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Abstract

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1 Introduction

The coronavirus pandemic (COVID-19) has accelerated skill-biased technological progress, bringing about dramatic changes in work styles. Working at home with information and communication technology (ICT) tools, so-called telework has spread widely as an effective countermeasure to COVID-19. Many people have been asked to work at home and engage in telework using various ICT communication tools. The lockdowns under a state of emergency increased teleworking in many countries. In the United States, according to Bick et al. (2020), the rate of teleworkers increased from 8% (February 2020) to 35% (May 2020). In Europe, teleworkers comprise 20–50% of workers (Alipour et al., 2020), with 37% of workers having newly taken it on (Eurofound, 2020).

The pandemic forced a major shift to telework for office jobs, which has steadily led to increased computerization, digitization and automation of the whole workplace, particularly offices. Theoretically, such skill-biased technological progress favors highly skilled over unskilled labor (Autor et al., 2013). Skill-biased technological progress has led to a gradual change in tasks and employment over recent decades. Non-routine cognitive and interpersonal tasks (so-called non-routine/abstract tasks) are complementary to ICT tools, and have increased over time. On the other hand, codifiable and repetitive tasks (so-called routine tasks) are substitute to ICT tool and have decreased in the last decade.

Relatively unknown is the nexus of workers' routine and non-routine tasks and the spread of telework as skill-biased technological progress. The COVID-19 pandemic has strongly encouraged telework, largely involving ICT progress as well as changing job content. Because ICT progress increases non-routine tasks (abstract tasks) and decreases routine tasks, telework might be complementary to highly skilled workers for carrying out non-routine tasks (abstract tasks). That is, telework is thought of as facilitating carrying out non-routine rather than routine tasks. On the other hand, non-routine tasks (abstract tasks) are interpersonal and interdependent and thus definitely need high-level communication and relations with coworkers such as informal information exchange, tacit knowledge spillovers, and deep discussion. Telework per se might not be sufficient for highly skilled workers to deeply communicate with coworkers and carry out such tasks.

Our question is whether routine or non-routine (abstract) tasks are suited to telework, which tasks, routine or non-routine, are adaptable to telework, and what impediments hamper carrying out such tasks by telework. Unlike previous studies

on tasks (e.g. Acemoglu,1999; Acemoglu and Autor, 2011), we do not study the long-run impact of ICT progress on employment and wages in terms of tasks or labor skills, but we investigate the short-run adjustment or misadjustment of workers teleworking.

Our study investigates the case of Japan. Telework use varies greatly between countries suffering the spread of COVID-19. In terms of telework use among developed countries, Japan is among the lowest and most stagnant. According to our COVID-19 survey conducted by the Nippon Institute for Research Advancement (NIRA) and Keio University (Okubo and NIRA, 2020), in January 2020, before the widespread emergence of COVID-19, the national average telework rate was only 6%.[1] In response to the first state of emergency from April to May 2020, the telework rate increased greatly, reaching 25%. However, after the first state of emergency was lifted in June 2020, the telework rate declined to 17%. Telework use in Japan remains low regardless of a large increase under the first state of emergency and does not seem to be an over-time increase in the era of the COVID-19 pandemic. There must be some impediments to allowing telework use.

There is an advantage to studying the case of Japan. Japanese infection control measures do not rely on legal sanctions or penalties and are instead request-based. During the so-called soft lockdown, people were asked to use telework voluntarily. Some workers' tasks are suited to telework and thus they adopted telework, while other workers were allowed to commute as usual and work at offices. Due to job content and traits, more than 80% of teleworkers combined working from home and commuting under the soft lockdown.[2] This therefore allows us to rigorously investigate how workers changed their work style by teleworking and what impediments hamper telework use.

We define telework as working at a specific place (i.e. 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. Although previous studies often use remote work, telework in our paper is more limited in the sense of requiring not only working

[1] During the first wave of COVID-19, Okubo (2020) reported some facts and anecdotal evidence on telework in Japan. Our paper investigates telework in greater detail by conducting an econometric analysis. 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.

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

remotely but also using ICT devices.

Literature Review

Various studies have been done on telework during the COVID-19 pandemic. Teleworkers tend to be higher-income (Mongey et al., 2020; Sostero et al., 2020) and younger workers (Adams-Prassl et al., 2020). In addition to task traits, working environments (e.g. flexible working hours, rich IT communication tools, and digitalized offices), company-wide reforms, and government-requested reforms to limit the spread of novel coronavirus infections largely promoted telework use (Okubo, 2021). Also, telework tends to reduce worker efficiency (Bartik et al., 2020; Morikawa, 2020; Okubo et al., 2021).

Before COVID-19, telework was seen as a means of improving work style and quality of life in the digitalized economy (Gajendran and Harrison, 2007; Bloom et al., 2015; Dutcher, 2012; Gimenez-Nadal et al., 2019). Telework could remove commuting and increase work performance (Helminen and Ristimäki, 2007; Mitomo and Jitsuzumi, 1999; Haddad et al., 2009), and increase flexibility regarding working hours (Coenen and Kok, 2014) as well as leisure time in daily life (Di Martino and Wirth, 1990; Tremblay, 2002; Baines and Gelde, 2003; Wheatley, 2012; Kazekami, 2020).

In the literature on telework, it has been shown that some tasks are suited to telework, whereas others are not. Some task traits are suited to telework and are positively associated with productivity; for instance, creative rather than dull tasks (Dutcher, 2012), non-routine and non-interactive tasks (Kawaguchi and Mogi, 2021), a relatively high level of discretion over work conditions (for example, choosing working hours so as to be more efficient) (Harpaz, 2002), and job autonomy (Gajendran et al., 2015).

On the other hand, it is well-known that there exist several impediments to telework. Social and professional isolation substantially reduces workers' productivity (Baruch and Nicholson, 1997; Golden et al., 2008). Professionally isolated teleworkers are less confident in their abilities to perform their own work because they have fewer opportunities to communicate with coworkers and it is difficult to make use of information for better job performance. Furthermore, information asymmetry and moral hazard always involve serious problems. Telework would largely reduce the possibilities for managers to observe workers and for teleworkers to work with diligence. When supervising teleworkers, managers tend to rely on output-based outcomes and high monitoring techniques

as well as putting trust in and giving guidance to teleworkers (Felstead et al., 2002). In addition, telework is not suitable for teamwork and informationally demanding jobs with homogeneous coworkers (Battiston et al., 2018). It also reduces the quality of coworker relationships when engaged in high interdependency tasks (Gajendran and Harrison, 2007).

Our contribution is twofold. First, our survey, conducted by Keio University and NIRA, covers more than 10,000 workers in Japan during COVID-19. In the literature, most studies conduct either experiments and interviews on a certain group or company (e.g. Battiston et al., 2018; Bloom et al., 2015), small surveys (Baruch, 2000), or field data (Gajendran, et al., 2015). Our survey involved a much larger sample (10,000 workers across Japan) and asked various questions about attitudes toward teleworking, working environments, and tasks. Second, although some previous studies discuss what tasks are suited or unsuited to telework, our investigation goes beyond this. Our question is why such tasks are suited, what impediments, if any, there are for suitable tasks, and what kind of impediments hamper carrying out tasks by telework. By investigating these questions, we discuss the low rate of telework use in Japan.

The remainder of this paper is structured as follows. Section 2 describes our data and stylized facts in Japan. Section 3 discusses routine and non-routine tasks. Section 4 provides some estimation results. Finally, Section 5 concludes.

2 Data and Stylized Facts

2.1 Data

We use the COVID-19 survey on telework conducted by NIRA and Keio University titled “Questionnaire Survey on the Effects of the Spread of COVID-19 on Telework-based Work Styles, Lifestyle, and Awareness” (Okubo and NIRA, 2020).[3] Our paper uses the survey as of June 2020, i.e. after the first wave of the pandemic and after the first state of emergency was lifted.[4] The sample size is 12,138. The survey asked questions about not only individual characteristics, working environments, working attitudes, daily tasks, work performance (efficiency), and mental health, but also telework, i.e. change in work styles and

[3] The survey was conducted on a website created by the Nikkei Research Co. The survey uses 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 is determined by population ratio. The Population Census (Ministry of Internal Affairs and Communications) is employed as a sampling unit.

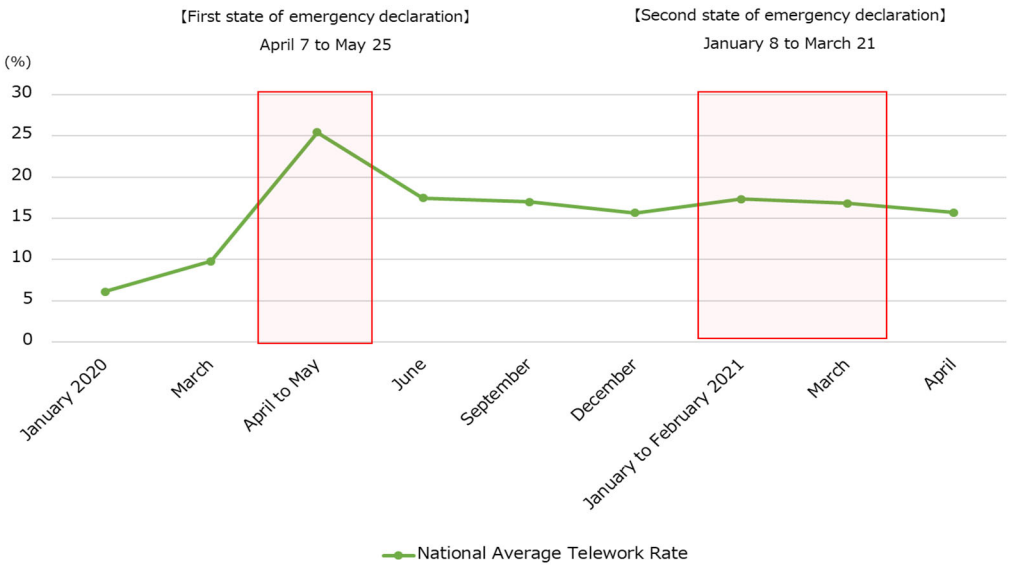
[4] There are four waves of the survey: March (first wave), June (second), December (third) 2020, and April 2021 (fourth). The sample size in the first, second, third, and fourth waves was 10,516, 12,138, 10,523, and 9,796, respectively.

impediments caused by teleworking.

2.2 Stylized facts

As shown in Figure 1, telework use remains low in Japan despite the pandemic. In the first state of emergency (April 7 to May 25, 2020), telework use increased from 6% (in January 2020) to a considerable 25% of workers. Because it was a soft lockdown in Japan, people were asked to telework voluntarily. Some workers who are suited to telework in their task traits followed the request.

Figure 1: Telework in Japan



National (January & March 2020: n=10,516, April to May and June: n=12,138, September & December: n=10,523, January to February 2021 & March & April: n=9,796)

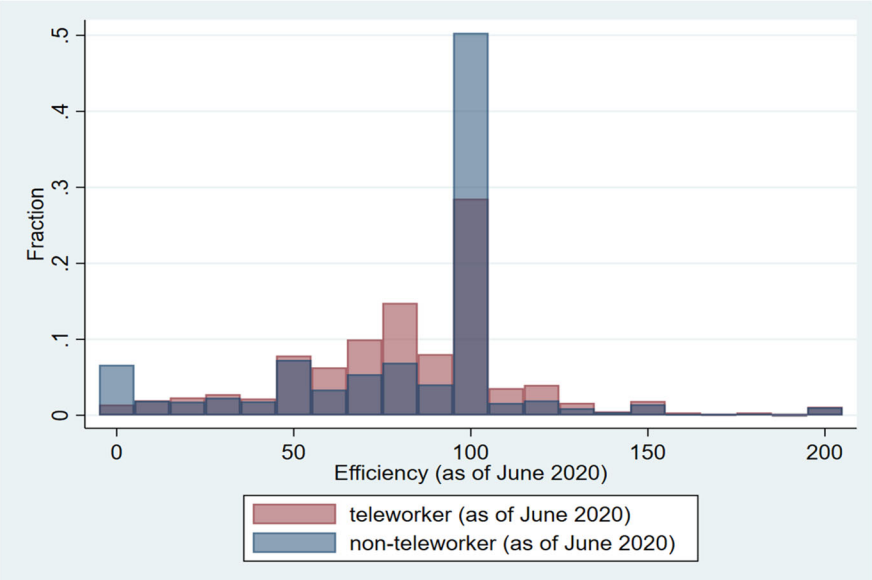
To investigate this fact, our survey asked whether worker performance is lower and mental health condition is worse for teleworkers.[5] The question on worker efficiency was as follows: “Suppose that the COVID-19 pandemic had not occurred, and you are now working as normal. Compared with this hypothetical situation, how is your per-hour teleworking performance as of June 2020? Suppose that your work efficiency is 100 if you were working as normal (i.e., without the COVID-19 pandemic). Then, estimate your efficiency in the range of

[5] Using the same dataset, Okubo et al. (2021) find that a teleworker’s efficiency is proportionate to experience (teleworking hours) rather than ICT skill.

0 to 200. For example, if your performance now is 1.3 times your normal work efficiency, you would answer 130. If your performance is half, you would answer 50, and so on. Answer in increments of 10 only."

Figure 2 displays the histogram of efficiency by teleworkers (red) and non-teleworkers (blue). Both distributions have the peak at 100 and have long downward tails below 100. A few workers claim more than 100 and thus work performance is maintained or reduced for the most part. Compared with non-teleworkers, fewer workers maintain 100 and more claim reduced efficiency (less than 100). However, the reduction is not great, mainly from 50 to 80. Rather than this, non-teleworkers' efficiency falls more than for teleworkers. During the crisis, telework diffuses but most teleworkers saw reduced performance by 10 to 50.

Figure 2: Workers' efficiency

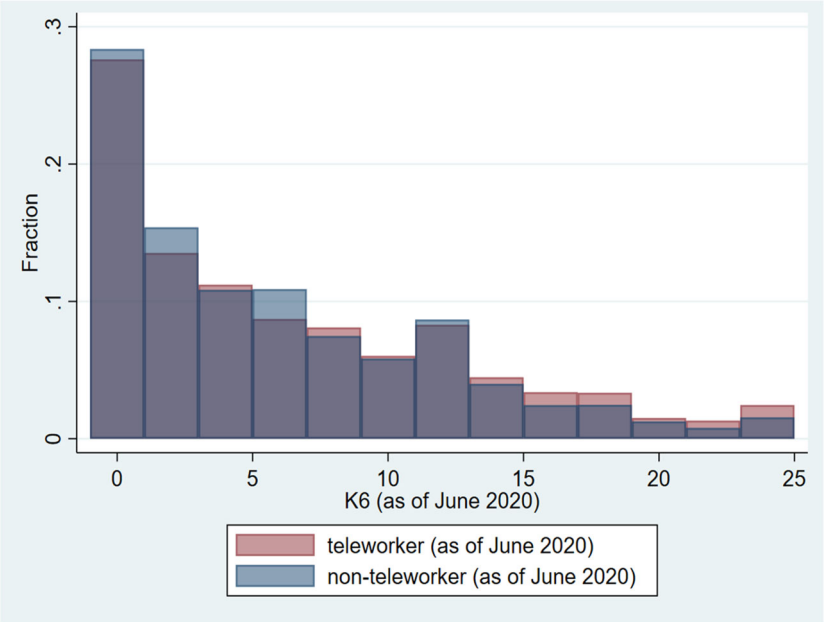


Next, the survey asked about the mental health condition expressed as the K6 scale index.[6] The scale has been widely used as a screen for mental health problems and as a measure of the severity of mental health problems. The K6 index is based on the sum of six questions on distress. A higher value indicates higher levels of anxiety and unease, and thus a more unstable mental condition. Figure 3 shows the histogram of the K6 measure by teleworker and non-teleworker. The distribution of teleworkers dominates that of non-teleworkers in

[6] The six-item Kessler Psychological Distress Scale as proposed by Kessler et al. (2003).

the range of middle and high values of the K6 index (i.e. around above 15). Teleworkers tend to take higher K6 values and worse mental health conditions, compared with non-teleworkers.

Figure 3: Workers' mental health condition



We note that the K6 index in the pandemic is much lower than in 2019, i.e. pre-pandemic. The Ministry of Health, Labour and Welfare (Comprehensive Survey of Living Conditions) annually reports the K6 index. According to the 2019 annual survey, a score of 0 accounts for 39% of the Japanese people and 1 to 4 (5 to 10) account for 29% (19%). By contrast, our survey as of June 2020 sees 19% for score 0, 27% for scores 1 to 4, and 31% for scores 5 to 10. Therefore, even though it is difficult to make a direct comparison between the surveys due to different survey methods and samples in spite of the same format of the questionnaire, the large gap of two periods tells us that the pandemic caused a deterioration in people's mental health.

3 Tasks and telework

3.1 Task measurements

Task characteristics are essential for our investigation. Tasks for each individual are divided into three components: "Routine", "Abstract", and "Manual". De la Rica and Gortazar (2016) constructed measures for the tasks by using the PIAAC

background questionnaire. “Routine” is defined as cognitive and manual routine tasks, “Abstract” is defined as cognitive and interpersonal non-routine tasks, and “Manual” is defined as physical work. Following De la Rica and Gortazar (2016), our survey asked respondents about their job tasks using the PIAAC questionnaire (see Table 1 for more details). The indexes for each of the three groups, routine, abstract, and manual tasks, are derived by the first component of principal component analysis and then standardized.

Table 1: Task question items from PIAAC (De la Rica and Gortazar, 2016)

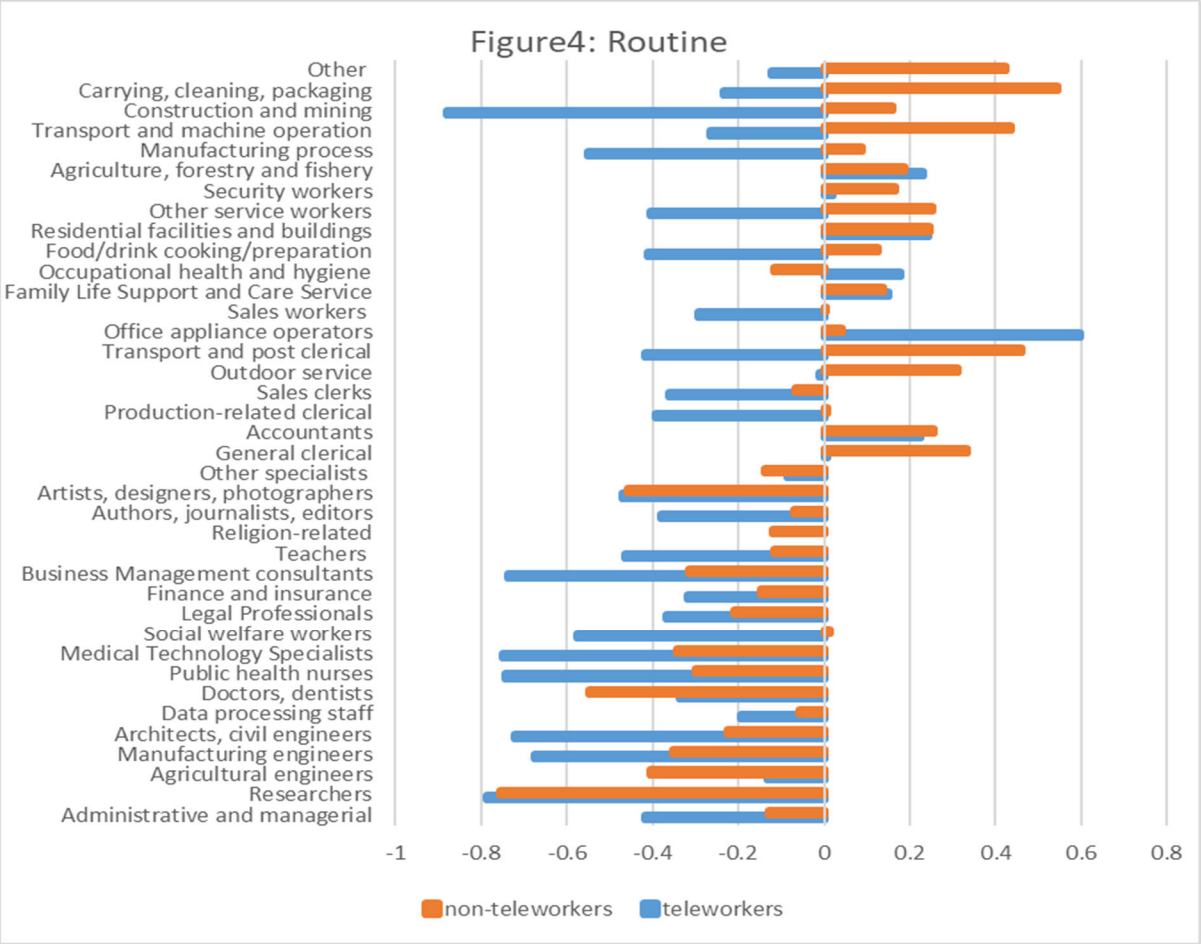
Task	Category	Items	PIAAC Item No.
Abstract (Non-routine)	Cognitive interpersonal and non-routine	Read diagrams, maps or schematics	G_Q01h
		Write reports	G_Q02c
		Face complex problems	F_Q05b
		Persuade, influence people	F_Q04a
		Negotiate with people	F_Q04b
Routine	Cognitive Routine	Change task sequence	D_Q11a
		Change how work is done	D_Q11b
		Change speed of work	D_Q11c
		Change working hours	D_Q11d
		Learn work-related things from coworkers	D_Q13a
		Learn by doing based on tasks performed	D_Q11d
		Keep up to date on new products/services	D_Q13c
	Manual Routine	Hand/finger skill accuracy	F_Q06c
Manual		Physical work	F_Q06b

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

3.2 Routine, Abstract, and Manual Tasks: Sorting by telework

The three task measurements are displayed by occupation as well as by telework use. Mean values of indices are reported. First, Figure 4 reports occupational-level routine task measures by telework use. Administrative workers, specialists, professionals, and technicians (e.g. researchers, engineers, doctors, nurses, business consultants, finance and insurance professionals, and authors) are negative both for teleworkers and non-teleworkers. The negative values tend to be larger for teleworkers (blue bars). In these occupations, all workers tend to engage in fewer routine tasks. On the other hand, sorting, i.e. negative values for

teleworkers (blue bars) and positive values for non-teleworkers (orange bars), happens for transport workers, some manual work (e.g. manufacturing process, carrying and cleaning, construction and mining), and food/drink preparation and service. In these occupations, teleworkers tend to carry out fewer routine tasks, while non-teleworkers carry out a higher number of routine tasks.



Next, Figure 5 shows abstract task measurement by occupation. Administrative workers, specialists, professionals, and technicians take positive values both for teleworkers and non-teleworkers. In particular, teleworkers tend to see higher values. Then, similar to the routine task measure, sorting, i.e. positive values for teleworkers and negative values for non-teleworkers, happens in manual work (e.g. security, agriculture, manufacturing process, carrying and cleaning, construction and mining). In these occupations, teleworkers tend to carry out a

greater number of abstract tasks, whereas non-teleworkers carry out fewer.

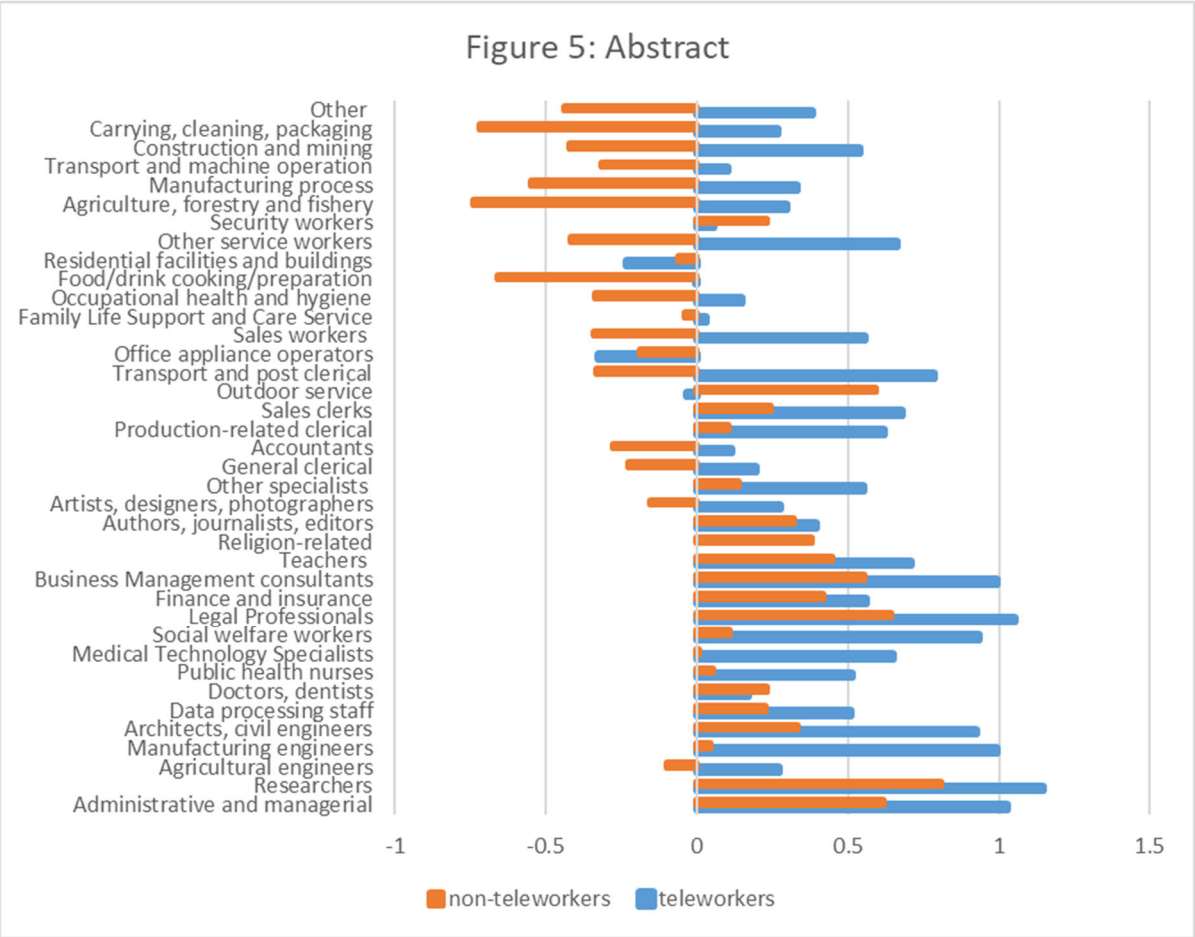
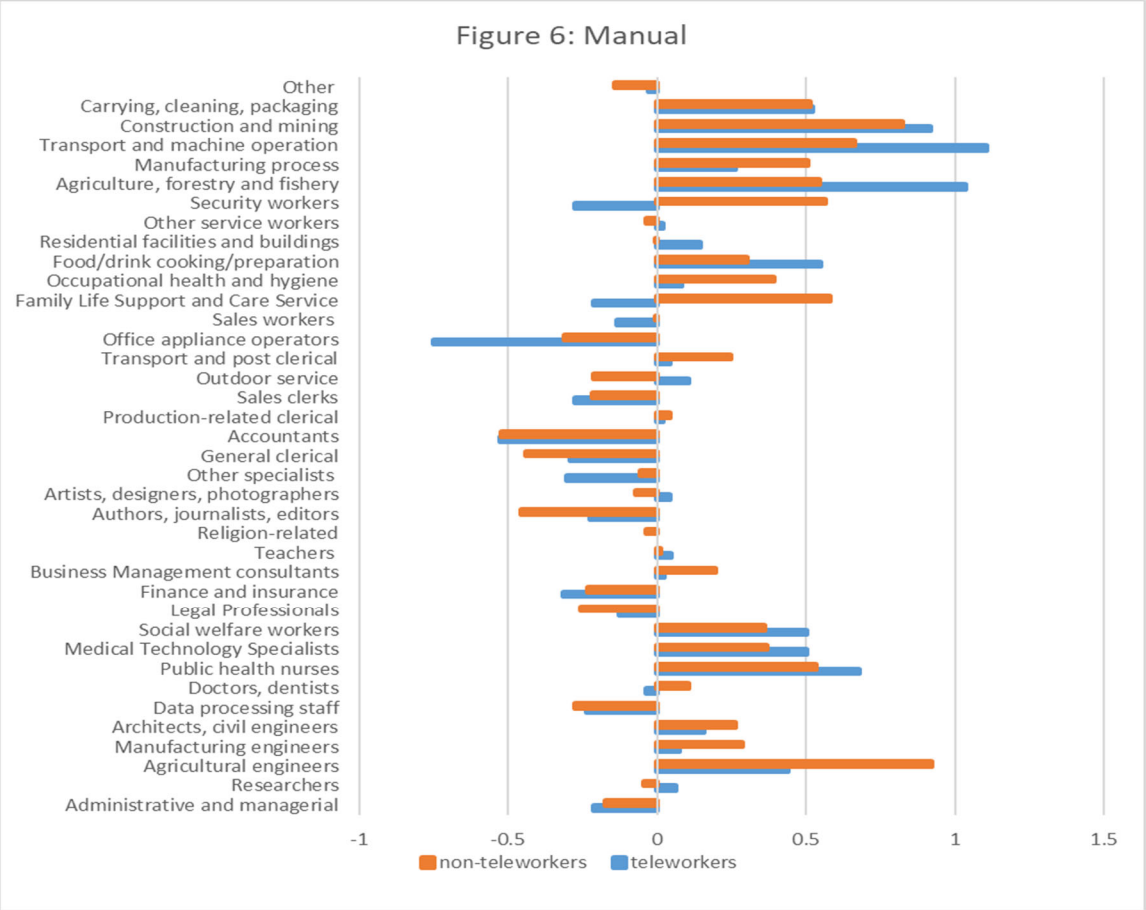
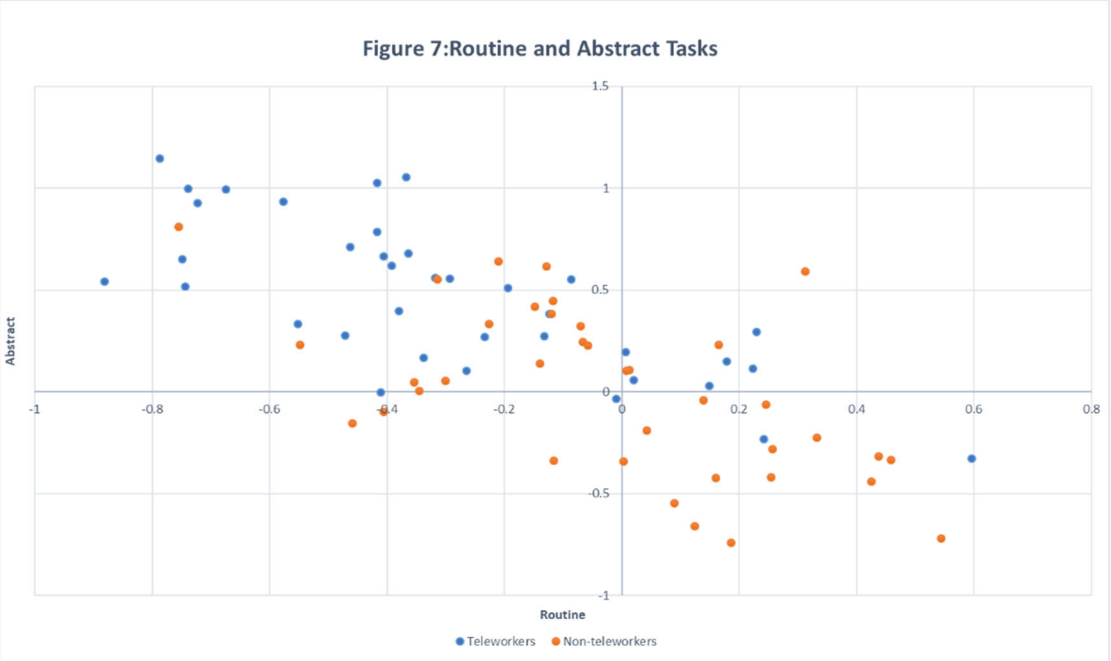


Figure 6 shows manual task measure by occupation. Some specialists, professionals, technicians (e.g. doctors and nurses), and some service workers (e.g. food drink preparation, social welfare services, health and hygiene services, family life support), and almost all manual workers (e.g. agriculture, manufacturing process, carrying and cleaning, construction and mining) are positive for teleworkers as well as for non-teleworkers. All workers in these occupations carry out manual tasks. On the other hand, clerical workers (e.g. accountancy, office work, and general administration) tend to be negative both for teleworkers and non-teleworkers. Workers in these occupations engage in fewer manual tasks. Unlike routine and abstract task measures, sorting does not happen, and each occupation sees the same direction of values regardless of teleworking or non-teleworking.



Regarding sorting patterns by telework, Figure 7 plots occupational-level abstract and routine measurements by telework. The vertical axis is the abstract measure, while the horizontal axis is the routine measure. Each dot indicates the average level of task measurements by teleworkers and non-teleworkers. The blue dots indicate teleworkers and orange ones indicate non-teleworkers. The figure indicates that teleworkers tend to locate positive in abstract and negative in routine, while non-teleworkers tend to locate negative in abstract and positive in routine. In other words, more abstract and less routine tasks are suited to telework, while more routine and less abstract tasks are suited to non-telework. That is, sorting by teleworking happens in routine and abstract tasks in many occupations.



4 Estimations and Results

4.1 Who teleworks?

Under the first state of emergency (April to May 2020), 25% of workers engaged in teleworking, compared with only 6% before the pandemic, in January 2020 (Figure 1). First, we investigated what individual and task characteristics affect telework use. The probit estimation is conducted using the following equation:

$$Prob(TELEWORK_i) = \Phi(\alpha + \beta_1 WCOVID_{j(i)} + \beta_2 X_i + Job_{o(i)} + Ind_{in(i)} + Emp_{f(i)} + Size_{s(i)} + Prefw_{j(i)} + \varepsilon_i) \quad (1)$$

where TELEWORK is the dummy for telework use. TELEWORK takes one if respondent *i* uses telework in April–May and/or June 2020, and zero otherwise. WCOVID denotes the number of daily new infections at respondent *i*'s workplace *j* (municipality level) as of June 1, 2020.[7] X denotes the set of an individual's

[7] In rural areas (e.g. villages), the number of new infections is not available at the municipality level but rather at the health-center level jointly handled by multiple municipalities. Thus, the number of municipality-level patients in rural areas is derived by the number of new infections at the health center weighted by the population of each municipality.

variables. Female is the female variable (2 = female, 1 = male), Age is the age variable (scaled by age 10), Income is the annual income in 2019 (scaled by 500,000 yen), Univ is a dummy for a university degree, and Com_time is the time for commuting (in minutes). PubTrans is a dummy for using public transportation for commuting (e.g. trains and buses). Several fixed effects are added. Job is the occupational fixed effect, Ind is the sector fixed effect, Emp is the employment-type fixed effect, Size is the firm-size fixed effect, and Prefw is the workplace prefectural fixed effect.[8] ε is the error term.

The first column of Table 2 reports the result. We note that standard errors in our estimations are clustered at firm size category. Telework use largely depends on firm size and working conditions/regulations are various across firm size. Larger firms tend to promote company-wide telework in response to government requests, while small self-employed enterprises are flexible to use telework due to a few employees. As a result of estimation, WCOVID, Female, Univ and income are significantly positive, while Age is significantly negative. Com_time and PubTrans are both significantly positive. In sum, younger, educated, female, and workers with higher income tend to use telework, while a larger number of new infections at the workplace (municipality) further promotes telework use. Longer commutes using public transportation tend to promote telework. This is consistent with evidence that longer commuting reduces well-being (Stutzer and Frey, 2008; Gottholmseder et al., 2009) and long commuting involves disutility and compensation (Van Ommeren et al., 2000).

[8] Job is 38 occupation categories. Ind is two-digit-level industries. Emp is regular employees, non-regular employees, executive management, self-employed business owner (with employees), self-employed business owner (no employees), helping with in-house sales, homemaker, student, and other. Firm size is categorized as 5–29 employees, 30–99 employees, 100–499 employees, more than 500 employees, and public offices. We note that there are 47 prefectures in Japan.

Table 2: Telework use

	1		2	
	Coeff	z	Coeff	z
ROUTINE			-0.03849	-2.87 ***
ABSTRACT			0.144299	12.04 ***
WCOVID	626.6172	5.61 ***	541.7078	4.21 ***
Female	0.068352	2.28 **	0.063973	2.11 **
Age	-0.01823	-1.8 *	-0.00359	-0.49
Univ	0.223898	4.84 ***	0.103711	1.59
Income	0.050985	6.77 ***	0.02529	7.91 ***
T_Com	0.0018	2.99 ***	0.001965	2.03 **
PubTrans	0.346547	12.64 ***	0.306391	6.65 ***
REC			2.270097	27 ***
ENV1			-0.12604	-9.45 ***
ENV2			-0.01082	-0.58
ENV3			0.180779	8.77 ***
ictskill			0.159683	4.3 ***
ICT_com			1.09344	17.6 ***
NoB	10,808		10,808	
Loglikelihood	-4384.91		-2867.58	

NOTE: All fixed effects (Job, Ind, Emp, Size, Prefw) are included, but omitted to report from the table.

***: p<0.01, ** p<0.05, * p<0.1

Next, we add some variables on task characteristics and working environments to the equation. The three categories for working environments are team-based working (Env1), outcome-based evaluation (Env2), and flexible working hours/holiday/on leave (Env3). See Okubo (2021) and the Appendix for more details on the construction of variables and question items. ICT_com is the dummy for whether the respondents' companies provide communication, chat, and file-sharing tools.[9] In addition, Rec is the dummy for whether respondents' employers suggested or requested telework use during the state of emergency. ICT_skill is an individual's ICT skills for working, 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,

[9] The questionnaire asked respondents whether to use (1) teleconference and web conference system (e.g. Zoom, Skype), (2) information share (e.g. Slack, Line), and (3) sharing file (e.g. Dropbox, One drive).

programming, and network management) (= 3). Our question follows the questionnaire in PIAAC and De la Rica and Gortazar (2016).[10]

Finally, individual routine and abstract task measures are used as routine intensity (Routine) and abstract intensity (Abstract). As mentioned in the last section, our routine (R), abstract (A), and manual (M) measures follow De la Rica and Gortazar (2016). For our estimation, we measure Routine and Abstract in relation to Manual, i.e. "Routine intensity" = R-M and "Abstract intensity" = A-M[11]. The second column of Table 2 reports the result. ICT_com, Rec and ICT_skills are significantly positive. Higher ICT skills and use of more ICT communication tools promote telework use. ENV1 (team task) is significantly negative, while Env3 (flexible working hours) is significantly positive. Teamwork is not suited to telework, but flexible working hours promote telework use. Since teamwork is information intensive and needs a high level of dense communication, communication by telework has some limitations and thus is not suited to telework. On the other hand, flexible working hours are essential for efficient use of telework. More importantly, we investigate task characteristics such as routine and abstract intensities. While Routine intensity is significantly negative, Abstract intensity is significantly positive. Less routine but more abstract tasks are suited to telework. Workers who carry out fewer routine tasks and more non-routine (abstract) tasks tend to use telework. This corresponds to our stylized fact on sorting by teleworking in the last section (Figure 7). In other words, telework can assist less routine tasks and more abstract tasks. This is consistent with evidence that skill-biased technology growth results in increasing non-routine tasks as complementary with ICTs and decreasing routine tasks as substitutes for ICTs.

4.2 Change of work styles for teleworkers

Many workers changed their work styles by using telework in the first wave of COVID-19. The survey asked how teleworkers changed their working style.

Question: What aspects of your work style and lifestyle changed by using telework?

[10] G_Q06 in PIAAC https://www.oecd.org/skills/piaac/BQ_MASTER.HTM#G_Q06

[11] The other method for a relative measurement is the routine task intensity (RTI) index proposed by Autor et al. (2006). Their formula is RTI = R-M-A.

Items:
1: planning/preparing for future tasks and business
2: coming up with innovative/creative business ideas
3: studying for new licenses (job training)
4: conducting daily tasks more easily/efficiently (administrative/office work)
5: time management for ease of working
6: communication with colleagues or business partners
7: receiving or giving advice about tasks
8: a sense of solidarity/belonging as a staff member
9: working under relaxed environments
10: having spare time during working hours
11: isolation from coworkers
12: physical and mental health control and management
13: communication with family and friends
14: hobbies, social activities, and volunteer work

The teleworkers were asked to choose between Increased (= 1), No change/unknown (= 0), Decreased (= –1). Based on these items, we established 8 categories:
Change_1) Facilitation of regular working tasks/task management (items 4 and 5)
Change_2) Communication with coworkers/colleagues (items 6 and 7)
Change_3) New ideas/plans for future tasks (items 1–3)
Change_4) Isolation (item 11)
Change_5) Health management (item 12)
Change_6) Relaxed working environment (items 9 and 10)
Change_7) Family time and leisure (items 13 and 14)
Change_8) Solidarity/identification as a member of company/office (item 8)
To construct each categorical variable, we take the mean of the items.

Now we conduct ordered logit estimations, which are given as

$$Pro(Change\_x_i \leq k) = F(\alpha + \beta_1 Y_i + Job_{o(i)} + Ind_{in(i)} + Emp_{f(i)} + Size_{s(i)} + Prefw_{j(i)} + \varepsilon_i) \quad (2)$$

where Change_x is the variable for each work style change category (Change_1 to Change_8) as defined above, Y denotes the individual's variables as Female, Age, Income, Univ, IT_skills, and then newly added family structure variables such as the dummy for having his/her child living with them (Child) and the dummy for being single (Single). Y also includes respondent *i*'s working environments such as ENV1, ENV2, ENV3, ICT_com as in the previous estimation. Several fixed effects are added. Job is the occupational fixed effect, Ind is the sector fixed effect, Emp is the employment-type fixed effect, Size is the firm-size fixed effect, and Prefw is the workplace prefectural fixed effect. ε is the error term.

Table 3 shows the results. Each column shows the category of change resulting from teleworking. For communication (Change 2, column 2 of the upper panel), ABSTRACT, Female, Age, Univ, Single, and ENV1 are significantly negative. Older, educated, female, and teleworkers carrying out more non-routine (abstract) tasks decrease communication. Workers with more teamwork tend to reduce communication with coworkers. A similar result can be seen in solidarity and identification (Change 8, column 4 of the lower panel). ABSTRACT, Age, ENV1, and ICT_com are significantly negative. ENV2 is significantly positive. Older workers with non-routine tasks tend to see reduced solidarity and bonds as members of the company. Column 4 of the upper panel is on isolation from coworkers (Change 4). ROUTINE and ABSTRACT are significantly positive. Female, Age, Income, Ict_skill, and ICT_com are significantly positive, while ENV3 is significantly negative. High-income, older, high-skilled, female, and workers with more routine and non-routine tasks, using IT communication tools tend to see increased isolation. Therefore, teleworkers, in particular workers carrying out abstract tasks by using IT communication tools, tend to see reduce communication with coworkers and solidarity as a member of company and increase isolation. Turning to the positive side, column 2 of the lower panel is relaxed time during working hours (Change 6). ROUTINE and ABSTRACT are both significantly positive. Female, ENV1, and ICT_com are significantly positive, while ENV2 is significantly negative. Similarly, column 3 of the lower panel reports the result on family and leisure time (Change 7). ROUTINE and ABSTRACT are both significantly positive. Female, Univ, ENV1, and ITC_com are significantly positive, while Single and ENV2 are significantly negative. Thus, teleworkers with routine and non-routine tasks both increased relaxed working environments and

time for family and leisure. In addition, Column 3 of the upper panel reports on inspiring new idea (Change 3). ABSTRACT, ENV 3, and ICT_com are significantly positive, while ENV2 is significantly negative. Workers carrying out non-routine/abstract tasks using IT communication tools tend to develop new ideas and business and preparation for future work by using telework.

Table 3: Change of life

	Facilitation of tasks		Communication		New ideas		Isolation	
	Change 1		Change 2		Change 3		Change 4	
	Coeff	z	Coeff	z	Coeff	z	Coeff	z
ROUTINE	0.061	1.56	-0.008	-0.12	-0.0128	-0.37	0.0714	3.2 ***
ABSTRACT	0.0446	1.52	-0.1966	-9.1 ***	0.13315	11.02 ***	0.106	2.76 ***
Female	-0.026	-0.3	-0.2333	-2.56 ***	0.06672	0.77	0.2624	3.26 ***
Age	-0.021	-1.28	-0.0663	-8.1 ***	-0.0024	-0.11	0.0359	2.07 **
Univ	-0.121	-1.83 *	-0.2162	-2.56 ***	-0.0634	-1.06	0.0167	0.33
Income	-4E-04	-0.05	-0.002	-0.22	-0.0084	-0.99	0.0298	1.88 *
Child	-0.096	-0.76	-0.0167	-0.13	-0.1156	-0.69	0.1207	1.03
Single	-0.083	-1.59	-0.2504	-2.85 ***	0.04228	0.6	0.1549	1.58
ENV1	0.0806	1.58	-0.137	-3.55 ***	0.02352	0.61	0.126	1.58
ENV2	-0.052	-0.75	0.11409	1.59	-0.1395	-5.64 ***	-0.027	-0.61
ENV3	0.0921	2.32 **	0.03123	0.58	0.08849	1.81 *	-0.106	-2.76 ***
ictskill	0.0781	1.22	0.03	0.89	-0.0144	-0.53	0.1263	4.54 ***
ICT_com	0.2245	4.86 ***	-0.1021	-1.17	0.11171	2.36 **	0.3117	6.56 ***
Num obs	3,066		3,066		3,066		3,066	
R-sq	0.0207		0.0428		0.0237		0.039	
Log likelihood	-3849		-3637.5		-4101.5		-2349	

NOTE: Clustered standard errors by firm size. All fixed effects (Job, Ind, Emp, Size, Prefw) are included, but omitted to report from the table.

***: p<0.01, ** p<0.05, * p<0.1

	Health management		Relax working		Family and leisure time		Solidarity/identification	
	Change 5		Change 6		Change 7		Change 8	
	Coeff	z	Coeff	z	Coeff	z	Coeff	z
ROUTINE	0.0556	1.02	0.0688	2.91 ***	0.0776	3.83 ***	0.0368	0.62
ABSTRACT	0.0005	0.01	0.114	2.57 ***	0.1575	5.9 ***	-0.17	-7.43 ***
Female	0.1164	1.87	0.1681	3.93 ***	0.1951	3.16 ***	-0.1335	-1.4
Age	-4E-04	-0.02	0.0148	0.76	-0.02	-1.02	-0.0806	-5.56 ***
Univ	0.0106	0.11	-0.0091	-0.08	0.2085	2.8 ***	-0.1409	-2.08 **
Income	7E-05	0	-0.0003	-0.03	0.007	0.62	0.0049	1.1
Child	-0.148	-2.08 **	-0.152	-1.55	0.0239	0.15	-0.0098	-0.08
Single	-0.18	-4.83 ***	0.0513	0.85	-0.857	-9.52 ***	-0.1319	-1.15
ENV1	0.0245	0.98	0.21	4.52 ***	0.1708	3.35 ***	-0.1013	-3.05 ***
ENV2	-0.021	-0.42	-0.1628	-2.11 **	-0.105	-2.02 **	0.1173	2.38 **
ENV3	-0.069	-1.99 **	0.0035	0.13	-0.048	-1.37	0.0163	0.45
ictskill	0.0211	0.24	0.0876	1.31	-0.022	-0.67	0.016	0.16
ICT_com	0.1162	1.95 *	0.4062	7.37 ***	0.3149	4.91 ***	-0.1722	-3.28 ***
Num obs	3,066		3,066		3,066		3,066	
R-sq	0.0273		0.032		0.0479		0.0522	
Log likelihood	-2359		-3909.6		-3560		-2316.8	

NOTE: Clustered standard errors by firm size. All fixed effects (Job, Ind, Emp, Size, Prefw) are included, but omitted to report from the table

***: p<0.01, ** p<0.05, * p<0.1

4.3 Impediments in teleworking

Telework can sometimes lead to impediments to working, and such impediments can in turn hamper the spread of remote working. The survey asked teleworkers about such impediments:

Question: To what extent does each item hamper your telework?

Items:

1. Difficult to grasp task progress of coworkers and business partners
2. Difficult to evaluate outcomes by colleagues or to be evaluated by managers, customers, and business partners
3. No/reduced access to internal servers and network systems from home (outside the workplace)
4. No/Lack of digitalized documents and resources
5. No/Lack of digitally shared files
6. No/Lack of digitalized payments, accounting, management decision system at the workplace
7. Anxiety about information security risks in the workplace
8. Anxiety or discomfort about lack of communication with coworkers

For each item, teleworkers were asked to choose one option for impediments and suitability for telework: serious impediments and not suitable for telework (= 5), some impediments and not suitable (= 4), neutral for suitability (= 3), insignificant impediments and suitable for telework (= 2), no impediment at all (= 1), not applicable (= 0).

The questionnaire notes that “not applicable” means that the impediment does not exist at all, for example, items 1 and 2: no need to see progress and evaluate due to independent tasks or high autonomy, item 3: accessible to internal servers system from home, item 4: digitalized documents and resources, item 5: digitally shared files, item 6: digitized management system, items 7 and 8: no anxiety.

We sum up these items in four impediment categories by taking the mean over each item.

Impediment_1) Non-visibility and unsupervised partners and coworkers (items 1 and 2)

Impediment_2) Poor data access and sharing, and paper documents in daily work (items 3, 4, and 5)

Impediment_3) Non-digitized management system in the whole company (item 6

and 7)
Impediment_4) Less daily communication and chat with coworkers (items 8)
Each impediment variable takes 0 to 5, which indicates the degree of impediments for teleworkers. Larger values mean telework involves more serious impediments to continue using telework.

We conduct ordered logit estimations given as

$$Prob(Imp_{x_i} \leq k) = F(\alpha + \beta_1 Y_i + Job_{o(i)} + Ind_{ind(i)} + Emp_{e(i)} + Size_{s(i)} + Prefw_{j(i)} + \varepsilon_i) \quad (3)$$

where Imp_x is the above-defined impediment variable (Impediment_1 to Impediment_4). All independent variables are the same as (2). If coefficients of variables are negative, the variables can reduce impediments to teleworking, and vice versa. We note that standard errors are clustered at firm size as in previous estimations.

Table 4 reports the results. Each column reports each category. All columns show ROUTINE as significantly negative, while non-visibility (column 1) and communication equations (column 4) observe significantly positive coefficients for ABSTRACT. Teleworkers carrying out more routine tasks (higher ROUTINE) tend to think no concerns are impediments to teleworking, while teleworkers carrying out more abstract tasks (higher ABSTRACT) tend to think fewer opportunities for communication and less visibility to coworkers are serious impediments.
ENV1 and ENV3 are significantly negative in many columns. Workers who are teamworking and under flexible hours tend to find fewer impediments to teleworking. They tend to adapt to teleworking flexibly. On the other hand, ICT_com is significantly positive for non-visibility and communication. Even though they can access rich communication IT tools, they cannot resolve the problem of communication with coworkers. Or, paradoxically, more IT tools make them feel lack of visibility and communication problems to be more important impediments to teleworking. If they try to use more IT tools for better teleworking, they recognize that it is more difficult than they expected to realize deep communication and information exchange.

Table 4: Impediments to teleworking

	Imp_1		Imp_2		Imp_3		Imp_4	
	Non-visibility		Poor digitalization in daily work		Non-digitalized management system		Lack of Communication	
	Coeff	z	Coeff	z	Coeff	z	Coeff	z
ROUTINE	-0.20551	-13.11 ***	-0.18729	-11.41 ***	-0.17673	-11.21 ***	-0.13671	-7.57 ***
ABSTRACT	0.179073	3.24 ***	-0.00142	-0.02	0.043269	0.57	0.079333	1.91 *
Female	-0.05103	-0.8	-0.27519	-4.07 ***	-0.15318	-1.89 *	0.047994	0.69
Age	-0.04494	-2.43 **	-0.06321	-2.74 ***	-0.02785	-1.28	-0.04437	-2.41 **
Univ	-0.02389	-0.18	0.10512	1.23	0.187637	2.55 **	-0.02066	-0.29
Income	0.00433	0.41	-0.01413	-2.32 **	-0.01508	-1.41	0.013919	1.59
Child	0.099258	0.85	0.181257	1.45	0.149089	0.81	0.104346	0.98
Single	0.03742	0.34	0.003482	0.05	0.008597	0.1	0.064937	0.54
ENV1	-0.05484	-1.68 *	-0.16502	-3.08 ***	-0.14243	-3.41 ***	-0.02561	-0.88
ENV2	0.027343	0.69	0.144615	2.7 ***	0.097998	1.83 *	0.077595	1.5
ENV3	-0.2248	-5.02 ***	-0.27745	-8.37 ***	-0.24242	-6.03 ***	-0.19126	-4.38 ***
ictskill	0.006719	0.23	0.014618	0.23	-0.01749	-0.35	-0.08514	-2.19 **
ICT_tool	0.327605	3.71 ***	-0.11194	-2.43 **	-0.01238	-0.16	0.16388	4.85 ***
Num obs	3,066		3,066		3,066		3,066	
R-sq	0.0326		0.0316		0.0285		0.0269	
Log likelihood	-6407.05		-7437.21		-6560.43		-5035.07	

NOTE: Clustered standard errors by firm size. All fixed effects (Job, Ind, Emp, Size, Prefw) are included, but omitted to report from the table.

***: p<0.01, ** p<0.05, * p<0.1

In sum, although non-routine workers (doing more abstract and non-routine tasks) tend to use telework (Table 2), communication with coworkers is reduced, there is less solidarity and bonding (columns 2 in the upper panel and 4 in the lower panel of Table 3), and relaxed working environments as well as more leisure time are increased (columns 2 and 3 in the lower panel of Table 3). Consequently, they tend to think less communication with and less visibility to coworkers are serious impediments to teleworking (columns 1 and 4 of Table 4). However, these impediments would be inherent in the current ICT technology and difficult to solve given current technological trajectories, even if companies aggressively introduce computerization and digitization. Rather than this, these impediments might be addressed by some organizational and humanistic devices such as guidance and detailed advice to teleworkers by managers and trust within the workplace.

4.4 Impact of teleworking on working performance and mental health

As seen in the previous sections, teleworkers carrying out non-routine/abstract

tasks tend to use telework but encounter some serious impediments in communication and visibility. Now we investigate whether these consequently reduce telework performance and mental health measured by K6 as discussed in section 2. We conduct simple OLS estimations.

$$Eff_i = \alpha + \beta_1 Routine_i + \beta_2 Abstract_i + \beta_3 AI\_ICT_i + \beta_4 RI\_ICT_i + \beta_5 Y_i + Job_{o(i)} + Ind_{ind(i)} + Emp_{e(i)} + Size_{s(i)} + Prefw_{j(i)} + \varepsilon_i \quad (4)$$

where Eff is the above-mentioned efficiency index for correspondent *i* in the range from 1 to 200 (see section 2). One hundred is the level of efficiency when commuting as normal without COVID-19. ABSTRACT and ROUTINE are abstract task intensity and routine task measurements as defined above. TELEWORK is the telework dummy. AI_ICT (RI_ICT) is the interaction of ABSTRACT (ROUTINE) and ICT_ENV. By extending ICT_com, we use ICT_ENV. ICT_ENV is the dummy for whether the respondents' companies provide not only communication tools but also digitalized management tools to thoroughly investigate work efficiency.

Y is the individual worker's characteristics (Female, Age, Income, Univ, Single, Child, ICT_skills) and working environments (ENV1, ENV2, ENV3, ICT_ENV). Then, we add fixed effects for job, industry, employment, firm size, and prefecture of their workplace.

Columns 1 and 2 of Table 5 report the result on efficiency. ROUTINE is insignificantly negative, while ABSTRACT is significantly positive. AI_ICT is significantly negative. On average, non-routine/abstract intensive teleworkers are higher, but moderate the increased efficiency by using ICT tools. At ICT_ENV = 0.466, the interaction term outweighs the negative impact of AI_ICT. Since they suffer from less communication and non-visibility, their efficiency can be decreased by ICT tools.

Next, we regress K6 on the same independent variables.

$$K6_i = \alpha + \beta_1 Routine_i + \beta_2 Abstract_i + \beta_3 AI\_ICT_i + \beta_4 RI\_ICT_i + \beta_5 Y_i + Job_{o(i)} + Ind_{ind(i)} + Emp_{e(i)} + Size_{s(i)} + Prefw_{j(i)} + \varepsilon_i \quad (5)$$

We note that a larger value of K6 means worse mental health (see section 2). Columns 3 and 4 of Table 5 report the results. ICT_Env is significantly positive. ROUTINE is significantly negative. Therefore, workers carrying out routine tasks

tend to be mentally healthier, although teleworking by using ICT tools itself compromises mental health.

Table 5: Telework performance and mental health

	1		2		3		4	
	Eff		Eff		K6		K6	
	Coeff	t	Coeff	t	Coeff	t	Coeff	t
ROUTINE	-0.45127	-0.4	0.09472	0.18	-0.69558	-4.83 ***	-0.8227	-12.6 ***
ABSTRACT	2.877109	14.73 ***	1.89405	5.49 ***	-0.00132	-0.01	0.0335	0.3
ICT_ENV	2.742291	0.89	2.10019	0.7	1.087154	5.12 ***	1.09752	5.52 ***
RI_ICT	0.779158	0.69			-0.17622	-1.35		
AI_ICT	-1.34135	-4.74 ***			0.053023	0.34		
WCOVID	1660.416	0.55	1676.36	0.55	-222.301	-0.65	-226.94	-0.66
Female	0.944601	1.06	0.86089	0.98	0.224434	1.03	0.23808	1.11
Age	0.385547	1.18	0.39359	1.2	-0.37343	-8.15 ***	-0.3745	-8.13 ***
Univ	2.384449	4.1 ***	2.43678	4.01 ***	-0.07214	-0.2	-0.0786	-0.22
Income	0.396903	2.58 ***	0.38367	2.44 **	-0.10772	-4.3 ***	-0.1063	-4.17 ***
T_Com	-0.04766	-2.04 **	-0.0483	-2.11 **	0.004805	1.28	0.00494	1.29
PubTrans	0.42922	0.26	0.47085	0.29	-0.14788	-0.63	-0.1638	-0.69
REC	0.25584	0.19	0.20861	0.15	0.234713	1.1	0.2368	1.14
ENV1	1.559276	2.77 ***	1.52982	2.71 ***	-0.84088	-7.78 ***	-0.8394	-8.09 ***
ENV2	-1.34833	-1.38	-1.3442	-1.37	0.598469	4.32 ***	0.5999	4.27 ***
ENV3	0.57011	1.98 **	0.52847	1.86 *	-0.77871	-7.92 ***	-0.7728	-7.78 ***
ictskill	0.78567	1.05	0.7906	1.03	-0.25662	-1.3	-0.253	-1.32
Num Obs	2,810		2,810		2,810		2,810	
R-sq	0.0889		0.0884		0.1905		0.1902	

NOTE: All fixed effects (Job, Ind, Emp, Size, Prefw) are included, but omitted to report from the table.

NOTE: Clustered standard errors by firm size.

***: p<0.01, ** p<0.05, * p<0.1

Overall, teleworkers carrying out routine tasks tend to enjoy better mental health (lower K6), while teleworkers carrying out non-routine tasks tend to increase efficiency. Once they use communication and management tools, their efficiency and health condition are reduced. In particular, teleworkers carrying out non-routine tasks reduce efficiency by ICT tools. Because teleworkers have fewer opportunities to communicate with coworkers as well as feeling such non-communication as a serious impediment, they are consequently less efficient in teleworking.

Abstract tasks tend to require a high level of communication (opportunity to convey feelings, atmosphere, know-how, and tacit knowledge and creation of something new through communication rather than just gathering and providing information) and thus a need for some face-to-face communication. Telework does not fully address this issue and thus workers with tasks that tend to be more

abstract than routine face a high level of such communication problems.
Due to skill-biased technological progress in the past decade, there has been a gradual shift in the Japanese economy of employment and income from low-skilled routine workers to high skilled non-routine workers. Telework might accelerate this shift in the era of COVID-19. Non-routine task workers are more likely to use teleworking than routine task workers. However, as shown in our results, telework use has been stagnant since the end of the first state of emergency (Figure 1). One possibility for reducing telework use might be that non-routine workers face serious impediments to communication with coworkers. Many Japanese companies hiring more non-routine workers are information intensive to provide high-quality services and products and have a traditional culture of working together in the same large room. Telework is not suitable for such informationally demanding jobs with homogeneous coworkers (Battiston et al., 2018). Thus, even though Japanese non-routine workers tend to use telework, their tasks tend to be informationally demanding and thus telework might be not suitable for such tasks requiring a high level of information-intensive communication.

5 Conclusions

This paper studies task traits and impediments to telework. As a result of estimations, non-routine/abstract task workers tend to use telework. By teleworking, they can enjoy relaxed working environments and increase their leisure time with family. However, they have fewer opportunities to communicate with coworkers and feel that less communication is a serious impediment. Consequently, their work efficiency and mental health suffer. Non-routine workers need a high level of communication, which cannot be provided by telework. This indicates that non-routine workers need some guidance from managers and some additional communication with teleworking coworkers.

Appendix: Construction of work environment variables[12]

Regarding Env1, ENV2, and Env3, a module of our survey asks about working environments in six items on team collaboration, outcome-based evaluation, and flexible employment systems

1. Tasks you are in charge of are clearly specified within the team
2. Your tasks require cooperation with the team
3. Your workplace highly evaluates working hard without considering working hours
4. Your job evaluation is based on outcomes
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)

For each item, a respondent chooses either disagree (= 1), somewhat disagree (= 2), neither agree nor disagree (= 3), somewhat agree (= 4), agree (= 5), or not applicable (e.g. self-employed), counted as neither agree nor disagree (= 3).

Env1 is calculated by taking the mean of the answering values in items 1 and 2, Env2 is calculated by taking the mean of answers to items 3 and 4, and Env3 is calculated by taking an average of the answering values in items 5 and 6.

[12] We follow Okubo (2021). See Okubo (2021) for more details.

Appendix Table: Basic Statistics

Variables	Definitions	mean	min	max	sd	n
Telework	Dummy for telework use	0.259215	0	1	0.438223	11828
ROUTINE	Routine task intensity	0.047411	-4.838	2.379	1.670909	11828
ABSTRACT	Abstract task intensity	0.025003	-3.221	3.345	1.248482	11828
WCOVID	No. of daily new infections per population	0.000242	0	0.002	0.000312	10818
Female	Male=1, Female=2	1.442509	1	2	0.496705	11828
Age	Age	7.792188	2	12	2.783031	11828
Univ	University degree dummy	0.503635	0	1	0.500008	11828
Income	Income	4.035868	0.25	21.25	3.432878	11828
Child	Dummy for having child	0.139584	0	1	0.34657	11828
Single	Dummy for single persons	0.22117	0	1	0.415052	11828
T_Com	Commuting time (min)	35.00042	0	300	31.00617	11828
PubTrans	Dummy for public transportation use	0.374873	0	1	0.484111	11828
REC	Dummy for company's telework request	0.119801	0	1	0.324742	11828
ENV1	Team based work	3.567425	1	5	0.908002	11828
ENV2	Outcome based work	2.940818	1	5	0.91863	11828
ENV3	Flexible working hours	3.00782	1	5	1.00689	11828
ictskill	ICT skills	1.383666	0	3	0.914864	11828
ICT_com	Dummy for ICT communication tools	0.249662	0	1	0.432836	11828
ICT_Env	Dummy for IT tools	0.301911	0	1	0.459106	11828
Eff	Efficiency	83.09943	0	200	35.10385	11828
K6	K6 index	5.495604	0	24	5.912018	11828
Change 1	Facilitation of tasks	-0.01288	-1	1	0.469716	3066
Change 2	Communication	-0.28523	-1	1	0.48276	3066
Change 3	New ideas	0.134703	-1	1	0.491317	3066
Change 4	Isolation	-0.23255	-1	1	0.539225	3066
Change 5	Health management	-0.02511	-1	1	0.364632	3066
Change 6	Relax working	0.069146	-1	1	0.535628	3066
Change 7	Family and leisure time	0.004566	-1	1	0.53153	3066
Change 8	Solidarity/identification	0.073549	-1	1	0.439919	3066
Imp 1	Non-visibility	2.328441	0	5	1.375711	3066
Imp 2	Poor digitalization in daily work	2.120026	0	5	1.40844	3066
Imp 3	Non-digitalized management system	2.271037	0	5	1.408176	3066
Imp 4	Lack of Communication	2.284083	0	5	1.49535	3066

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