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Telework in the spread of COVID-19

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ABSTRACT

In the spread of coronavirus disease (COVID-19), people have been requested to work from home with information and communication technology (ICT) tools, i.e. telework. This paper investigates which factors (infection of COVID-19, individual characteristics, task characteristics, and working environments) are associated with telework use in Japan. Using the unique panel survey on telework, our estimation finds that although telework use remains low in Japan, educated, high ICT-skilled, younger, and female workers who engage in less teamwork and less routine tasks tend to use telework. Working environments such as the richness of IT communication tools, digitalized offices, and flexible-hour working systems are all positively correlated with telework use.

1. Introduction

The coronavirus disease (COVID-19) virus commenced its worldwide spread in February 2020. In the COVID-19 pandemic, people have been requested to work from home and refrain from commuting. Telework, i.e., working at home with information and communication technology (ICT) tools, has attracted considerable attention as an effective countermeasure against infection. However, some impediments hamper the use of telework for some workers. Telework is unsuitable for some workers (e.g., old uneducated workers) (Adams-Prassl et al., 2020) as well as some occupations (e.g., manual laborers and medical service workers) (Dingel and Neiman, 2021). Telework tends to reduce workers' performance due to less face-to-face communication (Bartik et al., 2020). For a variety of reasons, some countries such as Japan have observed a low percentage of telework utilization.

A further reason for lower telework use is the government's infection controls. Unlike many other developed countries, Japan has seen a lower percentage of infections in the total population (on a cumulative basis, 6.1% in Japan, 24.6% in the US, 29.1% in Germany, 32.6% in the UK, and 43.8% in France, as of April 28, 2022).[1] Japan has taken a unique approach to infection controls. In particular, lockdown was request-based and did not involve any legal restrictions, sanctions, and punishments, which originates from the Constitution of Japan.[2] The Prime Minister, the government's COVID-19 subcommittee, and local governments just asked for the cooperation of all people. Such a request-based lockdown might not greatly boost telework use. Therefore, it seems that many factors result in a low percentage of telework use in Japan.

This paper studies telework in Japan with regard to the COVID-19 pandemic using the unique panel survey on telework. In particular, the following questions are addressed in this paper: to what extent is telework used in Japan following the spread of COVID-19, whether occupation-based suitability of telework can be related to actual telework use, and how basic individual traits (e.g., gender, age, education, and income), working environments (e.g., flexible working hours and ICT tools at the workplace), and task characteristics (e.g., nonroutine tasks) are associated with telework use.

As a result of the investigation, we draw several conclusions. First, telework use in Japan remains low in some occupations. Some occupations are suitable for telework (e.g., information processing, business consultants, and finance insurance workers), whereas some are not (e.g., food services, hotel accommodation, doctors, and nurses). Second, according to our estimation results, female, educated, and younger workers with higher income tend to use telework. The occupational index for teleworkability is positively associated with telework use. Third, persons with higher ICT skills and carrying out fewer routine tasks tend to use telework.

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[1] https://coronavirus.jhu.edu/data/cumulative-cases.

[2] For reference, see e.g., https://www.japantimes.co.jp/news/2020/03/10/national/politics-diplomacy/cabinet-bill-shinzo-abe-state-of-emergency-coronavirus/.A major reason for the request-based policies is related to the Constitution. See e.g., https://www.japantimes.co.jp/opinion/2020/04/14/commentary/japan-commentary/coronavirus-japans-constitution/.

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0167-6245/

Workers under the flextime employment system and with a wide variety of available ICT tools are positively correlated to telework use.

The remainder of this paper is structured as follows. Section 2 reviews the literature and Section 3 describes the background. Section 4 shows data and some evidences. Sections 5 and 6 provide some estimation results. Finally, Section 7 concludes the paper.

2. Literature review

2.1. Previous studies on telework

Before the COVID-19 pandemic, telework was attracting attention as a means of improving work styles and quality of life in the digitalized economy (Gajendran and Harrison, 2007; Dutcher, 2012; Bloom et al., 2015; Gimenez-Nadal et al., 2019). Although the mechanisms that will fully enable telework are not yet in place, it is regarded as a means of increasing work efficiency by reducing commuting (Mitomo and Jitsuzumi, 1999; Helminen and Ristimäki, 2007; Haddad et al., 2009) and increasing flexibility in working hours (Coenen and Kok, 2014), giving workers more time for their daily lives (Di Martino and Wirth, 1990; Tremblay, 2002; Baines and Gelde, 2003; Wheatley, 2012; Kazekami, 2020).

Although previous efforts were to promote telework to enable better work styles, telework is now promoted as a countermeasure against the spread of COVID-19 infection. The government has requested workers to exercise self-restraint by staying home and has sought to promote telework. However, it may also be the case that some occupations and tasks are suited to teleworking, and some working environments allow workers to use teleworking. Telework use has increased over the world during the pandemic. In the United States, those who work from home increased from 8% in February 2020 to 35% in May 2020 (Bick et al., 2020). According to Eurofound (2020), 37% of workers began to telework in Europe in response to the spread of COVID-19. Alipour et al. (2020) found that the extent of teleworkers comprises 20–50% in Europe. In Japan, the extent increased from 6% in January to 17% in June 2020 (Okubo, 2020).[3]

Further investigations are being conducted by several researchers on telework using unique labor surveys. Telework reduces worker's efficiency (Bartik et al., 2020; Morikawa, 2020; Okubo et al., 2021) but tends to be used by higher-income workers (Mongey et al., 2020; Sostero et al., 2020) and younger and male workers (Adams-Prassl et al., 2020). In the long run, telework will promote income inequality and benefit male and educated workers (Bonacini et al., 2021).

More analytically, the crucial issue is how many jobs can be carried out at home. Some current studies found that working from home is potentially suitable for some specific occupations. Dingel and Neiman (2021) identified which occupations are potentially suitable for remote work.[4] They precisely defined which occupations could be performed entirely at home and estimated how much of the population could possibly work from home using job characteristic information on O*NET and the US Bureau of Labor Statistics data. They found that 37% of workers could possibly perform their jobs entirely at home in the United States.[5] Likewise, some studies in other countries estimated possible jobs for remote work and found that 24% of the jobs in Italy (Boeri et al., 2020) and 39% of the jobs in Norway (Holgerson et al., 2021) can be performed at home. This study is in this line, but we are not aimed at estimating possible jobs for remote work. Using unique data on the individual-level surveys, this paper uncovers which factors are associated with telework use under such soft lockdown, individual traits, occupational characteristics, and working environment.

2.2. The case of Japan: Surveys on the pandemic of COVID-19 in Japan and survey-based empirical analysis

During the spread of COVID-19, several surveys on remote work or telework have been undertaken by several bodies in Japan, e.g., the Japan Household Panel Survey (JHPS) by Keio University, the survey on the Impact of COVID on Individual's Job and Life by JILPT, the Japanese Panel Study of Employment Dynamics (JPSED) by the Recruit Works Institute, Survey on Individual's Life and Behaviours by the Cabinet Office of Japan, and Survey on Telework by the Japan Trade Union Confederation (Rengo), Line Research, PERSOL Research and Consulting[6], and our telework survey by Okubo and NIRA (Okubo and NIRA, 2020a,b,c, 2021a,b).[7]

Using these surveys, several studies investigated remote work. Using JHPS, Ishii et al. (2021) found that highly ICT-skilled workers with abstract tasks tended to enjoy the benefit of remote work under the first state of emergency (April and May 2020). Using the same data, Ishino et al. (2021) found that teleworkers who own their houses tended to increase hours for childcare by 17%. Using the survey by JILPT, Takami and Yamamoto (2021) found that workers increased telework use under the first state of emergency, but some occupations and tasks were not suited.[8] Using JPSED,Kawaguchi and Motegi (2021) found that workers who engage in nonroutine tasks and human resource management tend to use telework, and then Ohtani (2021) found that telework did not greatly change task-sharing for housekeeping and childcare between wife and husband. These previous studies on Japan focus on which personal traits (gender, age, and occupation) affect telework and how telework changed work and lifestyle, using one or a few waves of surveys in the first state of emergency (April to May, 2020).

Our contribution is threefold. First, the literature on a relationship between occupation-level suitability for remote work (telework) and actual telework use is relatively sparse. Previous studies propose suitability for remote work at the occupation level based on task information such as O*NET, but do not fully investigate how such occupational suitability results in the actual use of telework and which factors other than occupational suitability would crucially affect the actual use of telework. This paper fills this gap.[9]

Second, compared with other current studies on telework in the early spread period of COVID-19 (around from April to July 2020), this paper uses the panel survey data with a much longer period, covering several waves of infections and several states of emergency (from March 2020 to September 2021) and investigates

[3] According to Gottlieb et al. (2021), the share of workers who work from home in urban areas is 20% in poor countries and 40% in rich countries.

[4] Similarly, using the Surveys of Adult Skills of PIAAC and STEP in 53 countries, Hatayama et al. (2020) estimated jobs' amenability to working from home and then constructed a work-from-home index.

[5] Subsequently, Alon et al. (2020) and Leibovici et al. (2020) identified the jobs that could be done from home based on O*NET.

[6] See Appendix 1 on data website information for more details.

[7] A link to the data: https://nira.or.jp/paper/data/2022/26.html.html.The data is panel structure with five waves. See also reports on each wave of the survey https://www.nira.or.jp/paper/report20200417.pdf, https://www.nira.or.jp/paper/NIRA_Report_20200805.pdf, https://www.nira.or.jp/paper/NIRA_report_20210611.pdf, https://www.nira.or.jp/paper/NIRA_Report_20201229.pdf, https://www.nira.or.jp/paper/report012110_pre.pdf.

[8] JILPT has undertaken a company survey on COVID-19. Using the JILPT company survey, Kambayashi (2021) studied traits of companies introducing telework and Ogishima et al. (2021) investigated teleworkable occupations and tasks.

[9] Exceptionally, Adams-Prassl et al. (2020), using a unique survey conducted in the US and UK, found that the tasks that could be done from home during the spread of COVID-19 are highly correlated with extant task measures for the feasibility of working from home.

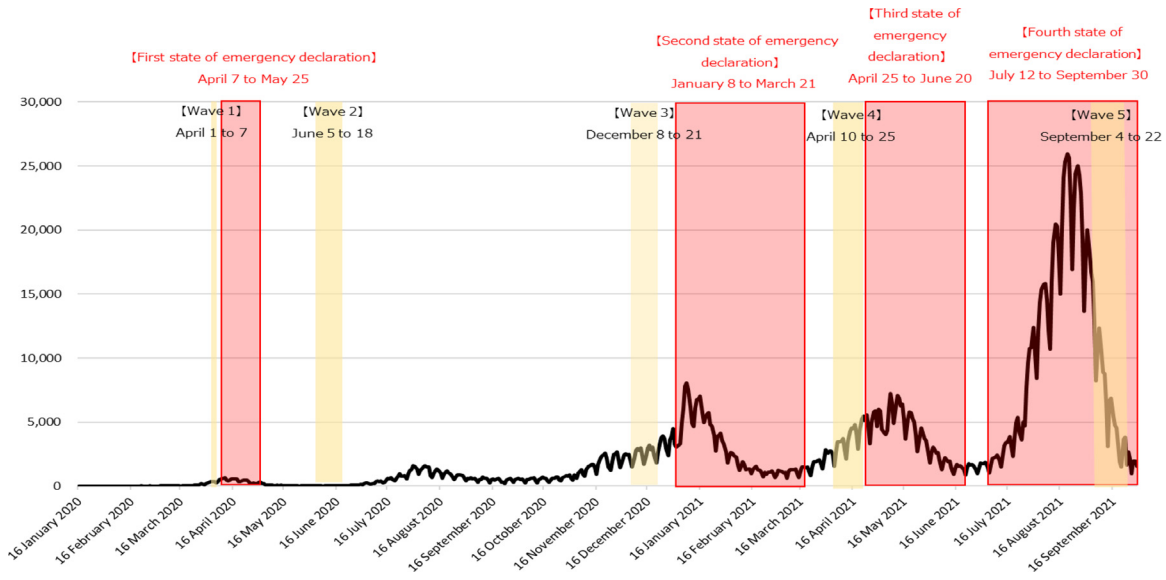

Fig. 1. Daily number of new infections in Japan
Source: https://www.mhlw.go.jp/stf/covid-19/open-data.html.

more varieties of factors for telework, in particular working environments (team-based working, outcome-based evaluation, and flexible working hours), digitalization (communication and IT tools, and automation of the office), and task traits (nonroutine or routine tasks).

Third, related to the second point, we have conducted five waves of surveys with more than 10,000 workers in Japan amidst COVID-19. Many other individual surveys during the COVID-19 pandemic are one-shot or conducted a few times without a panel sample.[10]

3. Background: COVID-19 in Japan

Fig. 1 plots the number of daily new cases of infections in the whole of Japan with dates of the states of emergency and timing of our survey (five waves). As seen in other countries, Japan has observed several waves of infections. In response to the waves, the government has taken several countermeasures and policies have swung between stringent infection controls and more economic activities. In the wake of the spread of COVID-19, the Japanese government declared a state of emergency on April 7, 2020. The government urged people to avoid nonessential trips, to work from home, and to use telework as much as possible, and requested retail shops, department stores, and restaurants to shut down or shorten business hours. Schools, public facilities, and amusement facilities were closed. Economic activity was slowed, but the lockdown by the state of emergency was soft. Thus, the economy did not completely stop; the public transport system worked as normal, and people were allowed to commute.

After the first state of emergency was lifted on May 25, economic activity resumed. In response, in June 2020, the government announced daily-life guidelines against COVID-19. The guidelines notified the public about how to use a mask, avoid mass gatherings, and follow social distancing. The public followed the guidelines. Then, the government shifted its focus from the pandemic strategy of reducing the spread of new COVID-19 infections to a strategy focused on economic countermeasures. To recover from the economic downturn, in particular, hotel and accommodation, in July 2020 the government initiated the “Go To Travel Campaign” and “Go To Eat Campaign” to cover some percentage of expenses.[11] The government policy “Go To Travel Campaign” remained in the second wave of COVID-19. However, in December 2020, as the third wave surged, the government again shifted its focus from a strategy focused on economic countermeasures to one of containing the spread of new infections. Finally, on December 15, 2020, the government stopped the “Go To Campaign” policy.

On January 8, 2021, the second state of emergency was declared. This was again a “soft” lockdown, and there were no restrictions on rights or penalties for noncompliance with government ordinances. The second state of emergency was much milder than the first one. The declaration was applied to 11 out of 47 prefectures. Requests were made to the restaurant industry to reduce working hours rather than shut down. It was not certain that these measures will be sufficient to control the spread of infections going forward. Thus, the number of infections in the third wave was larger than in the first and second waves (7,880 new infections per day at the peak of the third wave; see Fig. 1). Although the second state of emergency was lifted on March 21, 2021, the further spread of infection was not curbed, and the third state of emergency was declared on April 25, 2021 due to the fourth wave.

On June 20, the third state of emergency was lifted. However, because the number of new infections was again not curbed, the fourth state of emergency was declared on July 12. The basic measures were the same as the third state of emergency. During this state of emergency, the Tokyo Olympic Games were held without spectators at the venues. In the meantime, vaccination greatly helped contain the spread of infections. Finally, the state of emergency was lifted on September 30, 2021. Importantly, even if the state of emergency was declared or lifted, the government always requested workers to use telework without legal restriction.

[10] Exceptionally, the individual survey by JILPT has conducted six waves (as of March 2022). Each wave mainly asked employment status, and the number of respondent is around 4,000. Likewise, the survey by PERSOL Research and Consulting has also conducted six waves (as of March 2022). The sample size is around 20,000 regular workers, but the survey does not have a panel structure. The survey simply asked whether workers used telework or not and whether they intend to keep on teleworking.

[11] See Okubo (2021) for more details.

4. Data and stylized facts

4.1. Data (Okubo-NIRA Teleworker Survey)

We use the COVID-19 survey on telework use by workers conducted by NIRA and Toshihiro Okubo (Keio University) entitled "Questionnaire Survey on the Effects of the Spread of COVID-19 on Telework-based Work Styles, Lifestyle, and Awareness" (Okubo-NIRA Teleworker Survey) (Okubo and NIRA, 2020a,b,c, 2021a,b) (See https://nira.or.jp/paper/data/2022/26.html.html for the data link). The survey asked about individual's characteristics and working environments. There were five waves of the survey: March (first wave of the survey), June (second wave), December (third wave) 2020, April (fourth wave), and September (fifth wave) 2021. The panel data were composed of five waves. The sample sizes in the first, second, third, fourth, and fifth waves were 10,516, 12,138, 10,523, 9,796, and 10,644, respectively. Many respondents continuously joined the survey for several waves.[12] As shown in Appendix Table 1, 4,444 respondents in the whole sample repeatedly joined the survey for all waves. This means that 42% of respondents in the first wave survive joined all subsequent surveys. In the second, third, and fifth waves, 3,731, 1,322, and 2,189 joined the survey as a new sample. We note that no new respondents joined in the fourth wave. Out of 3,731, 1,617 respondents repeatedly joined all waves after the second wave. Likewise, out of 1,322, 741 respondents joined all waves after the third wave.

Our survey was conducted between waves of infections and the state of emergency. In Fig. 1, the survey periods are shaded yellow, and the states of emergency are shaded red. March 2020, the timing of the first wave of the survey, is the early period, before the first state of emergency when COVID-19 had not yet spread in Japan. June 2020, the timing of the second wave of the survey, is the period after the first state of emergency was lifted and the first wave of COVID-19 was contained. December 2020, the timing of the third wave of the survey, is the period after containing the second wave of COVID-19. However, the new cases of infections gradually increased, which is the initiation of the third wave of infection. April 2021, the timing of the fourth wave of the survey, is after the second state of emergency was lifted and the third wave of infection was partly contained, and the new cases of infections continued at a high level. Likewise, September 2021 was the timing of the fifth wave of the survey. This was when the fifth wave of infection was close to being contained.

Importantly, telework in our survey and paper is defined as follows. Our definition of telework is basically consistent with several other surveys, e.g., the above-mentioned surveys by MLIT, JILPT, JPSED, and JHPS. However, JILPT, JPSED, and JHPS asked about remote work regardless of use of ICT tools. Because telework generally refers to a way of working using ICT tools (MLIT, 2020), we adopt a stricter definition.[13] We define telework as remote working using ICT tools at a specific place (at home or in a public facility) for certain hours. Our definition, therefore, does not include the use of ICT devices at locations such as stations, airports, transportation facilities, and the premises of business partners. In addition, our definition does not include working from home without ICT devices. Therefore, whereas previous studies investigated "remote work" regardless of using or not using ICT devices (e.g., Ishii et al., 2021, Ishino et al., 2021, using the JHPS survey), telework defined in our paper is more limited in the sense of working remotely using ICT devices.

The survey asked about whether to use telework or not, "*Telework*," (dummy for telework use) as well as many individual's traits such as gender variable, "*Female*," (female = 2, male = 1), age variables, "*Age*," (scaled by age 10), the annual income in 2019, "*Income,*" (scaled by 500 thousand yen), and university degree variable, *"Univ,"* (a dummy for a university degree). Workstyle is various across gender and age. Teleworking is helpful for some age and gender groups. Income and educational attainment would also affect workers' workstyle and use of telework. All of these personal traits could crucially influence a worker's telework use. In addition, commuting is also crucial for telework use. Long-time commuting by public transportation is more likely to be replaced by telework. Our survey asked about the time for commuting (minutes), "*Com_time*," as well as the mode for commuting, where *PubTrans* is a dummy for using public transportation for commuting (e.g., trains and buses). The space for telework in a worker's living place is also crucial in telework. The survey asked about owning a house, expressed as a dummy for owning a house ("*house_own*"). All of the commuting environment and residential environment would crucially affect telework use.

4.2. Stylized facts on telework use

Fig. 2 presents the telework rate over time.[14] The green line indicates the national average, and the blue line indicates Greater Tokyo (Tokyo, Kanagawa, Chiba, and Saitama prefectures). In January 2020, before the widespread emergence of COVID-19, the national average of telework was only 6%, and the average for Greater Tokyo was about 10%.[15] In response to the first state of emergency from April to May 2020, the telework rate drastically increased, reaching 25% nationally and 38% in Greater Tokyo. However, after the first state of emergency was lifted in June 2020, the telework rate greatly decreased. Nonetheless, although the rate has remained lower than that seen during the first declaration of a state of emergency, it has remained higher than pre-COVID-19 pandemic levels, January 2020, and has stabilized with the second wave of the COVID-19 pandemic that began in September 2020, and even more so with the third to fifth waves of infections. In sum, telework use in Japan remains low despite a large increase under the first state of emergency and does not show an over-time increase in the era of the COVID-19 pandemic.

Fig. 3 shows the telework rate by occupation. We follow 38 occupation classifications, based on the middle classification of

[12] The data are panel structure by five waves including the same respondents. The survey was conducted on a website constructed by Nikkei Research Co. The survey takes a stratified random sampling strategy. Japan is stratified into five regions by regional classification and six age groups for each gender (12 age groups per region). The number of samples for 60 region–age groups was determined by population ratio. The Population Census (Ministry of Internal Affairs and Telecommunication) was employed as the sampling unit. The survey intended to construct the panel structure and thus keep the same respondents over waves as much as possible. Some respondents repeatedly joined the survey and some did not. Thus, new respondents were added to fill in the allocated number of samples in each unit. See Appendix Table 1.

[13] JHPS asked "remote work" with and without using ICT tools. The JILPT survey asked "remote work and telework" altogether without distinction by exact definition in its questionnaire. JPSED also asked "remote work" without and with using ICT tools, which defined telework as "working at a specific place other than an office, such as working at home, satellite office, café, and restaurant" in the questionnaire. MLIT adopted the definition of telework as remote work using ICT tools but the location includes such places as stations, airports, transportation facilities, and the premises of business partners. This is in sharp contrast to us.

[14] Each wave of the survey asks for telework use at multiple time points. January and March 2020 are covered by the first wave of the survey, April–May (under the first state of emergency) and June 2020 are covered by the second wave of the survey, September and December 2020 are covered by the third wave of the survey, and January–February, March (under the second state of emergency), April 2021 are covered by the fourth wave of the survey, and June and July 2021 are covered by the fifth wave.

[15] This is lower than the survey by MLIT (2020), 16.6% as of November 2019 due to MLIT's broader definition of telework. MLIT's definition includes the number of workers who use ICT devices at public transportation spaces, transportation facilities, and the premises of business partners. The special survey by JILPT and JHPS asked about remote work including telework.

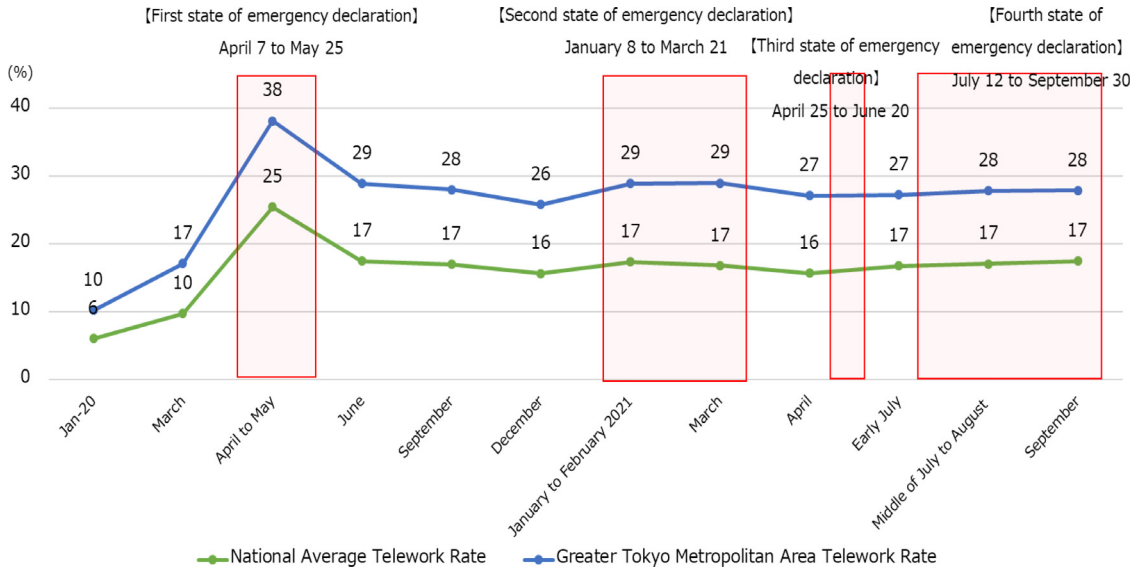

Fig. 2. Telework use in Japan.

Japan Standard Occupational Classification (See Appendix Table 2 for the classification). There are some variations across occupations. For instance, data processing engineers, management consultants, administrative and management workers, and researchers display higher rates of utilization, whereas carrying, cleaning, packaging and related workers, workers in family support, food and drink/cooking and customer service workers, and manufacturing process workers display low rates. This indicates that some occupations related to information and office workers tend to have a comparatively high rate of the utilization of telework, whereas telework is not suited to face-to-face services and manual labor.

5. Estimations and results

5.1. Basic estimations

First, we conduct basic estimations on individual characteristics and COVID-19 infection in telework use. The panel data are composed of five waves: March, June, and December 2020, April, and September 2021. Appendix Table 3 provides basic statistics.[16] The equation for estimation is given as:

$$TELEWORK_{it} = \beta WCOVID_{j(i)t} + \gamma X_i + Ind_{I(i)t} + Emp_{e(i)t} + Size_{s(i)t} + Prefr_{r(i)t} + Prefw_{j(i)t} + \mu_t + \xi_i + \varepsilon_{it}. \quad (1)$$

TELEWORK is the dummy for telework use for worker i at time t (waves of the survey). *TELEWORK* takes the value of one if a respondent uses telework, and zero otherwise. *WCOVID* denotes the number of daily new infections per population (i.e., infection rate) at respondent i's working place j (municipality level) at time t (the first day of the month when the survey was conducted).[17] X denotes a set of aforementioned individual's traits such as *Female, Age, Income, Univ, House_own, Com_time*, and *PubTrans*. Several fixed effects are added. *Ind* is the sector fixed effect, *Emp* is the employment-type fixed effect, *Size* is the firm-size fixed effect, *Prefr* is the residential prefectural fixed effect, *Prefw* is the workplace prefectural fixed effect, μ is the time dummy, and ξ_i is the individual effect.[18] We estimate eq. (1) using the linear probability model with random effects. ε is the error term.

The first column of Table 1 reports the results. *Female, Univ, Income*, and *house_own* are significantly positive, whereas *Age* is a significantly negative factor. The share of new daily COVID-19 infections in the total population at workplace municipality (*WCOVID*) is significantly positive. *Com_time* and *PubTrans* are both significantly positive. Thus, the higher percentage of new infections in the working place (municipality) is positively associated with telework use. Moreover, female, younger, and educated workers with higher income are also positively correlated with telework use. This is consistent with the observations in many previous studies (e.g., Mongey et al., 2020; Sostero et al., 2020). Longer commutes using public transportation are positively associated with telework use. The result of commuting can be interpreted as a long commute involves distress. Longer commute reduces well-being (Stutzer and Frey, 2008; Gottholmseder et al., 2009) and involves disutility and compensation (Van Ommeren et al., 2000).

5.2. Occupation-level teleworkability

Next, the occupation-level teleworkability index, i.e., the remote workability index of Dingel and Neiman (2020), is added to the equation:

$$TELEWORK_{it} = \beta WCOVID_{j(i)t} + \gamma X_i + \eta Teleworkable_{o(i)} + Ind_{I(i)t} + Emp_{e(i)t} + Size_{s(i)t} + Prefr_{r(i)t} + Prefw_{j(i)t} + \mu_t + \xi_i + \varepsilon_{it}, \quad (2)$$

where *Teleworkable* denotes Dingel and Neiman's (DN) index. The index is time-invariant at the occupational level. We note that the DN index is based on US occupation information (US O*NET) and thus Kotera (2020) recalculated the DN index using the Japanese

[16] Our estimation sample eliminated respondents who have no precise information on municipalities of residential and working places or are temporarily unemployed.

[17] In the rural area, the number of new infections is not available at the municipality level but available at the health-center level jointly handled by multiple municipalities. Thus, the number of the municipality-level patients in the rural area is derived by the number of new infections at the health center weighted by the population of each municipality.

[18] *Ind* is two-digit-level industries. *Emp* is regular employees, nonregular employees, executive management, self-employed business owner (with employees), self-employed business owner (no employees), helping with in-house sales, housekeeper, student, and others. *Size* is categorized as 5–29 employees, 30–99 employees, 100–499 employees, more than 499 employees, and public offices. We note that there are 47 prefectures in Japan.

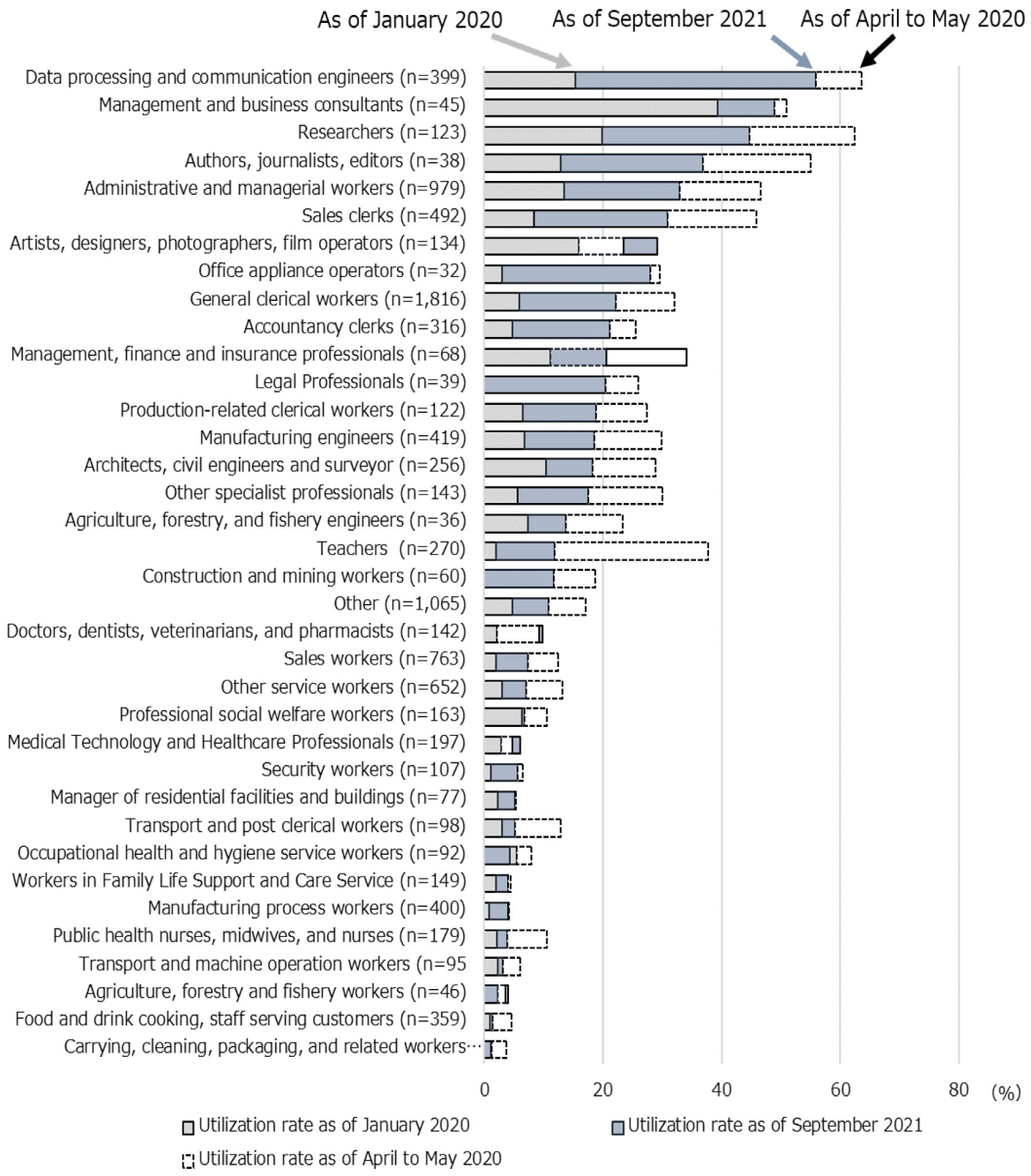

Fig. 3. Telework use by occupation.

O*NET.[19] We employ Kotera (2020) at 38 occupation classifications (Appendix Table 2).

Column 2 of Table 1 reports the results. *Teleworkable* is positive and significant. Then, we investigate the transitional change of the impacts of the teleworkability index. Because the teleworkability index is time-invariant, we decompose the indexes by time by interacting with the time dummy (e.g., "*Teleworkable1*" in Table 1 stands for teleworkability index for the first wave of the survey). Column 3 reports the results. All teleworkability indexes on the first to fifth waves are significantly positive. Then, the magnitude of the teleworkability index in June 2020 (*Teleworkable2*) is the largest and is slightly lower in December 2020 (*Teleworkable3*), April 2021 (*Teleworkable4*), and September 2021 (*Teleworkable5*). These interaction terms can capture the time-variant magnitude of the impact of occupational teleworkability. The request-based government policies were sometimes stringent and sometimes idiosyncratic, influenced by politics, economic situation, and infections. Thus, it is reasonable to think that the magnitude of the impact of teleworkability on telework use is time-variant. The most stringent was the first state of emergency, which results in the largest magnitude. Therefore, after the first wave of COVID-19 and the first state of emergency, June 2020 (*Teleworkable2*), teleworkability of occupations is highly correlated with telework use.

[19] We aggregate the index by Kotera (2020) to 38 occupations, weighted by the number of workers in the Population Census.

Table 1
Basic results.

	1			2			3		
	Coeff	z		Coeff	z		Coeff	z	
WCOVID	2.581	7.38	***	2.6413	7.26	***	2.3112	6.29	***
Female	0.025	5.15	***	0.021	4.04	***	0.021	4.04	***
Age	-0.002	-2.60	***	-0.004	-4.25	**	-0.004	-4.21	***
Univ	0.053	11.47	***	0.0384	7.83	***	0.0384	7.84	***
Income	0.013	14.14	***	0.0119	12.5	***	0.0119	12.48	***
House_own	0.014	2.89	***	0.0122	2.46	***	0.0123	2.49	***
Com_time	0.000	3.18	***	0.0004	3.4	***	0.0004	3.38	***
PubTrans	0.055	8.62	***	0.0509	7.53	***	0.0515	7.63	***
Teleworkable				0.1293	17.7	***			
Teleworkable1							0.0454	5.1	***
Teleworkable2							0.1722	17.74	***
Teleworkable3							0.1255	13.05	***
Teleworkable4							0.1461	15.25	***
Teleworkable5							0.1604	15.9	***
N obs	47,271			43,195			43,195		
R-sq	0.1964			0.2124			0.2146		

NOTE: Ind, Emp, Size, Prefr, Prefw, and Time are included, but ommited to report from the table. Statistical significance shown by ***1%, **5%, and *10%.

5.3. Tasks and working environments

Telework might also depend on an individual's ICT skills, tasks, and working environment.[20]

First, an individual's ICT skills would be related to the use of telework. The survey asks about an individual's ICT skills for working. The variable of ICT skills (*ICT_skill*) is measured by four levels: [1] not using PC for work (= 0 for our calculation), [2] introductory level (e-mail and data input by PC) (= 1), [3] intermediate level (data processing, calculations, and documentation) (= 2), and [4] advanced level (development of software, programming, and network management) (= 3).[21]

Second, task characteristics are essentially important for teleworking. The task characteristics are measured using routine task intensity (RTI), proposed by Autor et al. (2006) and De la Rica and Gortazar (2016). In general, tasks are characterized as Abstract, Routine, and Manual. As shown in Appendix Table 4, Abstract is defined as cognitive and interpersonal nonroutine tasks, Routine is defined as cognitive and manual routine tasks, and Manual is defined as nonroutine manual tasks. Our survey asked respondents about their job tasks (Routine, Abstract, and Manual tasks), originally from the PIAAC background questionnaire. Then, these three task measures are combined as RTI.[22]

Third, the working environment is also crucial for teleworking. The working environments are characterized by team-based working (*Env_A*), outcome-based evaluation (*Env_B*), and flexible working hours/holiday/on leave (*Env_C*). *Env_A* to *Env_C* ranged from 1 to 5. As the working environment becomes more available for the respondent, the variable takes a higher value. See Appendix 2 about how to construct the variables for more details.

Table 2 reports basic statistics. Outcome-based evaluation is low (2.97), whereas flexible working system and team-based task

Table 2
Working environments (average scores).

	ENV A Team-based work	ENV B Outcome-based evaluation	ENV C Flexible working hours
Non-teleworker	3.53	2.91	2.96
Teleworker	3.66	3.23	3.63
Total	3.55	2.97	3.08

NOTE: The values are as of wave 5.

are relatively high (3.08 and 3.55, respectively). Teleworkers report higher values in flexible working systems than nonteleworkers (3.63 for teleworkers and 2.96 for nonteleworkers).

Now, we add each worker's ICT skills, task characteristics, and working environments to the previous estimation:

$$TELEWORK_{it} = \beta WCOVID_{it} + \gamma X_{it} + \eta Teleworkable_i + \zeta TaskEnv_{it} + Ind_{it} + Emp_{it} + Size_{it} + Prefr_{it} + Prefw_{it} + \mu_t + \xi_i + \varepsilon_{it}, \quad (3)$$

where *TaskEnv* is a set of variables for each worker's skills, task, and working environments at time *t*. *TaskEnv* is composed of [1] respondent's ICT skill (*ICT_skill*), [2] routine task intensity measure (*RTI*), [3] working environments characterized by team-based working (*Env_A*), outcome-based evaluation (*Env_B*), and flexible working hours/holiday/on leave (*Env_C*). We estimate eq. (3) using the linear model with a random effect. Column 1 of Table 3 reports the results.

Respondent's ICT skill is significantly positive, whereas *RTI* is significantly negative. Flexible working hours (*Env_C*) is also significantly positive, although the teamwork job system (*Env_A*) is significantly negative, and outcome-based evaluation (*Env_B*) is not significant but negative. Therefore, those who work under flexible working hours are positively associated with telework use. Workers who do fewer team-based tasks and fewer routine tasks tend to use telework.

Originally, having flexible working hours was a necessary condition for teleworking. Thus, we find that flexible working hours are positively associated with telework use. This makes sense. Teleworking always faces the risk of information asymmetry and moral hazard. In detail, telework greatly reduces the possibility for supervisors to observe workers and reduces the opportunity for fostering relationships with co-workers. As shown in some studies, telework is not suitable for tasks such as teamwork jobs and informationally demanding jobs with homogeneous co-workers (Battiston et al., 2018) and is associated with a decline in the co-

[20] The correlations among teleworkability index, ICT skills, and working environments are low overall. Almost all are in the range from –0.2 to 0.2.

[21] Appendix Table 3 reports basic statistics. In our data, the mean value is 1.38, and the standard deviation is 0.91.

[22] The item of this question follows the questionnaire in PIAAC and De la Rica and Gortazar (2016). G_Q06 in PIAAC https://www.oecd.org/skills/piaac/BQ_MASTER.HTM#G_Q06. We use the formula RTI = R – A – M. R, A, and M denote the values of routine, abstract, and manual task indexes for each respondent, respectively. R, A, and M are constructed using the first component of principal component analysis. Then, RTI is derived and standardized. The range of RTI is from –3.14 to +1.47 (see Appendix Table 3). The mean value of RTI for teleworkers is –0.264, and that of nonteleworkers is +0.077. Higher values mean more routine tasks, and thus teleworkers' tasks tend to be less routine than those of nonteleworkers on average.

Table 3
Working environment.

	1			2			3		
	Coeff	z		Coeff	z		Coeff	z	
WCOVID	2.3004	5.8	***	1.2629	3.43	***	1.205	3.03	***
Female	0.0278	5.26	***	0.022	4.16	***	0.0246	4.49	***
Age	-0.002	-2.71	***	-0.002	-2.16	**	-0.002	-1.69	*
Univ	0.0231	4.62	***	0.0156	3.1	***	0.0073	1.38	
Income	0.0096	9.74	***	0.0083	8.81	***	0.0072	7.18	***
House_own	0.0136	2.72	***	0.0102	1.99	**	0.0122	2.32	**
Com_time	0.0003	3	***	0.0003	2.51	**	0.0003	2.26	**
PubTrans	0.0475	7.01	***	0.0469	6.84	**	0.0465	6.56	**
Teleworkable1	0.0062	0.68							
Teleworkable2	0.1328	13.29	***	0.1074	11.49	***	0.0793	8.1	***
Teleworkable3	0.0855	8.62	***	0.0546	5.8	***	0.0261	2.64	**
Teleworkable4	0.1057	10.59	***	0.0784	8.37	***	0.0497	5.02	***
Teleworkable5	0.1134	10.17	***	0.0968	9.83	***	0.0611	5.51	***
ICTskill	0.0364	12.74	***				0.0239	8.03	***
RTI	-0.018	-7.2	***				-0.004	-1.39	
ENV A	-0.006	-2.74	***				-0.009	-3.72	***
ENV B	-0.002	-0.99					-0.002	-1.02	
ENV C	0.0396	19.76	***				0.0331	15.02	***
IT tool				0.1807	29.07	***	0.1708	26.76	***
Digital Office				0.07	10.93	***	0.0637	9.74	***
Auto office				0.1094	6.32	***	0.1062	5.97	***
Survey waves	1,2,3,4,5			2,3,4,5			2,3,4,5		
N obs	41,400			34,409			32,614		
R-sq	0.2443			0.3294			0.3426		

NOTE: Ind, Emp, Size, Prefr, Prefw, and Time are included, but ommited to report from the table. Statistical significance shown by ***1%, **5%, and *10%.

Table 4
Digitalization at the workplace (%).

	Communication	Digitalized office	Auto-Office
Non-teleworker	20.5%	14.3%	1.0%
Teleworker	78.1%	50.6%	6.9%
Total	30.6%	20.7%	2.1%

NOTE: The values are as of wave 5.

worker relationship quality and co-worker satisfaction in high-interdependency tasks (Gajendran and Harrison, 2007). This can be seen in our teamwork variable result. Furthermore, outcome-based evaluation mitigates the difficulty of supervising the process of tasks and would be suitable for teleworking (Mayo et al., 2009).[23] However, our results are the opposite. We can interpret that tasks and occupations in an outcome-based evaluation system tend to be not or less interdependent on tasks carried out by co-workers and tend to have a high level of job autonomy and discretion without teleworking with co-workers. Thus, they might not need teleworking according to our estimation result.

5.4. Company-wide digitalization

Many companies and enterprises have introduced several dimensions of digitalization. The survey asks whether the respondents' companies provide [1] communication, chat, and file-sharing tools, [2] digitalized office management tools (e.g., attendance management, IT accounting system, and health management), and [3] automation office (e.g., virtual office and robotic process automation), for regular use. Teleworkers tend to use these tools in the workplace. See Appendix 3 for how to construct the variables for more details.

Table 4 reports the percentage of use of ICT tools by teleworkers and nonteleworkers in each category. A total of 78% of teleworkers can use (at least one) communication tools, whereas only 21% of nonteleworkers can use them in the workplace. A total of 50% of teleworkers use IT management tools for business, whereas only 14% of nonteleworkers use them. A total of 7% of teleworkers use automation office, whereas only 1% of nonteleworkers use it in the workplace. Thus, teleworkers tend to use communication tools and IT management tools for business, although many teleworkers do not use advanced digitalization such as automation office.

For estimations, the dummies are constructed, "*IT_tool*" dummy for [1], "*Digital_office*" dummy for [2], and "*Auto_office*" dummy for [3]. Each dummy takes the value of one if the companies provide the tool and zero otherwise. See Appendix 3 for more details. Now, we add the dummy variables for digitalization to the previous estimation:

$$\begin{aligned} TELEWORK_{it} = {} & \beta WCOVID_{it} + \gamma X_{it} + \eta Teleworkable_i + \zeta TaskEnv_{it} \\ & + \delta DigitalEnv_{it} + Ind_{it} + Emp_{it} + Size_{it} \\ & + Prefr_{it} + Prefw_{it} + \mu_t + \xi_i + \varepsilon_{it}, \end{aligned} \tag{4}$$

where *DigitalEnv* is a set of variables for digitalization of the worker's office, "*IT_tool*," "*Digital_office*," and "*Auto_office*" dummies at time *t*.

Columns 2 and 3 of Table 3 report the result. We note that *DigitalEnv* variables are available only for waves 2 to 5. These three variables are significantly positive, although the magnitude of coefficients of *Digital_office* and *Auto_office* is smaller than IT communication tools (*IT_tool*). This indicates that not only individual ICT skills and use of ICT communication tools but also digitalized offices are crucial for telework use, although the impact of digitalized offices is relatively small. All of the digitalization can replicate the working space as the usual workplace to some extent, which enables us to promote collaboration with co-workers through discussion on the progress of tasks and exchange of ideas. Supporting our result, Turetken et al. (2011) found that teleworkers see a positive relationship between the richness of the communication tools and their performance and that teleworkers communicating more via communication tools such as Zoom and Skype video calls tend to have higher levels of job satisfaction and performance than those

[23] We note that whereas Mayo et al. (2009) interviewed 122 CEOs of listed companies, our sample covers all types of workers including self-employed and small business employees.

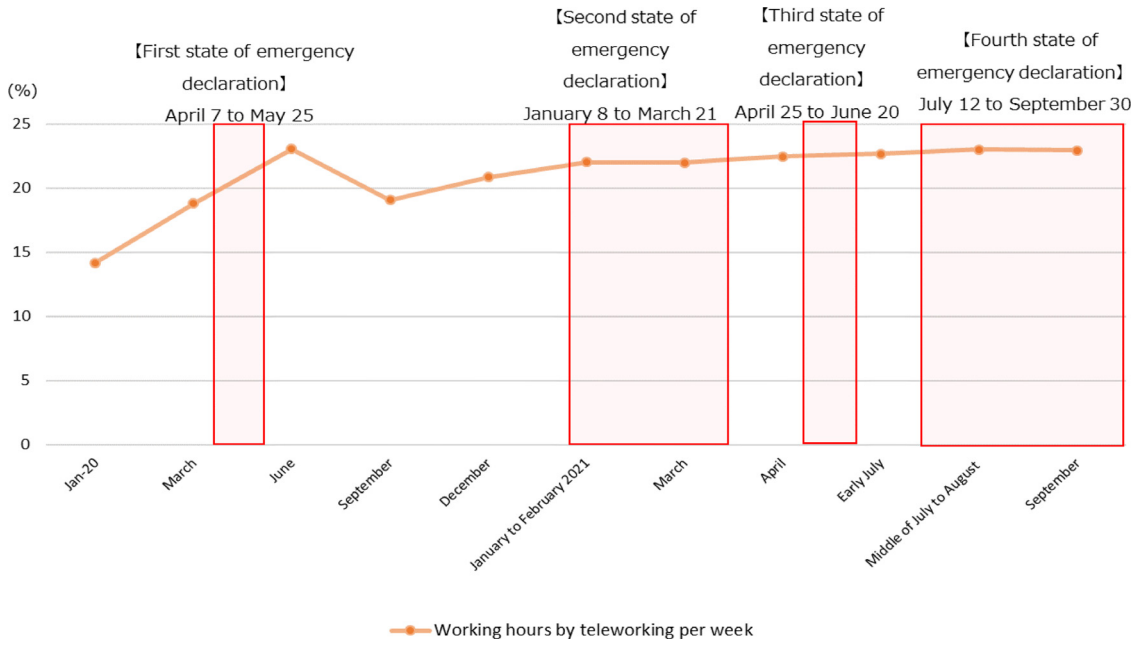

Fig. 4. Working hours by teleworking per week.

using messaging applications and e-mails. According to them, text-based forms of communication such as e-mail are not able to remove impediments fully of no in-person and face-to-face communication. Their findings support our result.

We note that simultaneity bias might potentially exist. Once the companies invest in the digitalization of office and IT tools to use telework following the spread of COVID-19, more employees would start teleworking using digitalized tools. It is hard in our survey to ask respondents to answer about when and how the respondents' companies introduced digitalized tools exactly.

6. Further Investigations

6.1. Telework hours

Now, we focus on teleworkers. A further investigation is conducted on teleworking hours. The mean of per-week teleworking hours (*TELEHOUR*) for teleworkers gradually increased from 14.2 hours as of January 2020 to 22.9 hours as of September 2021 (Fig. 4). Although the telework utilization extent stays around 17% after the first state of emergency (Fig. 2), teleworking hours gradually increased over time. This implies that each teleworker increased teleworking hours.

We investigate which factors affect telework hours. In other words, this indicates what percentage of the task per worker is teleworkable. We estimate the following using the tobit model, where nonteleworkers are zero for teleworking hours:

$$\begin{aligned} TELEHOUR_{it} = {} & \beta WCOVID_{j(i)t} + \gamma X_{it} \\ & + \eta Teleworkable_i + \zeta TaskEnv_{it} + \delta DigitalEnv_{it} \\ & + Ind_{it} + Size_{it} + Emp_{it} + Prefr_{it} + Prefw_{j(i)t} \\ & + \mu_t + \xi_i + \varepsilon_{it}. \end{aligned} \tag{5}$$

The dependent variable now uses per-week telework hours (ln) (*TELEHOUR*) for teleworker i, whereas the independent variables are the same as presented in eqs. (3) and (4). Table 5 reports the results. Overall, almost all variables except *WCOVID, House_own*, and *Env_B* are significant. Therefore, female, younger, educated, high income, and highly ICT-skilled teleworkers who commute for longer hours by train and/or bus, use IT communication tools, and work under a flexible hour system tend to work longer hours by telework. Rich IT communication tools at the workplace facilitate long teleworking hours.

Table 5
Telework hours (Tobit estimations).

	1			2		
	Telehour			Telehour		
	Coeff	z		Coeff	z	
WCOVID	4.4674	0.97		7.0901	1.56	
Female	0.4588	4.91	***	0.3767	4.41	***
Age	-0.0864	-5.08	***	-0.066	-4.18	***
Univ	0.4365	4.69	***	0.1513	1.77	*
Income	0.1099	8.31	***	0.0754	6.21	***
House_own	0.1158	1.3		0.1009	1.24	
Com_time	0.0058	3.78	***	0.0042	2.93	**
PubTrans	0.7573	6.9	***	0.6495	6.39	***
Teleworkable1	1.5665	6.94	***			
Teleworkable2	2.0221	10.93	***	1.2857	7.6	***
Teleworkable3	1.5887	7.91	***	0.8577	4.63	***
Teleworkable4	2.0966	9.89	***	1.4352	7.34	***
Teleworkable5	1.8094	8.46	***	1.1673	5.94	***
ICTskill	0.9629	15.98	***	0.6545	11.72	***
RTI	-0.304	-6.69	***	-0.037	-0.86	
ENV A	-0.1976	-5.62	***	-0.228	-6.63	***
ENV B	0.0444	1.25		0.0281	0.81	
ENV C	0.6121	17.96	***	0.4577	13.8	***
IT tool				2.0454	30.65	***
Digital Office				0.6181	10.33	***
Auto office				0.5229	4.38	***
Survey waves	1,2,3,4,5			2,3,4,5		
N obs	41,400			32,614		
Log likelihood	-22350			-18212		

NOTE: All fixed effects (Ind, Emp, Size, Prefr, Prefw, Time) are included, but ommited to report from the table. Statistical significance shown by ***1%, **5%, and *10%.

6.2. Who stopped and who started teleworking?

As shown in Fig. 2, telework use sharply increased in the first state of emergency, but afterward greatly decreased and then hovered over time. Although some workers initiated teleworking in

Table 6
Stop and start of telework.

Independent var	Stop			Start		
	1			2		
	Coeff	z		Coeff	z	
WCOVID	1.0802	0.93		0.1066	0.24	
Female	-0.045	-2.48	**	0.0138	2.6	***
Age	-1E-03	-0.28		-0.001	-1.46	
Univ	0.0246	1.28		0.0101	1.99	**
Income	-0.002	-0.69		0.0056	5.21	***
House_own	-0.003	-0.15		0.0127	2.48	**
Com_time	-3E-04	-1.22		0.0001	0.95	
PubTrans	-0.048	-2.07	**	0.0402	5.58	***
Teleworkable2	-0.155	-2.31	**	0.0642	6.04	***
Teleworkable3	-0.038	-0.76		0.018	1.9	*
Teleworkable4	-0.11	-2.33	**	0.0139	1.54	
Teleworkable5	-0.072	-1.44		0.0289	2.81	***
ICTskill	-0.063	-4.96	***	0.0175	5.99	***
RTI	-0.018	-1.93	*	-0.002	-0.81	
ENV A	0.009	1.01		-0.007	-3.14	***
ENV B	0.0105	1.07		-4E-04	-0.16	
ENV C	-0.055	-6.53	***	0.0176	7.98	***
IT tool	-0.26	-12.74	***	0.1121	17.26	***
Digital Office	-0.068	-4.46	***	0.0424	5.91	***
Auto office	-0.083	-3.33	***	0.0999	3.29	***
Survey waves	2,3,4,5			2,3,4,5		
N obs	4,248			24,376		
R-sq	0.2498			0.1645		

NOTE: Ind, Emp, Size, Prefr, Prefw, and Time are included, but ommited to report from the table. Statistical significance shown by ***1%, **5%, and *10%.

the first state of emergency, they eventually stopped teleworking. We focus on respondents who joined at least two consecutive waves, i.e., $t-1$ as well as t. The upper panel of Appendix Table 5 shows the transition of teleworkers at $t-1$. Out of all teleworkers as of t = wave 1, 528 teleworkers kept teleworking at t = wave 2, while 301 stopped teleworking. At the time t, 60–70% of teleworkers continued teleworking ("keep rate" in Appendix Table 5). The below panel of Appendix Table 5 shows the transition of nonteleworkers at $t-1$. Out of all non-teleworkers as of t = wave 1, 908 non-teleworkers start to use telework at t = wave 2, while 6,670 kept not using telework. A total of 5–12% of nonteleworkers at $t-1$ started teleworking at t ("start rate" in Appendix Table 5).

We estimate the end of telework. The sample is limited to teleworkers at $t-1$. The following equation at t is estimated by the linear model:

$$\begin{aligned} STOP_{it} = {} & \beta WCOVID_{j(i)t} + \gamma X_{it} + \eta Teleworkable_i + \zeta TaskEnv_{it} \\ & + \delta DigitalEnv_{it} + Ind_{it} + Emp_{it} + Size_{it} + Prefr_{it} \\ & + Prefw_{j(i)t} + \mu_t + \xi_i + \varepsilon_{it}. \end{aligned} \quad (6)$$

STOP indicates the dummy for stopping telework use. If a respondent used teleworking at $t-1$ but had stopped teleworking at t, the dummy takes the value of one. If a respondent keeps teleworking at $t-1$ and t, then the dummy is zero.

Column 1 of Table 6 reports the result. *WCOVID* as well as many individual characteristics are insignificant. However, the female variable and *PubTrans* are significantly negative. Male and nonpublic transport system commuters are more likely to stop telework. Then, *ICT_skill* is significantly negative. Workers with lower IT skills tend to stop teleworking. More importantly, *Env_C* is significantly negative. Workers under an unavailable flexible working system tend to stop. Furthermore, *IT_tool, Digital_office*, and *Auto_office* are all significantly negative. Therefore, workers who do not use communication IT tools for work, digitalized management tools, and office automation find it difficult to keep on using telework and eventually stop teleworking. Because they are not suited to telework, they gradually stopped using it. The poor environment of IT communication tools and nonflexible working environments dissuade the use of telework.

Lastly, by contrast, who started teleworking? We estimate the same Eq. (6) by replacing the dummy by the start of telework, *START*. *START* indicates the dummy for starting telework use.

The sample is now nonteleworkers at $t-1$. If a respondent did not use teleworking at $t-1$ but had started teleworking at t, the *START* dummy takes the value of one. If a respondent keeps nonteleworking at $t-1$ and t, then the dummy is zero. Column 2 of Table 6 reports the results on starting. Similar to the results on telework use, rich, educated, highly ICT-skilled, and female workers who use communication IT tools and work under a flexible working hour system tend to start telework. The digitalized office tends to promote starting telework use.

6.3. Which tasks require commuting under the state of emergency?

Some workers must sometimes communicate complex information to their colleagues at the office. According to Battiston et al. (2017), productivity is higher in some tasks when the teammates are in the same room and their desks are close together. Thus, some tasks might involve high opportunity costs of face-to-face communication. Now, we investigate which tasks are not allowed to use telework by utilizing "soft" lockdown in the first state of emergency. The soft lockdown could be a good situation to investigate which tasks are crucially impossible to telework and require a workplace and commute. A key is that the government asked people to show voluntary self-restraint and work from home as much as possible. The government did not impose any penalties and asked for cooperation from the people, and the public transportation system was working as normal. In response, telework use sharply increased under the first state of emergency and reached its peak (25%, Fig. 2). However, many workers did not spend all their working hours teleworking, and many teleworkers could not help commuting sometimes for certain reasons. In our estimation data, 80.2% of teleworkers (2,477 out of 3,088 teleworkers) could not help commuting for at least one day despite the state of emergency.

The survey asked all teleworkers about task items at the workplace by commuting under the first state of emergency. They were asked to choose all (at least one) tasks out of 11 items that they did at the office, or otherwise noncommuting.[24] As shown in the left panel of Table 7, item 3 (paper documents and clerical work) and item 4 (communication and meeting) require the largest numbers of teleworkers (801 and 799, respectively), whereas item 7 (human resource and management) requires the smallest (122). The right panel of Table 7 presents the number of teleworker's tasks at the office. A total of 1,084 teleworkers commuted to engage in one task item at the office, whereas 522 (304, 139) workers did for two (three, four) task items, respectively. Many teleworkers engaged in multiple tasks at the office.

Then, to construct variables, the items (the left panel of Table 7) were summed into five office task categories by taking the average of items for each category for each respondent (from 0 to 1) and in addition noncommuting.

(1) NC: noncommuting and teleworking only.

[24] The questionnaire asks 12 items for tasks. Item 1: face-to-face services and manual labor, 2: public administrative tasks, 3: making paper documents and regular clerical work, 4: contact with customers and transaction partners and check post mails, 5: meeting and conference, 6: human resource and management, 7: use of facilities, machines, tools, and office equipment, 8: data and information access, 9: maintenance of facilities and buildings, and 10: research, investigation, and experiments. 11: others. 12: noncommuting (NC). Then, we summed these items into five task categories (T1–T5) and NC: T1: item 1; T2: items 4 and 5; T3: items 7, 9, and 10; T4: items 2 and 3; T5: items 6 and 8; NC: item 12. We dropped item 11.

Table 7
Office tasks under the first state of emergency.

All teleworkers (choose multiple items)			Teleworkers with commuting	
item No.	Task contents	num of teleworkers	num of office tasks	num of commuters
item 1	face-to face	476	1 task	1,084
item 2	public administration	235	2 tasks	522
item 3	paper documents and clerical	801	3 tasks	304
item 4	contact with customers	799	4 tasks	139
item 5	meeting and conference	499	More than 5 tasks	139
item 6	human resource	270	**Total**	**2,188**
item 7	use of facilities and equipments	122		
item 8	data access	216		
item 9	Maintenance	322		
item 10	research and experiments	597		
item 11	Others	100		
NC	**No commuting**	**552**		

(2) T1: face-to-face and physical tasks: face-to-face services and manual labor tasks (item 1).
(3) T2: meeting and communication: meetings, conferences, contact with business partners, and checking postal mails (items 4 and 5).
(4) T3: use of facilities and experiment: using office facilities, machine equipment and tools, research, experiments, investigations, maintenance of offices, and working places (items 7, 9, and 10).
(5) T4: clerical work: office work, paper documents, registration for public offices, and government and formal administration (items 2 and 3).
(6) T5: management and information access: management, human affairs, information access, and information management (items 6 and 8).

These variables were used as dependent variables. The sample is teleworkers under the state of emergency. The simultaneous equation system by SUR is given as follows:

$$\begin{aligned}
NC_i &= \beta WCOVID_{j(i)} + \gamma X_i + \eta Teleworkable_i + \zeta TaskEnv_i + Ind_i + Emp_i + Size_i + Prefr_i + Prefw_{j(i)} + \varepsilon_i,\\
T1_i &= \beta WCOVID_{j(i)} + \gamma X_i + \eta Teleworkable_i + \zeta TaskEnv_i + Ind_i + Emp_i + Size_i + Prefr_i + Prefw_{j(i)} + \varepsilon_i,\\
T2_i &= \beta WCOVID_{j(i)} + \gamma X_i + \eta Teleworkable_i + \zeta TaskEnv_i + Ind_i + Emp_i + Size_i + Prefr_i + Prefw_{j(i)} + \varepsilon_i,\\
T3_i &= \beta WCOVID_{j(i)} + \gamma X_i + \eta Teleworkable_i + \zeta TaskEnv_i + Ind_i + Emp_i + Size_i + Prefr_i + Prefw_{j(i)} + \varepsilon_i,\\
T4_i &= \beta WCOVID_{j(i)} + \gamma X_i + \eta Teleworkable_i + \zeta TaskEnv_i + Ind_i + Emp_i + Size_i + Prefr_i + Prefw_{j(i)} + \varepsilon_i,\\
T5_i &= \beta WCOVID_{j(i)} + \gamma X_i + \eta Teleworkable_i + \zeta TaskEnv_i + Ind_i + Emp_i + Size_i + Prefr_i + Prefw_{j(i)} + \varepsilon_i.
\end{aligned} \tag{7}$$

Table 8 reports the result. *WCOVID* is significantly positive in the NC equation, whereas it is significantly negative in the T1 (face-to-face and manual task) equation. The *Teleworkable* index in the T1 equation is significantly negative, whereas it is significantly positive in the T2 (communication task), T4 (clerical work), and T5 (management task) equations. Thus, communication tasks, clerical works, and management tasks complement telework. Even if occupations are teleworkable, these tasks being done at the office helps teleworking. By contrast, face-to-face and manual tasks appear to not be substitutable with telework. Because these tasks are not fully teleworkable, workers need to commute to engage in the task.

Turning to individual's characteristics and working environments, younger, less-ICT-skilled, female teleworkers who engage in routine tasks using IT tools tend to do only telework without commuting in NC (noncommuting). Those who utilize IT tools and work with autonomy or with less interdependency on co-workers tend to complete their tasks only by telework. This is consistent with the implications of Battiston et al. (2017).

7. Conclusion

This paper investigates the association of COVID-19 infection, individual characteristics, task characteristics, and working environments. Using the unique panel survey on telework, we find that educated, highly ICT-skilled, younger, and female workers who engage in fewer teamwork tasks and whose workplace municipalities see a larger number of infections tend to use telework. Working environments are much more crucial. The richness of IT communication tools, digitalized office management, and flexible hours working systems could promote telework use and its continuation.

Our estimation results suggest that an individual's socioeconomic factors are not the sole factors for telework use. The working environment and digitalized offices are also crucial factors for telework, although we cannot determine the causal impact of these factors on telework use due to identification problems. Furthermore, digitalized office and working environments are particularly important for workers to keep teleworking for long hours and frequent use in the spread of COVID-19.

One remaining question is why telework use remains low in Japan. The Japanese corporate culture puts stress on commuting and working at the office. This system works well in team-based tasks, informal information-intensive workings, less discretion, and less autonomy. However, our result implies that all of them are unsuited to teleworking. Furthermore, Japanese society sometimes involves some informal communication and implicit consensus. As seen in the COVID-19 pandemic, the government asked for self-constraint behaviors from the public, and the people understood the importance as a whole society and followed the guidance. Accordingly, telework might be less suitable in Japan. On the other hand, many workers well understand the effectiveness of teleworking in terms of flexible working and work–life balance in the presence of COVID-19. Thus, the use of telework will not greatly increase but might increase to some extent in the post-COVID-19 era. Many workers might seek the best combination of teleworking and commuting over time.

A remaining technical issue is the identification problem, which prevents us from reaching more causal conclusions. This is related

Table 8
SUR estimation.

	NC: Non-commuting			T1: Face-to-face			T2: Meeting			T3: Use of facilities			T4: Clerical work			T5: Management		
	Coeff	z		Coeff	z		Coeff	z		Coeff	z		Coeff	z		Coeff	z	
WCOVID	78.0751	4.2	***	-90.1939	-3.94	***	9.4620	0.45		-27.5552	-1.47		18.4031	0.86		-17.1521	-0.93	
Female	0.0315	3.87	***	-0.0616	-6.14	***	-0.0039	-0.42		-0.0626	-7.63	***	0.1141	12.18	***	-0.0056	-0.69	
Age	-0.0092	-6.3	***	-0.0077	-4.28	***	0.0105	6.42	***	0.0061	4.17	***	0.0048	2.89	***	0.0070	4.86	***
Univ	-0.0022	-0.3		-0.0247	-2.52	**	0.0594	6.63	***	0.0278	3.47	***	0.0313	3.41	***	0.0260	3.29	***
Income	-0.0012	-0.9		-0.0014	-0.86		0.0087	5.8	***	0.0015	1.11		-0.0011	-0.73		0.0051	3.87	***
House_own	-0.0094	-1.2		0.0158	1.66	*	-0.0008	-0.09		-0.0078	-1		0.0139	1.57		-0.0064	-0.83	
Com_time	0.0000	-0.1		-0.0004	-2.28	**	0.0000	0.16		-0.0003	-2.24	**	0.0001	0.72		0.0000	-0.02	
PubTrans	0.0222	2.24	**	-0.0669	-5.47	***	0.0088	0.78		-0.0020	-0.2		0.0214	1.87	*	-0.0004	-0.04	
Teleworkable	0.0040	0.32		-0.2076	-13.36	***	0.1647	11.59	***	-0.0131	-1.03		0.2123	14.63	***	0.1386	11.05	***
ICTskill	-0.0339	-7	***	-0.0669	-11.17	***	0.0413	7.53	***	0.0457	9.33	***	0.0942	16.85	***	0.0418	8.65	***
RTI	0.0312	7.7	***	-0.0798	-16.04	***	-0.0403	-8.85	***	-0.0345	-8.47	***	0.0184	3.96	***	-0.0191	-4.76	***
ENV A	0.0117	1.21		-0.0576	-4.85	***	0.1175	10.81	***	0.0521	5.36	***	0.0104	0.94		0.0761	7.94	**
ENV B	-0.0189	-4.5	***	0.0278	5.36	***	-0.0058	-1.23		0.0043	1.01		-0.0033	-0.69		0.0113	2.7	***
ENV C	0.0048	1.1		-0.0144	-2.68	***	-0.0005	-0.11		0.0062	1.4	***	-0.0112	-2.22	**	-0.0048	-1.1	
IT tool	0.0269	6.76	***	-0.0360	-7.36	***	-0.0132	-2.96	***	-0.0088	-2.21	***	-0.0072	-1.57		-0.0101	-2.55	**
RMSE	0.350			0.430			0.175			0.352			0.179			0.136		
R-sq	0.1075			0.2067			0.393577			0.1052			0.401919			0.347189		

NOTE: All fixed effects (Ind, Emp, Size, Prefr, Prefw, Time) are included, but ommited to report from the table. ***: p<0.01, ** p<0.05, * p<0.1
Nob: 10119, Parm 138.

to the qualification of our survey data. By collecting more detailed data and using good instrumental variables, or developing microeconomics theory (e.g., principal-agent theory), it might be possible to investigate the impact of many aspects on telework use and clarify the causal relationship.

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Appendix 1. Data Websites on other COVID-19 surveys in Japan

Japan Household Panel Survey (JHPS) by Keio University https://www.pdrc.keio.ac.jp/paneldata/datasets/jhpskhps/.

The survey on the Impact of COVID on Individual's Job and Life by JILPT https://www.jil.go.jp/institute/siryo/2021/242.html.

The Japanese Panel Study of Employment Dynamics (JPSED) by the Recruit Works Institute https://www.works-i.com/surveys/panel_surveys.html.

Survey on Individual's Life and Behaviours by Cabinet Office of Japan https://www5.cao.go.jp/keizai2/wellbeing/covid/index.html.

Survey on Telework by Japan Trade Union Confederation (Rengo) https://www.jtuc-rengo.or.jp/info/chousa/data/20200630.pdf.

Line Research https://research-platform.line.me/archives/36328781.html.

PERSOL Research and Consulting https://rc.persol-group.co.jp/thinktank/data/telework-survey6.html.

Appendix 2. Construction of variables for working environment

A module of our survey asks about working environments in six items on team collaboration, outcome-based evaluation, and flexible employment systems[25]:

[25] The items of the question follow Japan Household Panel Survey (JHPS/KHPS) 2019 conducted by Keio University and 'Work-life Balance Survey' by RIETI.

Appendix Table 1
Patterns of respondents across waves.

NOTE: Shaded cells are the group of respondents joined the survey.

	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Num respondents	Subtotal
Sample in Wave 1	■	■	■	■	■	4,444	
	■	■	■	■		940	
	■	■	■			556	
	■	■				1,439	
	■					1,348	
	■		■	■	■	278	
	■	■		■	■	372	
	■	■			■	142	
	■	■		■		228	
	■	■	■		■	286	
	■		■	■		48	
	■		■			135	
	■			■	■	115	
	■				■	65	
	■			■		56	
	■					64	10,516
New sample in wave 2		■	■	■	■	1,617	
		■	■	■		393	
		■	■		■	120	
		■	■			269	
		■		■	■	160	
		■		■		112	
		■			■	70	
		■				990	3,731
New sample in wave 3			■	■	■	741	
			■	■		247	
			■		■	56	
			■			278	1,322
New sapmple in wave 5					■	2189	2189
	10,516	12,138	10,523	9,796	10,644		16,436

NOTE: Shaded cells are the group of respondents joined the survey.

Appendix Table 2
Dingel=Neiman Teleworkable Index (Dingel and Neiman, 2020; Kotera, 2020).

code	Occupation	Index
1	Administrative and managerial	1
2	Researchers	0.716347
3	Agricultural engineers	0
4	Manufacturing engineers	0.411605
5	Architects, civil engineers	0.914138
6	Data processing	1
7	Doctors, dentists	0.049448
8	Public health nurses	0
9	Medical Technology Professionals	0.058163
10	Social welfare workers	0.767763
11	Legal Professionals	0.626851
12	Finance and insurance	0.588255
13	Management Business consultants	0.9
14	Teachers	0.996145
15	Religions	1
16	Authors, journalists, editors	1
17	Artists, designers, photographers	0.757791
18	Other specialist professionals	0.969823
19	General clerical	0.780455
20	Accountancy	0.5
21	Production-related clerical	0
22	Sales clerks	1
23	Outdoor service	1
24	Transport and post clerical	0.390674
25	Office appliance operators	1
26	Sales workers	0.44064
27	Family Life Support and Care Service	0
28	Occupational health and hygiene	0.089499
29	Food and drink cooking	0.070122
30	Residential facilities and buildings	0.186605
31	Other service workers	0.344695
32	Security workers	0.009223
33	Agriculture, forestry and fishery	0.071757
34	Manufacturing process	0.043541
35	Transport and machine operation	0
36	Construction and mining	0.058424
37	Carrying, cleaning, packaging	0
38	Other	
	Total	0.569045

NB: "38 other" is missing, because of the composition of many occupations.
NB: Re-calculated Kotera(2020).

Appendix Table 3
Basic statistics.

stats	mean	Min	max	sd	N
TELEWORK	0.150497	0	1	0.357562	47290
WCOVID	0.004462	0	0.0494933	0.007898	47271
Female	1.446077	1	2	0.497089	47290
age	7.895454	2	12	2.750385	47290
Univ	0.505371	0	1	0.499976	47290
Income	4.077738	0.25	21.25	3.430612	47290
house_own	0.641869	0	1	0.479456	47290
Com_time	34.47462	0	360	29.66718	47290
PubTrans	0.375872	0	1	0.484352	47290
Teleworkable	0.570049	0	1	0.365442	43214
ICTskill	1.384851	0	3	0.909289	45454
RTI	0.042291	-3.14331	1.47734	0.972203	45454
Env A	3.548237	1	5	0.884388	47059
Env B	2.938226	1	5	0.894208	47059
Env C	3.017584	1	5	0.982503	47059
IT tool	0.28463	0	1	0.451244	37684
Digital Office	0.185357	0	1	0.388592	37684
Auto Office	0.020141	0	1	0.140485	37684
TELEHOUR	22.21266	0.5	120	14.60024	7117
STOP	0.299689	0	1	0.458173	4508
START	0.072113	0	1	0.258679	26944

Appendix Table 5
Transitions of telework use.

Teleworkers at t-1				
	t=wave 2	**t=wave 3**	**t=wave 4**	**t=wave 5**
Keep teleworking	528	944	1,087	1,041
Stop teleworking	301	617	449	291
Keep rate	*0.637*	*0.605*	*0.708*	*0.782*
Non-teleworkers at t-1				
	t=wave 2	**t=wave 3**	**t=wave 4**	**t=wave 5**
Start teleworking	908	472	461	431
Non-teleworking	6,670	7,168	7,799	6,692
Start rate	*0.120*	*0.062*	*0.056*	*0.061*

1 Your tasks under charge are clearly specified in the team.
2 Your tasks are co-operated by the team.
3 Your workplace highly evaluates working hard without taking care of working hours.
4 Your job evaluation is based on the outcome.
5 You can flexibly choose working hours and places.
6 You can easily take leave due to family reasons (taking care of kids and nursing elderly persons).

In each item, a respondent chooses either disagree (= 1 for our calculation), weakly disagree (= 2), neutral (= 3), weakly agree (= 4), agree (= 5), or not applicable (e.g. self-employed), counted as neutral (= 3).

To construct variables for working environments, we sum up to three categories, characterized by team-based working (Env A), outcome-based evaluation (Env B), and flexible working hours/holiday/on leave (Env C). Env A is calculated by taking mean of the answering values in items 1 and 2, Env B is calculated by

Appendix Table 4
Task question items from PIAAC.

Task	Category	Items
Abstract	Cognitive and non-routine	Read diagrams, maps or schematics Write reports Faced complex problems Persuading, influencing people Negotiating with people
Routine	Cognitive Routine	Change sequence of task Change how do work Change speed of work Change working hours Learn work-related things from co-workers Learning-by-doing from tasks performed Keeping up to date with new products/services
	Manual Routine	Hand/finger skill accuracy
Manual		Physical work

Source: De la Rica and Gortazar (2016, Table 1).

taking mean of answers to items 3 and 4, and Env C is calculated by taking an average of the answering values in items 5 and 6.

Appendix 3. Construction of variables for variables for digitalization

The questionnaire asked respondents to choose from all 16 items on ICT tools with raising some representative tools available in Japan if they usually use them at workplace: item (1) teleconference and web conference system (e.g. Zoom, Skype), (2) information share (e.g. Slack, Line), (3) sharing file (e.g. Dropbox, One drive), (4) remote access (e.g. SWANStor, Platform V system), (5) task project management (e.g. Trello, Backlog), (6) electric payment (e.g. Creat!Web flow), (7) attendance management (Office365, Cybozu), (8) mental health management (e.g. jinjer work vital, onsei kokoro bunseki service (voice mental analysis service, MIMOSYS)), (9) business management (e.g. Sales cloud, kintone), (10) sale management, production management, stock management (e.g. Rakusho, Arajin Office), (11) employment management system (e.g. HRMOS Kanri, Jobukan Saiyo Kanri), (12) human resource management (e.g. Smart HR, OBIC7), (13) accounting management (e.g. Yayoi Kaikei, Super-Stream NX), (14) RPA (robotic process automation)(e.g. WinActor, Robotic Crowd), (15) virtual office (e.g. Sococo, Remo), and (16) contactless technology (e.g. robot for automatic operation, automated checkout). In our data, IT communication tool is defined as items 1, 2, and 3. Digitalized office management tool is defined as items 4–13. Automation office is defined as items 14, 15, and 16.

For estimations, the dummies are constructed, “IT_tool” dummy for IT communication tool, “Digital_office” dummy for digitalized office, and “Auto_office” dummy for automation office. Each dummy takes one if the companies provide at least one above-mentioned item, vice versa.

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