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Teleworkability and the COVID-19 crisis: potential and actual prevalence of remote work across Europe

Abstract

This paper develops a conceptual analysis to identify the jobs that can be done from home and those that cannot, and on this basis quantifies the fraction of employees that are in teleworkable occupations across EU countries. Using detailed data on occupational tasks, we construct two teleworkability indices. The first core technical teleworkability index, based on the prominence of physical tasks, implies that 36% of dependent employment in the EU is technically teleworkable. However, our second social interaction index shows that only one third of teleworkable employment is in occupations that require limited social interactions, thus ideally suited to telework. To validate our approach, we compare our measures of teleworkability with data on the actual prevalence of telework before and during the COVID-19 outbreak. We show that our measures correlate with the observed increase in telework across countries and occupations in the EU during the outbreak. However, the prevalence of telework among employees appears to have remained below its full potential in 2020, as measured by our technical teleworkability index. This is especially the case for lower-level white-collar occupations as well as for countries with limited previous experience with teleworking. These patterns suggests that, despite the rapid increase in teleworking, the same barriers that prevented the diffusion of telework before the outbreak – lack of ICT infrastructure, fears of losing managerial control, position in the occupational hierarchy, limited workforce's digital skills, awkwardness of remote social interaction – are likely to continue playing an important role in shaping the diffusion of telework after the outbreak.

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1 Introduction

The telework revolution has been predicted intermittently for over a generation without ever arriving (Toffler, 1980; Messenger, 2019). In 2019 fewer than one in twenty employees were regularly teleworking in the EU, and less than one in ten was doing so occasionally – a share that had only slightly increased since the early 2000s. This all changed, abruptly and of necessity, in the first semester of 2020 as a result of public health measures designed to stem the spread of COVID-19. As discussed in Fana et al. (2020a), in the extraordinary circumstances of a viral pandemic, most European governments explicitly required that whenever possible people should telework rather than physically go to their employers' premises. As a result of these measures, a vast ad-hoc social experiment took place in which teleworking suddenly became the customary mode of working for millions of workers in the EU, and worldwide. Data from EU Labour Force Survey (EU-LFS) show that almost 20% of EU employees usually or sometimes teleworked throughout 2020. Figures from real-time surveys conducted in the midst of the pandemic hint to even higher fractions of teleworkers. For instance, Eurofound (2020) show that over a third (39%) of employees working in the EU started to work from home during the first wave of the pandemic. Other real-time surveys confirm the sudden and unprecedented spread of teleworking in the aftermath of the outbreak both across EU and non-EU countries (Adams-Prassl et al., 2020; Gottlieb et al., 2021).

As a result of the sudden growth of telework during the pandemic, and its potential long-lasting changes to working modes, several studies recently tried to identify which jobs can be done remotely, and estimate their share in total employment (Dingel and Neiman 2020; Boeri et al. 2020; Leibovici et al. 2020; Adams-Prassl et al. 2020; Mongey et al. 2020; Pouliakas and Branka, 2020). Most of these studies were inspired by the work of Dingel and Neiman (2020), who were the first to measure the feasibility of working at home of occupations using US O*NET data on detailed descriptions of work tasks at the occupational level, finding that around 37% of US employment is amenable to working from home.

Our study – which focuses only on telework among dependent employees, and therefore on the remote provision of labour that would otherwise be carried out within the employer's premises[1] – adds to this strand of literature. A first important difference between this study and previous ones is the conceptual framework used to identify the telework potential of occupations. We argue that, given the state of current technology, the ultimate determinant of occupational teleworkability from a purely technical perspective is the lack of physical handling tasks. Instead, related studies, whilst also emphasising the role of physical tasks as the one main bottlenecks of teleworkability, have also considered additional criteria to assess the potential for telework. For instance, Dingel and Neiman (2020) assess the teleworkability of occupations also according to physical exposure to external conditions, the use (or lack thereof) of emails, and the intensity of face-to-face social interactions. In our view this approach is not entirely justified, especially when it comes to evaluate the strict technical feasibility of remote work. Unlike Dingel and Neiman (2020), we consider that the intensity of social interaction affects the quality rather than the strict feasibility of remote work for any given occupation. Applying our framework to survey data with detailed information on the task content of work of

1 This definition of *telework* is used in EU legislation and agreements between social partners, e.g., https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM:c10131.

fine-grained occupations, we estimate that around 36% of dependent employment in the EU is currently teleworkable. However, we show that only one third of technically teleworkable occupations require limited social interaction, and can therefore be carried out remotely without any quality losses.

A second contribution of this study is that we try to validate our indices of teleworkability, by comparing them with figures on the actual prevalence of telework both before and after the COVID-19 outbreak. In particular, we discuss why, for whom, and by how much the prevalence of telework before the outbreak deviated from its potential as measured in this paper, and to what extent the advent of the outbreak has contributed to closing this gap. To the best of our knowledge, this is the first study which compares "theoretical" measures of telework potential with actual figures on teleworking during and immediately after the outbreak across EU countries. Such a comparison provides useful insights. We show that all EU countries and occupations for which telework was a viable option experienced increased access to this work arrangement during and immediately after the COVID crisis. This is particularly visible in the period going from March to May 2020 when European governments often required, or strongly recommended, that all of those who could telework had to do so (Hale et al., 2021). Over this period, close to 27% of EU employees were working from home regularly or occasionally – a share that is close to our estimate of teleworkable employment. However, the gap between our measure of potential telework and the actual prevalence of telework becomes wider when we restrict our observations to the second half of 2020, when containment and closure policies typically eased. The fact that a large proportion of workers returned to their workplace when it became possible suggests a certain reluctance of managers and employers in maintaining teleworking beyond the emergency sanitary situation in several EU Member States. Overall, these results are consistent with the conjecture that some of the barriers that have prevented the diffusion of telework before the outbreak – e.g. lack of ICT infrastructure, fears of losing managerial control, limited workforce's digital skills (Milasi et al, 2021) – are likely to continue playing a crucial role in explaining countries' and companies' attitudes towards scaling-up telework in the post-outbreak period.

The paper is structured as follows. In Section 2, we present a conceptual framework of teleworkability based on the task content of work developed following Fernández-Macías and Bisello (2021). We then present the data (Section 3) and the methodology (Section 4) used to construct the teleworkability indices of physical tasks and social interaction. The main source for this classification is the detailed occupational task descriptions from the Italian *Indagine Campionaria delle Professioni*, modelled on the US O*NET, with one additional indicator from the European Working Conditions survey. Section 5 presents some descriptive analysis of the teleworkability and social interaction indices at the ISCO 3-digit occupational level, and quantifies the share of current dependent employment in the EU that is employed in technically teleworkable occupations, further distinguishing between those requiring extensive social interactions and those that do not. Section 6 presents a comparison of our technical teleworkability index, with data on the pre- and post-outbreak prevalence of telework across occupations, and EU Member States. Finally, Section 7 discusses the main implications of our findings for the future of telework.

2 A conceptual framework

In this section, we provide an explicit theoretical foundation to classify the teleworkability of occupations, meant as *the technical possibility of providing labour input remotely into a given economic process*. We say "technical possibility" to emphasize that teleworkability depends on what types of tasks can be remotely provided given the available technology.

Following the framework developed by Fernández-Macías and Bisello (2021), we first differentiate three broad categories of tasks, and then assess their teleworkability potential given the state of existing technology. In particular, we classify tasks according to the object on which they operate and the type of transformation process involved:

1. **physical tasks**: manipulating objects or people
2. **information-processing (or intellectual) tasks**: operating on information or ideas
3. **social interaction tasks**: operating on social relations

We argue that the crucial determinant of whether a certain job can be done remotely or not is the relative importance of physical tasks. Physical tasks are the ones where remote labour input remains most difficult. Although there have been important advances in recent years in the fields of telepresence and telerobotics (for a discussion, see Baldwin, 2019), being able to remotely manipulate objects with a level of precision similar to actual presence is still beyond the capabilities of even the most advanced technologies. Therefore, within our framework, physical tasks are the real bottleneck of the teleworkability of occupations. As explained in greater detail in Section 4.1, this allows to create a negative and binary technical teleworkability index: if a job has a significant amount of physical tasks content that requires the physical manipulation of objects or people, then we can classify it as *not* teleworkable. Dingel and Neiman (2020) also use a binary and negative approach to measure teleworkability, although they include other types of tasks in addition to those proxying for physical interactions (see Section 4.1 for more details).

As discussed in Fernández-Macías and Bisello (2021), in practice the majority of jobs incorporate a mix of physical, information-processing, and social interaction tasks. Therefore, an approach where the sole determinant of occupational teleworkability is the lack of physical tasks would not be able to capture the fact that for certain occupations requiring extensive social interaction, remote work, whilst technically feasible, may entail a loss of quality. According to this logic, for instance, a psychotherapist job, which is almost entirely composed by (non-physical) social interaction, can be classified as teleworkable, adding the further qualification that in this case, telework implies a significant loss of quality in the provision of the service. Following the taxonomy of social interaction tasks of Fernández-Macías and Bisello (2021), some categories of social tasks that can be remotely performed but with a loss of quality include: teaching, selling, negotiating, caring, coordinating. From a technical perspective any of these tasks could be conducted remotely, thanks to technologies such as videoconference that allow the digital encoding of visual and auditory information transmitted via the internet. Yet, even in the most flawless videoconference, there are small lags or informational noise that can be quite disruptive, and also many non-verbal or connotative clues are likely to get lost (see Schoenenberg et al., 2014).

Therefore, we assume that for a given job, the decline in quality associated with telework can be approximated by the amount of social interaction tasks typically required in that job. To operationalise this qualitative assessment into a continuous index for occupations, we

use indicators of social interaction tasks at work and aggregate them into an index under the assumption that *the more an occupation requires social interaction tasks, the lower the quality of the service provided if it is via telework* (see Section 4.2 for more details).

Since in our framework the physical and social task contents are sufficient to determine the teleworkability of a given job, we do not explicitly consider the extent to which the same job involves information-processing tasks – e.g. operating with ideas or information – that are arguably the most suited to telework. In fact, information-processing tasks are also implicitly and negatively included in our framework: only the jobs that involve no physical or social interaction tasks are classified as fully teleworkable, and those are the jobs that mostly involve information processing task content. What follows presents the data and the methodology used to generate indices of *technical teleworkability* and *social interactions*.

3 **Data**

To construct the teleworkability indices of physical tasks and social interaction, we rely on existing European data sources that measure the task content of specific occupations with some level of detail. In particular, we used the Italian ICP, and the EWCS.

The ICP (*Indagine Campionaria delle Professioni*) is a survey of occupations conducted by the National Institute for Public Policy Analysis (INAPP) in collaboration with the Italian National Statistical Institute (ISTAT). It follows closely the structure of the American O*NET database, and thus incorporates very detailed information on tasks, skills, work contexts and organisational characteristics, collected at the 5-digit level of occupations (*Codici Professionali*, or CP). There are two waves currently available (2007 and 2012), the most recent being the one used in this paper. In total, 16 thousand Italian workers were interviewed, representative of sectorial, occupational and geographic heterogeneity (see also Cetrulo et al. 2019). On average, 20 workers per each 5-digit occupation were interviewed face to face for around one hour. The scope and depth of the survey, at the level of detailed occupations, makes it uniquely able to measure the content of work across occupations. We chose to use this source over the data of American O*Net because we believe it better reflects the characteristics of occupations, tasks, and work organisation found in the European economy. In recent work adapting the Dingel and Neiman approach to the Italian labour market, Cetrulo et al. (2020) have made a similar use of the ICP to that in this paper estimating that 30% of Italian workers are employed in teleworkable jobs.[2]

The EWCS (European Working Conditions Survey), conducted by Eurofound, focuses on the conditions of work and employment of European workers. It is representative of the entire EU employed population and conducted every five years since 1991. The wave we use in this paper (2015) covered 35 countries and nearly 44,000 interviews (between 1,000 and 2,000 interviews per country). It was also conducted face to face, in the homes of the respondents, for an average duration of about 45 minutes.

2 Although there is some evidence that the task content of occupations changes over time (see Bisello et al. 2019; also Spitz-Oener 2006), those changes are slow and only become significant in the medium-long run. The 7-year period that goes from the collection of the Italian O*Net data and its application in this paper is not long enough as to affect the results in any significant way. Additionally, Fernández-Macías et al. (2016) document a broad consistency in the task content of occupations of similarly developed economies (there is less consistency in forms of work organisation, which are not used in this paper), especially within Europe. In a specific analysis of teleworkability in Greece, Pouliakas (2020) conducts two robustness tests that support the use of teleworkability indices derived from data from other developed economies.

4 Methodology

4.1 Technical teleworkability

The technical teleworkability index[3] is based primarily on the ICP. We used the detailed information on tasks in this survey to classify fine-grained occupations (over 750 5-digit occupations in the Italian professional classification) as technically teleworkable or not, based on the amount of physical interaction captured by six variables, covering most of the spectrum of physical tasks. All of these tasks involve the direct and physical operation with things or people, generally requiring strength, dexterity and hand-eye coordination that cannot be performed remotely with current technologies (with a reasonable level of cost and quality). In addition to the six physical interaction variables contained in ICP, we also drew from the EWCS to add a physical interaction variable providing information on another type of physical interaction not covered in ICP, namely the frequency of lifting or moving people.

Once these variables were identified, we proceeded to standardise and aggregate them. Since physical tasks are the real bottleneck of the teleworkability of occupations, we can construct a binary technical teleworkability index, equal to one if a job has a significant amount of task content that requires the physical manipulation of objects or people (*not teleworkable*), and equal to zero otherwise (*teleworkable*). In the case of ICP, this means that whenever any indicator of the six physical task variables was above a threshold of 40 points, we classified each of the corresponding 5-digit occupation as *not teleworkable*.[4] In the case of EWCS, the original 7-point measurement scales for the variable "Lifting or moving people" were first translated into a continuous scale of 0-100 (from lowest to highest physical task intensity in the occupation). As for variables drawn from ICP, each of the 3-digit occupations in the EWCS was then classified as *not teleworkable* if the value was above a threshold of 40 points.

This classification is based on our understanding that if respondents from a given occupation report that even one physical task is sufficiently important for their job, then the job in question cannot technically be carried out remotely. Setting a numeric threshold to indicate when a physical task is "sufficiently important" is necessarily an arbitrary choice. However, we

Table 1 Variables selected for technical teleworkability index

Variable	Scale reported	Unit	Source
Manual Dexterity	Importance (0-100)	CP 5 digit	ICP
Finger Dexterity	Importance (0-100)	CP 5 digit	ICP
Performing General Physical Activities	Importance (0-100)	CP 5 digit	ICP
Handling and Moving Objects	Importance (0-100)	CP 5 digit	ICP
Inspecting Equipment, Structures, or Material	Importance (0-100)	CP 5 digit	ICP
Operating Vehicles, Mechanized Devices, or Equipment	Importance (0-100)	CP 5 digit	ICP
Lifting or moving people	Frequency (7-point scale)	ISCO 3 digit	EWCS

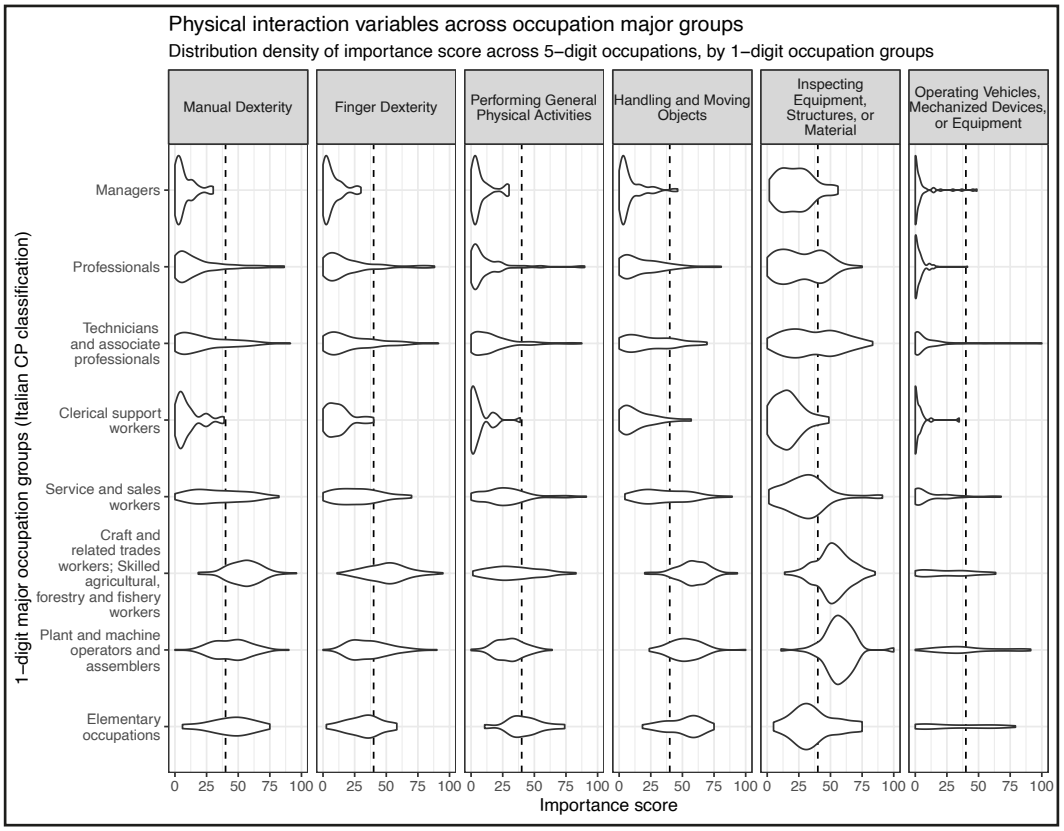
3 The code to construct the indices is available at https://github.com/m-sostero/telework-occupations

4 For instance, the occupation 3.1.1.2.0 (*Tecnici chimici*, Chemistry technicians, belonging to ISCO group 311 *Physical and engineering science technicians*) received the following scores: 29.8 for manual dexterity, 32.1 for finger dexterity, 15.5 for performing general physical activities, 40.5 for handling and moving objects, 54.8 for inspecting and 10.0 for operation with vehicles or equipment. Since the scores were above the threshold of 40 in "handling and moving objects" and in "inspecting equipment, structures or materials", the occupation *Tecnici chimici* was classified as not teleworkable.

settled on a value of 40 on the importance scale because it divided most accurately those occupations that involve manual and physical tasks, from those that do not – as shown by the distribution of the importance scores of each of the six variables from ICP, presented in Figure 1. The plot shows the density distribution of the importance scores for all 5-digit occupations, divided by one-digit occupation major group. For managerial, professional, and clerical occupations, the bulk of the distribution (i.e., most 5-digit occupations) are to the left of the threshold of 40 points (the dashed line) for manual dexterity, finger dexterity, general physical activity, and handling and moving objects. Most craftspeople, plant and machine operators and assemblers, and a significant share of technical professionals report values higher than 40 points for inspecting equipment, structures, and materials. Similarly, Figure A1 in Appendix A shows that a value of 40 on a the 100-point scale seems to well capture the division of occupations that involve the task "lifting and moving people" from those that do not.

After each of the 798 5-digit occupations in ICP was classified as either technically teleworkable or not, to allow for international comparisons, we aggregated them into 121 3-digit

Figure 1 Values of technical teleworkability variables from ICP survey.



Note: The figure shows the density distribution plot for the values of physical interaction variables across 798 different CP 5-digit occupations, divided by 1-digit occupation major groups. Wider sections of the density curves mean that more occupations are clustered around that value of the importance score. The dashed line represents the threshold used to classify the technical teleworkability of occupations.

ISCO occupations, using the official mapping published by Istat.[5] Since 3-digit ISCO groups may occasionally bring together occupations with different levels of physical interaction, when aggregating from 5-digit CP into 3-digit ISCO we weighted the binary values of the teleworkability index based on the relative share of employment in each 5-digit occupation among the 3-digit group, based on recent Italian Labour Force Statistics. Thus, the value of teleworkability of a 3-digit occupation reflects the employment-weighted share of 5-digit occupations within it that are teleworkable.[6]

The result is a continuous variable measuring the technical teleworkability of each 3-digit occupational code, ranging from zero (the occupation is fully non-teleworkable) to 100 (the occupation is fully teleworkable). Values between zero and 100 correspond to 3-digit occupational categories, which incorporate some more detailed 5-digit occupational codes that are teleworkable and some that are not.[7] The resulting detailed classification is reported in Appendix B. In the majority of cases, our classification is consistent with intuition and anecdotal evidence on whether different occupations have been able to telework during the lockdown. Unsurprisingly, there are, however, some exceptions of occupations that are classified as teleworkable when experience suggests they should not be, or vice-versa, for which a manual adjustment was needed. We present the classification and discuss all such cases in Appendix B. However, these ad-hoc adjustments only concern a tiny minority of the occupations classified: two occupations out of 798 at 5-digits or out of 121 at 3-digits.

We can compare the methodology used to compute our technical teleworkability index with the seminal one developed by Dingel and Neiman (2020), which has widely inspired the work of subsequent studies (e.g. Mongey et al. 2020; Leibovici et al. 2020). Dingel and Neiman (2020) also define teleworkability in a *negative* and *binary* way: when the intensity of a specific work task is above a certain threshold, the associated occupation is classified as non-teleworkable. Similarly to our approach, it seems that performing a significant amount of physical activity is the most important criterion to determine whether an occupation cannot be performed remotely. However, Dingel and Neiman (2020) also consider other criteria in addition to those of physical tasks. These include: physical exposure to external conditions at work (3 variables); to face-to-face social interaction (2); and use (or lack thereof) of email. As previously argued, this seems reasonable and may work as a practical approximation to identify the teleworkability of occupations, but it lacks an explicit justification and some of the underlying choices are difficult to understand. For instance, if the average worker in a given occupation uses email less than once a month, Dingel and Neiman (2020) classify the occupation as non-teleworkable. Yet, the use of emails is just too pervasive to be used for identifying (non-)teleworkable jobs. Moreover, it remains unclear why only one variable related to the use of communication devices, (i.e. email) is considered, when other equivalent variables (use of phones or other communication devices) are also considered in O*NET.

5 https://www.istat.it/en/files/2013/07/la_classificazione_delle_professioni.pdf.

6 Following with the previous example, the final value of teleworkability for ISCO 3-digits code 311 (*Physical and engineering science technicians*) is 0.7 (in a scale of 0-100), because 13 of the 14 5-digit occupations within 311 are not teleworkable, and the one that is teleworkable (*Disegnatori tessili, Textile designers*) accounts for less than 1% of employment within that 3-digit code.

7 For instance, ISCO 3-digit code 221 (Medical doctors) has a value of teleworkability of 39.2. This is because within that code there are six 5-digit occupational codes: general practitioners, specialists, surgeons, pathologists and radiotherapists. While GPs, surgeons, pathologists and radiotherapists are classified as not teleworkable, specialists are teleworkable because none of their physical task indices go beyond 40. Since 39.2% of the 3-digit code 221 corresponds to the teleworkable occupation of medical specialist, that is the value we assign to ISCO code 221.

Our approach differ more significantly from that of Dingel and Neiman (2020) when it comes to the role of social interactions. First, they only use two indicators of social interaction tasks, one of which does not necessarily impede remote work (i.e., dealing with violent people, which is not something that can only be done face to face). Instead, we believe that it is important to assess a wider range of social interactions. Secondly, in this case they also apply a negative and binary approach that in our view does not capture the complexity of social interaction and the fact that they affect the quality rather than the strict feasibility of remote work. Therefore, what follows presents the methodology used to create a richer social interaction index.

4.2 **Social interaction index**

As explained in Section 2, any occupation which is totally or partially teleworkable from a technical perspective can also be assessed in terms of how socially comfortable and efficient the remote provision of labour will be, depending on the degree of social interaction involved. Therefore, we constructed a continuous social interaction index task content, which is intended as a qualification of the assessment of technical teleworkability. For constructing this second indicator, we used five variables from the ICP detailed in Table 2.

These five variables cover all the main dimensions of social interaction task content of the framework of Fernández-Macías and Bisello (2021). As in the variables measuring physical task content, the five variables were originally measured in a 5-point importance scale, which was converted into a continuous 0-100 scale. For each 3-digit occupation (in this case, there was no need to aggregate from the 5-digit level), we computed the final social interaction index as the arithmetic average of the two highest scores in any of the five social interaction variables. We only average over the two variables with the highest scores because, in our view, this allows to capture in a more realistic way the prevalence of social interaction for a given occupation. For instance, the work of a salesperson typically requires selling and influencing, as well as working directly with the public, but it is unlikely that the same salesperson is also engaged in teaching or coordinating. The opposite could hold for the work of a teacher. Computing our index as an average of all the five dimensions of social interactions listed in Table 2 would bias the indicator towards zero, as it is very unlikely that a job requires simultaneously performing all of them in a significant way.

We report the value of the social interaction index across 3-digit occupations in Appendix B. A value of zero in this index (meaning no social interaction tasks) would be the most teleworkable, and a value of one the least, with values in between reflecting the degree of social interaction tasks present in the job. However, it is important to note that this index may not be interpreted in terms of teleworkability on its own, but only in combination with the technical teleworkability index previously discussed. This is because, as already argued, physical

Table 2 Variables selected for social interaction index

Variable	Scale	Unit	Source
Selling or Influencing Others	Importance (0-100)	CP 5 digit	ICP
Training and Teaching Others	Importance (0-100)	CP 5 digit	ICP
Assisting and Caring for Others	Importance (0-100)	CP 5 digit	ICP
Performing for or Working Directly with the Public	Importance (0-100)	CP 5 digit	ICP
Coordinate the work and tasks of others	Importance (0-100)	CP 5 digit	ICP

interaction task content is the technical bottleneck, and thus a value of zero in that index implies absolute non-teleworkability; if a job has a value of zero in terms of technical teleworkability, the value of social interaction is irrelevant. Only when a job is technical teleworkable we can use the social interaction index to qualify its teleworkability as continuous attribute: a technically teleworkable job with a lot of social interaction is less suitable to remote provision than a technically teleworkable job with no social interaction.

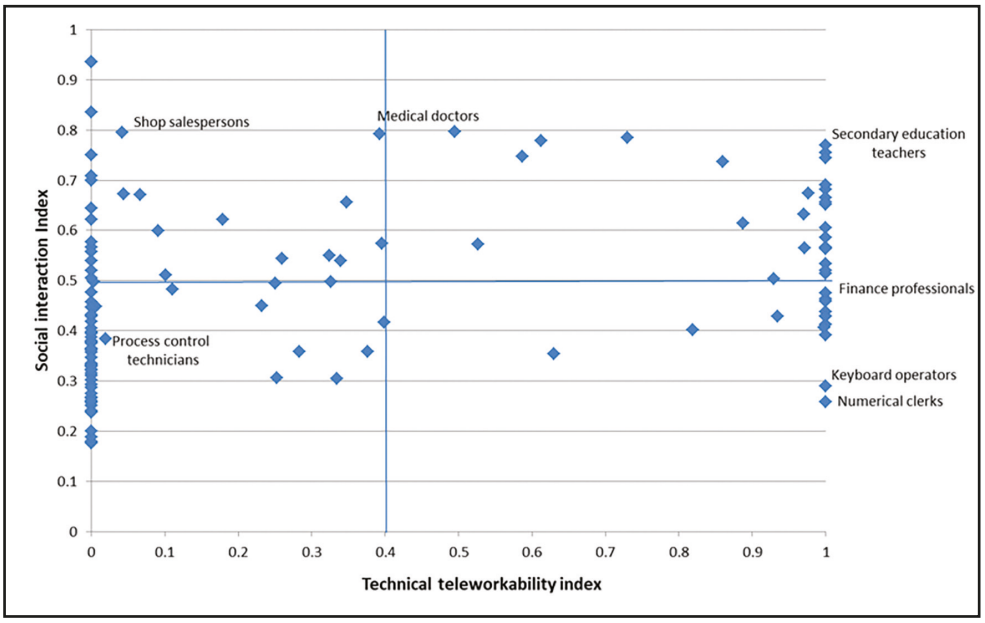
One may be tempted to integrate the technical and social indices into a single index, so that a value of zero in the resulting composite index reflects no teleworkability (based on the physical content of the job), a value of one reflects the highest teleworkability (no physical or social interaction tasks), and values in between reflecting (in reverse) the degree of social interaction tasks for non-physical (and thus technically teleworkable) jobs. However, in practice, it is useful to keep the two indices separate because the two indices are not substitutable, and convey more information separately, as illustrated in the next sub-section.

5 Which jobs are teleworkable?

Figure 2 shows graphically the distribution of values for the technical teleworkability and the social interaction indices for the 121 ISCO 3-digit occupation groups. This provides a good summary of our assessment of teleworkability across detailed occupational categories in Europe, based on a framework that focuses on the physicality of jobs and the degree of social interaction as explained in the previous section. Since the horizontal axis reflects technical teleworkability and the vertical axis reflects social interaction, we can also analyse the figure by splitting the points in four quadrants:

- *Teleworkable, with limited social interaction:* The bottom right quadrant would include the most easily teleworkable jobs, involving little to no physical task content and limited social interaction. Examples of occupations in this quadrant are: clerks, ICT professionals, authors, secretaries. It is interesting to note that some of these occupations, as we will discuss later, did not display particularly high levels of telework before the COVID-19.
- *Teleworkable, with extensive social interaction:* The top right quadrant mainly includes jobs that are physically teleworkable but that require extensive social interaction, and thus the remote provision of labour is likely to be less than optimal or comfortable, for both the worker and the public or client. Here we find many types of managers and professionals, as well as teachers. These were often the jobs with higher levels of telework prevalence (in most cases occasional, though) before the COVID-19 outbreak.
- *Technically and socially non-teleworkable:* The top left quadrant includes jobs which in our assessment are the least teleworkable because they require significant amounts of both physical and social tasks. This category includes nurses, salespersons, sports and fitness workers, childcare workers.
- *Only technically non-teleworkable:* the bottom left quadrant includes jobs that are not technically teleworkable because they require a significant amount of physical interaction with things or people, but they require very low levels of social interaction. Thus, the bottleneck in this case is purely technical, and a breakthrough in telerobotics for instance could make these jobs teleworkable in the future. It is interesting to note also

Figure 2 Relationship between technical teleworkability and social interaction index by 3-digit ISCO08



Note: The four quadrants are generated as follows. A cut-off point of 40 on the physical teleworkability scale to differentiate between teleworkable and non-teleworkable occupations (ISCO 3d) – as in the construction of the original index itself. We then further differentiate teleworkable jobs based on the social interaction scale discussed in the previous section and use a cut-off to differentiate between occupations with limited (<50) or extensive (>=50) social interaction. More detailed information on values of the "technical teleworkability" and "social interaction" indeces by occupations are provided in Appendix B.
Source: Authors' calculations from ICP and EWS.

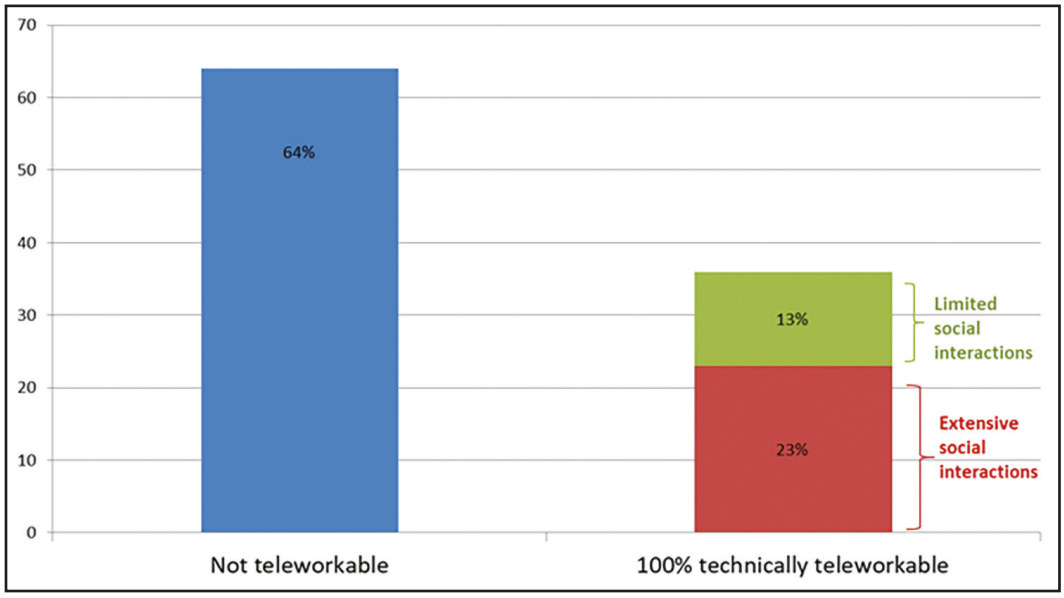
> that these jobs are probably the most automatable, since existing robotic technology can perform physical manipulation tasks with a high degree of precision (especially if they are repetitive and standardised; see Fernández-Macías et al 2020).

By combining the information on the technical teleworkability and social interaction scores of ISCO 3-digit occupation groups and their employment levels across the EU as measured by the 2018 EU-LFS, it is possible to estimate the share of current dependent employment in the EU that falls in each of the categories defined above.[8] Figure 3 shows that the large majority (64%) of employees in the EU are in occupations that cannot be performed remotely. Among the remaining 36% of employees in the EU who are in occupations that are fully teleworkable form a purely technical perspective, around two-thirds are in occupations with extensive social interaction. Thus, only 13% of employment is in occupations that are technically teleworkable and also involve limited social interaction, and can thus it can in principle be carried out with no or limited loss of quality. Prospectively, it is in these occupations (e.g., finance professionals or ICT technicians) where the general increase in teleworking post-outbreak could be expected to persist in the longer term. Conversely, in occupations such as those of secondary school

8 For those 3-digit ISCO occupations groups that are only partially teleworkable – those with a technical teleworkability score between zero and one – this projection implies that only a corresponding share of those employed in the group are considered teleworkable

teachers which require extensive social interaction, the expectation would be that post-COVID most work, while technically teleworkable, would revert to its traditional locus in schools and classrooms. In what follows, we provide a more detailed assessment of our measures of technical teleworkability against the actual prevalence of telework, both before and after the outbreak.

Figure 3 % of EU dependent employment by level of teleworkability and social interaction



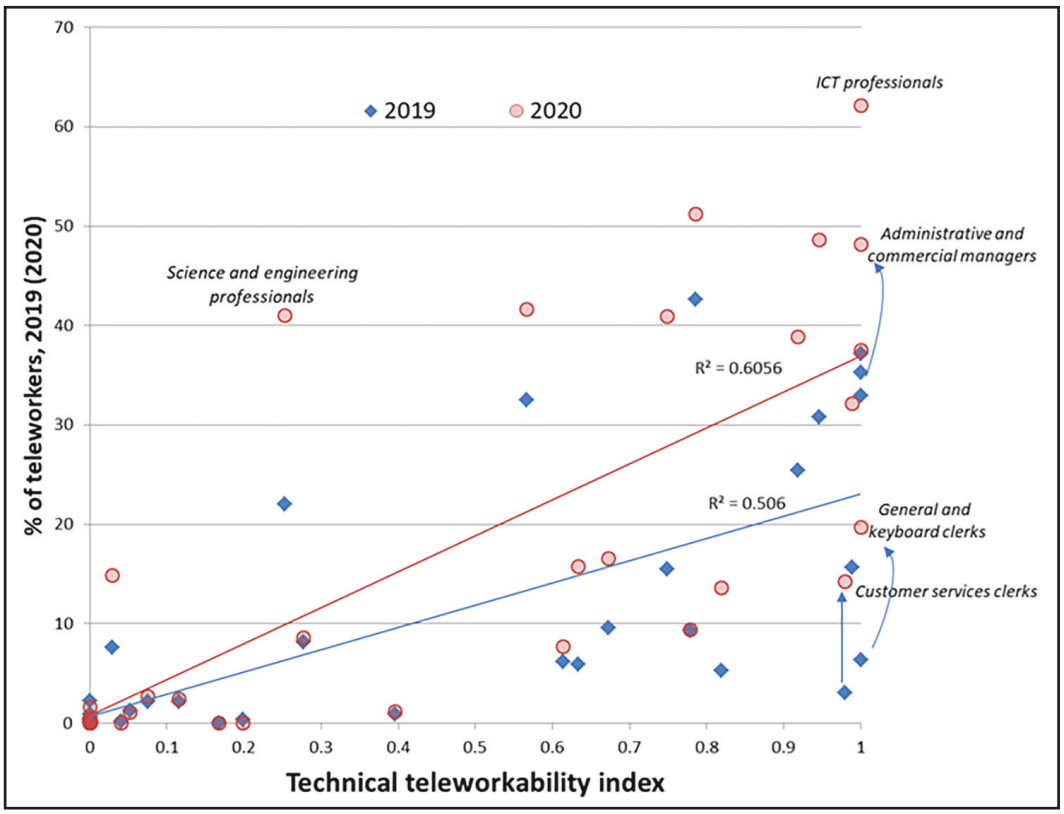
Source: Authors' calculations from EU-LFS, EWCS, ICP.

6 Estimated ability to telework and actual outcomes pre- and post-outbreak

To better interpret our measures of technical teleworkability, and validate them, it is useful to compare our indicator of technical teleworkability with data on the prevalence of telework before and during the COVID-19 crisis. This section presents this comparison by occupation and EU Member State. Figure 4 shows that there is a positive association between our measure of technical teleworkability and the actual prevalence of telework, both pre- and post-outbreak across 2-digit ISCO-08 occupations. With few exceptions (e.g., science and engineering professionals), the left-hand side of the figure shows that the vast majority of occupations that are classified as non-teleworkable (or almost non-teleworkable) in our approach had an extremely low prevalence of telework before the COVID-19 crisis, a situation which remained virtually unchanged in 2020. However, for occupations with very high or full teleworkability, the relationship between potential and actual telework is less straightforward. On the one hand, most managerial and professional occupations, which receive very high scores of teleworkability in our index, show a relatively high prevalence of telework in the pre-outbreak period, which increased further since the onset of the crisis (e.g., ICT professionals). On the other hand, there are many occupations that we classified as highly teleworkable (mostly, clerical workers and administrative assistants) which before the COVID-19 outbreak had instead very low rates of telework. After the outbreak, these occupations experienced a rapid increase in access to telework, although not to the level one could have expected by looking at their jobs' task composition.

This divide between lower-level white-collar occupations and higher-level ones is evident when looking at figures on the technical teleworkability against pre- and post-outbreak telework prevalence at the 1-digit occupational level. As shown in Figure 5, the gap between actual and potential telework is considerably wider in the case of clerical support workers for whom – despite involving tasks that can be technically teleworked (84%) – teleworking prevalence was very marginal pre-outbreak (5%); and, although tripling, it remained relatively low also in 2020 (16%). By contrast, the gap between technical teleworkability and the actual prevalence of teleworking is considerably smaller, and narrowing further since the advent of the outbreak, among higher-level white-collar occupations. For instance, among the 71% of professionals who, in our assessment, could technically work from home, over 43% did so in 2020 – up from 29% pre-outbreak. Overall, these results are consistent with our conjecture that the actual uptake of telework is not only a matter of technical feasibility, but it also depends on the way work is organised and regulated, and the values and preferences of employers. In particular, these results support the hypothesis that access to teleworking has hitherto been conditioned by the position in the occupational hierarchy and associated privileges, more than by the task

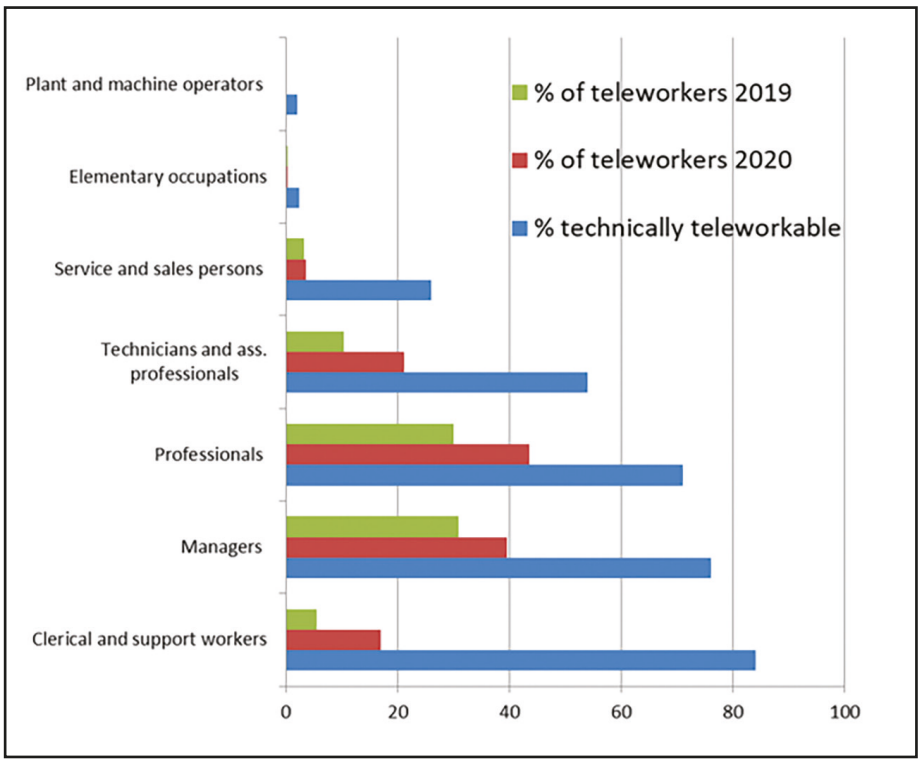
Figure 4 Relationship between technical teleworkability and prevalence of telework in 2018 by 2-digit ISCO08



Note: Employees only. "Teleworkability" refers to share of employment in teleworkable occupations according to our operationalisation; 'telework, 2019 (2020)' refers to share of employment working from home usually or sometime according to EU-LFS 2019 (2020) microdata (EU27).

Source: Authors' calculations from ICP, EWS, and EU-LFS.

Figure 5 Teleworkability and actual teleworking among employees by broad occupation group



Note: Employees only. "Teleworkability" refers to share of employment in teleworkable occupations according to our operationalisation; 'telework, 2019 (2020)' refers to share of employment working from home usually or sometime according to EU-LFS 2019 (2020) microdata (EU27).
Source: Authors' calculations from ICP, EWS, and EU-LFS.

composition of the job. This trend appears to persist even post-outbreak, even though there are signs that access to telework has become more evenly distributed within white-collar occupations, as enforced closures have resulted in many new teleworkers amongst low and mid-level clerical and administrative workers who previously had limited access to remote work.

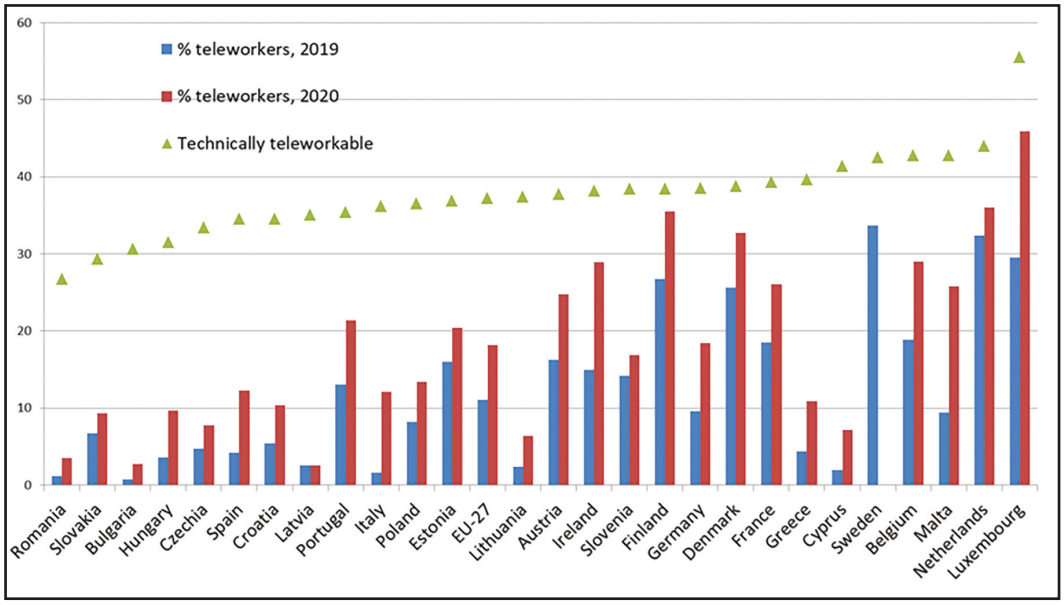
Finally, it is interesting to explore how the share of technically teleworkable employment differs across EU Member States, and to what extent this share deviates from figures on the prevalence of telework both before and after the outbreak. Since we measure teleworkability as an attribute of occupations, constant for the same occupations across different countries, the share of teleworkable employment varies across Member States based only on the composition of their workforce. This means that countries with higher shares of white-collar occupations have a larger share of employment that is teleworkable. The estimates thus cannot take into account differences between Member States in ICT technology, regulation, size of companies, or management culture. According to our estimation, the share of teleworkable employment ranges from 27% in Romania to just over twice that in Luxembourg (54%) (see Figure 6). Overall, there is relatively limited variation between countries: in all Member States except five, the fraction of teleworkable employment ranges between 33 and 44% of total employment, with the highest shares in the Nordic and Benelux countries and the lowest in Eastern Europe and also in some of the larger Member States in Southern Europe.

A first observation we can make from Figure 6 is that that the share of dependent employment in the EU that is potentially teleworkable (around 36%) is much greater than the actual prevalence of teleworking observed in 2020 (18%). This largely reflect the fact that 2020 figures refer to the whole year, and therefore they include the pre-outbreak period (Q1-2020), as well as Q3 and Q4-2020 when workplace closures and containment policies were generally less stringent (see Figure 7). However, when we compare our estimates of technically teleworkable employment with figures on teleworking prevalence just after the onset of the pandemic, the gap between actual and potential telework becomes considerably smaller. For instance, in April-May 2020 when governments often required, or strongly recommended, that all of those who could telework had to do so (Hale et al., 2021), close to 20% of EU employee was regularly working from home, and some 7% doing so occasionally. On the one hand, this shows that, when required, a much larger share of EU employees can actually work from home. On the other hand, the fact that a large proportion of workers returned to their offices when containment and closure policies eased, hints to a certain reluctance of managers and employers in maintaining teleworking beyond the emergency sanitary situation in several EU Member States.

Another important observation coming from Figure 6 is that the extent to which the gap between potential and actual teleworkers has closed after the onset of the outbreak differs significantly across countries. In some Member States, such as Finland, Denmark, and Luxembourg, where telework was already widespread in 2019, the prevalence of telework has further increased in 2020, approaching values that are quite close to our estimates of technically teleworkable employment. A somewhat similar remark can be made for some other countries, such as Austria, Ireland, Belgium, where the gap between the share of potential and actual teleworkers in 2020, whilst still significant, is also relatively narrow. This gap remains instead considerable in virtually all the other Member States, despite the fact that most of them were able to scale up teleworking during the outbreak, often starting from a very low base. This is notably the case of Italy and Spain, two countries where the share of teleworkers in 2020 surpassed 12%, up from 1.6% and 4.2% respectively in 2019. Yet, despite the impressive improvement, actual telework figures remain far below our estimates of teleworkable employment in these two countries, as well as in several others EU Member States.

The fact that our estimates of teleworkable employment are close to 2020 telework figures in countries that already had widespread experience with telework, whereas they are far higher in those countries where telework was marginal before the outbreak, may suggest that bringing telework to its full potential in a short time span was arguably easier in the former group of countries that in the latter, where pre-existing barriers to remote work could not be suddenly removed. In other words, the same barriers that prevented the diffusion of telework before the outbreak – e.g. lack of ICT infrastructure, fears of losing managerial control, limited workforce's digital skills (Milasi et al, 2021) – are likely to have continued playing an important role in explaining companies' resistance to scale-up telework also in the post-outbreak. This should partly explain why our estimates of potential telework differ from actual figures, mostly in those countries with little prior experience with teleworking.

Figure 6 Share of teleworkable employment, by country, in EU27



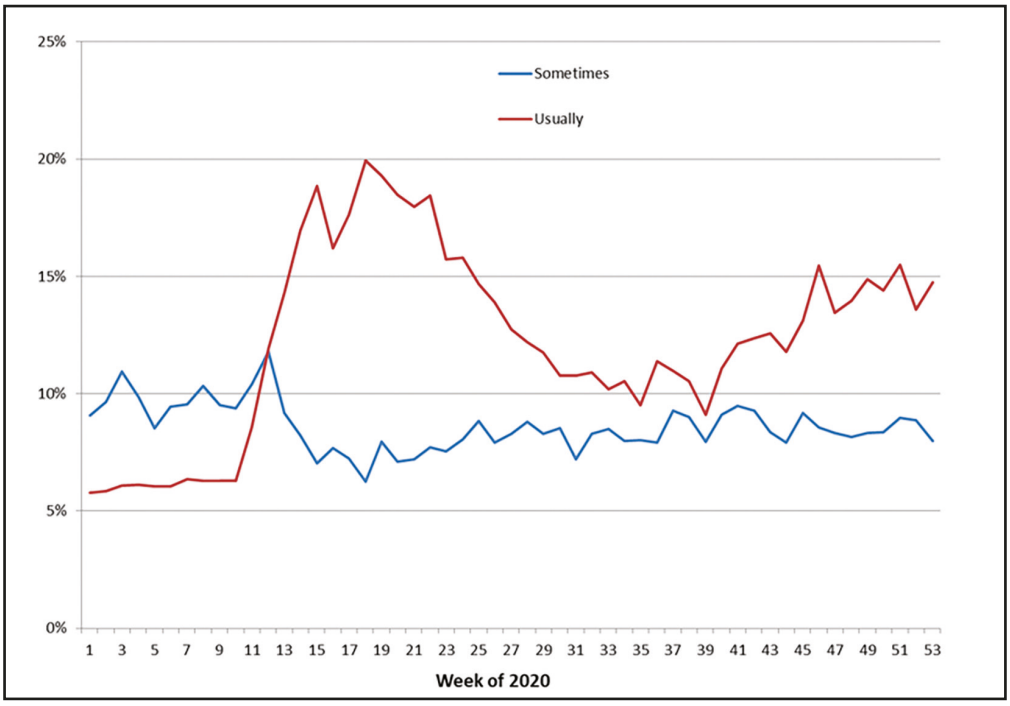
Note: Employees only. Changes in the survey methodology have led to a break in German data in 2020. Estimates for 2020 therefore cannot be compared directly with those of previous years. In addition, data collection during 2020 was impacted by technical issues and COVID-19 measures. The German data published is therefore preliminary and may be revised in the future. For more information, see here.
Source: Authors' calculations from ICP, EWS, and EU-LFS.

7 Conclusions

As the COVID-19 crisis finally abates, many employees are resuming their routine commute to and from work and the incidence of "full-time" teleworking will in all probability decline from the pandemic highs. There are however many reasons to believe that there will be a legacy from the pandemic episode. Some employers are considering changes to their working arrangements, extending the possibility to telework, and may even rethink office-based work altogether. The ability to telework (at least some of the time) may even become a prominent feature of working conditions, one that potentially further divides occupation groups, or even social classes. Policymakers have the opportunity to reflect on what the current experience of teleworking means about the nature of work and its future.

What are the implications of this ad-hoc experiment in mass telework for the future of teleworking and its distributional consequences? To the extent that this episode is assessed positively by employees and employers, it may extend access to telework within knowledge-based organisations for all employees whose jobs allow it, regardless of their occupational status. In this paper, we have defined teleworkability in terms of technical feasibility, which we have argued depends essentially on the technologies available for remote communication and their interaction with the different types of task content (physical, intellectual or social). But the conceptual framework that we use in this paper includes as crucial determinants of the actual teleworkability also the extent of social interactions and the way work is organised. We have shown that two-thirds of employees in the EU who are in occupations that are fully teleworkable from a purely technical perspective (36% in total), are in occupations which require extensive social

Figure 7 Week-by-week share of employee usually (sometimes) working from home in 2020 in the EU27



Note: Employees only. Figures refer to the weighted data for EU27 countries combined.
Source: Authors' calculations from EU-LFS ad-hoc extractions provided by Eurostat.

interaction. Only 13% of employment is in occupations that are technically teleworkable and involve limited social interaction. As previously discussed, it is in these occupations where, if there is a general increase in teleworking post-outbreak, it could be expected to occur earliest and fastest. Conversely, in occupations such as those of secondary school teachers which require extensive social interactions, the expectation would be that post-outbreak, most work while technically teleworkable would revert to its traditional place of work.

Moreover, one of the main findings of this study is that the share of work that could be carried out remotely is much greater than the pre-outbreak prevalence of teleworking, which was marginal in most countries. In fact, before the outbreak teleworking was mostly reserved to experienced employees in high-paid occupations, often employed in knowledge-based services. Yet, as we show, a much larger pool of employees, mostly in clerical and administrative jobs who had no access to telework before the pandemic, can in fact telework and have, in all probability, started doing so for the first time in March 2020. Data on actual prevalence of telework for 2020 confirm that this was the case for millions of workers. Yet, these data also reveal that the spread of telework in the post-outbreak was ultimately less than expected, at least for some countries and occupations. This suggests that the outbreak-induced necessity to work from home, while removing at least temporarily, some of the "soft" barriers to telework – e.g. employers' and managers' reluctance to extend unsupervised autonomy – has likely not been able to push the adoption of telework to its full potential. Looking forward, although initial evidence from surveys points to a growing acceptance of teleworking both across organisations and workers, it remains difficult to predict whether the adoption of telework will continue to grow further, even after the pandemic passes.

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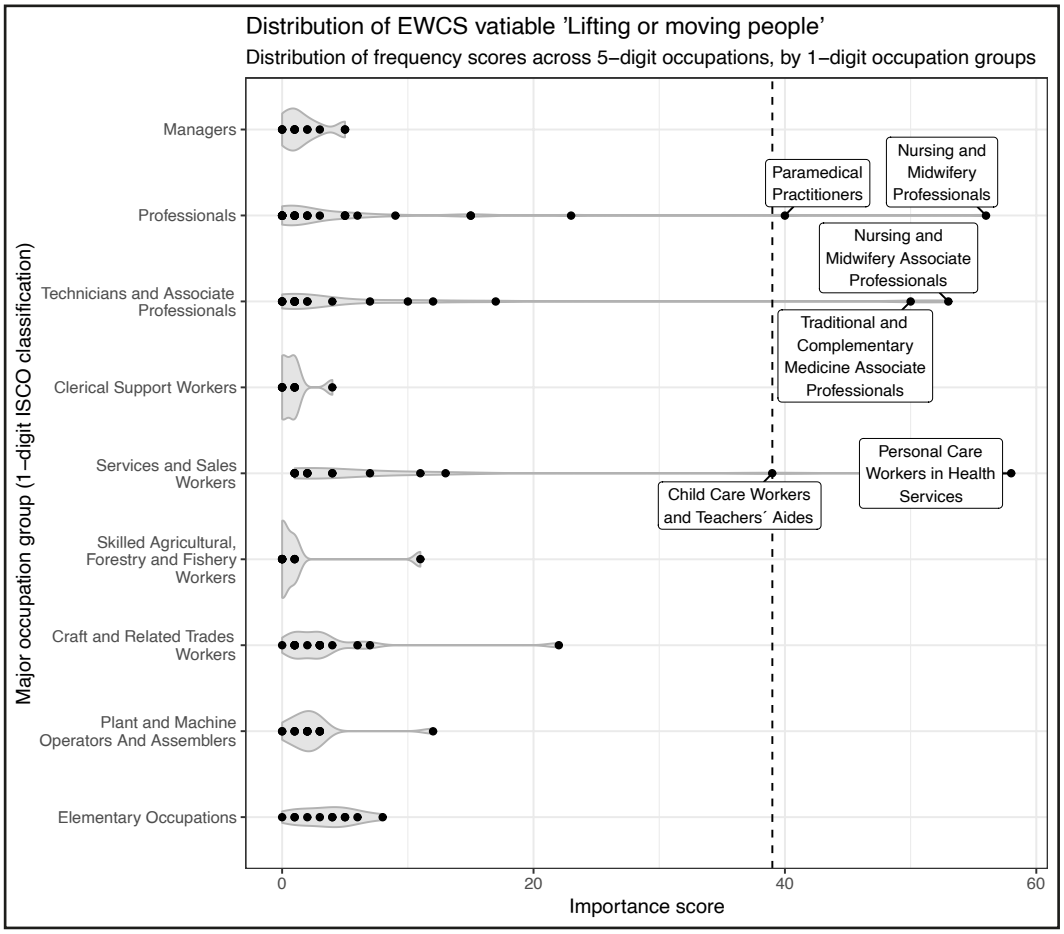
Appendix A: Distribution of EWCS variable "Lifting or moving people"

Figure A1 shows that the values of the EWCS indicator "lifting or moving people" are zero or very low for most ISCO 3-digit occupations, but there is a distinct cluster of occupations for which it is high, mostly in health and social care. As it happens, the value for *Child care and teacher's aides* (ISCO 531) fell slightly below the threshold of 40. Because this occupation has clearly much in common with all the other caring professions that report physically handling people, we decided to include it among the not teleworkable.

Figure A1 Distribution of physical interaction variable "Lifting or moving people" from EWCS



Note: The figure shows the distribution of the values of Lifting or moving people for 129 different ISCO 3-digit occupations, divided by 1-digit occupation major groups. The dashed line represents the threshold used to classify the technical teleworkability of occupations.

Appendix B: Values of technical teleworkability and social interaction indices

Table B1 shows the values of the technical teleworkability and social interaction indices for ISCO 2008 3-digit occupation groups.[9] In the majority of cases, the resulting classification, reported in the table below is consistent with intuition and anecdotal evidence on whether different occupations have been able to telework during the lockdown. Unsurprisingly, there are also some exceptions of occupations that are classified as teleworkable when experience suggests they should no bet, or vice-versa. This is especially the case when aggregating the scores from the original CP 5-digit occupations that the ICP survey measures, to more diverse ISCO 3-digit occupation groups used for further analysis. Upon closer inspection, many of these classifications follow quite consistently from the values of the physical task indicators of the underlying occupations. In two cases, we decided to re-classify some occupations, on the grounds that the physical interaction variables reported in the survey fell slightly below the threshold, but did not seem to accurately reflect the task profile of those occupations. Therefore we made one ad-hoc adjustment for cashiers in retail (CP 5.1.2.4.0, part of ISCO 523), who reported values at or below 34.8 for all physical interaction variables, including 30.4 for Handling and Moving Objects. These values appeared implausible, not only in comparison with similar occupations like ticket sellers, but also with the task descriptions of that occupation, reported in a dedicated section of the ICP. We decided to override the data-driven classification of ISCO 523, and marked them as *not* teleworkable. As explained in Appendix A, we also reclassified child care and teacher's aides as not teleworkable, on the same grounds. Finally, we duplicated the values of ISCO *322: Nursing and Midwifery Associate Professional* into ISCO *222: Nursing and Midwifery Professional*, because the official CP to ISCO mapping of occupations did not distinguish between the two. All these changes are commented and reported in the code to construct the indices which is available at https://github.com/m-sostero/telework-occupations.

9 The table is available in electronic format at https://doi.org/10.5281/zenodo.7716420

Table B1: Technical teleworkability index and social interaction index by ISCO08 3-digit occupations

ISCO08 code	Occupation title	Technical teleworkability	Social interaction
111	Legislators and senior officials	1.00	0.68
112	Managing directors and chief executives	1.00	0.69
121	Business services and administration managers	1.00	0.61
122	Sales, marketing and development managers	1.00	0.65
131	Production managers in agriculture, forestry and fisheries	0.00	0.62
132	Manufacturing, mining, construction, and distribution managers	0.18	0.62
133	Information and communications technology service managers	1.00	0.57
134	Professional services managers	1.00	0.67
141	Hotel and restaurant managers	0.97	0.63
142	Retail and wholesale trade managers	0.07	0.67
143	Other services managers	0.89	0.61
211	Physical and earth science professionals	0.23	0.45
212	Mathematicians, actuaries and statisticians	1.00	0.59
213	Life science professionals	0.26	0.54
214	Engineering professionals (excluding electrotechnology)	0.25	0.50
215	Electrotechnology engineers	0.00	0.51
216	Architects, planners, surveyors and designers	0.38	0.36
221	Medical doctors	0.39	0.79
222 [10]	Nursing and Midwifery Professionals	0.00	0.94
225	Veterinarians	0.00	0.64
226	Other health professionals	0.59	0.75
231	University and higher education teachers	0.49	0.80
232	Vocational education teachers	1.00	0.76
233	Secondary education teachers	1.00	0.77
234	Primary school and early childhood teachers	0.61	0.78
235	Other teaching professionals	0.86	0.74
241	Finance professionals	1.00	0.46
242	Administration professionals	0.97	0.57
243	Sales, marketing and public relations professionals	1.00	0.56

(Continued)

10 Value duplicated from 322: Nursing and midwifery associate professionals, because the official CP-ISCO mapping does not distinguish between the two.

Table B1 Continued

ISCO08 code	Occupation title	Technical teleworkability	Social interaction
251	Software and applications developers and analysts	1.00	0.46
252	Database and network professionals	1.00	0.41
261	Legal professionals	1.00	0.43
262	Librarians, archivists and curators	1.00	0.51
263	Social and religious professionals	0.98	0.67
264	Authors, journalists and linguists	1.00	0.43
265	Creative and performing artists	0.34	0.54
311	Physical and engineering science technicians	0.01	0.45
312	Mining, manufacturing and construction supervisors	0.00	0.57
313	Process control technicians	0.02	0.38
314	Life science technicians and related associate professionals	0.63	0.35
315	Ship and aircraft controllers and technicians	0.09	0.60
321	Medical and pharmaceutical technicians	0.00	0.39
322	Nursing and midwifery associate professionals	0.00	0.94
324	Veterinary technicians and assistants	0.00	0.39
325	Other health associate professionals	0.35	0.66
331	Financial and mathematical associate professionals	1.00	0.41
332	Sales and purchasing agents and brokers	1.00	0.66
333	Business services agents	1.00	0.52
334	Administrative and specialised secretaries	1.00	0.53
335	Regulatory government associate professionals	0.53	0.57
341	Legal, social and religious associate professionals	1.00	0.74
342	Sports and fitness workers	0.04	0.67
343	Artistic, cultural and culinary associate professionals	0.11	0.48
351	Information and communications technology operations and user support technicians	0.93	0.43
352	Telecommunications and broadcasting technicians	0.00	0.32
411	General office clerks	1.00	0.39
412	Secretaries (general)	1.00	0.44
413	Keyboard operators	1.00	0.29
421	Tellers, money collectors and related clerks	0.93	0.50

(Continued)

Table B1 Continued

ISCO08 code	Occupation title	Technical teleworkability	Social interaction
422	Client information workers	1.00	0.48
431	Numerical clerks	1.00	0.26
432	Material-recording and transport clerks	0.40	0.42
441	Other clerical support workers	0.82	0.40
511	Travel attendants, conductors and guides	0.73	0.78
512	Cooks	0.00	0.48
513	Waiters and bartenders	0.00	0.56
514	Hairdressers, beauticians and related workers	0.00	0.58
515	Building and housekeeping supervisors	0.00	0.70
516	Other personal services workers	0.32	0.55
521	Street and market salespersons	0.00	0.84
522	Shop salespersons	0.04	0.80
523 [11]	Cashiers and ticket clerks	0.10	0.51
524	Other sales workers	0.33	0.50
531 [12]	Child care workers and teachers' aides	0.00	0.75
532	Personal care workers in health services	0.00	0.54
541	Protective services workers	0.40	0.57
611	Market gardeners and crop growers	0.00	0.43
612	Animal producers	0.00	0.33
613	Mixed crop and animal producers	0.00	0.36
621	Forestry and related workers	0.00	0.46
622	Fishery workers, hunters and trappers	0.00	0.41
711	Building frame and related trades workers	0.00	0.27
712	Building finishers and related trades workers	0.00	0.38
713	Painters, building structure cleaners and related trades workers	0.00	0.31
721	Sheet and structural metal workers, moulders and welders, and related workers	0.00	0.38
722	Blacksmiths, toolmakers and related trades workers	0.00	0.32
723	Machinery mechanics and repairers	0.00	0.33
731	Handicraft workers	0.00	0.36
732	Printing trades workers	0.33	0.30
741	Electrical equipment installers and repairers	0.00	0.40

(Continued)

11 Value for the main subgroup (CP 5.1.2.4.0) changed manually from teleworkable to non teleworkable.

12 Value just below the threshold, moved from teleworkable to non teleworkable.

Table B1 Continued

ISCO08 code	Occupation title	Technical teleworkability	Social interaction
742	Electronics and telecommunications installers and repairers	0.00	0.42
751	Food processing and related trades workers	0.00	0.50
752	Wood treaters, cabinet-makers and related trades workers	0.00	0.37
753	Garment and related trades workers	0.00	0.36
754	Other craft and related workers	0.00	0.36
811	Mining and mineral processing plant operators	0.00	0.27
812	Metal processing and finishing plant operators	0.00	0.33
813	Chemical and photographic products plant and machine operators	0.00	0.30
814	Rubber, plastic and paper products machine operators	0.00	0.28
815	Textile, fur and leather products machine operators	0.25	0.31
816	Food and related products machine operators	0.00	0.33
817	Wood processing and papermaking plant operators	0.00	0.35
818	Other stationary plant and machine operators	0.00	0.29
821	Assemblers	0.00	0.26
831	Locomotive engine drivers and related workers	0.00	0.18
832	Car, van and motorcycle drivers	0.00	0.52
833	Heavy truck and bus drivers	0.00	0.18
834	Mobile plant operators	0.00	0.25
835	Ships' deck crews and related workers	0.00	0.26
911	Domestic, hotel and office cleaners and helpers	0.00	0.32
912	Vehicle, window, laundry and other hand cleaning workers	0.00	0.45
921	Agricultural, forestry and fishery labourers	0.00	0.24
931	Mining and construction labourers	0.00	0.19
932	Manufacturing labourers	0.00	0.24
933	Transport and storage labourers	0.00	0.20
941	Food preparation assistants	0.00	0.26
951	Street and related service workers	0.00	0.43
952	Street vendors (excluding food)	0.00	0.71
961	Refuse workers	0.00	0.29
962	Other elementary workers	0.28	0.36