Work from home and Firm Productivity: The Role of ICT and Size*

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Abstract

This paper examines the short- and longer-term effects of the COVID-19-induced rise in work-from-home (WFH) on firm performance and productivity. Using administrative data on WFH for Italy and leveraging exogenous variation in pre-pandemic broadband fibre availability, we find a large negative impact on firm productivity in 2020. This evidence is driven by firms with a higher mix of manual and office workers, suggesting that coordination and communication costs may be an important source of the decline in firm productivity. Further evidence shows that firms with prior ICT investments and larger size mitigated these negative effects. Firms where 45% of the workforce had laptops before the pandemic experienced no impact. By 2022, the effects of WFH on productivity were no longer significant, suggesting that Italian firms required approximately two years to adapt effectively to WFH practices.

Keywords: Work-from-home; Firms; Productivity; ICTs; COVID-19.
JEL: D22; J21; J24; L25; O33

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1 Introduction

The rise of work-from-home (WFH) represents a global technological and organisational shift triggered by the COVID-19 pandemic. Recent studies indicate that the adoption of WFH practices has stabilised at levels significantly higher than those before the pandemic, indicating a lasting transformation of the workplace in advanced economies.[1] However, the impact of WFH on firm performance and productivity remains unclear, with existing studies finding both positive and negative effects (Angelici & Profeta, 2024; Bloom, Han, & Liang, 2022; Emanuel & Harrington, 2024; Gibbs, Mengel, & Siemroth, 2023; Yang et al., 2022). Moreover, these studies focus on a single company or group of workers, neglecting the potentially heterogeneous effects of WFH adoption. This gap is important, as larger and better-managed firms are typically more able to capitalise on new technologies (Bloom, Sadun, & Reenen, 2012).

The first objective of this paper is to examine the short- and longer-term impact of WFH on firm performance and productivity. We address the traditional endogeneity issue in the relationship between technological adoption and firm performance by using the local availability of high-speed broadband internet connection as an instrument. The effect of WFH adoption is estimated by comparing firms within the same local labour market, with and without broadband access, in terms of performance and productivity over the three years following the pandemic (2020, 2021, and 2022). The findings indicate significant negative effects in 2020, which become non significant by 2022. A second objective is to document the cross-firm heterogeneous effects to shed light on the mechanisms through which remote working affects firm operations. Leveraging unique administrative data on WFH for Italy, we show that information and communication technologies (ICTs) and firm size mitigated the negative impact of WFH. Such analysis was previously unfeasible due to the lack of firm-level

[1] Barrero, Bloom, and Davis, 2023 show that the proportion of full paid workdays conducted from home in the United States increased from around 5% in 2019 to approximately 25% in 2023. Similarly, Crescenzi, Martino, and Rigo, 2023 leverages the *Labour Force Survey* to document that the share of workers engaged in full or hybrid WFH rose from 10% in 2019 to 25% in 2022 in European countries. In the United Kingdom, the rate surged from 20% in 2019 to around 40% by 2023.

data on WFH for an entire economy.

Our identification strategy relies on a massive public investment implemented by the Italian Government in 2015, namely the 'National Ultra-Broadband Plan' (NUBP), aimed at ensuring 100% fibre coverage by 2020. In order to cover the whole territory in a relatively short period, whilst minimising public spending, the NUBP was implemented progressively in adjacent territories. Although there is a large literature suggesting that infrastructure rollout might be targeted towards economically growing areas or top-performing firms, we provide evidence that the NUBP's deployment was not influenced by pre-pandemic characteristics or trends of firms or areas. Furthermore, our analysis is conducted by comparing firms within Italian travel-to-work areas, allowing us to control for a wide range of potential unobserved geographical determinants of the broadband roll-out.[2] Lastly, we focus on the broadband supply measure, rather than measuring its actual consumption, allowing us to bypass the endogeneity that may characterise the internet usage measures frequently used in the literature. Collectively, our findings suggest that the broadband rollout was independent of firm or local area characteristics and can be considered as good as random.

To tease out the causal impact of WFH, we exploit the pre-pandemic cross-sectional variation in the local availability of fibre technology among Italian firms. Unlike ADSL, the previous technology available in Italy, fibre broadband supports the high-bandwidth activities and scalability essential for effective remote working, such as simultaneous videoconferencing and high-volume data transfer. Therefore, only firms with access to fibre technology were able to effectively transition to WFH during the initial lockdown in 2020. The impact of WFH is estimated by comparing changes in firm-level outcomes before and after the pandemic outbreak and between firms that adopted WFH and those that did not.[3] By comparing firms within travel-to-work-areas and narrow industries (at the 2-digit level), this empirical

[2]The Italian territory is currently divided into 610 travel-to-work areas based on commuting patterns information from the 2011 population census.

[3]We focus our analysis on measures of sales and productivity because it depends on the extent to which the firm was subject to the exogenous COVID-19 shock and on its capacity to contain its effects, while the evolution of employment was heavily influenced by government policies introduced during the pandemic that forbade layoffs and offered an encompassing employment protection scheme.

framework allows us to isolate the specific contribution of WFH to firm performance and productivity amid the broader economic disruptions caused by the pandemic.

We find an average short-term negative effect of WFH on firms' labour productivity and total factor productivity (TFP) growth in 2020. This finding aligns with (Gibbs, Mengel, & Siemroth, 2023), showing that the government-mandated shift to remote work reduced workers' productivity for a large IT company in India. However, we complement existing studies by showing evidence of the impact of WFH on an entire economy, in a setting where firms can choose whether to adopt or not WFH based on their access to high-speed broadband internet.[4] In the medium term, we find that by 2022 Italian firms did not experience any negative effects on their productivity, suggesting that it takes time to effectively assimilate WFH practices. Our analysis is the first to track WFH adopters over time allowing us to shed light on the long-term impact of WFH on firms.

A second contribution to the literature is to argue that the effects of WFH are heterogeneous across firms. Given the unanticipated nature of the pandemic shock, firms' responses to the pandemic are likely to be even more pronounced (Calvino, Criscuolo, & Ughi, 2024; Crescenzi, Giua, & Rigo, 2024; Riom & Valero, 2020). While some firms were 'ready', equipped with the necessary organisational flexibility and complementary assets to efficiently integrate remote work practices, others were not. Moreover, small and medium-sized enterprises (SMEs), which represent more than half of the aggregate employment and gross output in most modern economies (Kalemlİ-Özcan et al., 2024), might have been less prepared to take advantage of WFH. Our analysis investigates the differential impact of WFH among Italian firms, comparing firms with a higher versus a lower mix of manual and office workers, more and less digitalised firms, and across firm size categories.

First, our findings highlight that firms predominantly composed of office workers managed to avoid disruptions associated with WFH adoption during the pandemic. In line with

[4]In our analysis, we exclude companies in non-essential industries, as these firms were not permitted to operate in person during the initial lockdown (from March to May 2020) and could only operate remotely. Consequently, all firms considered in our analysis were classified as essential by the Italian government and therefore could independently decide whether to implement remote working practices.

this evidence, we find a null effect for firms operating in knowledge-intensive industries. In contrast, the adverse impacts were primarily concentrated in firms with a higher mix of remote and in-person workers (e.g. manufacturing firms). This evidence is consistent with previous studies showing that the negative impact of the shift to WFH during the COVID-19 pandemic is primarily due to increased coordination and communication costs among employees (Gibbs, Mengel, & Siemroth, 2023; Yang et al., 2022).

Second, we test whether the adoption of remote working practices requires complementary investments in information and communication technologies (ICTs) to work efficiently. Introducing remote working may have been easier for firms that were more digitalised before the pandemic, as they already possessed the complementary technologies and skills necessary for its adoption. In line with our hypothesis, we find that firms that had made significant investments in laptops and server setups before the pandemic had better performance when adopting WFH in 2020.[5] Notably, firms with 45% of the workforce with laptops experienced a null impact on TFP. Lastly, we show that larger firms were less negatively affected by the adoption of WFH. Given that firm size is a well-established proxy for organisational and managerial capabilities (Bloom, Sadun, & Van Reenen, 2010), this finding suggests that better-managed firms were more prepared to take advantage of remote work practices.

Our findings remain robust when controlling for the non-random exposure of firms to the COVID-19 pandemic.[6] More urbanised areas are not only more likely to be served by fibre (due to cost-minimisation reasons) but also more exposed to the COVID-19 virus because of their higher population density. Consequently, a firm's exposure to the pandemic is likely non-random, potentially introducing omitted variable bias and undermining the validity of

[5]During the pandemic outbreak, companies primarily used servers to enable remote work by hosting and providing access to essential business applications, data, and communication tools, ensuring business continuity and employee collaboration.

[6]The deployment of fibre technology depended on the location of the national optical packet backbone nodes (*hereafter* nodes). These nodes are upgraded facilities of the old telephone communication network, originally constructed around the early 2000s. The fibre deployment strategy prioritised areas closer to these nodes to maximize coverage efficiency and reduce the initial investment in new infrastructure. This proximity-based deployment leveraged existing node locations to accelerate the rollout of broadband services. As a result, highly densely populated places received the fibre first because the fibre was rolled out in locations closer to these nodes (Cambini, Grinza, & Sabatino, 2023).

our instrumental variable approach. To address this issue, we follow Borusyak and Hull, 2023 by introducing a measure of the expected probability of being served by fibre technology. Including this measure in our baseline specification accounts for the aforementioned omitted variable bias and, conditional on the fixed effects, should identify the causal effect of actual fibre technology on WFH adoption. Our results indicate that both estimation strategies yield very similar results because our granular set of fixed effects (at the travel-to-work-area) are already able to account for the non-random exposure of firms to the COVID-19 pandemic.

This paper highlights the critical role that complementary investments in ICTs and intangible assets play in enabling firms to effectively adapt to and benefit from remote working arrangements. As a result, the sudden worldwide shift to WFH induced by the COVID-19 pandemic may have exacerbated existing disparities between larger and more digitalised firms and the rest of the business population. These diverging patterns might reinforce large firms' market position and lead to winner-takes-most dynamics due to scalability and the high fixed costs of intangible investments (Andrews, Criscuolo, & Gal, 2016; De Ridder, 2024). Moreover, slow diffusion of technology and knowledge could have significant consequences for economies (Berlingieri et al., 2024). As shown by Akcigit and Ates, 2023 and Akcigit and Ates, 2021, a decline in knowledge diffusion is the most powerful force driving the current productivity slowdown, declining business dynamism, and rising market concentration.

Related literature. Our findings contribute to a recent and growing body of research exploring the effects of WFH on firms' performance. On one hand, relying on randomised control trials, Bloom, Han, and Liang (2022), Bloom et al. (2015), and Choudhury et al. (2022) find a positive effect of WFH on workers and firms' productivity. On the other hand, evidence from firms shifting to WFH during the COVID-19 pandemic finds negative effects (Bao et al., 2022; Emanuel & Harrington, 2024; Gibbs, Mengel, & Siemroth, 2023; Yang et al., 2022), with WFH increasing coordination and communication costs among employees (Gibbs, Mengel, & Siemroth, 2021). However, these studies focus on a single company or context. Instead, we provide causal evidence on the adoption of WFH for the quasi-universe of Italian private

firms, showing for the first time that WFH has uneven effects across firms.

Our instrumental variable approach contributes to a recent body of literature that exploits the availability of broadband internet to estimate its causal effect on firms' performance. While previous studies examined the impact of Asymmetric Digital Subscriber Line (ADSL) technology on firms' size and productivity (Canzian, Poy, & Schüller, 2019; De Stefano, Kneller, Timmis, et al., 2014; DeStefano, Kneller, & Timmis, 2018) or trade (Kneller & Timmis, 2016; Malgouyres, Mayer, & Mazet-Sonilhac, 2021), our analysis relies on the diffusion of fibre technology. To the best of our knowledge, DeStefano, Kneller, and Timmis (2023) and Cambini, Grinza, and Sabatino (2023) are the only other studies using the availability of fibre as an instrumental variable. DeStefano, Kneller, and Timmis (2023) leverage the cross-sectional firms' distance from the exchange and over-time variation in fibre roll-out to study the impact of cloud computing on a sample of UK firms. Cambini, Grinza, and Sabatino (2023) use the deployment of fibre in Italy to explore its impact on firms' performance and productivity. However, our study focuses on the relevance of high-speed internet connection in the adoption of WFH practices.[7] We also contribute to this literature by providing a novel solution to the non-randomness of broadband roll-out to the economic geography of a country. Following Borusyak and Hull (2023), our approach considers the geography of Italy, giving us a control variable for the non-randomness of the availability of fibre technology that is based on a more realistic counterfactual topography.

Our paper is also related to a recent body of pandemic-related research studying the role of digital practices and technologies more generally on firms' resilience to the COVID-19 crisis. By relying on ex-ante measures of WFH feasibility, Bai et al. (2021) and Papanikolaou and Schmidt (2022) find that firms with high pre-pandemic WFH potential were more resilient during the crisis. Moreover, recent papers highlight the impact of managerial practices (Lamorgese et al., 2024), technological sophistication (Comin et al., 2022), digital capabilities (Cariolle & Léon, 2022; Oikonomou, Pierri, & Timmer, 2023) and digital infrastructure

[7] In Section 4.2, we explain in detail the importance of fibre technology for effectively implementing remote working practices.

(Doerr et al., 2021) to mitigate the effects of the pandemic on businesses. Our study is the first contribution providing causal evidence on the effects of WFH on firms' performance and productivity in response to the COVID-19 pandemic.

The rest of the paper is organised as follows. Section 2 describes the evolution of the pandemic and related governmental restrictions imposed in Italy. Section 3 presents the data used in our empirical analysis and descriptive statistics. Section 4 introduces our empirical design, and Section 5 provides novel evidence on the impact of WFH on firm performance and productivity. Section 6 presents heterogeneous results across different groups of firms, highlighting key mechanisms at play behind the relationship between WFH adoption and firm productivity. Section 7 concludes.

2 Institutional Setting

We consider the pandemic period as an ideal laboratory to study the impact of WFH on firms' responses for several reasons. First, Italy, being the first advanced economy to be significantly impacted by the pandemic, faced unexpected governmental restrictions that firms could not have foreseen or prepared for. Second, the Italian economy is predominantly comprised of small and medium-sized enterprises (SMEs), providing an ideal setting to explore the uneven effects of WFH. In 2019, SMEs accounted for 80% of the labour force and two-thirds of the total turnover and value-added. Overall, the COVID-19 shock had a dramatic impact on the Italian economy in the year 2020. The Italian GDP witnessed a 9% contraction in 2020 (compared to the previous year), reaching an all-time low of -12.6% in the second quarter of 2020.

Italy was the first advanced economy to be severely affected by the COVID-19 pandemic, triggering immediate reactions by national and regional government. The first official case of COVID-19 in the country was found on February 21st. Initially, the Italian government imposed local restrictions to mobility and social distancing to 11 municipalities in Lombardy and Veneto, which were declared red zones. The red zone status was then extended on March

9th, when the Italian government imposed a national quarantine, mandating the temporary closure of non-essential shops and businesses. In particular, on March 22nd the government provided a list of industrial activities (only marginally updated on March 25th and April 10th) to be considered as 'essential': only those industries in the list were allowed to work, while the other industries had to cease their activities. Until May 18th, when the Italian government legislated another decree reopening the economy and ending the lockdown.

In response to resurging COVID-19 cases, Italy faced its second lockdown in late 2020, marking another severe phase of the pandemic. Following a summer with relatively lower infection rates, the resurgence led the Italian government to reintroduce stringent measures in November. This second lockdown was not as uniform as the first; instead, it featured a tiered system where regions were classified into three zones—yellow, orange, and red—based on their epidemiological risk. Each zone had varying restrictions on mobility, business operations, and social activities, with the red zones facing the strictest controls, including the closure of most non-essential businesses and severe limitations on movement. Unlike the first lockdown, this approach aimed to balance public health needs with economic impacts by localizing restrictions according to the severity of outbreaks. Essential industries remained operational as defined in the earlier phases of the pandemic, but many sectors still faced significant operational challenges. The second lockdown continued intermittently in various capacities until early 2021, when the government began to gradually lift restrictions in response to declining case numbers and the commencement of the vaccination campaign.

3 Data

To study Italian firms' responses to the COVID-19 crisis, we built a unique data infrastructure. This section outlines the main data sources used in our analysis. We have integrated various types of data, including administrative declarations on the adoption of WFH, balance sheet information from Orbis and web-scraped data on broadband internet availability. Additionally, we purchased proprietary data on firms' adoption of ICTs from Spiceworks,

e-commerce activities from BuiltWith, and information regarding the presence of employees in managerial roles and their educational level from Revelio Labs.

WFH. To identify firms adopting WFH, we rely on a unique source of information. In Italy, firms must report those workers contractually fully or partially working from home to guarantee their insurance coverage with INAIL (National Institute for Insurance against Accidents at Work). The insurance with INAIL is mandatory and employers have to pay every year an insurance prize to INAIL. Since the first of March 2020, due to COVID-19, the procedure has been simplified, with firms that just need to make an online declaration with information on the firm's tax identifier, workers details (date of birth, city or foreign country of birth, gender), start and end date of WFH, occupation based on INAIL 4-digit classification. The data are high quality and require little cleaning. This dataset therefore provides us with the population of firms adopting remote working since 2017.

Table A.1 shows summary statistics on WFH by 1-digit ATECO rev. 2 industries.[8] The industries with the largest shares of firms and workers in WFH are knowledge-intensive services industries, such as energy (D), information & communication (J), financial & insurance (K) and professional activities (M). This finding is in line with recent studies showing that high-skilled intensive occupations (e.g. managers and professionals) rely the most on WFH practices (Alipour, Fadinger, & Schymik, 2021; Crescenzi, Giua, & Rigo, 2022; Mongey & Weinberg, 2020).

We validate this dataset by comparing the share of employees in WFH at the 2-digit NUTS (equivalent to Italian provinces) and 1-digit industry level with what is reported in the Labour Force Survey (LFS). The LFS is a national household survey on labour participation published by Eurostat, covering people aged 15 and above, representative of the Italian population at the 2-digit NUTS $\times$ 1-digit industry level. Figures B.1 and B.2 show that our data are highly collinear with the LFS: the correlation between the two sets of data stands at 84% in 2020 levels, and at 82% in 2019-2020 changes.

[8]These statistics are based on the whole sample of firms, including both essential and non-essential industries.

Orbis. By relying on firms' unique tax identifiers, we can merge the data on WFH with firm-level financial information from Orbis. This database, produced by Bureau Van Dijk (BVD), is a commercial product providing administrative information on over 170 million firms around the world. Although its primary purpose is to provide information on specific firms to the private sector, it is widely recognised as one of the most comprehensive and reliable sources of international data on firm performance. For this paper, we exploit the Orbis Historical product, which allows us to follow firms over time. In terms of data cleaning, we adopt the following modifications to the original data. First, we exclude companies that consist solely of a single employee to maintain focus on an employment framework where firms offer designated office spaces for their staff. Second, we drop firms that appear more than once in the dataset (as done in Bajgar et al. (2020)) by keeping companies' unconsolidated accounts. This is because sometimes multiple financial accounts are available for the same firm in a given year (e.g. when a firm appears with both a consolidated and unconsolidated account). Third, we exclude companies operating in the primary (agriculture and mining) and public sector (education, health, etc.). Lastly, to increase the robustness of our estimates, we exclude companies with limited financials since these observations are mainly imputed and have lower quality. A detailed description of our cleaning procedure is available in Section C in the Appendix.

Broadband. Data on broadband coverage over the period 2016-2021 are gathered by Infratel, a state company in charge of the implementation and monitoring of the Italian Ultra-Broadband Plan. Since 2014, once a year all internet providers are requested to provide information on the availability of broadband telecommunication infrastructures and on the private investment plans for the following three years. The data are collected for each house number and then aggregated at the census area level.[9] In Italy, there are 402'678 census areas. The dataset can be linked to a spatial dataset providing geocoded boundaries for each section. In this way, the information gathered can be easily matched with other spatial datasets.

[9]The Census area is the minimum level at which the Census survey is administered every ten years.

Infratel provides information on the share of buildings with access to fiber-to-the-cabinet (FTTC) and fiber-to-the-home (FTTH) technologies, ensuring, respectively, a minimum of 30mbps and 100mbps internet speed. Thanks to these data, we identify the availability of fibre technology (at the Census area level), when the share of buildings covered by FTTC technology is higher than 75%.[10] Figure B.3 in the Appendix shows the geographical distribution of fibre in Italy in 2019. Table A.2 shows the share of firms with access to fibre technology in 2019 across Italian industries (1-digit) and regions (1-digit) and by firm's size class (micro, small, medium and large). The availability of fibre technology (at least 30 Mbps) is quite high (at 86%). Larger firms and companies operating in knowledge-intensive industries (such as financial services) have higher access to a fast internet connection, consistent with the fact that these firms are usually located in more urbanised areas.

ICTs. We use data on ICTs purchased from the Aberdeen Computer Intelligence Database (CiTDB), previously known in the literature as the Harte Hanks Database, provided by Spiceworks Ziff Davis Aberdeen Group. This is one of the best sources of ICT data available for Italy, providing detailed information on heterogeneous ICT capital (PCs and laptops), IT infrastructure (servers and data storage) as well as various forms of software like business management systems. This database is constructed through a combination of survey-based interviews and web-scraping techniques. The database has been extensively used for the analysis of the role of ICT, including the seminal work by Bloom, Sadun, and Reenen, 2012 to study the relationship between management practices, ICT and productivity for the US and European countries, DeStefano, Kneller, and Timmis, 2018 to study the effects of ICT on firm performance in the UK, and more recently by Oikonomou, Pierri, and Timmer, 2023 and Calvino, Criscuolo, and Ughi, 2024 to examine the impact of the COVID-19 pandemic on labour markets and the adoption of new technologies. However, this dataset has partial coverage and tends to be skewed towards medium and larger firms.

[10] Our results are consistent with the use of different thresholds.

E-commerce. Information on firms' e-commerce activities is obtained from BuiltWith. The BuiltWith data are available for the near universe of websites around the world (roughly 550 million websites) and have been collected in the same manner from 2018 onwards. BuiltWith scrapes the source-code information embedded in websites across the globe every 1 to 4 weeks. The set of websites is obtained from public secure socket layer (SSL) lists on a monthly basis. This became a de-facto public ledger of all secure websites (i.e. those with SSL certificates) since becoming a Google Chrome requirement in April 2018, so-called Certificate Transparency. As such, the BuiltWith data includes high-frequency technology diffusion, which is ideal for examining firms' e-commerce activities during the pandemic shock. Following Ragoussis and Timmis (2023), we build two measures to proxy for firms' e-commerce activities: whether the firm uses its website for online sales; and whether its website includes an online payment technology. Measures of e-commerce embedded in a firm's website are likely to be a lower bound since firms can engage in e-commerce by using social media or other digital platforms rather than through their website. However, while data on platform use is scarce, firm websites appear to reflect the bulk of e-commerce activity and there is no evidence of greater use of platforms as opposed to own websites in Italy. In Europe, for example, nearly 90% of firm e-commerce sales are through their website rather than a platform, while even for small firms, sales through their website account for 80% of e-commerce (European Commission, 2024).

Management quality. *We are currently in the process of integrating this data source in the analysis.* We use data from Revelio Labs, which gathers information from public LinkedIn profiles and other sources. LinkedIn, launched in 2003, is a widely used online platform for professional networking with over 700 million users worldwide. On LinkedIn, users create profiles that list their educational and employment histories, including the universities they attended, their fields and degrees, their employers, job titles, and the dates they held these positions. Revelio Labs provides access to publicly available information from over 15 million LinkedIn accounts for Italy as of early 2024. The presence of individuals' profiles on

LinkedIn varies greatly by occupation, location, and time. Individuals with a college education and those in white-collar jobs are more likely to have a LinkedIn profile compared to those without higher education or in bluecollar positions. Therefore, we consider LinkedIn as a representative source of information on the management quality of Italian companies. Amanzadeh and McQuade, 2024 confirms that LinkedIn coverage in Italy is exceptionally comprehensive, nearing 100% when compared to International Labour Organization (ILO) figures. Additionally, the LinkedIn data coverage is most extensive for the years relevant to our analysis (from 2019 onwards).

Descriptive statistics. In Table 1, we present basic summary statistics for the variables included in our empirical analysis. As expected, the average Italian firm was negatively affected by the crisis, experiencing negative sales growth rates. It is interesting to note that 38% of firms in our sample did not record any change in their number of employees between the 2019 and 2020 period. An explanation for this fact is that the government put in place a job retention scheme and a layoff ban after the start of the pandemic in 2020 to contain the potential wave of job destruction. Table 1 also shows that 18% of firms switched to remote working in 2020, and (on average) these firms let 10% of their workforce work at home in 2020.

Table 1: Summary statistics

Variables	Mean	St. Dev.	Median	Min	10pct	90pct	Max	Obs
Firm Variables								
Δ log Sales	-0.07	0.34	-0.05	-1.44	-0.42	0.25	1.64	114894
Δ log VA	-0.07	0.41	-0.04	-1.41	-0.53	0.33	1.55	114894
Δ log TFP	-0.15	0.36	-0.12	-1.24	-0.58	0.22	1.21	114894
Employees	22	110	8	2	3	38	15684	114894
Age	17	14	14	0	3	36	119	114894
Labour productivity (log)	11	1	11	6	10	11	17	114894
WFH Variables								
WFH (dummy)	0.18	0.39	0	0	0	1	1	114894
WFH (share)	0.1	0.27	0	0	0	0.5	1	114894
ICT Variables								
No Laptops per employee	0.15	0.15	0.1	0	0.02	0.33	1	42137
No Servers per employee	0.05	0.11	0	0	0	0.14	1	42211
E-commerce Variables								
E-commerce (dummy)	0.1	0.3	0	0	0	1	1	114894
Online Payment (dummy)	0.19	0.39	0	0	0	1	1	114894

4 Empirical Design

In this section, we describe the empirical strategy adopted to estimate the causal effects of the pandemic adoption of WFH on firm-level outcomes. The shift to WFH is not random, but rather driven by firms' organisational capabilities and degree of digitalisation that may correlate with firms' responses to the health crisis. To deal with this endogeneity concern, we instrument WFH adoption with the local availability of fibre technology. Another empirical challenge arises from the non-random roll-out of the fibre network. The deployment of the fibre in space may be determined by the factors (e.g., population density) that may correlate with the spread and severity of the COVID-19 pandemic and so with our firm-level outcomes of interest. Our solution is to control for the presence of this non-randomness in our instrument by recentering our baseline specification around plausibly exogenous variation in access to fibre technology.

4.1 First-Difference Framework

Italy was the first Western country affected by the pandemic and the policy measures implemented during the COVID-19 crisis could neither be known to nor anticipated by Italian firms. Using a first-difference framework, we document firms' performance before and after the start of the COVID-19 pandemic by comparing firms' using or not flexible work arrangements during the 2020 lockdown. Our baseline model is defined as follows:

$$\Delta log(Y_i) = \alpha + \beta WFH_i + \theta X_i^{2019} + \gamma_j + \gamma_p + \varepsilon_i; \tag{1}$$

where $\Delta log(Y_i)$ indicates the difference in (log) sales, labour productivity (as value added per employee) or total factor productivity (TFP) between the years 2020 and 2019.[11] WFH_i is a binary variable that equals one when firm i adopts WFH in the year 2020. Our coefficient of interest is β which is identified by comparing firms that started using WFH as a result of the COVID-19 pandemic and firms that did not adopt WFH.

To improve the comparability between the treatment and control groups, we exclude firms using WFH before the pandemic (accounting for less than 1% of the sample). To control for the differential severity of the lockdown imposed by the Italian government and the spread of the virus in the working population, we also include travel-to-work-areas (γ_p) and 4-digit industry fixed-effects (γ_j). This is the same detail of classification that was used to define the essential industries allowed to operate during the lockdown in 2020.[12] As a result, we compare firms' performance within the same travel-to-work-area and (4-digit) industry. Lastly, X_i is a vector of firm controls, measured in 2019, including a measure for firms' size (log of

[11] TFP provides a commonly used indicator for the overall productive performance of a company (DeStefano, Kneller, & Timmis, 2018) and it is calculated using the methodology developed in Wooldridge (2009) using information on value added, cost of materials and total fixed assets to define the production function. One potential shortcoming of this measure is that the decline in office valuations and the increase in vacancies due to the shift to remote working (Bergeaud et al., 2023) may affect firms' fixed assets (as reported in firms' balance sheets). This in turn could affect our measure of productivity, with WFH adopters experiencing a reduction in fixed assets and mechanically an increase in TFP. However, Table A.3 shows that there are no statistically significant differences between WFH adopters and non-adopters in change of log fixed assets once controlling for our set of firm-level characteristics and fixed effects.

[12] A list of essential industries is available at this link.

the number of employees), the firm's age and labour productivity (log of value added per employee).

To study whether the role played by WFH in firms' responses to the COVID-19 crisis is heterogeneous, we include in equation 1 an interaction term between WFH_i and X_i. This results in the following specification:

$$\Delta log(Y_i) = \alpha + \beta_1 WFH_i + \beta_2 Z_i + \beta_3 WFH_i \times Z_i + \theta X_i^{2019} + \gamma_j + \gamma_p + \varepsilon_i; \tag{2}$$

where Z_i denotes one of the following variables: $Size_i^{h,l}$ that equals 1 when firm i has fewer than h employees and at least l employees; ICT_i indicating the number of laptops or servers per employee. Section 6 shows the results of estimating this equation where our measure of WFH adoption and the interaction term with Z_i are instrumented by the local availability of fast broadband internet and its interaction with Z_i.

Lastly, to investigate the medium-term effects, we estimate equation 1 while taking the difference in log Y_i between the years 2021 or 2022 and 2019. Our variable of interest, WFH_i, is defined to equal 1 when a firm i adopted WFH from 2020 until the end of 2021 or 2022. To avoid firms moving from the control group to the treatment group or vice versa, we exclude those firms adopting WFH in 2021 or 2022 and those firms stopping using WFH in 2021 or 2022. We also consider a balanced panel of firms.

4.2 Instrumental Variable

We are interested in the causal impact of the pandemic-induced adoption of WFH on Italian firms' performance and productivity. However, the literature on technology adoption has highlighted that better-managed firms are the ones able to reap the benefits of new digital investments. As a result, the quality of management could have caused at the same time the adoption of WFH and the firms' growth during the COVID-19 crisis. To overcome this endogeneity concern in our estimation, we plan to adopt an instrumental variable (IV) approach using as an instrument of WFH the local availability of high-speed fibre broadband in the

year 2019.[13]

IV relevance. Italy underwent a significant upgrade in broadband technology starting in 2015. In 2014, nearly all Italian municipalities had ADSL coverage but lacked fibre access; by 2019, however, fibre reached 85% of the population Cambini, Grinza, and Sabatino (2023). Unlike ADSL, which operates over copper cables, fibre offers higher suitability for remote work due to its symmetrical upload and download speeds. This is essential for remote work activities centralised at firms, such as video conferencing, large file transfers, and other real-time applications. Moreover, fibre supports multiple simultaneous connections without major performance degradation, whereas ADSL faces constraints in handling multiple devices effectively. While ADSL typically offers download speeds in the range of 1 Mbps to 7 Mbps, fibre guarantees at least 30 Mbps for both downloads and uploads.

The data indicate that fibre broadband is a strong predictor of firms' WFH adoption during the pandemic. Table A.5 shows the relationship between firms' WFH adoption and the local availability of high-speed broadband internet. Column 1 shows a positive and strong relationship between our instrument (the local availability of FTTC) and the adoption of WFH in 2020, reassuring us about the relevance of our instrument. Column 2 also includes the availability of FTTH, which provides at least 100 Mbps of download and upload capability and should further improve the capacity of firms to operate WFH-related technologies. The results confirm that firms with access to FTTH had an even greater probability of adopting WFH in 2020. Note that the coefficient of $WFH(FTTH)$ is equivalent to an interaction term with $WFH(FTTC)$, as in our empirical framework, firms with access to FTTH also mechanically have access to FTTN. Thus, the coefficient of $WFH(FTTH)$ captures the additional effect of having access to FTTH.[14]

[13] Although we do not find plausible that any firm had the opportunity to capture the central Government and speed up the rollout of broadband in a certain area in the immediate aftermath of the COVID-19 outbreak, we still use the pre-treatment infrastructure to address any endogeneity concern. Moreover, between 2019 and 2020, due to the disruption caused by the pandemic, only 1.2% of Census areas recorded a relevant increase in broadband coverage. We exclude the 3,686 firms located in these territories.

[14] A potential alternative instrument considers that workers may also be negatively affected by the lack of fast broadband internet connection. Due to data limitations, we do not know where the workers reside and are therefore unable to construct a measure of fibre availability at the worker level. However, since we are com-

IV validity. In this paragraph, we provide evidence supporting the claim that the fibre roll-out can hardly be related to firms' performance and was implemented progressively in adjacent territories to minimise public spending. First, as shown in Figure B.5, the probability of being served by fibre technology quickly decays with distance, with areas more than 6 km away (from areas already covered) with close to zero probability of being served by fibre in the future. Second, a simple correlation analysis (Table A.6) reveals that economic factors, such as the growth in labour productivity, wages, employment and the share of large firms, are not statistically related to the probability of being served by high-speed broadband internet in the future. In contrast, distance matters, with areas closer to existing fibre technology being more likely to be covered by the fibre infrastructure in the coming year.

Third, to rule out even further that the broadband roll-out was not driven by economic factors, we examine whether areas covered by fibre technology may be different from areas not covered by high-speed internet (in 2019). Figure B.6 shows that firms located in areas with access to a slower internet connection have similar sales, labour productivity and TFP than firms located in areas with access to fibre broadband. Lastly, to test whether the broadband roll-out was targeted at areas where firms were expected to grow quickly in the future, we examine whether the timing of the access to the fibre infrastructure is related to firm performance. Figure B.7 shows the absence of pre-trends in sales, labour productivity and TFP in the years before treatment. As an additional robustness, we implement an event study design, relying on the estimator developed by Callaway and Sant'Anna (2021). Figure B.8 shows once again the absence of pre-trends. We also find no increase in firms' outcomes after the fibre becomes available in the local area. This is consistent with previous studies finding (on average) no effects from access to high-speed internet connection on firm productivity (DeStefano, Kneller, & Timmis, 2023).

Another concern is that access to a fast broadband internet connection may affect firm performance through channels other than the adoption of remote working practices. To

paring companies within local labour markets, the companies' workforce should have homogeneous internet coverage. Moreover, while a worker could potentially work remotely using wireless technology, this would be impractical for a company.

test whether we are picking up the effect of a technological change, we examine whether the instrument is related to alternative types of digital technologies that may have helped firms during the crisis. First, firms with access to high-speed broadband internet may have been able to more efficiently switch to e-commerce sales during the lockdown periods. Even though Italian firms do not rely intensively on e-commerce, as shown by Figure B.9, it could be possible that online sales allowed Italian firms to adapt and respond effectively to the challenges imposed by the pandemic. We test the relationship between the local availability of fibre technology and firms' shift to online sales by examining the adoption of online payment methods and online e-commerce technologies on their websites. Table A.7 indicates that access to fibre technology is not significantly related to any of these measures. Second, while the pandemic pushed firms to introduce a wide range of digital technologies, the large majority are related to the adoption of WFH, including cloud computing, collaboration software, laptops, IT security, etc. (Calvino, Criscuolo, & Ughi, 2024). As a result, the impact of these new technologies on firm performance should be considered as a direct consequence of the shift to WFH.

4.3 Controlling for non-random exposure

The availability of fibre technology depends on non-random factors. For example, geography matters since the fibre was rolled out sequentially starting from 35 nodes located in city centres around Italy (as shown in Figure B.4). Typically, city centres were more negatively affected by the COVID-19 pandemic; therefore, a firm located near population centres is more likely to receive the fibre and thus adopt WFH, but is also more likely to be disrupted by the pandemic than a firm in the periphery. This factor could violate our exclusion restrictions, potentially biasing our estimates.

To address this endogeneity concern, we control for the non-random exposure to fibre technology by introducing a novel measure of the expected access to fibre. We construct this measure based on the insights of Borusyak and Hull (2023), by deriving a counterfactual

fibre network modelled as a function of the geographical and institutional characteristics of Italy. The rationale is as follows: the likelihood of a census area receiving a fibre connection depends on its proximity to the nearest node (for cost-minimizing reasons) and the node's capacity to deliver the fibre (*hearafter* referred to as decay). The node's decay may be influenced by the topography of an area (delivering fibre in mountainous areas can be challenging) and its institutional characteristics (some areas are more efficient in delivering public infrastructure). We construct our counterfactual fibre network by permuting our measure of decay across nodes, while maintaining the geographical node-census area distance and the overall dimension of the fibre network (the total number of census areas covered by fibre in 2019) constant.

By design, our measure of expected access to fibre should approximate a census area's exposure to high-speed broadband connection. Table A.8 confirms that our counterfactual fibre network is a strong predictor of the actual fibre availability, except when we control for travel-to-work areas fixed effects. This latter finding reassures us that our baseline specification should be able to control for the role played by the non-random exposure of firms to fibre technology. In our analysis, we still follow Borusyak and Hull (2023) by including our counterfactual fibre variable in our baseline specification. This should recenter the impact of actual fibre availability, providing us with a non-biased effect on our firm-level outcomes of interest.

Modelling expected fibre network. We assume that the probability of receiving fibre technology is a function of i) the distance between the census area and the node ($DistanceNode$; and ii) the node's ability to deploy fibre effectively over space ($Reach$). In particular, we model this probability as a logistic function as follows:

$$P(Fibre_i) = \frac{1}{1 + \exp(\beta DistanceNode_{ij} - \gamma Reach_j)}.$$

Where $DistanceNode_{ij}$ is the log distance between census area i and its closest node j and $Reach_j$ is node j capacity to deploy the fibre. Intuitively, the further the distance, the lower

the probability of fibre coverage; and the higher the decay, the stronger the node's coverage capability, and this should increase the probability of fibre coverage. By subtracting $Reach_j$ from log distance, we are effectively capturing the trade-off between the negative impact of distance and the positive impact of $Reach_j$. β and γ are determined by a linear regression of the observed availability of fibre on $DistanceNode_{ij}$ and $Reach_j$, while $Reach_j$ is estimated as the fixed effects (α_j) in the following specification:

$$P(Fibre_i) = \beta DistanceNode_{ij} + \alpha_j + \varepsilon_i.$$

5 Results

In this section, we explore the relationship between WFH and firms' responses to the COVID-19 pandemic. We start by estimating the naive effect of WFH adoption on firms' growth in sales, value-added and productivity. We then instrument WFH with the local availability of fibre technology. Lastly, we replicate our analysis using different specifications and cut of the data to confirm our main conclusions.

OLS results. Table 2 shows that firms starting to use remote working as a result of the lockdown measures imposed in 2020 performed better than firms that didn't adopt WFH. The coefficient in column (1) indicates that firms adopting WFH in 2020 recorded 5% higher growth in sales than companies not adopting remote working. We also examine the intensive margin of WFH adoption during the crisis, measured as the firm's share of workers in WFH in 2020 (in the total number of employees). Table A.4 shows that firms with a larger share of workers in WFH experienced larger growth in sales and productivity during the pandemic. These findings may be however driven by firms' underlying characteristics: better-managed firms may be better able to shift to WFH arrangements and at the same time more prepared to face the health crisis.

Table 2: OLS results of WFH adoption.

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	0.0504***	0.0453***	0.0462***
	(0.00304)	(0.00377)	(0.00323)
Observations	110,915	110,915	110,915
R-squared	0.197	0.163	0.164
Firm-level controls	✓	✓	✓
TTWA $\times$ 2-digit industry fixed effects	✓	✓	✓

Notes: The dependent variable is the 2020-2019 change in log sales in column 1, log labour productivity in column 2 and log TFP in column 3. All specifications include travel-to-work area $\times$ 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area $\times$ 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Short-term results. Table 3 presents the results instrumenting the adoption of WFH in 2020 with a dummy indicating whether firms have access to fibre technology in 2019. The instrument seems a good predictor of the treatment. The F-test is well above the conventional value of 10, meaning that we can safely exclude weak instrument concerns. Columns (1) to (3) show the second-stage estimates. The coefficients represent the average percentage variation over the post-treatment period for firms adopting WFH, relative to the pre-treatment period and to firms not using WFH. We find a negative and large impact of WFH on firms' labour productivity and TFP, but not significant for sales. The coefficient in column (3) indicates that firms adopting WFH during the COVID-19 pandemic experienced a reduction of 38% of their TFP. This growth rate appears large, however the summary statistics in Table 1 show that the mean firm has a TFP growth rate of -15% in 2020. Moreover, Gibbs, Mengel, and Siemroth, 2023 found for a large IT company in India that the government-mandated shift from in-person to remote work led to a 20% reduction in workers' productivity. Our larger estimates can be reconciled with the fact that, as shown in Section 6, firm size and the mix between in-person and remote workers matter in amplifying the negative impact of WFH adoption.

Table 3: IV results of WFH adoption.

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	-0.0782	-0.427***	-0.384***
	(0.122)	(0.164)	(0.147)
Observations	110,915	110,915	110,915
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	61.8	61.8	61.8

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Robustness checks. Our findings are robust to alternative specifications and various cuts of the data. First, we test alternative measures of WFH, including the share of employees in WFH (Table A.9), the duration in months of WFH adoption (Table A.10), and a definition capturing firms that implemented WFH for the first time during the initial lockdown and continued until the end of 2020 (Table A.11). Results remain consistent across these measures. Second, to minimise the role played by unobserved factors in driving our results, we augment our set of fixed effects by comparing firms within TTWAs and by area type (residential, industrial, rural or, mountainous) and by interacting TTWAs with 4-digit industry fixed effects. As shown in Tables A.12 and A.13, the coefficients are quantitatively unchanged. Third, we account for the severity of the pandemic by excluding firms that exited the market in 2021. Results in Table A.14 confirm the robustness of our findings. Lastly, we exclude large firms (with over 250 employees) and as shown in Table A.15, results remain unchanged. This robustness excluding large firms controls for the fact that a few very large firms might have dedicated access to a high-speed broadband internet connection, or might have influenced the deployment of the fibre by the government.

Medium-term results. To estimate the impact of WFH on firm performance and productivity growth in 2021 and 2022, we focus on firms that adopted WFH in 2020 and continued its use through 2021 and 2022. Firms that began WFH in 2021 or 2022 are excluded to concentrate our analysis on the longer-term adjustments of the early adopters. Tables A.16-A.18 show that while the coefficients for labour productivity and TFP are negative and statistically significant in 2020, their magnitude and significance decrease in 2021 and disappear by 2022. These results suggest that Italian firms adopting WFH, on average, took about two years to fully adapt and mitigate any initial disruptions associated with the shift.

6 Heterogeneous Effects

Our baseline results indicate that during the COVID-19 pandemic, Italian firms adopted WFH practices despite encountering adverse disruptions, including reduced growth in labour productivity and TFP. The abruptness of the COVID-19 shock meant many firms were inadequately equipped for the shift, lacking essential ICT infrastructure, digital skills, and organisational resources. Additionally, with limited pre-pandemic experience in flexible work arrangements, most firms were unprepared for the complex organisational adjustments necessary for effective remote working, which extend beyond a mere change in work location and (as shown) require time for proper implementation.

In this section, we explore the potential mechanisms underlying the negative relationship between WFH and firm productivity. First, we investigate whether the increased communication and coordination costs from WFH adoption could explain our negative findings. Second, we examine whether pre-pandemic investments in WFH-related ICTs and firm size (as a proxy of organisational capital) helped mitigate the adverse effects associated with WFH adoption.

Manual versus office workers. Existing literature shows that the pandemic-driven shift to WFH raised communication and coordination costs (Emanuel & Harrington, 2024; Gibbs,

Mengel, & Siemroth, 2023; Yang et al., 2022). To assess the role of these costs in our findings, we construct a measure of WFH potential at the 4-digit industry level, representing the share of workers who could feasibly work remotely based on task requirements.[15] We anticipate that WFH disproportionately affected firms with lower WFH potential, where in-person and remote work were more mixed.

Table A.19 shows a positive effect of WFH adoption in industries with high WFH potential and a negative impact in those with low WFH potential. This indicates that industries with over two-thirds office-based workers benefited from WFH in 2020, whereas industries with less than two-thirds office-based workers experienced negative impacts. Sector-specific analysis supports these conclusions. Table A.20 reports results for the manufacturing sector, which employs about one-third of Italy's workforce. Despite relatively low WFH adoption during the pandemic, manufacturing firms that adopted WFH showed lower productivity growth. This outcome may stem from coordination and communication challenges between remote and on-site functional areas (e.g., production and warehousing versus support services). Conversely, firms in knowledge-intensive sectors - such as information and communication, financial and insurance services, and professional activities - showed no significant disruptions (Table A.21).

Firm's size. To assess the role of firms' organisational and managerial capabilities in the relationship between WFH and productivity, we proxy these capabilities with firm size, measured by the number of employees. Previous studies suggest a close association between the presence of organisational and knowledge-based assets and firm size (Bloom, Sadun, & Van Reenen, 2010). We implement this analysis by categorising firms into groups based on their number of employees. Tables A.22 and A.23 show that small firms (with less than 10 employees) were the most negatively impacted by WFH adoption, while larger firms, although they

[15] Our measure of WFH potential reflects the proportion of employees able to perform their tasks remotely, derived using the method of Dingel and Neiman (2020), who classify occupations by home-based work suitability for the U.S. based on O*NET data. We aggregate this measure at the 4-digit industry level using employment data from the LFS; further details are provided in Crescenzi, Giua, and Rigo (2024). High (low) WFH potential indicates that more (fewer) than 66% of employees in an industry could work remotely.

still encountered productivity losses, were less disrupted by the shift to remote working.

ICTs. We focus our analysis on two key measures of ICT capital complementary to WFH: the use of laptops and presence of servers. Tables A.24 and A.25 show that firms with higher pre-pandemic investments in laptops and servers had better performance when adopting remote work in 2020. Importantly, the mitigating effect of ICT capital can offset the negative effect of WFH adoption; firms with 45% of their workforce equipped with laptops experienced no adverse effect of WFH on TFP. These findings highlight the essential role of digital investments in enabling firms to adapt to and fully leverage remote work arrangements.

7 Conclusions

This paper provides causal evidence on the effects of the pandemic-induced adoption of WFH for the quasi-universe of private firms in a major economy, addressing limitations of previous studies relying on survey data or small samples. Specifically, we provide three main contributions to the existing literature on the impact of WFH on firms' performance and productivity. First, our study reveals that the adoption of WFH practices during the COVID-19 pandemic had, on average, a negative impact on Italian firms' productivity. Importantly, this is the first study where the shift to WFH is not mandated by the government but instead represents an independent choice by the firm. We also find that the negative effects of WFH were particularly pronounced for firms employing a higher mix of manual and office workers, consistent with previous studies showing that the shift to WFH increased communication and coordination costs (Emanuel & Harrington, 2024; Gibbs, Mengel, & Siemroth, 2023; Yang et al., 2022). The medium-term results show that it took Italian firms an average of two years to effectively integrate WFH practices, highlighting the complexity of this transition.

Second, our analysis examines the heterogeneity in firms' ability to adapt to WFH. Firms equipped with complementary ICTs and larger firms were able to mitigate the negative effects of WFH adoption. This finding highlights the critical role of investments in digital tech-

nologies and organisational capital in determining a firm's capacity to effectively integrate WFH. While our paper provides comprehensive evidence on the short- and medium-term effects of remote work on firms, several important questions remain. First, we still know relatively little about the long-term implications of WFH, especially regarding the potential costs that WFH may pose for innovation and in building up corporate culture, both long-term drivers of firm growth. Second, we show that the impact of WFH is heterogeneous across firms, a key follow-up question concerns how these effects aggregate and which firms and workers win and lose from its adoption.

This study also matters for policy. Our findings suggest that the sudden shift to WFH during the COVID-19 pandemic might have exacerbated existing disparities between highly digitalised and larger firms and the rest of the business population. Accordingly, we caution against one-size-fits-all approaches to promoting WFH or digital adoption. Untargeted public interventions may not yield positive outcomes if firms lack the absorptive capacity or organisational capital to leverage new digital technologies effectively. Lastly, our study highlights the importance of a gradual and well-supported transition to new working arrangements. The two-year time frame for effective WFH integration suggests that policies should provide long-term support and guidance to firms, particularly SMEs, in adapting to remote working practices.

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A Additional Tables

Table A.1: Summary statistics on WFH by 1-digit ATECO rev. 2

Ateco 1-digit	Description	Sh firms in total	Sh firms in WFH	Sh Employees in total	Sh Employees in WFH
C	Manufacturing	0.28	0.18	0.38	0.13
D	Electricity, gas, steam & air conditioning supply	0.00	0.37	0.00	0.47
E	Water supply; sewerage & waste management	0.01	0.18	0.02	0.11
F	Construction	0.14	0.06	0.09	0.05
G	Wholesale & retail	0.25	0.10	0.18	0.09
H	Transportation & storage	0.05	0.10	0.09	0.09
I	Accommodation & food service activities	0.08	0.01	0.05	0.01
J	Information & communication	0.05	0.40	0.04	0.61
K	Financial & insurance	0.01	0.27	0.00	0.38
L	Real estate activities	0.02	0.15	0.00	0.19
M	Professional, scientific & technical activities	0.06	0.36	0.04	0.41
N	Administrative & support service activities	0.05	0.15	0.09	0.12

Table A.2: Share of firms with access to fibre

	All	Micro	Small	Medium	Large
All	0.86	0.86	0.83	0.83	0.88
Region (1-digit)					
South	0.85	0.85	0.84	0.84	0.87
Center	0.87	0.87	0.84	0.84	0.89
North	0.86	0.86	0.82	0.82	0.89
Industry (1-digit)					
Manufacturing	0.78	0.79	0.76	0.74	0.82
Energy	0.82	0.79	0.81	0.87	0.83
Construction	0.83	0.82	0.81	0.83	0.87
Non-financial services	0.89	0.89	0.89	0.89	0.89
Type of location					
Residential area	0.90	0.92	0.88	0.90	0.88
Mountain area	0.66	0.73	0.64	0.65	0.66
Industrial area	0.79	0.81	0.76	0.81	0.78
Rural area	0.64	0.67	0.63	0.64	0.63

Table A.3: Fixed asset and WFH adoption

VARIABLES	(1) 2019-2020 Δ log(Fixed assets)	(2) 2019-2021 Δ log(Fixed assets)	(3) 2019-2022 Δ log(Fixed assets)
WFH (dummy)	-0.000926	-0.0124	0.00330
	(0.00506)	(0.00753)	(0.0115)
Observations	101,461	98,215	91,827
Firm-level controls	✓	✓	✓
TTWA $\times$ 2-digit industry fixed effects	✓	✓	✓

Notes: The dependent variable is the 2019-2020 change in log fixed asset in column 1, the 2019-2021 change in log fixed asset in column 2 and the 2019-2022 change in log fixed asset in column 3. All specifications include travel-to-work area $\times$ 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area $\times$ 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.4: OLS results of WFH adoption - Intensive margin.

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (share)	0.0154***	0.0252***	0.0235***
	(0.00130)	(0.00162)	(0.00142)
Observations	110,915	110,915	110,915
R-squared	0.196	0.165	0.166
Firm-level controls	✓	✓	✓
TTWA $\times$ 2-digit industry fixed effects	✓	✓	✓

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log labour productivity in column 2 and log TFP in column 3. All specifications include travel-to-work area $\times$ 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area $\times$ 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.5: First-stage results

VARIABLES	(1) Extensive WFH (dummy)	(2) Extensive WFH (dummy)	(3) Intensive WFH (share)	(4) Intensive WFH (share)
Fibre (FTTC)	0.0261***	0.0182***	0.0179***	0.0112***
	(0.00334)	(0.00342)	(0.00201)	(0.00200)
Fibre (FTTH)		0.0196***		0.0166***
		(0.00291)		(0.00222)
Observations	110,915	110,915	110,915	110,915
R-squared	0.318	0.319	0.342	0.342
Firm-level controls	✓	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓	✓

Notes: The dependent variable is a dummy indicating whether a firm adopted WFH in 2020. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.6: Adjacent roll-out correlations

	(1) Fiber adoption New infrastructure in t	(2) Fiber adoption New infrastructure in t	(3) Fiber adoption New infrastructure in t
log distance from infrastructure (t-1)	-0.0507***	-0.0473***	-0.0462***
	(0.00558)	(0.00369)	(0.00308)
Δlog employment (t-4 - t-1)	-0.00163	-0.00167	-0.00148
	(0.00148)	(0.00145)	(0.00152)
Δlog avg. wage (t-4 - t-1)	0.000758	0.000956	0.00107
	(0.00144)	(0.00119)	(0.00115)
Δlog large firms share (t-4 - t-1)	0.00138	0.000865	0.00184*
	(0.00101)	(0.000975)	(0.00111)
Observations	100,094	100,094	100,094
R-squared	0.058	0.094	0.144
FE	NO	Province	TTWA

Notes: The dependent variable is a dummy that equals 1 if the census area is covered by fibre technology. All the variables are taken at the Census area level by aggregating information at the firm-level. Standard errors are clustered at the Census area level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.7: Instrument and E-commerce

VARIABLES	(1) WFH (dummy)	(2) Δ E-commerce	(3) Δ Online payment
Fibre	0.0262***	-0.000199	-0.00135
	(0.00332)	(0.00222)	(0.00232)
Observations	110,915	110,915	110,915
R-squared	0.318	0.086	0.080
Firm-level controls	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓

Notes: All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.8: Actual and expected fibre.

VARIABLES	(1) Fibre	(2) Fibre	(3) Fibre	(4) Fibre
Expected fibre	0.117***	0.157***	0.127***	0.0257
	(0.0245)	(0.0186)	(0.0264)	(0.0399)
Observations	124,127	124,023	124,023	124,124
R-squared	0.014	0.064	0.108	0.243
NUTS-2 fixed effects	.	✓	.	.
NUTS-3 fixed-effects	.	.	✓	.
TTWA fixed effects	.	.	.	✓

Notes: The dependent variable is a dummy that equals 1 if the census area is covered by fibre technology. All the variables are taken at the census area level. Standard errors are clustered at the travel-to-work-area level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.9: IV results - Intensive margin of WFH

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (share)	-0.113	-0.619***	-0.557***
	(0.176)	(0.233)	(0.210)
Observations	110,915	110,915	110,915
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	81.0	81.0	81.0

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.10: IV results - Duration in months of WFH

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (no. months)	-0.0126	-0.0688***	-0.0620**
	(0.0196)	(0.0267)	(0.0241)
Observations	110,915	110,915	110,915
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	53.4	53.4	53.4

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.11: IV results - In WFH until the end of 2020

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	-0.110	-0.599**	-0.539**
	(0.171)	(0.235)	(0.212)
Observations	110,915	110,915	110,915
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	43	43	43

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.12: IV results - TTWA × Area × 2-digit industry FEs

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	-0.0436	-0.377**	-0.385**
	(0.126)	(0.172)	(0.155)
Observations	107,564	107,564	107,564
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	56.1	56.1	56.1

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log labour productivity in column 2 and log TFP in column 3. All specifications include travel-to-work areas × Area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log labour productivity per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.13: IV results - TTWA × Area × 4-digit industry FEs

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	0.0193	-0.334*	-0.357**
	(0.128)	(0.174)	(0.156)
Observations	95,977	95,977	95,977
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	49.0	49.0	49.0

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log labour productivity in column 2 and log TFP in column 3. All specifications include travel-to-work areas × Area × 4-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log labour productivity per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.14: IV results - Exclude firms exiting in 2021 or 2022

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	-0.0572	-0.360**	-0.334**
	(0.117)	(0.158)	(0.141)
Observations	100,118	100,118	100,118
Firm-level controls	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	61.5	61.5	61.5

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.15: IV results - Exclude large firms (with over 250 employees)

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	-0.0875	-0.418**	-0.372**
	(0.112)	(0.164)	(0.151)
Observations	109,770	109,770	109,770
Firm-level controls	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	57.3	57.3	57.3

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.16: IV results - Medium-term effects - Sales

VARIABLES	(1) 2019-2020 Δ log(Sales)	(2) 2019-2021 Δ log(Sales)	(3) 2019-2022 Δ log(Sales)
WFH (dummy)	-0.314	-0.293	-0.166
	(0.217)	(0.250)	(0.262)
Observations	74,074	74,074	74,074
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	31.9	31.9	31.9

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, the 2019-2021 change in log sales in column 2 and the 2019-2022 change in log sales in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.17: IV results - Medium-term effects - Labour Productivity

VARIABLES	(1) 2019-2020 Δ log(VA/Empl)	(2) 2019-2021 Δ log(VA/Empl)	(3) 2019-2022 Δ log(VA/Empl)
WFH (dummy)	-0.689**	-0.665**	-0.222
	(0.300)	(0.286)	(0.281)
Observations	74,074	74,074	74,074
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA $\times$ 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	31.9	31.9	31.9

Notes: The dependent variable is the 2019-2020 change in log labour productivity in column 1, the 2019-2021 change in log labour productivity in column 2 and the 2019-2022 change in log labour productivity in column 3. All specifications include travel-to-work area $\times$ 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area $\times$ 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.18: IV results - Medium-term effects - TFP

VARIABLES	(1) 2019-2020 Δ log(TFP)	(2) 2019-2021 Δ log(TFP)	(3) 2019-2022 Δ log(TFP)
WFH (dummy)	-0.585**	-0.474*	-0.0519
	(0.266)	(0.253)	(0.250)
Observations	74,074	74,074	74,074
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA $\times$ 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	31.9	31.9	31.9

Notes: The dependent variable is the 2019-2020 change in log TFP in column 1, the 2019-2021 change in log TFP in column 2 and the 2019-2022 change in log TFP in column 3. All specifications include travel-to-work area $\times$ 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area $\times$ 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.19: IV results - High versus Low WFH potential

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy) × Low WFH potential	-0.117**	-0.226***	-0.207***
	(0.0485)	(0.0580)	(0.0504)
WFH (dummy) × High WFH potential	0.244***	0.129**	0.0500
	(0.0548)	(0.0585)	(0.0472)
Observations	110,915	110,915	110,915
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	94.1	94.1	94.1

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.20: IV results - Only manufacturing firms

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	-0.329	-0.688**	-0.712**
	(0.216)	(0.320)	(0.301)
Observations	23,683	23,683	23,683
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	16.2	16.2	16.2

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.21: IV results - Only firms in knowledge-intensive service industries

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	0.0614	-0.0484	-0.107
	(0.107)	(0.136)	(0.122)
Observations	27,855	27,855	27,855
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	42.2	42.2	42.2

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.22: IV results - Firms' size - WFH dummy

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy) × Employees <= 5	-0.100	-0.483***	-0.440***
	(0.116)	(0.158)	(0.142)
WFH (dummy) × Employees 6-10	-0.164	-0.435**	-0.389**
	(0.132)	(0.178)	(0.159)
WFH (dummy) × Employees 11-25	-0.0740	-0.390**	-0.357**
	(0.131)	(0.175)	(0.158)
WFH (dummy) × Employees >= 26	0.0145	-0.404***	-0.346**
	(0.115)	(0.153)	(0.138)
Observations	110,915	110,915	110,915
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	15.2	15.2	15.2

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.23: IV results - Firms' size - WFH share

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (share) × Employees <= 5	-0.117	-0.977***	-0.876***
	(0.199)	(0.342)	(0.307)
WFH (share) × Employees 6-10	-0.228	-0.439*	-0.418*
	(0.173)	(0.242)	(0.217)
WFH (share) × Employees 11-25	-0.116	-0.207	-0.232
	(0.164)	(0.184)	(0.166)
WFH (share) × Employees >= 26	0.0421	-0.0821	-0.0993
	(0.157)	(0.135)	(0.122)
Observations	110,915	110,915	110,915
Firm-level controls	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	17.8	17.8	17.8

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.24: IV results - Number of laptops per employee

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	-0.178	-0.311	-0.232
	(0.167)	(0.212)	(0.191)
WFH (dummy) × Laptops per employee	0.406	0.538	0.522*
	(0.255)	(0.332)	(0.306)
Observations	41,467	41,467	41,467
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	10.8	10.8	10.8

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.25: IV results - Servers-employee ratio

VARIABLES	(1) Δ log(Sales)	(2) Δ log(VA/Empl)	(3) Δ log(TFP)
WFH (dummy)	-0.296*	-0.292	-0.206
	(0.167)	(0.205)	(0.186)
WFH (dummy) × Servers per employee	0.0908	0.533*	0.482*
	(0.248)	(0.305)	(0.271)
Observations	41,163	41,163	41,163
Firm-level controls	✓	✓	✓
Counterfactual fibre control	✓	✓	✓
TTWA × 2-digit industry fixed effects	✓	✓	✓
K-Papp F-stat	12.7	12.7	12.7

Notes: The dependent variable is the 2019-2020 change in log sales in column 1, log value added in column 2 and log TFP in column 3. All specifications include travel-to-work area × 2-digit industries fixed effects as well as a set of firm-level controls taken in the year 2019 (including log employees, log value added per employee and age). Standard errors are clustered at the travel-to-work area × 2-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

B Additional Figures

Figure B.1: Validation WFH Admin versus LFS - Levels

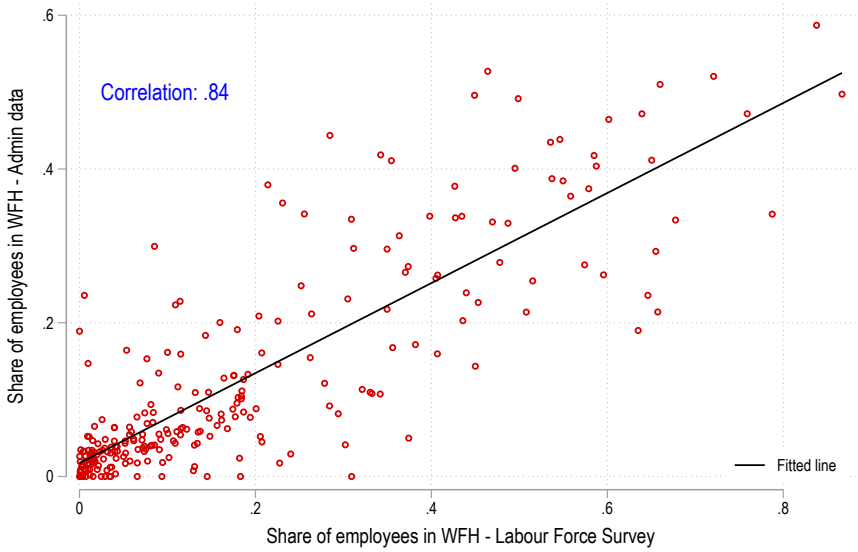


Figure B.2: Validation WFH Admin versus LFS - Changes

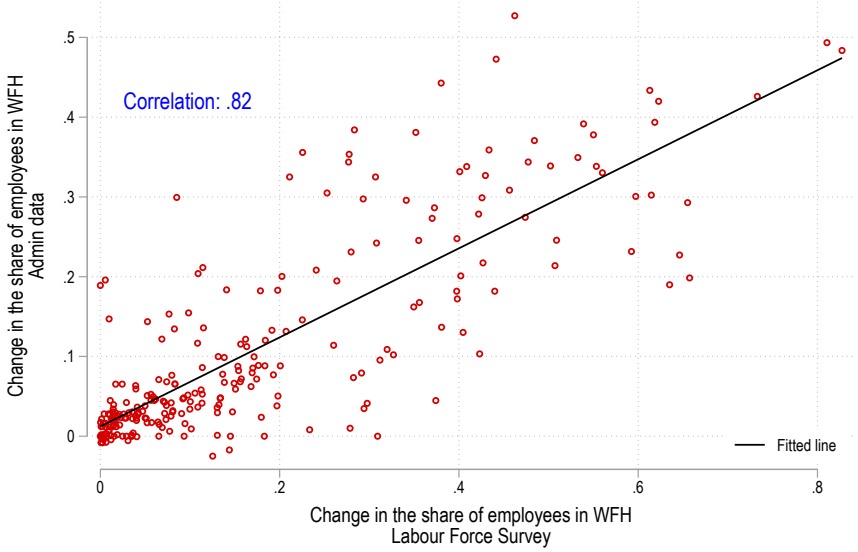


Figure B.3: Broadband coverage, by census area



Figure B.4: Location of optical packet backbone



Figure B.5: Adjacent roll-out and distance

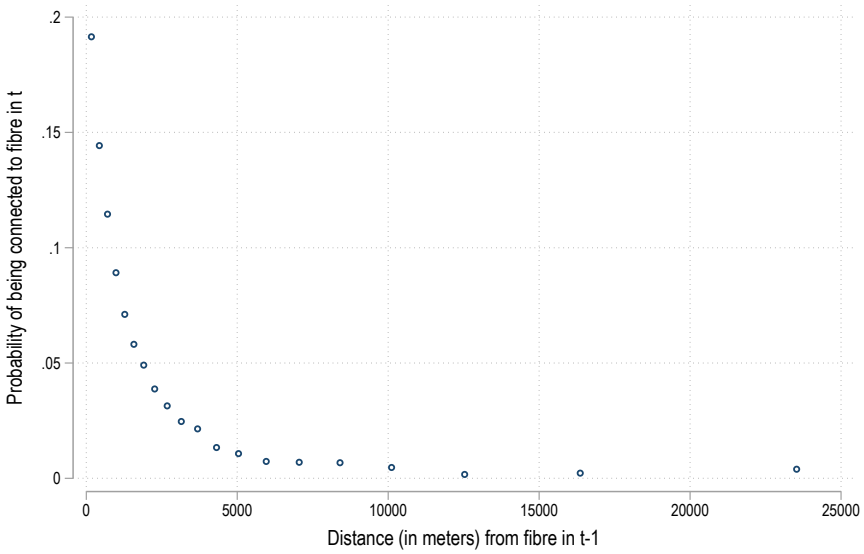


Figure B.6: Balancing tests

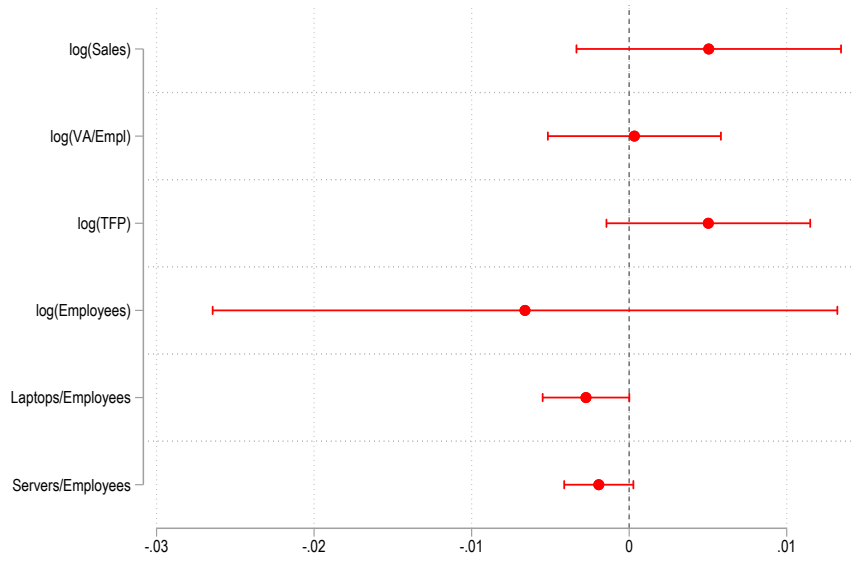


Figure B.7: Fibre technology and pre-trends

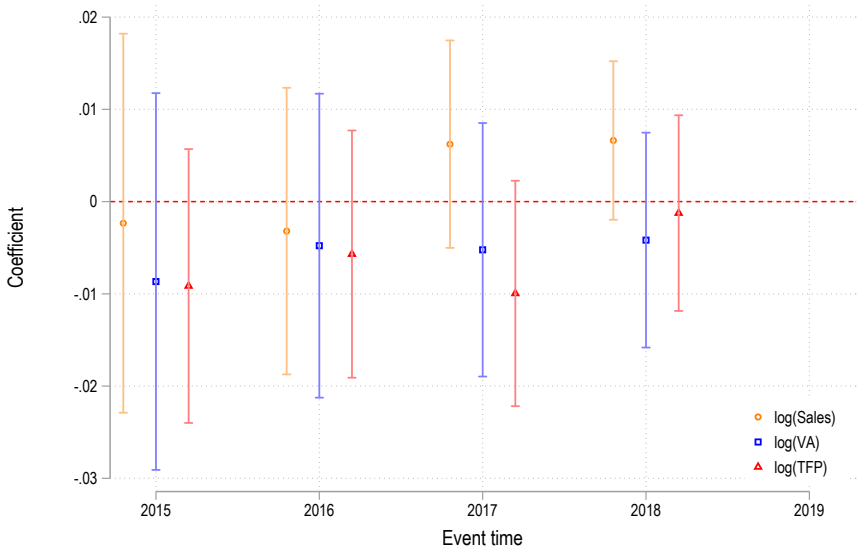


Figure B.8: Fibre technology and pre-trends - Callaway & Sant'Anna (2021)

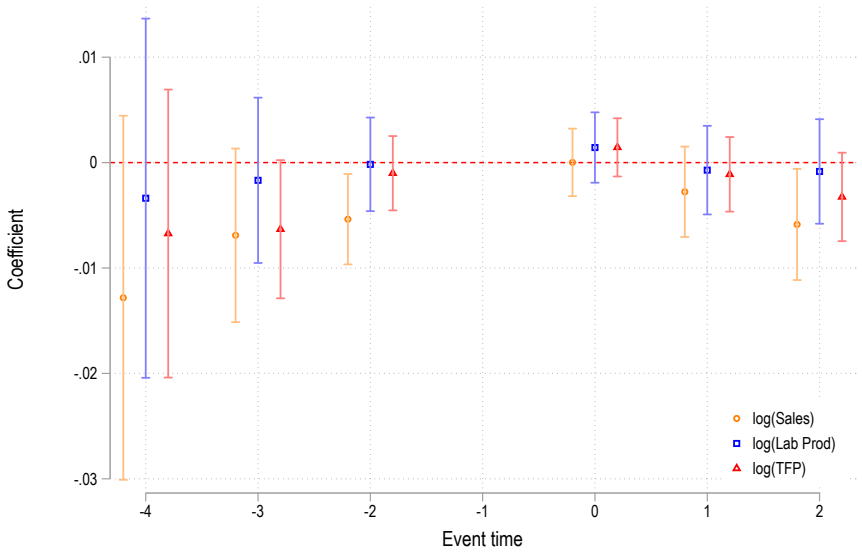
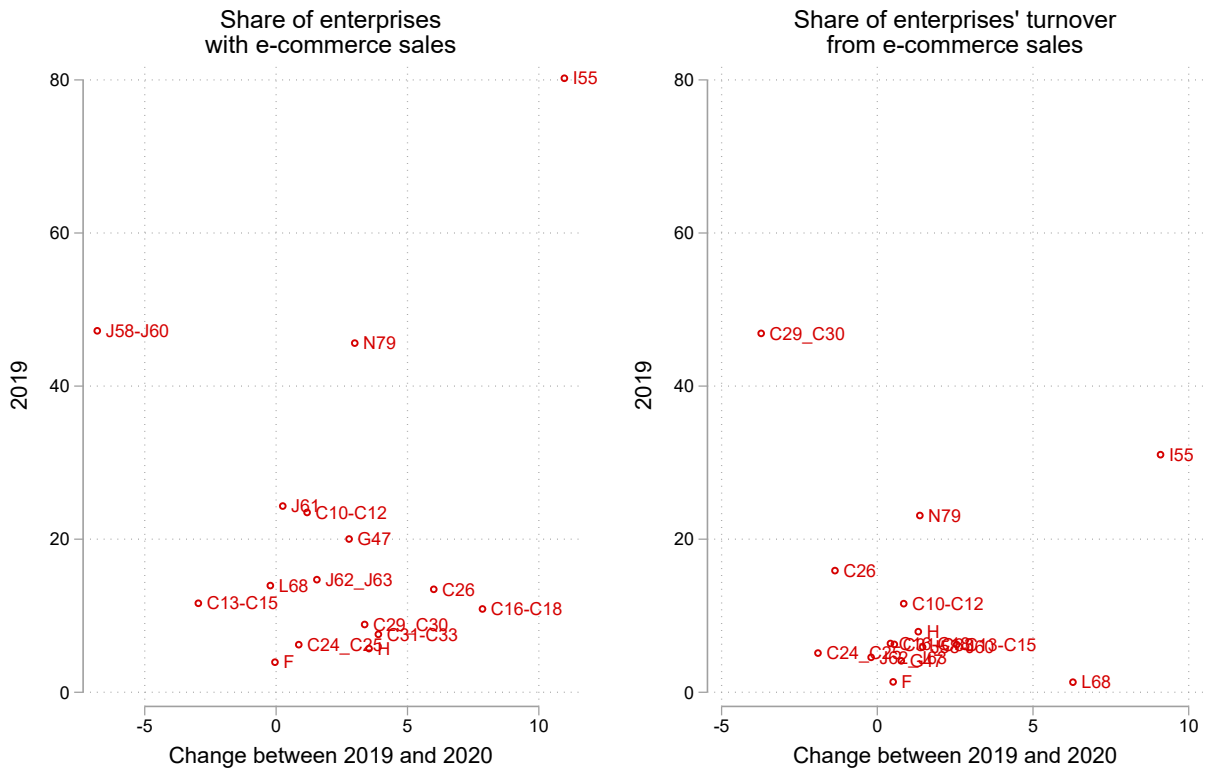


Figure B.9: E-commerce adoption, by ATECO 2-digit industries



C Orbis cleaning steps

To clean the Orbis raw data we follow and extend the Kalemlİ-Özcan et al., 2024 and Bajgar et al., 2020 cleaning procedure as follows.

- Keep accounts that refer to entire calendar years.
- Drop observations with missing information on the number of employees, operating revenue and sales (simultaneously).
- Exclude inactive firms.
- Deal with company-year duplicates as follows:
  - Drop company-year duplicates by keeping the ones with non-missing employment and revenue and with the minimum number of missing values for the set of variables used in our analysis.
  - Drop duplicate accounts of the same firm in the same year by keeping its unconsolidated account (U1 or U2).
- Exclude accounts with limited financial information (LF)
- Drop the entire company (all years) when it changes the filing of its account over the 2017-2022 period.
- Deal with outliers as follows over the 2017-2022 period:
  - Drop the entire company (all years) if total assets, employment or sales are negative in any year.
  - Exclude the entire company (all years) if its employment is larger than 1 million employees in any year.
  - Drop the entire company when reporting in any year a value of employment per million of total assets larger than the 99.9 percentile of the distribution.
  - Drop the entire company when reporting in any year a value of employment per million of sales larger than the 99.9 percentile of the distribution.
  - Drop the entire company when reporting in any year a value of sales to total assets larger than the 99.9 percentile of the distribution.
  - Drop the entire company when reporting in any year a ratio of sales, number of employees or revenue to the previous year that is larger than the 99.9 percentile of the distribution.

– Drop the entire company when reporting for number of employees, total assets, sales and operating revenue a max/min ratio with a value 10 times higher than the median.