Department of Geography and Environment

Papers in Economic Geography and Spatial Economics

How many jobs can be done at home? Not as many as you think!

Riccardo Crescenzi, Mara Giua and Davide Rigo

Paper No. 37
Geography and Environment Discussion Paper Series

November 2022

Editorial Board

Published by
Department of Geography and Environment
London School of Economics and Political Science
Houghton Street
London
WC2A 2AE

geog.comms@lse.ac.uk
www.lse.ac.uk/Geography-and-Environment

How many jobs can be done at home? Not as many as you think![*]

Riccardo Crescenzi
Department of Geography and Environment
London School of Economics, UK
r.crescenzi@lse.ac.uk

Mara Giua
Department of Economics
Roma Tre University, Italy
mara.giua@uniroma3.it

Davide Rigo
Department of Geography and Environment
London School of Economics, UK
d.rigo@lse.ac.uk

Abstract

COVID-19 has dramatically accelerated the uptake of work-from-home (WFH) practices worldwide. However, there is no consensus on the importance of this phenomenon for workers and firms. Unique administrative data on the universe of Italian workers make it possible to assess for the first time the actual diffusion of WFH across sectors, regions and firms. Our data show that 12% of workers have in fact worked from home at the peak of the pandemic in 2020, suggesting that existing studies overestimate the share of jobs that can be undertaken remotely by at least 50%. We also provide suggestive evidence that existing studies are unable to account for technological and cultural barriers that in practice prevent firms and workers from adopting WFH practices.

Keywords: Work-from-home; Remote work; Teleworking; COVID-19.

[*]The authors gratefully acknowledge help, support and guidance by the Italian Ministry of Work and Social Policies. This project is developed as part of the framework "Convenzione per attività di monitoraggio sugli impatti della crisi occupazionale nelle imprese a seguito dell'emergenza epidemiologica da COVID-19 e analisi della rilevanza del lavoro agile nella mitigazione degli effetti economici del Coronavirus" between the Italian Ministry for Work and Social Policies and Roma Tre University. Input and insights by Grazia Strano, Daniele Lunetta and Giacomo Masi are gratefully acknowledged. The authors remain responsible for all errors and omissions included in the paper. This project has received funding under the COVID-19 Rapid Response Funding made available by the London School of Economics.

1 Introduction

From the early days of the COVID-19 crisis, throughout the resulting lockdowns and continuing into the present, work-from-home (WFH) has become a necessary practice for many firms and workers. While the transition to remote working is expected to have an enormous impact on our economies (Barrero, Bloom, & Davis, 2021), the literature has not reached a consensus on the magnitude of this change (Brynjolfsson et al., 2022). Our main contribution here is to document the diffusion of WFH practices in a major advanced economy by leveraging unique population data and to compare our aggregate remote work figures with existing estimates based on survey data.

The rise in homeworking due to COVID-19 has disrupted the need for geographical proximity between workers and firms by enabling firms to tap into a global labour pool (Baldwin & Forslid, 2020). As a result, teleworking may become a catalyst for a collective reorganisation of work, potentially pushing firms and workers to relocate away from expensive cities (Althoff et al., 2022; Coven, Gupta, & Yao, 2021; De Fraja, Matheson, & Rockey, 2021; Delventhal & Parkhomenko, 2020; Ramani & Bloom, 2021). WFH has also weakened the link between individuals and their workplaces, with profound implications for face-to-face interactions, team work, managerial oversight and the exchange of knowledge and ideas. The consensus in the literature is that knowledge spillovers depend heavily on face-to-face interactions, which improve the flow of information and therefore facilitate innovation (Storper & Venables, 2004). The impact of teleworking, which reduces the number (and often the nature) of in-person interactions, is expected to have an impact on productivity and innovation. Finally, since the clustering of workers and firms is a strong contributor to urbanisation and the rise of knowledge-intensive economic structures (Duranton & Puga, 2020), teleworking may also re-balance regional disparities within countries, with core regions which may lose the collective benefits of interactions among firms and workers.

A first step to answer these fundamental questions about modern economies is to quantify how many jobs can be performed from home. Given the lack of official statistics all existing analyses of WFH and its diverse impacts on economies and societies across the globe have relied on estimates based on survey data. Conversely, this paper sheds new (and alternative) light on WFH by leveraging for the first time official population data on WFH in Italy, offering unique evidence on the actual number of jobs undertaken from home during the 2020 lockdown. In particular, this

paper makes two main contributions to the existing literature. First, it documents with hitherto unexplored administrative data novel stylised facts about the adoption of remote working. Second, it benchmarks recent estimates on the share of jobs that can potentially be done from home to the actual share of jobs that were done from home. By exploring the differences between potential and actual measures, we provide suggestive evidence that firms and territorial characteristics may favour or hamper the adoption of WFH.

During the first lockdown in Italy (March-May 2020), around 2.4 million employees worked remotely, accounting for roughly 12% of the Italian workforce. Our figure is in line with Eurostat's estimates on WFH for Italy: the percentage of employed persons (aged 15 to 64) who usually work from home is estimated to be at 12.2% in 2020. However, the actual share of WFH is significantly lower than the potential share circulated so far on the basis of national survey data on occupational characteristics. Looking at the Italian case, recent studies have estimated that 25% to 50% of jobs could potentially be performed from home. Our finding suggests that these studies have overestimated the share of jobs that can be undertaken remotely by at least 50%.

The discrepancy between 'real' and 'potential' figures on remote working may be reconciled by the fact that firms' decisions to rely on WFH during the COVID-19 pandemic were not automatic, depending crucially on firms' internal and external factors. In relation to WFH practices, the key 'enabling' technology that has been identified in the literature is the availability of a fast internet connection between the firm and its employees' homes (Andrews, Nicoletti, & Timiliotis, 2018; OECD, 2020). In addition, security software, such as Virtual Private Networks (VPN) and virtual desktop applications, needs to be in place to safeguard the integrity and safety of firms' data and systems. These enabling technologies also need to be associated with workers' characteristics and firms' organisational flexibility (Brynjolfsson, Rock, & Syverson, 2019). In particular, the literature shows that a lack of ICT skills in the workforce is a barrier to the adoption of new technologies (Autor, Levy, & Murnane, 2003; Bartel, Ichniowski, & Shaw, 2007; Machin & Van Reenen, 1998). As a result, a task that potentially can be done from home might be tele-workable only for those firms with the capacity to do so (*firm specificities*), moreover located in a supportive territorial context in terms of communication infrastructure and other characteristics (*local specificities*).

By exploiting the granularity of our population data, this paper studies for the first time the importance of firm and local specificities in determining the adoption of WFH practices. Firstly, we

find that existing measures proxy better actual WFH figures for those Italian regions with higher living standards and accounting for a large share of Italian GDP, suggesting that unobserved factors determining WFH go hand in hand with the economic development of the local economy where firms are located. Secondly, by linking the universe of workers in WFH with their employers, we document a strong firm-level heterogeneity in the adoption of digital practices. We find that the use of remote working is more common among larger and more productive firms. In particular, we find that 70% of large firms (those with 250 or more employees) had at least one worker teleworking during the 2020 lockdown, while only 1% of micro firms (those with fewer than 10 employees) adopted WFH practices. Our evidence highlights that existing studies, based on survey data (Alipour, Fadinger, & Schymik, 2021; Dingel & Neiman, 2020), are unable to capture the different forms of heterogeneity in the feasibility of working from home across firms and territories, significantly over-estimating this phenomenon.

This paper is structured as follows. Section 2 reviews the recent literature measuring the potential for WFH during the COVID-19 crisis. In Section 3, we describe the Italian institutional setting during the pandemic in 2020. Section 4 describes the data sources used in our analysis, including our unique data on the universe of workers working remotely. In Section 5, we present novel stylised facts about the adoption of WFH during the pandemic, and Section 6 concludes.

2 Related Literature

Since the wake of COVID-19, many studies have focused on measuring the extent to which different occupations can be pursued in WFH regimes. National survey data on occupational characteristics (e.g. the O*Net data for the US, or the Italian Sample of Survey on Professions for Italy) have been predominantly leveraged both in academic studies[1] and policy reports[2] in order to identify those occupations that, given their characteristics (such as ICT intensivity), have the highest potential to be pursued from home. These surveys ask respondents a very broad set of questions on the activities being performed by workers and on the characteristics of their occupations. For instance, to identify WFH-prone occupations, these studies discriminate between occupations which require

[1] For the US (Dingel & Neiman, 2020), for Italy (Barbieri, Basso, & Scicchitano, 2022; T. Boeri, Caiumi, & Paccagnella, 2020), and for a set of developing countries (Gottlieb et al., 2021).

[2] For example, this OECD report on WFH available at this link.

outdoor work or manual vehicle operation from those that do not. Finally, using aggregate data on employment (e.g. Labour Force Survey for European countries, or Bureau of Labor Statistics for the US), these studies estimate the share of total jobs that can be done from home.

Based on this approach, Dingel and Neiman (2020) (hereafter DN) suggest that 33% of jobs in Italy could be performed entirely by working from home. Using the same methodology, T. Boeri, Caiumi, and Paccagnella (2020) estimate that between 24% to 49% of Italian jobs could potentially be carried out at home based on different lockdown constraints (from total lockdown to relaxing mobility constraint and no-contact constraint). Finally, Barbieri, Basso, and Scicchitano (2022) (hereafter BBS) estimate that 35% to 49% of Italian employees could potentially work remotely, depending on more or less conservative assumptions.

However, two important limitations of these studies can be identified for the purpose of this paper. First, the share of tasks that can be done from home is assumed to be constant within each occupation. Existing studies are unable to capture any within-occupation heterogeneity in the feasibility of working from home across firms. For instance, Adams-Prassl et al. (2020) and Alipour, Fadinger, and Schymik (2021) find that occupations can only explain 20% to 27% of the variation in the share of tasks that can be undertaken from home. Second, these measures are based on some ad hoc assumptions in the identification of occupations that can be done at home. As a result, changing the set of questions, used to identify potential WFH occupations, leads to very different results.

Other studies draw on country-specific representative surveys (usually run by national statistical offices) that directly report on workers' home-working practices before the COVID-19 outbreak (such as the American Time Use Survey for the US or the Office for National Statistics' Annual Population Survey for the UK). These surveys have been used to derive industry and regional measures of WFH for Germany (Alipour, Fadinger, & Schymik, 2021), the US (Hensvik, Le Barbanchon, & Rathelot, 2020) and the UK (Watson, 2020). These measures rely on employees' own assessment concerning the feasibility of performing their jobs from home, which are aggregated at the occupational level and then combined with administrative data on occupational employment counts. The obvious limitation is that these measures are entirely retrospective and not sensitive to actual changes in WFH patterns observed during the COVID-19 crisis, that acted as a powerful push factor for firms' decisions regarding the adoption of new technologies and work arrangements.

Finally, online surveys of individuals aimed at collecting information on WFH have been set for the US, such as the Survey of Working Arrangements and Attitudes (Barrero, Bloom, & Davis, 2021), the Real-time Population Survey (Bick, Blandin, Mertens, et al., 2020), or the Remote Life Survey (Brynjolfsson et al., 2022), and for the UK (Adams-Prassl et al., 2020). For instance, Brynjolfsson et al. (2022) find that nearly half of the individuals they surveyed said they were working remotely, including 35% who reported they were commuting and recently switched to working from home. Still, for the US, Barrero, Bloom, and Davis (2021) determined that 20% of full workdays will be supplied from home after the pandemic ends, compared with just 5% before. The key limitation of these studies is that the workers who can work remotely are inevitably over-represented in online surveys. However, these surveys provide unique and detailed information on WFH, complementing our work.

3 Institutional Setting

Italy was the first advanced Western economy to be severely affected by the COVID-19 pandemic, triggering immediate reactions by the Italian government that imposed regional and national restrictions. On 9th March 2020, the Italian government imposed a national quarantine, mandating the temporary closure of all non-essential shops and businesses. On 22nd March the Government published a list of industrial activities (only marginally updated on 25th March and 10th April) to be considered as 'essential': only firms operating in industries included in this list were allowed to operate, while firms in all other industries had to cease their activities with immediate effect. Until 18th May, when the Italian Government ordered the gradual reopening of the the economy and the relaxation of lockdown restrictions.

The progressive lockdown of different areas of the country and compulsory social distancing measures have pushed firms to identify new ways to run their businesses and continue with their core activities. In order to maintain their operational capacity, firms needed to create technical and managerial conditions for their employees to be able to work from home (alternative options being quitting their activities with consequent furlough leave, salary reductions or redundancy). Firms were faced by this choice at different points in time in different local areas and sectors, depending on the restrictions imposed by the Italian government.

In addition, Italy is an interesting case study due to its very low adoption of WFH prior to the pandemic. Given the low propensity to work from home, Italy is one of the European Union (EU) member states with the largest proportion of workers switching to WFH arrangements in response to the pandemic (Eurofound, 2020). According to Eurostat, the percentage of Italian workers who usually work from home was roughly 4% in 2017, one of the lowest shares among EU countries.[3] The lower adoption of flexible working arrangements is mainly due to the nature of the Italian industrial system, characterised by the presence of mostly micro and small enterprises, and to the cultural and institutional resistance to the adoption of digital technologies. For example, Schivardi and Schmitz (2020) argue that the Italian divergence in productivity with respect to other advanced European countries may be due to the failure of Italian firms to take advantage of the ICT revolution.

4 Data

To quantify the importance of WFH during the pandemic, this paper leverages a unique data source on the official (real time) notifications submitted by individual firms regarding employees that are (voluntarily or not) working from home. This is established by law[4] since firms have a legal duty to report all workers fully or partially working from home in order to guarantee their insurance coverage with INAIL (National Institute for Insurance against Accidents at Work). Since 1st March 2020, due to COVID-19, the notification procedure has been simplified, with firms needing to submit only an online declaration with information on the firm's tax identifier, workers' details, start and end date of the WFH period, and occupation based on INAIL 4-digit classification. Each declaration also includes the firm's geographical location and its industry classification (ATECO 2007 6-digit).

This dataset allows us to reconstruct the population of employees working from home and track its evolution over time. The data are high quality and require minimal cleaning. The only adjustment from the original data is the exclusion of those tax identifiers in the public administration (e.g. schools, governmental agencies, etc.) to focus our analysis on the universe of private sector workers.

[3] For more statistics on the adoption of WFH practices across EU countries, see the Eurostat website at the following link.

[4] Here is the link to the law.

In the empirical analysis, this condition is operationalised by excluding those firms operating in the 2-digit NACE rev. 2 codes 84 and 85.

With the aim of deriving the shares of jobs done from home (to be compared with the shares of jobs that can be potentially done from home), we merge our dataset with occupational employment data for Italy provided by the Labour Force Survey (LFS) conducted by ISTAT (Italian Statistical Institute). The LFS is a large household sample survey providing quarterly results on labour participation of people aged 15 and over as well as on persons outside the labour force. The LFS covers all industries and occupations, providing us with a complete picture for Italian workers. The shares are calculated as follows: the numerator includes all employees who were reported by their firms as working from home at least 1 day in the March-May 2020 period, while the denominator is based on aggregate employment statistics from the Italian Labour Force Survey for the year 2019.

Finally, by using the unique firms' tax identifier, we are able to match data on the population of employees working from home with balance sheet information (value added, number of employees, sales, turnover, tangible fixed capital and cost of production) on their employers and the list of all their workers' occupations (at the 4-digit level) from INAIL. The source of firms' financials is Orbis (by Bureau Van Dijk), which provides very good coverage of Italian firms with at least 10 employees (Bajgar et al., 2020; F. Boeri, Crescenzi, & Rigo, 2022). The only modification to the original data is to drop firms that appear more than once in the dataset (as done in Bajgar et al. (2020)). 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).

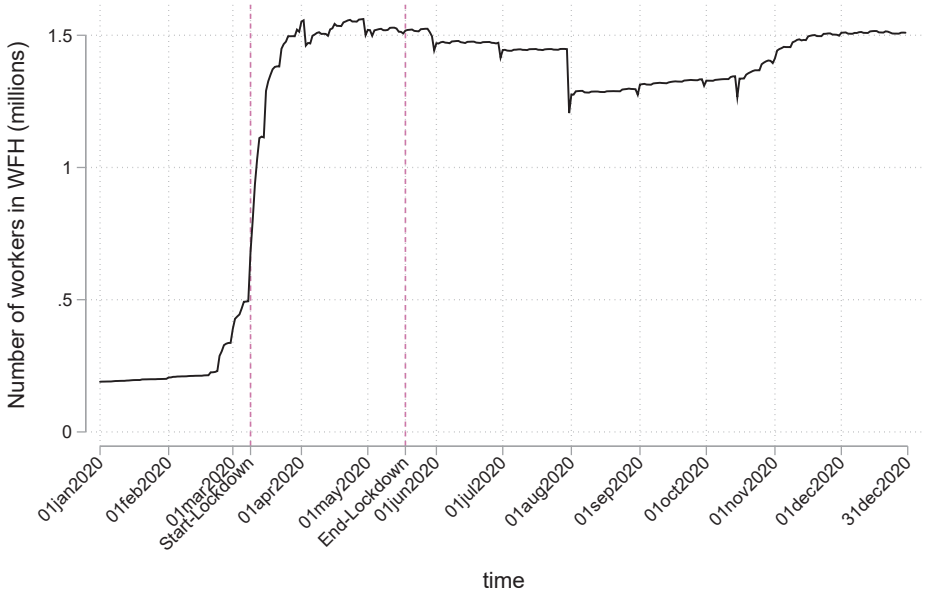
5 Results

This section presents our main findings. First, we present evidence on WFH for the whole country and over time. Second, we benchmark our findings on WFH with existing measures from the literature applied to the Italian economy as a benchmark. Third, we look at the heterogeneity in remote working across (1-digit) industries and Italian sub-national regions. Fourth, we merge our data on WFH with firm-level information (from Orbis) in order to present some initial insights on how firm-level characteristics shape the probability of adoption of these digital practices.

Aggregate evidence. Using our unique dataset on the universe of WFH declarations for all Italian employees, we find that, as a result of COVID-19, around 2.4 million workers were working from home and roughly 100,000 private firms have had at least one worker working remotely during the pandemic in 2020. Figure 1 shows the number of workers working from home during the January-December 2020 period. With the start of the Italian lockdown (on 9th March), the number of workers working remotely increased exponentially. At the beginning of 2020, only 200,000 workers were working from home. By the end of March however, 1.6 million workers were adopting WFH practices. Interestingly, the number of employees working remotely started increasing by the end of February 2020. This trend coincides with the first cases of COVID-19 discovered in Northern Italy which resulted in the first localised lockdowns in Lombardy, Emilia-Romagna, Friuli-Venezia Giulia, Veneto, Piedmont and Liguria towards the end of February. Moreover, the number of workers working from home only slightly decreased during the Summer of 2020. This implies that even after the end of the very restrictive lockdown measures imposed on Italian citizens, firms opted for a conservative approach keeping their employees at home following the adoption of this regime in the emergency phase. With the second wave of COVID-19 infections (beginning in the Autumn of 2020) the number of WFH jobs jumped back to its peak.[5]

[5]To note that the drops observed at the end of every month are mainly due to an accounting procedure, with firms declaring when their workers work from home at the end of each month (and week).

Figure 1: Number of workers working from home, January-December 2020, millions.



Note: This figure shows the number of jobs done at home during the COVID-19 pandemic (January-December 2020). To smooth the pattern of workers working remotely, we set the worker as working from home when the firm does not provide a declaration for up to 7 days in between two declarations. Firms operating in NACE rev. 2 codes 84 and 85 are excluded from this analysis.

We also look at firms' responsiveness to the pandemic restrictions, by identifying the number of days elapsed before firms could reach the peak in the share of their employees working from home following the Government ban on their in-person operations.[6] For the median firm, it took less than one month (22 days) to reach its peak. The same analysis across industries highlights that manufacturing firms were slower in reaching their peak compared to firms in skill-intensive industries, such as financial & insurance and information & communication. This finding might also be related to differences in organisational complexity across industries, with firms managing many occupations (as in the manufacturing sector) taking more time to organise their WFH activities, contrary to knowledge-intensive services industries which mainly rely on office workers.

Thanks to the granularity of our data, we also have information on workers' 4-digit occupations. We use this information to describe the main tasks performed by the workers in WFH. We find that 80% of employees working from home used to work in an office before the pandemic. By

[6]The starting point to count the number of days is 1st March 2020.

examining the distribution of these broad occupational categories across all firms, we learn that the distribution is skewed, with more than 75% of firms having only one 4-digit occupation with at least one worker working from home. This evidence highlights even further the constrained potential of working from home, which is limited to certain industries and occupations.

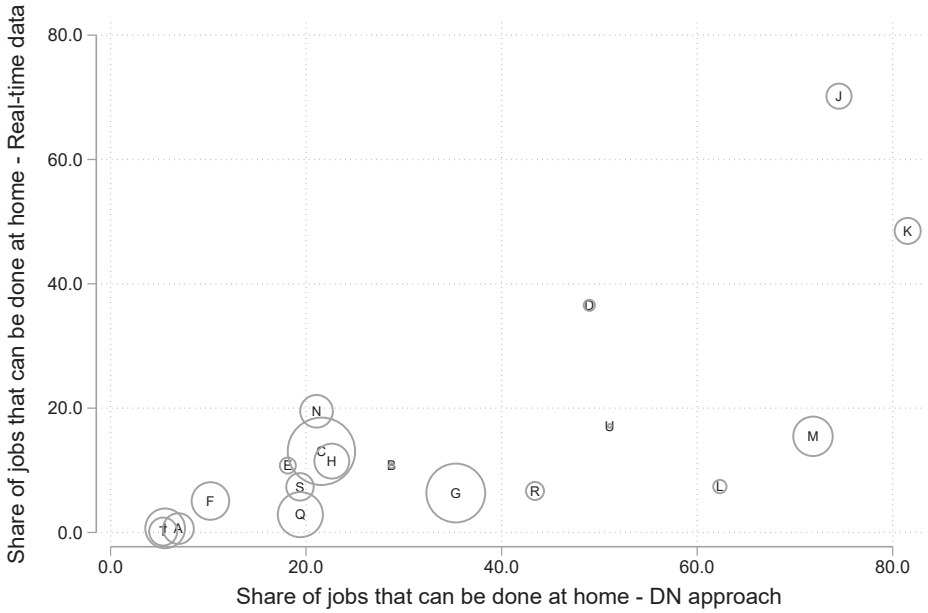
Potential vs actual WFH. If we benchmark the total number of employees working from home during the pandemic with official statistics on the total number of employees and firms from ISTAT, we find that roughly 12% of the total workforce was working from home during the 2020 lockdown. This finding suggests that the existing literature has significantly overestimated the diffusion of WFH practices. Recent studies have estimated that at least 25% of jobs could potentially be done from home in Italy during the pandemic. This gap is also apparent when looking at the share of jobs done from home across industries. First, we find that in Italy firms more prone to WFH are active in finance & insurance, information & communication and energy supply. These are high-skilled industries, consistent with the evidence in the literature that high-skilled intensive occupations (e.g. managers and professionals) rely the most on WFH practices.[7]

Second, in Figure 2, we compare our results with the shares of jobs done at home based on DN, and we find large and heterogeneous differences across industries. The task-based measures proposed in the literature work better for industries prone to WFH, such as information & communication, administrative & support services and energy supply, as well as for manufacturing, construction and water supply.[8] DN are, however, significantly overestimating the share of jobs that could be done from home in key industries during the crisis, such as wholesale & retail and accommodation & food service activities. These differences could also be partially explained by the fact that firms in some of these industries provided essential services which were allowed to operate during the lockdown. However, the magnitude of the overall gap between potential and actual population-based measures remains significant and deserving of further exploration.

[7] Alipour, Fadinger, and Schymik (2021) show for Germany that having management responsibilities and using computers at work are strongly associated with the possibility of WFH. Holding an academic degree also increases the chance both of having a WFH feasible job and engaging in remote work Mongey and Weinberg (2020).

[8] See Table A2 in Appendix, for a complete overview of these differences across industries.

Figure 2: Potential vs actual WFH shares, by industry of activity (1-digit).



Note: This figure shows the actual share of jobs done at home during the COVID-19 pandemic (March-May 2020) and DN's share of jobs that could be done at home across 1-digit NACE rev. 2 industries. These shares are weighted by their employment level. Firms operating in NACE rev. 2 codes 84 and 85 are excluded from this analysis.

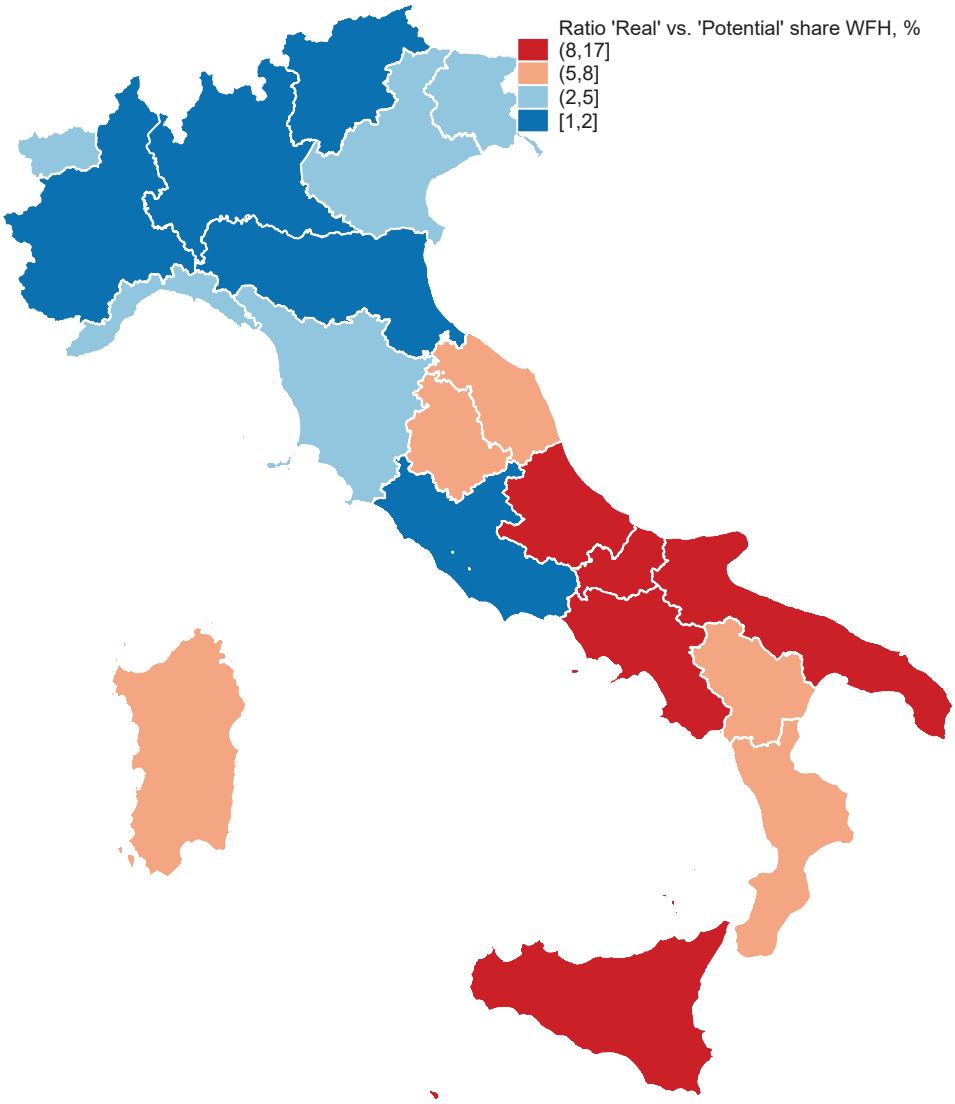
Now we turn our attention on the potential mechanisms explaining these large differences. In particular, we focus on the analysis of two dimensions, local and firm characteristics, as determinants of the differences between what can be done potentially given the occupation, and what actually happened when firms were forced to adopt WFH in order to be able to operate during the 2020 lockdown.

Local specificities. By looking at the share of jobs done from home across Italian regions, we see a stark divide between Northern and Southern regions. While in Lazio and Lombardy, which are service-intensive regions, more than 21% of workers adopted WFH practices during the lockdown, in Calabria, Molise, Apulia and Sicily only 2% of workers worked from home. This finding could be explained by both differences in industrial composition (with northern regions characterised by a higher share of knowledge intensive industries), and the lower adoption of digital technologies in

Southern regions. Figure 3 highlights the stark difference in shares between DN and our results.[9] For instance, the ratio equals 1.5 for Lombardy, telling us that DN's WFH share is one and a half the actual WFH share. Similarly, the task-based measures seem to fit the actual importance of WFH better for those regions in the North of Italy (plus Lazio, with the Capital City Rome). These regions have higher living standards and account for a large share of Italian GDP, suggesting that potential unobserved factors determining WFH may go hand in hand with the level of economic development of the local regional economy. This finding is consistent with DN and Gottlieb et al. (2021), showing that lower-income economies have a lower share of jobs that can be undertaken at home.

[9] As done for industries, Table A1 in the Appendix shows a comparison between DN, BBS and our WFH shares.

Figure 3: Potential vs actual WFH shares, by NUTS-2 regions.

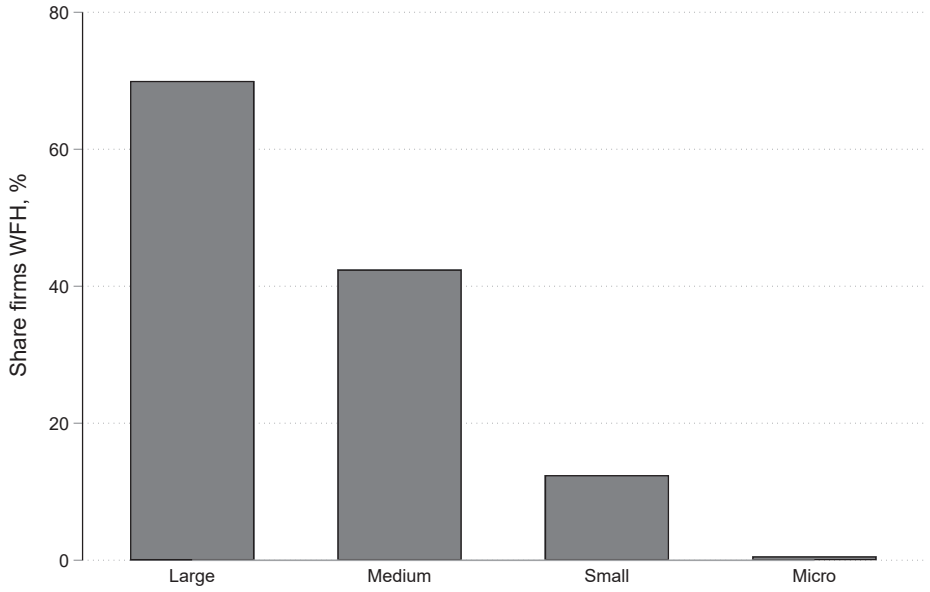


Note: This figure reports the ratio between the share of jobs done at home during the COVID-19 pandemic (March-May 2020) and DN's share of jobs that can be done at home across NUTS-2 regions. Firms operating in NACE rev. 2 codes 84 and 85 are excluded from this analysis.

Firm specificities. Firms are ultimately the entities deciding whether to adopt digital practices in their activities. Thanks to matched Orbis data, we shed light on the characteristics that make firms more prone to employ WFH practices. Figure 4 shows that remote working is more widespread

among larger firms, with 70% of *large* firms using WFH during the 2020 COVID-19 crisis. Instead, *micro* firms (with fewer than 10 employees) rarely adopted WFH. Relying on an econometric analysis (see Section C in Appendix), we find suggestive evidence that this finding may be driven by the fact that larger firms are more 'ready' to adopt WFH practices due to better managerial and organisational practices.

Figure 4: Share of firms adopting WFH, by size.



Note: This figure shows the share of firms adopting WFH practices during the COVID-19 pandemic by size. Firms' size is measured based on their number of employees: *Micro* denotes firms with fewer than 10 employees, *Small* denotes firms with 10 or more and fewer than 50 employees, *Medium* denotes firms with 50 or more and fewer than 250 employees and *Large* denotes firms with 250 or more employees. Firms operating in NACE rev. 2 codes 84 and 85 are excluded from this analysis. Firms' financials are based on information for the year 2019.

To shed further light on the determinants of working from home, we investigate if and how firms' size, productivity, age and organisational complexity affect their capacity for WFH. Hence, we estimate the following specification at the firm level:

$$WFH_i = \alpha + \beta_1 ln(Size_i) + \beta_2 ln(LabourProd_i) + \beta_3 Young_i + \beta_4 Occupations_i + \varepsilon_i. \quad (1)$$

Where WFH_i is one of the following outcome variables identifying different dimensions of the

phenomenon of WFH: i) a dummy variable indicating whether the firm i has at least one worker working from home (i.e. extensive margin of WFH), ii) the log of the number of workers working from home and iii) the number of broad occupations with at least one worker working remotely. As explanatory variables, we include the (log) number of employees (as a measure of a firm's size), the (log) of sales per worker (as a measure of labour productivity), a dummy variable indicating whether the firm has 9 or fewer years of age and the number of broad occupations at the firm level (as a measure of a firm's organisational complexity).[10] We also control for industry (2-digit NACE rev. 2) and region (NUTS-3) fixed-effects to account for differences in the propensity of WFH across industries and Italian provinces. We estimate this model using OLS for analysing the probability of firms to undertake WFH. Instead, we use the PPML estimator, proposed by Silva and Tenreyro (2006), for studying the intensive margin of working from home due to the large presence of zeros.[11]

We present the results of this analysis in Table 1. We find that larger, older and more productive firms were more likely to engage in WFH during the crisis. Also, a firm's organisational complexity (proxied by the firm's number of broad occupations) is positively associated with the capacity of the firm to adopt WFH.[12] In columns 2 and 3, we look at the intensive margin of WFH, and we find qualitatively similar coefficients. These results are consistent with the OECD (2020), showing that larger and more productive firms in Germany were more likely to use trust-based working time arrangements (their proxy for the adoption of WFH practices).[13] This evidence suggests that the task-based measures, currently dominant in the literature, are unable to capture the heterogeneity in the feasibility of WFH across firms.

[10]Since the latter variable is available only for a subset of firms, below we also report the regression tables on the whole sample. The results are qualitatively and quantitatively consistent.

[11]Table A3 in the Appendix presents basic summary statistics for the variables included in our empirical analysis.

[12]When excluding our measure of organisational complexity, available for only a sub-sample of firms, the results are qualitatively and quantitatively consistent. See Table A4 in the Appendix.

[13]Our main conclusions are confirmed also when looking only at the sample of manufacturing firms (except for the variable $Young$). See Table A5 in Appendix which estimates equation 1 only for the manufacturing sector.

Table 1: Firm-level determinants of WFH, all industries.

	(1)	(2)	(3)
VARIABLES	WFH (dummy)	# workers WFH	# 4-digit Occ WFH
# workers (log)	0.0785***	1.133***	0.600***
	(0.000374)	(0.0114)	(0.00518)
Sales/workers (log)	0.0197***	0.0935***	0.262***
	(0.000338)	(0.0187)	(0.00687)
Young	-0.00339***	-0.293***	-0.123***
	(0.000577)	(0.0366)	(0.00931)
# 4-digit occupations	0.00809***	0.0200**	0.0791***
	(0.000404)	(0.00837)	(0.00826)
Observations	682,079	682,079	681,307
MODEL	OLS	PPML	PPML

Note: This table presents the estimated coefficients from equation 1 across different dependent variables. The dependent variable in Column 1 is a dummy indicating whether the firm was adopting WFH practices during the COVID-19 pandemic; in Column 2, the number of workers working remotely during the COVID-19 pandemic; in Column 3, the number of 4-digit occupations with at least one worker working remotely during the COVID-19 pandemic. All specifications include NUTS-3 regions and 2-digit industry fixed effects and are estimated using OLS or PPML. Firms operating in NACE rev. 2 codes 84 and 85 are excluded from this analysis. Firms' financials are based on information for the year 2019. Robust standard errors in parentheses. The p-values read as follows: *** p<0.01, ** p<0.05, * p<0.1.

6 Conclusions

The COVID-19 pandemic has altered firms' and workers' behaviours, accelerating the uptake of WFH practices across the world. To quantify the importance of this phenomenon, we rely on a unique administrative dataset on WFH for a large advanced economy (Italy). To the best of our knowledge, Italy is the only advanced economy that, due to its unique labour law and administrative procedures, has systematically collected data on the population of employees working from home. Italy is also a unique case study, given its early exposure to COVID-19 and the corresponding adoption of restrictive measures for in-person activities. The analysis of this new dataset shows that

roughly 12% of Italian workers worked remotely during the lockdown imposed in 2020. Importantly, the actual share of WFH was significantly lower than the potential for WFH, as predicted by task-based measures developed in the literature. We also find that there are large differences in WFH adoption across Italian sub-national regions and firms, with larger and more productive firms being more likely to adopt WFH practices. This evidence suggests that the discrepancy between potential and actual WFH shares is partly explained by the heterogeneity in the adoption of WFH across firms and places.

Accurately quantifying the role played by WFH during the pandemic is crucial to shed light on the prevalence of this phenomenon. Moreover, acknowledging and understanding the limitations of task-based indicators may inform a number of current scholarly and policy debates, ranging from the future of work and cities to economic resilience to future pandemics and other natural shocks. All these debates need to rely on realistic and accurate measures of the diffusion and adoption of WFH, its heterogeneity across sectors and space and its impeding factors. For instance, correctly measuring WFH adoption is crucial when evaluating its impact on agglomeration economies, given the risks of over-estimating the effects of remote working on aggregate productivity or regional disparities.

Finally, the evidence presented in this paper suggests that public policies cannot assume the generalised demise of the physical workplace. The large majority of workers, given current technological, infrastructural and organisational conditions, need physical presence in order to pursue their daily tasks. For this reason, many employees still require physical offices and supportive transport infrastructure. This also makes them (and their firms) more exposed to the economic impacts of possible future shocks than envisaged on the basis of more optimistic measures of WFH adoption. In order to support an inclusive digital transition, public polices should pro-actively target the removal of barriers to the adoption of digital practices in the workplace along systemic (spatial and sectoral) and micro firm-level lines.

References

Adams-Prassl, A., Boneva, T., Golin, M., & Rauh, C. (2020). Inequality in the impact of the coronavirus shock: Evidence from real time surveys. *Journal of Public economics*, *189*, 104245.

Alipour, J.-V., Fadinger, H., & Schymik, J. (2021). My home is my castle–the benefits of working from home during a pandemic crisis. *Journal of Public Economics*, *196*, 104373.

Althoff, L., Eckert, F., Ganapati, S., & Walsh, C. (2022). The geography of remote work. *Regional Science and Urban Economics*, *93*, 103770.

Andrews, D., Nicoletti, G., & Timiliotis, C. (2018). Digital technology diffusion: A matter of capabilities, incentives or both? *OECD Economics Department Working Papers*, *No. 1476*.

Autor, D. H., Levy, F., & Murnane, R. J. (2003). The skill content of recent technological change: An empirical exploration. *The Quarterly Journal of Economics*, *118*(4), 1279–1333.

Bajgar, M., Berlingieri, G., Calligaris, S., Criscuolo, C., & Timmis, J. (2020). Coverage and representativeness of orbis data. *OECD Science, Technology and Industry Working Papers*, *No. 2020/06*.

Baldwin, R., & Forslid, R. (2020). *Globotics and development: When manufacturing is jobless and services are tradable* (tech. rep.). National Bureau of Economic Research.

Barbieri, T., Basso, G., & Scicchitano, S. (2022). Italian workers at risk during the covid-19 epidemic. *Italian Economic Journal*, *8*(1), 175–195.

Barrero, J. M., Bloom, N., & Davis, S. J. (2021). Why working from home will stick. (28731). https://doi.org/10.3386/w28731

Bartel, A., Ichniowski, C., & Shaw, K. (2007). How does information technology affect productivity? plant-level comparisons of product innovation, process improvement, and worker skills. *The Quarterly Journal of Economics*, *122*(4), 1721–1758.

Bick, A., Blandin, A., Mertens, K., et al. (2020). Work from home after the covid-19 outbreak.

Boeri, F., Crescenzi, R., & Rigo, D. (2022). Work-from-home and firms' resilience: Evidence from the covid-19 pandemic.

Boeri, T., Caiumi, A., & Paccagnella, M. (2020). Mitigating the work-safety trade-off. *Covid Economics*, *2*(8), 60–66.

Brynjolfsson, E., Horton, J., Makridis, C. A., Mas, A., Ozimek, A., Rock, D., & TuYe, H.-Y. (2022). How many americans work remotely?

Brynjolfsson, E., Rock, D., & Syverson, C. (2019). *Artificial intelligence and the modern productivity paradox: A clash of expectations and statistics*. University of Chicago Press.

Coven, J., Gupta, A., & Yao, I. (2021). Urban flight seeded the covid-19 pandemic across the united states. *Journal of Urban Economics: Insights, R&R*.

De Fraja, G., Matheson, J., & Rockey, J. (2021). Zoomshock: The geography and local labour market consequences of working from home. *Covid Economics*, (64), 1–41.

Delventhal, M., & Parkhomenko, A. (2020). Spatial implications of telecommuting. *Available at SSRN 3746555*.

Dingel, J. I., & Neiman, B. (2020). How many jobs can be done at home? *Journal of Public Economics*, *189*, 104235.

Duranton, G., & Puga, D. (2020). The economics of urban density. *Journal of Economic Perspectives*, *34*(3), 3–26.

Eurofound. (2020). *Working and covid-19 - first findings* (tech. rep.). April.

Gottlieb, C., Grobovšek, J., Poschke, M., & Saltiel, F. (2021). Working from home in developing countries. *European Economic Review*, *133*, 103679.

Hensvik, L., Le Barbanchon, T., & Rathelot, R. (2020). Which jobs are done from home? evidence from the american time use survey.

Machin, S., & Van Reenen, J. (1998). Technology and changes in skill structure: Evidence from seven oecd countries. *The Quarterly Journal of Economics*, *113*(4), 1215–1244.

Mongey, S., & Weinberg, A. (2020). Characteristics of workers in low work-from-home and high personal-proximity occupations. *Becker Friedman Institute for Economic White Paper*.

OECD. (2020). *Productivity gains from teleworking in the post COVID-19 era: How can public policies make it happen?*

Ramani, A., & Bloom, N. (2021). *The donut effect of covid-19 on cities* (tech. rep.). National Bureau of Economic Research.

Schivardi, F., & Schmitz, T. (2020). The IT revolution and southern Europe's two lost decades. *Journal of the European Economic Association*, *18*(5), 2441–2486.

Silva, J. S., & Tenreyro, S. (2006). The log of gravity. *The Review of Economics and statistics*, *88*(4), 641–658.

Storper, M., & Venables, A. J. (2004). Buzz: Face-to-face contact and the urban economy. *Journal of Economic Geography*, *4*(4), 351–370.

Watson, B. (2020). Coronavirus and homeworking in the uk labour market: 2019. *UK Office of National Statistics (ONS)*.

APPENDIX

A Additional tables

Table A1: Potential vs real WFH shares, by NUTS-2 regions.

NUTS-2 label	Actual WFH	DN WFH	BBS WFH	BBS2 WFH	No Empl
Abruzzo	2.8	23.2	47.5	28.5	431955
Basilicata	2.9	21.2	47.3	25.5	158228
Calabria	3.1	23.4	47.3	28.5	455543
Campania	2.6	24.0	47.2	29.7	1367320
Emilia-Romagna	12.2	28.1	49.8	35.2	1836642
Friuli-Venezia Giulia	10.2	26.5	48.9	34	446066
Lazio	20.7	33.0	50.7	43.1	2022412
Liguria	7.6	27.9	48.2	35.1	538274
Lombardia	21.4	31.5	50.6	39	4124653
Marche	4.2	26.8	49	35.1	568970
Molise	1.3	23.3	47.2	28	91503
Piemonte	15.3	28.6	49.6	35.1	1653201
Puglia	2.4	23.1	46.8	28.2	1053709
Sardegna	3.1	21.7	46.1	29.3	487046
Sicilia	1.8	23.0	46.7	28.1	1097689
Toscana	8.1	26.7	48.6	34.7	1429472
Trentino-Alto Adige	10.6	25.7	47.8	30.6	427506
Umbria	3.4	25.1	48.3	33.4	315238
Valle d'Aosta	9.3	23.3	46.6	29	45826
Veneto	9.0	26.8	48.9	33.3	1977005

Note: This table reports the share of jobs that can be done at home across NUTS-2 regions. Column 2 shows the share of jobs done remotely based on our real-time data on WFH. Column 3 reports the estimates calculated using Dingel and Neiman (2020)'s methodology. In column 4 and 5, the estimates are taken from Barbieri, Basso, and Scicchitano (2022). In column 8, the values are taken from the Labour Force Survey available from ISTAT for the year 2019. Firms operating in NACE rev. 2 codes 84 and 85 are excluded from this analysis.

Table A2: Potential vs real WFH shares, by industry of activity (1-digit).

NACE	Label	Actual WFH	DN WFH	BBS WFH	BBS2 WFH	No Empl
A	AGRICULTURE, FORESTRY & FISHING	0.6	6.5	46.4	9.2	896697
B	MINING & QUARRYING	10.7	28.7	53.8	38.6	24451
C	MANUFACTURING	13.0	21.6	51.7	33.9	4319168
D	ELECTRICITY, GAS, STEAM & AIR CONDITIONING SUPPLY	36.5	49.0	59.1	70.4	118073
E	WATER SUPPLY; SEWERAGE, & WASTE MANAGEMENT ACTIVITIES	10.8	18.1	52	29	244691
F	CONSTRUCTION	5.1	10.2	42.2	13.6	1344670
G	WHOLESALE & RETAIL	6.3	35.3	40.3	15.3	3289082
H	TRANSPORTATION & STORAGE	11.5	22.6	50.6	30.2	1157432
I	ACCOMMODATION & FOOD SERVICE ACTIVITIES	0.7	5.6	34.6	7.4	1503814
J	INFORMATION & COMMUNICATION	70.2	74.5	66.8	91.5	600653
K	FINANCIAL & INSURANCE	48.5	81.5	61.6	72.9	643730
L	REAL ESTATE ACTIVITIES	7.4	62.3	60.3	47.2	169977
M	PROFESSIONAL, SCIENTIFIC & TECHNICAL ACTIVITIES	15.5	71.8	65.5	92.5	1480816
N	ADMINISTRATIVE & SUPPORT SERVICE ACTIVITIES	19.5	21.1	53.5	31.4	1015892
Q	HEALTH SERVICES	2.9	19.4	42.9	23	1936611
R	ARTS & SPORTS	6.7	43.4	48.6	44.4	309617
S	OTHER SERVICES	7.3	19.4	43.5	26.8	715510
T	ACTIVITIES OF HOUSEHOLDS	0.2	5.4	53.5	54.6	744108
U	ACTIVITIES OF EXTRA-TERRITORIAL ORGANISATIONS	17.2	51.1			13265

Note: This table reports the share of jobs that can be done at home across 1-digit NACE rev. 2 industries. Column 3 shows the share of jobs done remotely based on our real-time data on WFH. Column 4 reports the estimates calculated using Dingel and Neiman (2020)'s methodology. In column 5 and 6, the estimates are taken from Barbieri, Basso, and Scicchitano (2022). In column 9, the values are taken from the Labour Force Survey available from ISTAT for the year 2019. Firms operating in NACE rev. 2 codes 84 and 85 are excluded from this analysis.

Table A3: Summary statistics.

	N	Mean	SD	Min	Max
WFH (dummy)	4477819	0.01	0.11	0	1
No workers WFH	4477819	0.45	44.12	0	53,373
No workers	3783659	4.39	97.11	1	117,865
No workers (log)	3783659	0.56	0.88	0	12
Sales/workers (log)	3170348	11.79	0.81	-4	19
No 4-digit Occ WFH	833552	0.13	0.55	0	75
No 4-digit occupations	834368	1.74	1.07	1	49
Young	4417829	0.43	0.49	0	1

Table A4: Firm-level determinants of WFH, all industries.

	(1)	(2)	(3)
VARIABLES	WFH (dummy)	# workers WFH	# 4-digit Occ WFH
# workers (log)	0.0642***	1.180***	0.638***
	(0.000264)	(0.00995)	(0.00332)
Sales/workers (log)	0.0269***	0.104***	0.259***
	(0.000241)	(0.0184)	(0.00680)
Young	-0.00637***	-0.352***	-0.145***
	(0.000194)	(0.0348)	(0.00939)
Observations	2,018,610	2,018,606	681,307
MODEL	OLS	PPML	PPML

Note: This table presents the estimated coefficients from equation 1 across different dependent variables. The dependent variable in Column 1 is a dummy indicating whether the firm was adopting WFH practices during the COVID-19 pandemic; in Column 2, the number of workers working remotely during the COVID-19 pandemic; in Column 3, the number of 4-digit occupations with at least one worker working remotely during the COVID-19 pandemic. All specifications include NUTS-3 regions and 2-digit industry fixed effects and are estimated using OLS or PPML. Firms operating in NACE rev. 2 codes 84 and 85 are excluded from this analysis. Firms' financials are based on information for the year 2019. Robust standard errors in parentheses. The p-values read as follows: *** p<0.01, ** p<0.05, * p<0.1.

Table A5: Firm-level determinants of WFH, manufacturing sector.

	(1)	(2)	(3)
VARIABLES	WFH (dummy)	# workers WFH	# 4-digit Occ WFH
# workers (log)	0.101***	1.271***	0.639***
	(0.000894)	(0.0125)	(0.00595)
Sales/workers (log)	0.0428***	0.170***	0.366***
	(0.00108)	(0.0182)	(0.0110)
Young	0.0184***	-0.0331	-0.0142
	(0.00161)	(0.0468)	(0.0192)
# 4-digit occupations	0.0150***	0.0361***	0.128***
	(0.000941)	(0.0123)	(0.00673)
Observations	122,114	122,114	121,961
MODEL	OLS	PPML	PPML

Note: This table presents the estimated coefficients from equation 1 across different dependent variables on the sample of firms operating in the manufacturing sector. The dependent variable in Column 1 is a dummy indicating whether the firm was adopting WFH practices during the COVID-19 pandemic; in Column 2, the number of workers working remotely during the COVID-19 pandemic; in Column 3, the number of 4-digit occupations with at least one worker working remotely during the COVID-19 pandemic. All specifications include NUTS-3 and 2-digit industry fixed effects and are estimated using OLS or PPML. Firms operating in NACE rev. 2 codes 84 and 85 are excluded from this analysis. Firms' financials are based on information for the year 2019. Robust standard errors in parentheses. The p-values read as follows: *** p<0.01, ** p<0.05, * p<0.1.