37
Observations	61,520	61,520	61,520	61,520	61,520	61,520	53,559	53,559	53,559

Presented are UBB estimated coefficients of equation (1) using the method proposed by Freyaldenhoven et al. (2019). In Columns 1,4, and 7, the dependent variable is the natural logarithm of municipality total labor income, employment, and self-employment income, respectively. Columns 2, 5, and 8 focus on the log-number of workers. Finally, Columns 3, 6, and 9 refer to the (log-)per capita income. Robust standard errors clustered by administrative province in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4: The impact of Ultra-Broadband on self-employment by income and education levels

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Income	N. of workers	Per capita	Income	N workers	Per capita
UBBx1st quartile Income	0.080***	0.053***	0.028			
	(0.027)	(0.019)	(0.024)			
UBBx2nd quartile Income	-0.009	-0.004	-0.005			
	(0.011)	(0.007)	(0.012)			
UBBx3rd quartile Income	-0.001	-0.007	0.005			
	(0.011)	(0.005)	(0.009)			
UBBxtop quartile Income	0.020**	0.025***	-0.005			
	(0.009)	(0.006)	(0.008)			
UBBx1st quartile Education				0.004	0.000	0.004
				(0.011)	(0.010)	(0.012)
UBBx2nd quartile Education				0.004	0.002	0.002
				(0.010)	(0.007)	(0.009)
UBBx3rd quartile Education				-0.004	0.003	-0.007
				(0.009)	(0.006)	(0.008)
UBBxtop quartile Education				0.031***	0.031***	0.000
				(0.010)	(0.006)	(0.008)
First Stage F-test	67.90	67.90	67.90	58.66	58.66	58.66
Observations	53,559	53,559	53,559	53,551	53,551	53,551

Presented are UBB estimated coefficients of equation (1) using the method proposed by Freyaldenhoven et al. (2019). The dependent variable is the natural logarithm of municipality labor income from self-employment (Columns 1-4), the log-number of self-employed workers (Columns 2-5), and their average log-per capita income (Columns 3-6). Income quartiles derive from the baseline (2012) municipality income distribution. Education quartiles come from the distribution of municipality share of the population with a university degree from the 2011 Italian Census. Robust standard errors clustered by administrative province in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5: The impact of Ultra-Broadband on self-employment by region and degree of urbanization

VARIABLES	(1) Income	(2) N. of workers	(3) Per capita	(4) Income	(5) N workers	(6) Per capita
UBBxCenter	0.004	0.017*	-0.013			
	(0.012)	(0.009)	(0.012)			
UBBxNorth-East	0.003	-0.002	0.005			
	(0.009)	(0.008)	(0.007)			
UBBxNorth-West	0.022**	0.007	0.014*			
	(0.010)	(0.007)	(0.007)			
UBBxSouth	0.017	0.029***	-0.013			
	(0.015)	(0.008)	(0.014)			
UBBxHigh Pop Density				0.050***	0.050***	0.000
				(0.010)	(0.013)	(0.015)
UBBxLow Pop Density				0.015	0.018***	-0.002
				(0.010)	(0.005)	(0.009)
UBBxRural				-0.003	-0.003	0.001
				(0.007)	(0.005)	(0.007)
First Stage F-test	56.72	56.72	56.72	58.44	58.44	58.44
Observations	53,559	53,559	53,559	53,559	53,559	53,559

Presented are UBB estimated coefficients of equation (1) using the method proposed by Freyaldenhoven et al. (2019). The dependent variable is the natural logarithm of municipality labor income from self-employment (Columns 1-4), the log-number of self-employed workers (Columns 2-5), and their average log-per capita income (Columns 3-6). Robust standard errors clustered by administrative province in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Dropping large cities

	Total Labor Income			**Employment Income**			**Self-Employment Income**		
VARIABLES	(1) Income	(2) N workers	(3) Per capita	(4) Income	(5) N workers	(6) Per capita	(7) Income	(8) N workers	(9) Per capita
UBB	-0.000	-0.000	0.000	-0.000	-0.000	-0.000	0.012	0.014***	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.008)	(0.004)	(0.007)
First Stage F-test	52.24	52.24	52.24	52.24	52.24	52.24	50.65	50.65	50.65
Observations	60,904	60,904	60,904	60,904	60,904	60,904	52,943	52,943	52,943

Presented are UBB estimated coefficients of equation (1) using the method proposed by Freyaldenhoven et al. (2019). In Columns 1,4, and 7, the dependent variable is the natural logarithm of municipality total labor income, employment, and self-employment income, respectively. Columns 2, 5, and 8 focus on the log-number of workers. Finally, Columns 3, 6, and 9 refer to the (log-)per capita income. Robust standard errors clustered by administrative province in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Assessing spatial spillovers

	Total Labor Income			Employment Income			Self-Employment Income		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	FE	FE	FHS	FE	FE	FHS	FE	FE	FHS
UBB	0.007***	0.006***	-0.001	0.006***	0.005***	-0.001	0.026***	0.024***	0.016**
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.005)	(0.005)	(0.008)
W UBB	0.004***	-0.000	0.002	0.003***	-0.001	0.002	0.004**	0.002	-0.011**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.004)
log-Pensions		0.120***	0.782***		0.110***	0.732***		0.317***	1.603*
		(0.037)	(0.174)		(0.042)	(0.171)		(0.103)	(0.955)
W log-Pensions		0.027***	-0.011		0.027***	-0.015		0.008	0.077
		(0.008)	(0.013)		(0.008)	(0.012)		(0.018)	(0.053)
First Stage F-test			18.34			18.34			15.72
Observations	61,520	61,520	61,520	61,520	61,520	61,520	53,559	53,559	53,559

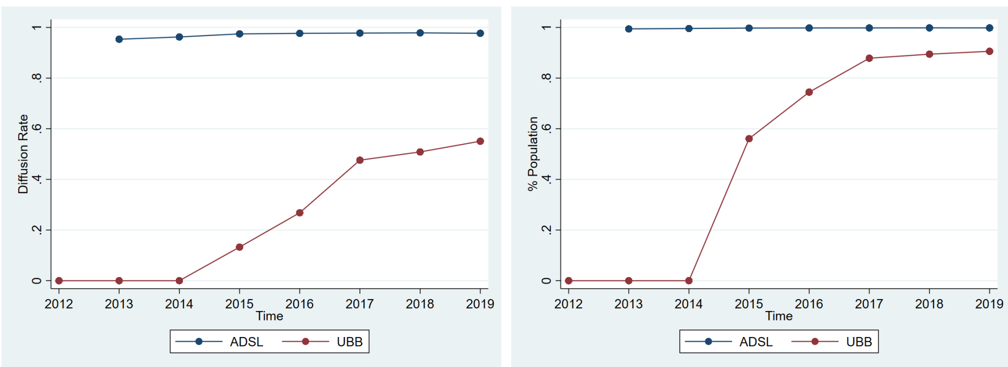
Presented are UBB estimated coefficients of equation (4). The dependent variable is the natural logarithm of municipality total labor income (Columns 1-3), employment (Columns 4-6) and self-employment income (Columns 7-9). Columns 1,2,4,5,7 and 8 present fixed effect estimates, while Columns 3,6, and 9 report the estimates from the method proposed by Freyaldenhoven et al. (2019). Robust standard errors clustered by administrative province in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 8: Aggregating at the Local Labor Market Level

	Total Labor Income		Employment Income		Self-Employment Income	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	FE	FE	FE	FE	FE	FE
UBB	0.013**	0.012***	0.013**	0.012***	0.038*	0.035***
	(0.007)	(0.004)	(0.006)	(0.004)	(0.021)	(0.013)
log-Pensions		0.516***		0.461***		1.721***
		(0.074)		(0.076)		(0.165)
Observations	4,840	4,840	4,840	4,840	4,838	4,838

Presented are UBB estimated coefficients of equation (1). The dependent variable is the natural logarithm of LLS total labor income (Columns 1-3), employment (Columns 4-6) and self-employment income (Columns 7-9). UBB measures UBB coverage within a LLS. Robust standard errors clustered by administrative province in parentheses. *** p<0.01, ** p<0.05, * p<0.1

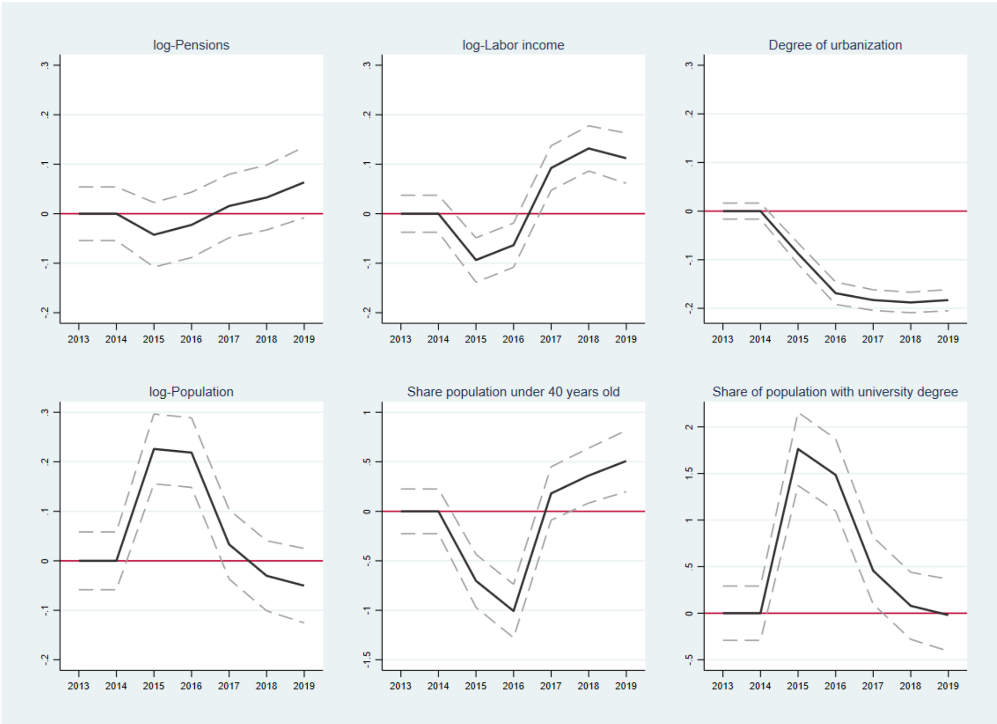
Figure 1: Broadband availability rates



(a) % of Municipalities (b) % of Population

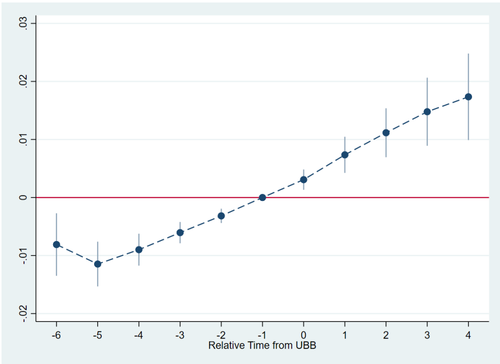
This figure shows the percentage number of municipalities (Panel a) and the corresponding percentage of population (Panel b) that have access to (copper-based) ADSL and (fiber-based) UBB connections. Source: TIM and OpenFiber data.

Figure 2: Validation test

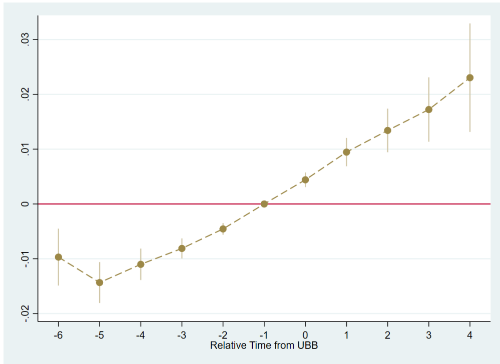


This figure shows estimated OLS coefficients of equation (3) together with their corresponding 95% confidence interval. Interactions associated with the baseline year 2012 are omitted to avoid multicollinearity. Standard errors are robust to heteroskedasticity.

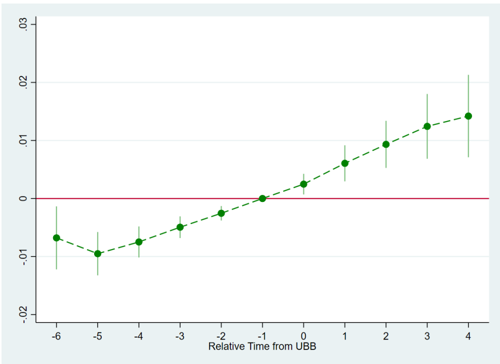
Figure 3: The impact of Ultra-Broadband on labor income



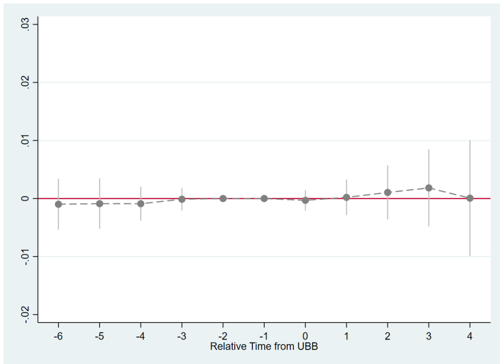
(a) Labor income



(b) Pensions



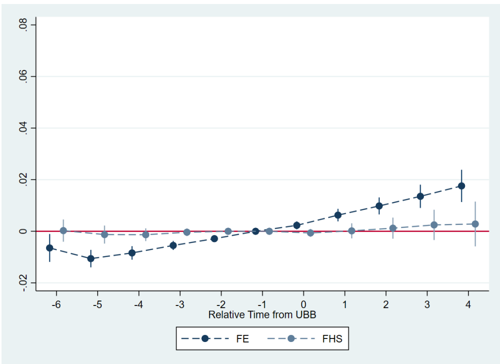
(c) Labor income when controlling for pensions



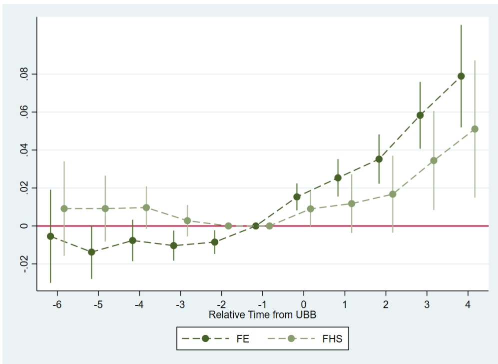
(d) FHS estimates

The figure plots event study coefficients of equation (2) with the associated 95% confidence interval. In Panel (a) the dependent variable is the natural logarithm of municipality total labor income. Panel (b) refers to model (2) when the dependent variable is the natural logarithm of municipality income from retired workers. In Panel (c), we estimate the event study model controlling for municipality log-pensions. Finally, in Panel (d) event study coefficients are estimated *via* the estimator proposed by Freyaldenhoven et al. (2019). All specifications include municipality and province-year fixed effects. Standard errors are clustered at the province level.

Figure 4: The impact of Ultra-Broadband on employment and self-employment income



(a) Income from Employment



(b) Income from Self-Employment

The figure plots event study coefficients of equation (2) with the associated 95% confidence interval. In Panel a, the dependent variable is the natural logarithm of municipality labor income from employed workers. In Panel b, the dependent variable is the natural logarithm of municipality labor income from self-employed workers. Dark dots refer to event study coefficients from fixed effect estimation, while light dots indicates the coefficients estimated *via* the estimator proposed by Freyaldenhoven et al. (2019). All specifications include municipality and province-year fixed effects. Standard errors are clustered at the province level.

Appendix A: Fixed effect results

Table A1: Ultra-Broadband fixed effect estimates on n. of workers and per capita income

	Total Labor Income			Employment Income			Self-Employment Income		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Income	N workers	Per capita	Income	N workers	Per capita	Income	N workers	Per capita
UBB	0.010***	0.009***	0.001	0.009***	0.009***	0.000	0.029***	0.009**	0.020***
	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.006)	(0.004)	(0.005)
Observations	61,520	61,520	61,520	61,520	61,520	61,520	53,559	53,559	53,559

Presented are fixed effect UBB estimated coefficients of equation (1) . In Columns 1,4, and 7, the dependent variable is the natural logarithm of municipality total labor income, employment, and self-employment income, respectively. Columns 2, 5, and 8 focus on the log-number of workers. Finally, Columns 3, 6, and 9 refer to the (log-)per capita income. Robust standard errors clustered by administrative province in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A2: Ultra-Broadband fixed effect estimates on self-employment by income and education levels

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Income	N. of workers	Per capita	Income	N workers	Per capita
UBBx1st quartile Income	0.043*	0.058***	-0.015			
	(0.023)	(0.016)	(0.019)			
UBBx2nd quartile Income	-0.012	-0.004	-0.008			
	(0.010)	(0.007)	(0.011)			
UBBx3rd quartile Income	0.022***	-0.010**	0.032***			
	(0.007)	(0.005)	(0.006)			
UBBxtop quartile Income	0.046***	0.021***	0.025***			
	(0.007)	(0.005)	(0.004)			
UBBx1st quartile Education				0.011	-0.001	0.013
				(0.011)	(0.011)	(0.012)
UBBx2nd quartile Education				0.013	-0.000	0.013*
				(0.009)	(0.007)	(0.007)
UBBx3rd quartile Education				0.017**	-0.001	0.018***
				(0.008)	(0.005)	(0.006)
UBBxtop quartile Education				0.055***	0.027***	0.028***
				(0.006)	(0.004)	(0.004)
Observations	53,559	53,559	53,559	53,551	53,551	53,551

Presented are fixed effect UBB estimated coefficients of equation (1). The dependent variable is the natural logarithm of municipality labor income from self-employment (Columns 1-4), the log-number of self-employed workers (Columns 2-5), and their average log-per capita income (Columns 3-6). Income quartiles derive from the baseline (2012) municipality income distribution. Education quartiles come from the distribution of municipality share of the population with a university degree from the 2011 Italian Census. Robust standard errors clustered by administrative province in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A3: Ultra-Broadband fixed effect estimates on self-employment by region and degree of urbanization

VARIABLES	(1) Income	(2) N. of workers	(3) Per capita	(4) Income	(5) N workers	(6) Per capita
UBBxCenter	0.016	0.013	0.003			
	(0.012)	(0.009)	(0.010)			
UBBxNorth-East	0.013	-0.005	0.018*			
	(0.011)	(0.007)	(0.009)			
UBBxNorth-West	0.033***	0.004	0.030***			
	(0.011)	(0.007)	(0.007)			
UBBxSouth	0.040***	0.022***	0.018*			
	(0.010)	(0.005)	(0.011)			
UBBxHigh Pop Density				0.062***	0.049***	0.013**
				(0.012)	(0.012)	(0.006)
UBBxLow Pop Density				0.043***	0.015***	0.029***
				(0.007)	(0.005)	(0.005)
UBBxRural				0.003	-0.004	0.007
				(0.008)	(0.005)	(0.007)
Observations	53,559	53,559	53,559	53,559	53,559	53,559

Presented are fixed effect UBB estimated coefficients of equation (1). The dependent variable is the natural logarithm of municipality labor income from self-employment (Columns 1-4), the log-number of self-employed workers (Columns 2-5), and their average log-per capita income (Columns 3-6). Robust standard errors clustered by administrative province in parentheses. *** p<0.01, ** p<0.05, * p<0.1