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Ultra-broadband investment and economic resilience: evidence from the Covid-19 pandemic*

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Abstract

We study the role of ultra-broadband infrastructures in reducing the economic recession caused by the 2020 pandemic. We exploit the variation in GDP and employment that happened between 2019 and 2020 as a result of the Covid-19 pandemic outbreak, and we investigate whether UBB investments had an impact on economic resilience. We use micro-level data on UBB exposure in 2019 matched with municipality-level information on local GDP and employment levels based on tax declarations for the period 2019-2020. We address the endogeneity between UBB and local income by exploiting the distance from the closest backbone node of the upstream telecommunication network. We find that exposure to UBB mitigates the negative effect of the pandemic on local employment. One additional year of UBB exposure increases local employment by 1.3 percentage points. The effect is stronger in areas hit more severely by the pandemic, thus confirming the role of advanced broadband infrastructures on the economic resilience from negative shocks.

Keywords: Ultra-broadband (UBB), fiber-based networks, GDP, Covid-19.

JEL codes: L96, D24, D22

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1 Introduction

The Covid-19 outbreak plummeted the global economy in unprecedented depths. The second quarter of 2020 has seen global GDP mark a contraction of -11.5% relative to 2019, resulting in an exceptional drop in activity and unprecedented job losses (OECD, 2022). The succession of local or national lockdowns and voluntary social distancing have led the economy to rely on e-commerce, remote working, and online learning more than ever. However, the subsequent increase in internet traffic has been accompanied by a degradation of its quality. Ultra-broadband (UBB) connections, by mitigating the increase in latency and drop in download speeds (Katz et al., 2020), have been fundamental in keeping economies and societies working and may have been a key factor in mitigating the economic slowdown during the pandemic (European Commission, 2021a).

In this paper, we use micro-level information in Italy to study the role played by UBB infrastructures in reducing the economic recession caused by the 2020 pandemic. We exploit the variation in GDP and employment that happened between 2019 and 2020 as a result of the Covid-19 pandemic outbreak, and we investigate whether UBB investments had an impact on economic resilience. UBB involves connections based on fiber optical cables in the *last mile*, which enable significantly higher performance compared to traditional copper-wire connections. Since UBB deployment started in 2015, we can identify municipalities relatively more exposed to such technology in 2019 by measuring the number of years since UBB was first introduced. In this way, we can explore whether pre-existing UBB infrastructures played a role in attenuating the negative economic shock induced by the Covid-19 pandemic. In this context, Italy represents an ideal research case, being one of the European countries that faced the strongest economic slowdown in 2020. Italian GDP recorded an impressive decline in terms of volumes of -8.9% compared to 2019, against the European average of -6% (European Commission, 2021b). The recession in Italy was accompanied by an unparalleled decline in employment, corresponding to a reduction of hours worked by 11% (Banca d'Italia, 2021).

We leverage on a unique dataset with municipality-level information on UBB exposure

in 2019. We match this data with granular information on GDP and employment from the tax declarations for the years 2019-2020 published by the Italian Ministry of Economy and Finance (MEF). We then derive the percentage difference in GDP (and related variables) between 2019 and 2020 to identify the variation induced by the Covid-19 pandemic outbreak. The data allow us to analyze the impact on municipality employment – measured as the number of taxpayers, and the average per capita income. Moreover, we gather municipality demographics from the Italian Statistical Office (ISTAT). Finally, we also obtain information on the number of infections at a provincial level at the end of 2020 using data from the Italian Ministry of Health.

Our empirical model identifies the impact of UBB exposure on the variation of GDP between 2019 and 2020 if, conditional on observable characteristics, UBB roll-out is exogenous to local GDP. We relax such an identifying assumption through an instrumental variable approach that exploits the upstream telecommunication infrastructure (Cambini and Sabatino, 2021; Campante et al., 2017; Falck et al., 2014). In particular, we construct the distance between each municipality and the closest backbone node of the national telecommunication network. Such a distance is negatively correlated with UBB exposure since distant municipalities are less likely to receive UBB connections. This happens because the main UBB input, called Optical Line Terminal (OLT), is first installed in locations relatively closer to the backbone nodes. The instrument is valid under the identifying assumption that any correlation with the dependent variable is fully driven by UBB exposure. We test such an assumption through a placebo test that shows no significant correlation between the instrument and GDP or employment variations in municipalities without UBB by 2019.

Our results show that UBB has a positive significant effect on employment during the pandemic. However, we do not detect any significant effect on both aggregate and per capita local income. Our estimates suggest that one additional year of UBB exposure increases local employment by 1.3 percentage points. Such a positive effect is stronger in municipalities more severely hit by the pandemic in terms of the percentage of the population infected. All in all, our results suggest that advanced broadband technologies increase the resilience of local areas to negative economic shocks, although only in terms of employment.

Our findings contribute to the literature on the economic impact of ultra-fast broadband

technologies. Such a literature is scant, and focuses on the effect of high speed networks on GDP, employment and market entry dynamics (Fabling and Grimes, 2016; Briglauer and Gugler, 2019; Briglauer et al., 2021; Hasbi, 2020). To the best of our knowledge, this is the first study to exploit detailed micro-level data to study the impact of last-generation broadband infrastructures on local economic resilience during the Covid-19 pandemic, using information on the availability of ultra-broadband connections.

The rest of the paper is organized as follows. Section 2 introduces the relevant literature. Section 3 describes the institutional background of UBB technology and roll-out in Italy, and the role of digitization during the pandemic period. Section 4 discusses the data in detail and presents preliminary descriptive evidence. Section 5 describes the empirical setting and the adopted identification strategy. Section 6 presents and discusses the results. Finally, Section 7 concludes.

2 Literature

The literature focusing on the effects of broadband during the pandemic consistently finds that the presence of broadband infrastructure has a positive effect on the economy, although such literature only focuses on basic broadband at an aggregated level. Zhang (2021), focusing on China from April 2019 to April 2020, shows that an increase of 10% in broadband penetration results in a growth rate of 1.3% of GDP during the first four months of 2020. Comparing the results in the same periods of 2019, the contribution of broadband to GDP growth during the period of the Covid-19 pandemic is greater than that of the same period of the previous year. Along the same lines, a study by Katz et al. (2020), using a data panel from 170 countries, finds that countries with higher broadband penetration could mitigate 75% of economic losses resulting from measures taken to control Covid-19 spread (e.g., quarantine, social distancing, disruption of air traffic). The authors also analyze the impact of broadband infrastructure on economic growth during the SARS-CoV pandemic.¹ Although the quarantine and social distancing measures, in that case, were more limited

¹In 2003, the virus of SARS-CoV spread from China to 26 other countries, causing around 800 deaths (Wilder-Smith et al., 2020).

and less stringent than the ones adopted to deal with Covid-19, Katz et al. (2020) find that countries with the most developed broadband infrastructure were better able to offset the negative economic effects of the pandemic. Finally, a study by Isley and Low (2022) explores the relationship between broadband and employment rates in April and May 2020 in rural US counties. They find that, during the height of the pandemic-related outages, broadband availability and wired broadband adoption had a statistically significant causal relationship with the employment rate in low-population rural counties. In particular, a one percentage point increase in the broadband availability rate results in a 0.37 percentage point increase in the employment rate. A one percentage point increase in the adoption rate of wired broadband would have led to a 0.87 percentage point increase in the employment rate.

Moving beyond the pandemic focus, the literature on the economic impact of UBB is extremely scant and mostly based on aggregated data at a country or regional level (Abrardi and Cambini, 2019). Nonetheless, it suggests that UBB has a positive, albeit small, effect on GDP at an aggregated level (Briglauer and Gugler, 2019; Briglauer et al., 2021).

At a micro-level, Fabling and Grimes (2016) do not find a significant impact of ultra-broadband on average employment in New Zealand, except for companies that make complementary investments in organizational capital. Other studies provide indirect information on the effects of UBB in the labor market by focusing on firm entry or exit dynamics, with mixed results. Cambini and Sabatino (2021) exploit municipality-level data to study the effect of UBB on firm turnover in Italy, finding that UBB increases firm exit - particularly that of small enterprises. On the contrary, Hasbi (2020), using data from almost 5,000 French municipalities for the period 2010-2015, finds that the presence of UBB increases the number of companies and enhances business creation, thus suggesting a positive impact on employment.

The available literature on the effects of broadband on micro-level GDP focuses on basic (first-generation) broadband networks, and finds a positive relationship between broadband expansion and economic growth (see, e.g., Kolko, 2012 for a study at the ZIP code level in the US), employment and wages, but only for specific types of workers or areas (Forman et al., 2012; Akerman et al., 2015; Czernich et al., 2011).

3 Institutional Background

Ultra-Broadband technology. The roll-out of fiber-based UBB in Italy 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.² Ultra-broadband networks are based on optical fiber cables in the last mile, which enable significantly higher performance compared to traditional copper-wire connections.

Two configurations were developed in Italy based on the portion of optical fiber deployed in the last mile. The first one is called Fiber-to-the-Cabinet (FTTC), and leverages on a first portion of optical fiber, up to a cabinet located nearby the customers' building from which copper line departs, allowing at least 30 Mbps speed. The second one is the Fiber-to-the-Home (FTTH), in which the last mile is full fiber-based, allowing 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 last leg - that is the distance between the cabinet and the final consumer - dampens connection performance because it is made of copper wire. Notably, in Italy, the average length of the last mile is 1.5 Km, with an average distance between the cabinet and consumers' premises of 200 meters. Hence, the short length of the final portion of the last mile ensures a significantly higher performance with respect to ADSL connections.³

Ultra-Broadband Roll-out. By the end of 2019, around 55% of Italian municipalities had access to UBB services with connection speeds higher than 30 Mbps, corresponding to about 90% of the Italian population. However, a large variation exists in terms of exposure to UBB. As shown in Figure 1, because of limited funding, only a few municipalities (around 10%) received UBB in 2015, with an exposure of 5 years in 2019. However, this accounts for more than 50% of the Italian population, since UBB was introduced first in large metropolitan areas. On the opposite side, 45% of municipalities do not have access to

²The Digital Agenda for Europe specifies the goals in terms of network coverage and service adoption for the whole European population. See here for more.

³Source: here.

UBB in 2019, which however accounts for a small proportion of the total population. We exploit the variability of UBB exposure in our empirical analysis, in which the main variable of interest counts the number of years since UBB introduction for each municipality.

The UBB deployment plan was implemented through a combination of public and private investments. The Italian telecommunication incumbent *Telecom Italia Mobile* (TIM) owns the main network, leveraging on the pre-existing telecommunication facilities used for voice telephone and ADSL connections. For this reason, TIM invested in UBB infrastructures throughout Italy since 2015,⁴ covering the vast majority of municipalities. However, in 2017 another wholesale operator entered the market, providing an alternative fiber-based network. This new player, called *OpenFiber*, is owned by *Cassa Depositi e Prestiti* – the investment branch of the Ministry of Treasury – and the electricity incumbent operator *Enel*. Since its entry, OpenFiber invested in fiber connections mainly in large cities. By the end of 2019, OpenFiber covers only 392 municipalities, 261 of which are also (fully or partially) covered by TIM.⁵

Covid-19 and digitization. The first cases of Covid-19 were reported in Italy at the end of January 2020. While initially the infection clusters were confined in a few municipalities in northern Italy, which were placed under quarantine, by March the lockdown measures were extended to the whole country. On 11 March 2020, the Italian government prohibited nearly all commercial activity except for supermarkets and pharmacies. By the end of the month, all non-essential businesses and industries were closed, and the movement of people was restricted. Such restrictions were gradually eased starting from May 2020, although they were brought again in place in October as Italy was hit by the second wave of the pandemic. Figure 2 illustrates the spread of the coronavirus at the end of 2020, showing the uneven diffusion of the virus across Italian provinces.

The availability of high-speed internet connections played a central role in Italy during the pandemic. In the second quarter of 2020, 33% of workers hired in the public administration carried out their homework at least once a week, while in the non-agricultural private sector

⁴Before 2015 only the city of Milan enjoyed fiber-based connections realized by the local company Metroweb.

⁵OpenFiber deployment plan can be found here.

remote working went from below 1.5% in 2019 to over 14% in the second quarter of 2020 (Depalo and Giorgi, 2021). The e-commerce sector also grew by 46% in 2020 (Statista, 2022). Daily internet traffic increased by 51% during March and April 2020, causing a deterioration in connection speed performance by 8.5% (Agcom, 2020a). Since access to the internet with a quality connection was essential to use many services, such as distance learning or smart working, the difficulties related to the connection speed have been one of the problems most felt by citizens. Indeed, in September 2020, accesses to ultra-broadband connections saw a +41.7% increase compared to September 2019 (Agcom, 2020b).

4 Data

We construct a rich cross-sectional municipality-level dataset matching information on UBB access in 2019 with the percentage variation in GDP between 2019 and 2020.

Broadband Data. For UBB data, we rely on two main sources. First, we have access to TIM network data, collecting information on UBB roll-out for the Italian incumbent operator since the introduction of UBB networks in Italy, which happened in 2015. In particular, we observe which municipalities have access to TIM’s UBB by 2019. The second data source comes from OpenFiber, which collects additional information on the municipalities covered by the only alternative UBB operator that entered the market in 2017. The combination of the two datasets provides us with the full picture of UBB roll-out in the Italian municipalities. From this information, we derive our main variable of interest, $yearsUBB_m$, which indicates the number of years since municipality m has access to UBB in 2019. This variable provides information on the intensity of exposure to last-generation broadband connections in each municipality, by the end of the year before the Covid-19 pandemic outbreak.

Moreover, we have information on the location of TIM’s national backbone nodes, that is, large telecommunication infrastructures that reroute the traffic at the national level. From this information, we construct our instrumental variable, which defines the distance (in kilometers) between each municipality and the closest backbone node. We also observe the diffusion of the main UBB input, called “optical line terminal” (OLT), from which we

the distance (in kilometers) between each municipality and the closest OLT.

Local Economic Data. From the Italian Ministry of Economy and Finance (MEF) we obtain data on municipal GDP. Data are based on tax declarations of Italian citizens and collect information on aggregate local income together with the number of taxpayers declaring that income. The number of taxpayers proxies the level of employment in each municipality, as it measures the number of workers gaining some income in a specific year. Moreover, from the aggregate income and the number of workers, we obtain the average per capita income in a municipality. We exploit the percentage difference between 2019 and 2020 to capture the variation in GDP (and related variables) induced by the Covid-19 pandemic. That is, our main outcomes of interest take the following form:

$$y_m = \frac{Y_{m,2020} - Y_{m,2019}}{Y_{m,2019}}, \quad (1)$$

where Y is either aggregate income, average per capita income, or employment as measured by the number of workers declaring some income.

Infections Data & Demographics. From the Italian Ministry of Health we exploit publicly available information on the cumulated number of infections at the provincial level⁶ at the end of 2020. This allows us to control for potential heterogeneities in the variation of GDP include by the Covid-19 outbreak based on the number of infections. Moreover, from this information, we also compute the share of the provincial population infected, which gives us a measure of the penetration of the virus. We exploit this information in the empirical analysis to assess the potential heterogeneous effects of UBB exposure on GDP based on the penetration of Covid-19 infections. We also gather provincial-level information on the number of minimum wage recipients from the Italian National Institute for Social Security (INPS), which allows us to control for heterogeneities in the variation of income and employment based on the implementation of such a policy, which was introduced in 2019.

⁶From a geographical perspective, Italy is partitioned into 107 provinces, and 20 administrative regions. From the data matching process, we lose one province because of an administrative change that occurred in Sardinia in 2020.

Finally, we obtain demographic information from the Italian statistical office (ISTAT), including municipality population, population density, employment rate, the share of the population with a university degree, together with topological characteristics such as altitude (in meters), and distance from the closest province capital. Our final datasets include 7485 municipalities for which we observe UBB exposure and GDP variation between 2019 and 2020. Table 1 provides summary statistics.

5 Empirical strategy

We employ two complementary approaches to estimate the causal impact of UBB on GDP growth, implementing a fixed-effects specification and an IV approach, respectively.

In the following, we provide more details on the models adopted in our analysis.

Main Specification. Our baseline econometric model is as follows:

$$y_m = \beta_0 + \gamma \text{yearsUBB}_m + \beta_1 X'_m + \beta_2 \text{covid}_{p(m)} + \beta_3 \text{minwage}_{p(m)} + \alpha_{r(m)} + \epsilon_m \quad (2)$$

where X_m is a vector of municipality-level characteristics, $\text{covid}_{p(m)}$ measures the number of infections in municipality's province $p(m)$, $\text{minwage}_{p(m)}$ is the number of recipients of the minimum wage policy in municipality's province $p(m)$, $\alpha_{r(m)}$ are administrative regional fixed effects, and ϵ_m is the mean-zero error term. yearsUBB_m is our main variable of interest, and it identifies the years since the municipality m has access to ultra-broadband connections in 2019. In all regressions, standard errors are robust to heteroskedasticity.

Our main outcome of interest is the percentage variation of income in municipality m between 2019 and 2020, both aggregate and disaggregated by the number of workers and their per capita income. This allows us to explore both the intensive and extensive margins of UBB impact on economic resilience.

IV Approach. Equation (2) resembles a first-difference model that exploits the variation of the dependent variable between 2019 and 2020 induced by the Covid-19 pandemic. The

model correctly predicts the impact of UBB exposure on such a difference if, conditional on controls, there is no correlation between $yearsUBB_m$ and the error term. However, broadband roll-out in Italy may have been driven by unobservable factors not included in (2), thereby confounding our results.⁷

We deal with the potential endogeneity of UBB roll-out by applying an instrumental variable approach that exploits plausibly exogenous variation in the physical and geographical peculiarities of the telecommunication infrastructure. Our instrument builds on the relative proximity of each municipality with the closest backbone node (Cambini and Sabatino, 2021; Campante et al., 2017; Falck et al., 2014). These nodes derive from pre-existing facilities of the old voice telecommunication network realized between 2001 and 2005. The actual location of the nodes was finalized in 2012. Distant municipalities are less likely to receive UBB because Optical Line Terminal nodes (OLTs) are first installed close to such nodes, so deployment costs are higher. In particular, the excluded instrument measures the distance (in kilometers) between each municipality and its closest backbone node. In the regression, we also control for the diffusion of the main UBB input. That is, we include as an additional control the distance (in kilometers) between each municipality and its closest OLT.⁸ Figure 4 shows the relevance of our proposed instrument. Municipalities closer to the backbone nodes are more likely to receive UBB first than distant municipalities, implying a negative first-stage correlation between the instrument and the endogenous variable.

We test the validity of the instrument through a placebo test that exploits the presence of municipalities without UBB by 2019. Recall that the instrument is valid if it does not correlate with confounders of GDP variation and UBB roll-out. Therefore, any correlation between the OPB_m and y_m should only be driven by the presence of UBB. That is, we should observe no significant correlation between OPB_m and y_m in municipalities without UBB in 2019. Table 2 collects reduced form estimates for the three outcomes of interest for subsamples of municipalities with (columns 2, 4, and 6) and without (columns 1, 3, 5)

⁷For instance, Cambini and Sabatino (2021) provides evidence of endogeneity of UBB roll-out in Italy through an event study design of firm dynamics that display non-parallel pre-trends.

⁸Because OLT acts as endpoint device in a passive optical network, and optical fibers need to be laid underground in the last mile, such distance proxies the deployment costs necessary to provide UBB services. Since OLT location choice is itself a decision of the telecommunication provider, this variable may correlate with both UBB deployment and local income.

UBB by 2019. It is reassuring to observe that the estimated coefficients show no significant correlation in municipalities that do not receive UBB 2019 for all dependent variables. On the contrary, our instrument correlates with y_m in municipalities with some UBB access, thus validating our identification strategy.

6 Results and discussion

Main Results. Table 3 collects the estimated coefficients of equation (2) when the dependent variable is the percentage variation of total municipal income between 2019 and 2020. Columns 1-3 estimate the model *via* OLS with different sets of controls. We find a positive and significant effect in column 1, which however does not survive the inclusion of additional controls. In columns 4 and 5, we estimate the model through 2SLS, exploiting the distance between each municipality and its closest backbone node as excluded instrument. We find a weak positive impact on local GDP (column 4), which however disappears when we include further controls (column 5), thus suggesting that ultra-broadband connection exposure had negligible effects in attenuating the economic downturn caused by the Covid-19 pandemic on local GDP.⁹

We iterate the same sort of analysis for employment and per capita GDP, to understand potential heterogeneous effects on the intensive and extensive margins of local GDP. Focusing on employment, as measured by the number of workers from tax declarations, OLS estimates in Table 4 columns 1-3 display a small but significant positive effect of UBB exposure on employment that survives to the inclusion of additional controls. When moving to the IV estimates (columns 4 and 5), the coefficient becomes even larger and economically meaningful. More specifically, the estimated coefficients suggest that one additional year of exposure to UBB increases employment by 1.3 percentage points. Given the general reduction in employment observed as a result of the Covid-19 pandemic, the IV estimate implies that municipalities more exposed to UBB are more resilient to the negative effect of the Covid-19 pandemic in terms of local employment.

⁹Notice that the first-stage coefficient is negative as expected and strongly significant at the 1% level in both specifications of columns 4 and 5.

In terms of intensive margin, we estimate equation (2) on the percentage variation of local per capita GDP, and we collect the results in Table 5. For this case, we find no evidence of any significant effect of UBB exposure on local per capita GDP during the Covid-19 pandemic. If anything, coefficients turn out to be negative, especially in IV, but never statistically significant at standard confidence levels.

UBB Exposure and Infection Penetration. Does the positive impact on employment concentrate in areas hit harder by the Covid-19 pandemic? We answer this question by exploiting the distribution of Covid-19 infection penetration in the Italian provinces. Through an indicator function, we identify provinces with high (low) penetration levels as those above (below) the median of the share of the population infected within a province. We then interact these indicators with our $yearsUBB_m$ variable in order to capture potential heterogeneous effects based on infections' penetration. When estimating the model in IV, we also interact with the instrument to have the same number of endogenous regressors and instrumental variables.

Table 6 collects the results from such an experiment for all outcomes of interest, both in OLS (columns 1, 3, and 5) and IV (columns 2, 4, and 6). First, we observe that local aggregate GDP is never affected by UBB exposure, and the same applies to its per capita levels. Second, the positive impact on local employment is mostly driven by municipalities hit harder by the Covid-19 pandemic. In particular, IV estimates in column 4 suggest a rise in employment of 1.8% in provinces above the median of infections, while below the median the impact is lower (1.5%). Moreover, the two coefficients are statistically different from each other, thus reinforcing the heterogeneous effects across provinces with high and low infection penetration.

All in all, our results suggest that last-generation high-speed connections had little impact on attenuating the negative impact of the Covid-19 pandemic on local aggregate and per capita GDP. However, when investigating the relationship between UBB exposure and employment, we find a positive and significant effect. Such a result is driven mostly by those provinces that were hit particularly hard by the Covid-19 outbreak, implying that the presence of UBB infrastructures significantly contributed to the resilience of local employment

during the crisis generated by the pandemic.

7 Concluding Remarks

As home working, online learning, and remote services surged during the coronavirus pandemic, past investments in telecommunication network upgrades in terms of higher speed, lower latency, and more bandwidth allowed broadband networks to manage the unprecedented spikes in internet traffic. High-speed broadband has been essential to keep our economy working. In this paper, we study how the presence of high-speed broadband in Italian municipalities has contributed to the resilience of their economy during the crisis caused by the pandemic. We exploit a unique dataset with information on the roll-out of fiber-based networks in Italy from 2015 to 2019 and take into account the potential endogeneity between local income and high-speed broadband investment.

Our results show that municipalities with access to high-speed broadband networks have coped better with the economic slowdown in 2020, exhibiting a lower reduction in the number of workers, the longer the UBB network has been present in the municipality. This effect is stronger in areas hit more severely by the pandemic, where social distancing measures were particularly strict and which had to rely more on remote working and services.

Our findings have relevant policy implications. The creation of a “Gigabit society” through the development of adequate broadband infrastructure has long been at the center of the attention of European policymakers. In September 2016, the European Commission identified, as strategic objectives for 2025, that all European households will be able to access internet connections with at least 100 Mbit/sec speed, and that connectivity at 1Gbit/sec will be guaranteed for key socio-economic development sites (such as schools, railways, subways, public service providers, etc.). Due to the generally very long repayment periods and the low financial returns, to achieve the goals of the Digital Agenda, a direct public intervention will be required to subsidize the large-scale deployment of the broadband infrastructure (Gruber et al., 2014). It is therefore important to fully understand the economic implications of such significant investments. In this paper, we provide further insights into the role that advanced digital technologies may play during negative economic shocks. Our work

highlights that access to high-speed internet can constitute an important engine of recovery, playing a crucial role in addressing the economic challenges of the post-pandemic world.

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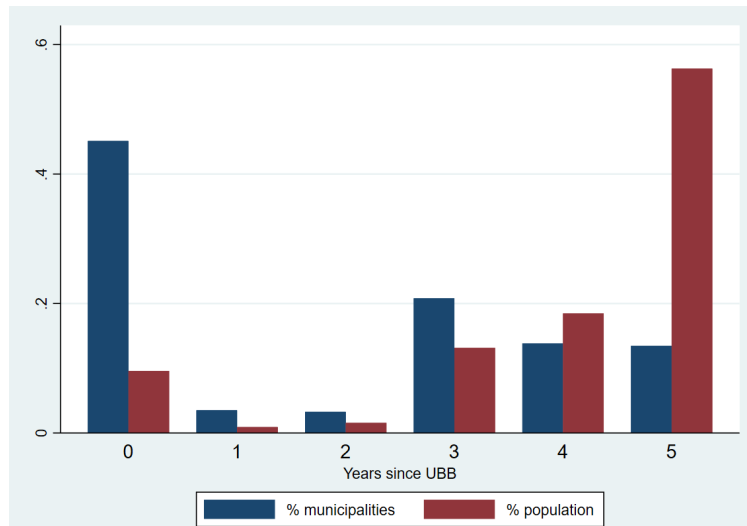
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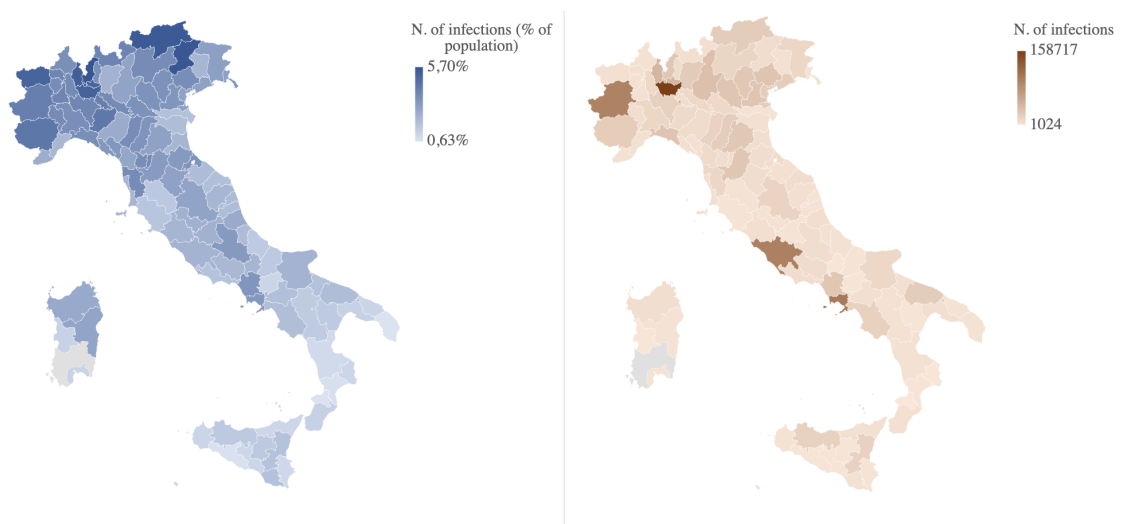
Tables and Figures

Figure 1: UBB Exposure across Italian Municipalities



The figure shows the share of municipalities (blue bar) and the share of population (red bar) for each year exposure since UBB introduction in 2019. When "Years since UBB" is equal to zero, municipalities do not have access to UBB connections in 2019. Source: TIM and OpenFiber data.

Figure 2: Covid-19 Infections in the Italian Provinces



The blue (yellow) figure shows the percentage (absolute number) of population infected by the coronavirus in the Italian provinces by the end of 2020. Source: Italian Ministry of Health.

Table 1: Summary Statistics

Variables	N	mean	sd	p50	min	max
GDP 2019	7485	75951252	555294167	20456588	154820	34836475904
GDP 2020	7485	72852587	532493208	19590914	161426	33383446528
$\Delta\%$ GDP	7485	-0.04	0.05	-0.04	-0.64	0.75
N Workers 2019	7485	5776.40	32856	1807	21	2132788
N Workers 2020	7485	5733.60	32494	1787	22	2109257
$\Delta\%$ N Workers	7485	-0.01	0.02	-0.01	-0.20	0.23
Per capita GDP 2019	7485	11427	2503.9	11366	4297.10	39427
Per capita GDP 2020	7485	11042	2355.7	10980	3970	29102
$\Delta\%$ Per capita GDP	7485	-0.03	0.05	-0.03	-0.46	1.15
Years since UBB	7485	1.95	1.95	2	0	5
Distance from closest OLT	7485	43.46	25.48	38.33	0	297.73
Distance from closest OPB	7485	5.18	5.31	4.24	0	59.99
N Infections	7485	23389	29379	13322	1024	158717
Share of population infected	7485	0.03	0.01	0.03	0.01	0.06
Recipients minimum wage	7485	28091	47030	12199	889	361124
Distance from closest prov capital	7485	23.32	13.43	21.15	0	219.12
Population	7485	7806.40	42865	2544	29	2752020
Unemployment Rate	7485	0.10	0.06	0.08	0	0.41
Population density	7485	310.22	651.49	112.48	0.92	12224
Share with higher education	7485	0.07	0.03	0.07	0	0.28
Altitude	7485	353.71	294.78	289	0	2035

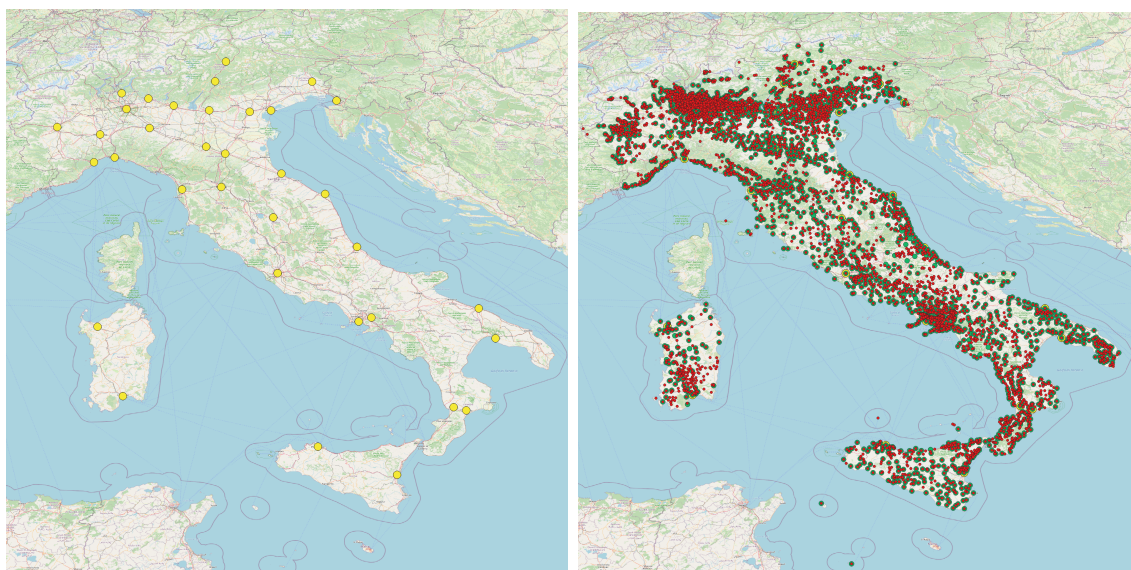
This table collects summary statistics for the main variables used in the analysis. All variables are at the municipality level excluding infections' and minimum wage recipients data, which are at the province level. Distances are measured in Kilometers, while altitude is measured in meters. Sources: TIM & OpenFiber, ISTAT, INPS, and Italian Ministry of Health.

Table 2: Placebo Test

VARIABLES	(1) $\Delta\%$ GDP	(2) $\Delta\%$ GDP	(3) $\Delta\%$ N Workers	(4) $\Delta\%$ N Workers	(5) $\Delta\%$ Per capita GDP	(6) $\Delta\%$ Per capita GDP
Distance from closest OPB	-0.0001 (0.000)	0.0000 (0.000)	-0.0000 (0.000)	-0.0001*** (0.000)	-0.0001 (0.000)	0.0001*** (0.000)
UBB by 2019	NO	YES	NO	YES	NO	YES
Observations	3,377	4,108	3,377	4,108	3,377	4,108

Presented are estimated OLS coefficients from reduced form regressions on sub-samples of municipalities with (columns 2, 4, and 6) and without (columns 1, 3, 5) UBB access in 2019. The instrument OPB measures the distance (in kilometers) between a municipality and its closest backbone node. All regressions include region fixed effects and the following additional covariates: distance from the closest OLT, provincial infection levels, provincial number of minimum wage recipients, distance from the closest provincial capital, population, population density, altitude, share of population with university degree and unemployment rate. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure 3: A Geographic Representation

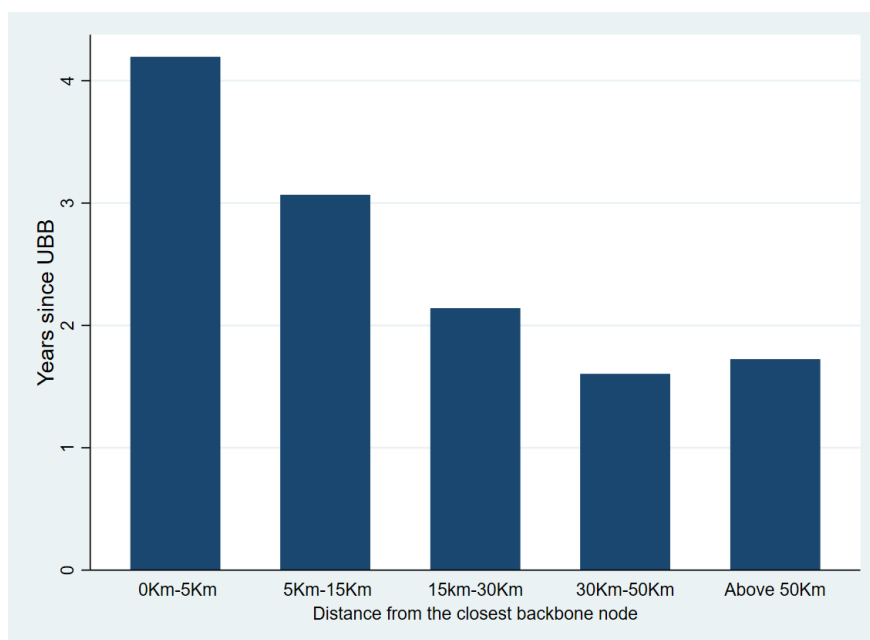


(a) Backbone Nodes' location

(b) UBB access in 2019

The figure shows the location of the backbone nodes used to derive the instrumental variable (Panel a), and the municipalities with access to UBB in 2019 (Panel b). Source: TIM & OpenFiber data.

Figure 4: Instrument's relevance



The figure plots the average years since UBB introduction over different distances from the closest backbone node. Source: TIM & OpenFiber data.

Table 3: Result - $\Delta\%$ GDP

VARIABLES	(1) OLS	(2) OLS	(3) OLS	(4) IV	(5) IV
Years since UBB	0.001*** (0.000)	0.000 (0.000)	0.000 (0.000)	0.010* (0.005)	-0.000 (0.011)
N infections		0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)
Recipients minimum wage		-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
Distance from closest OLt		-0.000** (0.000)	-0.000 (0.000)	0.001 (0.001)	-0.000 (0.001)
Population		-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Distance from closest prov capital			-0.000*** (0.000)		-0.000*** (0.000)
Unemployment rate			0.058** (0.027)		0.059 (0.038)
Population density			-0.000* (0.000)		-0.000 (0.000)
Share with higher education			0.044 (0.029)		0.048 (0.124)
Altitude			-0.000** (0.000)		-0.000** (0.000)
First Stage F-test				37.29	8.417
First Stage Coeff.				-0.006*** (0.001)	-0.003*** (0.001)
Observations	7,485	7,485	7,485	7,485	7,485

Presented are estimated coefficients of equation (2). Columns 1-3 estimated the model *via* OLS, with different sets of controls. Columns 4-5 report 2SLS estimates, exploiting the distance between a municipality and its closest backbone node in the first stage. All regression include region fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Result - $\Delta\%$ N Workers

VARIABLES	(1) OLS	(2) OLS	(3) OLS	(4) IV	(5) IV
Years since UBB	0.001*** (0.000)	0.000** (0.000)	0.000* (0.000)	0.013*** (0.003)	0.013** (0.007)
N infections		0.000 (0.000)	0.000 (0.000)	-0.000*** (0.000)	-0.000 (0.000)
Recipients minimum wage		0.000** (0.000)	0.000** (0.000)	-0.000 (0.000)	0.000** (0.000)
Distance from closest OLT		-0.001*** (0.000)	-0.000*** (0.000)	0.002*** (0.001)	0.001 (0.001)
Population		-0.000*** (0.000)	-0.000*** (0.000)	-0.000* (0.000)	-0.000 (0.000)
Distance from closest prov capital			-0.000*** (0.000)		-0.000*** (0.000)
Unemployment rate			-0.009 (0.012)		-0.040* (0.020)
Population density			-0.000 (0.000)		-0.000* (0.000)
Share with higher education			0.000 (0.014)		-0.136* (0.073)
Altitude			-0.000 (0.000)		0.000 (0.000)
First Stage F-test				37.29	8.417
First Stage Coeff.				-0.006*** (0.001)	-0.003*** (0.001)
Observations	7,485	7,485	7,485	7,485	7,485

Presented are estimated coefficients of equation (2). Columns 1-3 estimated the model *via* OLS, with different sets of controls. Columns 4-5 report 2SLS estimates, exploiting the distance between a municipality and its closest backbone node in the first stage. All regression include region fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Result - $\Delta\%$ Per capita GDP

VARIABLES	(1) OLS	(2) OLS	(3) OLS	(4) IV	(5) IV
Years since UBB	-0.001** (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.003 (0.004)	-0.011 (0.011)
N infections		-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Recipients minimum wage		-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
Distance from closest OLT		0.000 (0.000)	0.000* (0.000)	-0.000 (0.001)	-0.001 (0.001)
Population		0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Distance from closest prov capital			0.000 (0.000)		-0.000 (0.000)
Unemployment rate			0.062*** (0.023)		0.086** (0.034)
Density			-0.000* (0.000)		0.000 (0.000)
Share with higher education			0.043 (0.027)		0.153 (0.120)
Altitude			-0.000** (0.000)		-0.000*** (0.000)
First Stage F-test				37.29	8.417
First Stage Coeff.				-0.006*** (0.001)	-0.003*** (0.001)
Observations	7,485	7,485	7,485	7,485	7,485

Presented are estimated coefficients of equation (2). Columns 1-3 estimated the model *via* OLS, with different sets of controls. Columns 4-5 report 2SLS estimates, exploiting the distance between a municipality and its closest backbone node in the first stage. All regressions include region fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Result - UBB Exposure and Infection Penetration

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta\%$ GDP OLS	$\Delta\%$ GDP IV	$\Delta\%$ N Workers OLS	$\Delta\%$ N Workers IV	$\Delta\%$ Per capita GDP OLS	$\Delta\%$ Per capita GDP IV
Years since UBB \times Infections $_{<p50}$	0.000 (0.000)	0.000 (0.011)	0.000 (0.000)	0.015** (0.008)	-0.000 (0.000)	-0.012 (0.011)
Years since UBB \times Infections $_{>p50}$	0.001 (0.000)	0.000 (0.012)	0.000* (0.000)	0.018** (0.008)	0.000 (0.000)	-0.014 (0.012)
$H_0 : \gamma_H = \gamma_L$, F-test				7.60		
Observations	7,485	7,485	7,485	7,485	7,485	7,485

Presented are estimated coefficients of equation (2) when we interact *yearsUBB* with dummies identifying provinces above and below the median in terms of Covid-19 infections. Columns 1,3, and 5 estimate the model *via* OLS, while columns 2, 4, and 6 account for the endogeneity of broadband roll-out through an IV approach that exploits the distance between a municipality and its closest backbone node. All regressions include region fixed effects and the following additional covariates: distance from the closest OLT, provincial infection levels, provincial number of minimum wage recipients, distance from the closest provincial capital, population, population density, altitude, share of population with university degree and unemployment rate. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1