

ESRI Discussion Paper Series No.375

Telework, Management, and Technology

Atsushi Ohyama, Ryo Kambayashi

April 2023



Economic and Social Research Institute
Cabinet Office
Tokyo, Japan

The views expressed in “ESRI Discussion Papers” are those of the authors and not those of the Economic and Social Research Institute, the Cabinet Office, or the Government of Japan. (Contact us: https://form.cao.go.jp/esri/en_opinion-0002.html)

Telework, Management, and Technology*

Atsushi Ohyama[†] and Ryo Kambayashi[‡]

Abstract

We empirically examine what factors facilitate remote work arrangements by using the data from the 2020 JP MOPS. In this study, we exploit variations in establishment characteristics and shed light on the relationships between telework, management, and technology. Our empirical investigation reveals several relationships between telework, management, and technology. First, well-management establishments tend to arrange telework environments. Second, both human resource and non-human resource management practices have positive impacts on the arrangement of telework. Third, it is a long-run improvement in the quality of management that is positively associated with telework arrangements. Finally, technology factors are strongly correlated with the adoption of telework. This study shows that management and technology contribute to telework adoption and that establishment heterogeneity regarding management and technology can explain an unexplained part of the variation in telework arrangement within a given occupation.

Keywords: Telework, Structured management, Technology

* We appreciate invaluable comments from Mari Tanaka. We are also grateful for the comments from ESRI researchers and participants at ESRI workshops in November of 2021 and April of 2023. This research is supported by the Japanese Society for Promotion of Science grant No. 18H03633.

[†] Hitotsubashi University, Institute of Innovation Research, ohyama@iir.hit-u.ac.jp

[‡] Hitotsubashi University, Institute of Economic Research, kambayashi@ier.hit-u.ac.jp

1. Introduction

Even before the 2010s, working from home (WFH) had become an increasingly important work arrangement, and the onset of the COVID-19 pandemic accelerated the number of WFH individuals. According to the OECD report (OECD, 2021), the rates of teleworking more than doubled compared to one year before the onset of the COVID-19 pandemic in many countries such as France, Japan, Italy, and Brazil. In Japan, for example, "telework rates increased markedly from 10% in December 2019 to almost 28% in May 2020" (p.4, OECD, 2021).

However, there are considerable variations in WFH rates across occupations, firms, industries, and countries. The occupation-level WFH variation is associated with job characteristics. This is mainly because some jobs and tasks are assumed to be technologically difficult to be performed at home, generating differences in the feasibility of WFH across occupations. Dingel and Neiman (2020) report the share of jobs that can be done at home based on the O*NET database. According to their calculations, more than 95 percent of jobs can be done at home for computer, education, and legal occupations, whereas the corresponding number is 1 percent or 0 percent for farming, production, and construction occupations. Adams-Prassl et al. (2022) examine the US and UK survey data and confirm considerable differences in the feasibility of WFH across occupations.

We examine what factors facilitate teleworking in this paper, but we take a different approach from the ones examining job characteristics and occupation-level variations. We shed light on establishment-level variations in teleworking by focusing on establishment heterogeneity regarding management and technology. As discussed in the literature on telework, management can affect telework arrangements because incentives and monitoring embedded in the output control and human resource management must be aligned with workers' incentives for taking desirable actions and behaviors when they work from home. Furthermore, Bloom et al. (2015) argue that telework is also one of the management practices. Therefore, management can be a potential driver for telework adoption. Similarly, advanced technology affects the feasibility of teleworking because access to advanced technology enables teleworking. The systematic analysis of how these factors contribute to telework arrangements is lacking mainly because high-quality data are not available. We try to fill this gap by overcoming the data limitations as well as providing findings that complement insights obtained from the individual- and occupational-level analyses.

Our data come from the Japanese version of the Management and Organizational Practices Survey for 2020 (manegimento-ya-soshiki-ni-kansuru-chosa, hereafter the 2020

JP MOPS). The 2020 JP MOPS follows the protocol of the previous JP MOPSs and collects information on the management practices of establishments in the manufacturing sector. Management scores are calculated from this information by using the procedure employed in the management survey literature (Bloom et al., 2019). In addition, survey respondents were instructed to answer what percentage of workers work from home at least once a week and to what extent their establishment introduces and uses the Internet of Things devices (IoT), Artificial Intelligence (AI), and 3D CAD/CAM, respectively. These pieces of information are utilized to construct telework and technology measures. We are thus able to use these empirical measures of telework, management, and technology to understand a mechanism that facilitates telework.

The main results of this paper are summarized as follows. First, management scores (a proxy for management quality) are positively associated with the likelihood of adopting telework even after technology factors are controlled for. This indicates that well-management establishments tend to arrange work-from-home environments. Second, it is a long-run improvement, not a short-run improvement, in the quality of management that is positively associated with the current telework adoption. One possible interpretation of this result is that the organization's ability to design, build, and implement good management practices over a long timeframe helps to adopt telework. Finally, technology factors are strongly correlated with the adoption of telework. The overall findings from this study suggest that establishment heterogeneity regarding management and technology contributes to variation in telework. This heterogeneity can explain an unexplained part of the variation in telework arrangement within a given occupation.

The paper is organized as follows. In Section 2, we briefly review the literature on the determinants of teleworking and its effects on performance. Section 3 describes the 2020 JP MOPS and explains how telework, management, and technology measures are constructed. In Section 4, we estimate the baseline specification in which the dependent variable is telework and the main independent variables are management and technology and report the results from the logit model estimations. Section 5 concludes.

2. Brief Literature Review

Job characteristics are an important determinant for enabling individuals to work from home. Dingel and Nieman (2020) use the O*NET database to compute a share of jobs that can be done at home, and report that this work-from-home measure varies considerably across occupations. According to their calculations, more than 95 percent of jobs can be done at home for computer, education, and legal occupations, and more

than 85 percent of jobs can be done at home for business and financial operation, and management occupations. The corresponding number is 1 percent or 0 percent for farming, production, and construction occupations. There are occupations where a moderate percentage of jobs can be done at home, such as community and social service (37 percent) and sales and related (28 percent) occupations. Adams-Prassl et al. (2022) use survey data on workers collected in the United States and the United Kingdom and examine who can work from home by paying attention to the heterogeneity in the ability to work from home. They find considerable variation in the ability to work from home not only across but also within occupations and industries. According to their estimation, occupation and industry fixed effects can only explain about one-quarter of the variation in the share of tasks that can be done at home. They also document that male workers, workers with a university degree, and workers with permanent contracts can perform higher shares of their tasks from home than female workers, workers without a university degree, and workers with temporary contracts.

Our study focuses on examining the heterogeneity in the ability to work from home across establishments within the manufacturing sector. In contrast to their study, a unit of analysis is an establishment in our study, not a worker or an occupation. This allows us not only to investigate this heterogeneity at the establishment level but also to answer what work environment facilitates telework arrangements. Especially, evidence is scant regarding whether good management, advanced technology, or both promote working from home. We try to answer this question in this study.

Kawaguchi and Motegi (2021) try to answer who can work from home by using the Japanese Panel Study of Employment Dynamics. They examine how job characteristics and human resource conditions facilitate a remote work arrangement. They find that those workers who perform routine, manual, interactive tasks or some combinations of these tasks are less likely to work remotely than those workers who perform non-routine, non-manual, non-interactive tasks or some combinations of these tasks. They also document that pay-for-performance, key performance indicators, and management by objectives have positive impacts on the likelihood of remote work experience. Given that these human resource management practices are adopted typically when outputs are measured and observed accurately, this renders support to the claim that the availability of output measures is a critical factor for remote work. However, it remains unclear whether such management practices per se or the ability to implement such management practices allow firms to arrange work-from-home environments. We try to offer some insight into this issue based on our empirical results. In addition to the analysis using the aggregate measure of management practices, we decompose

management practices into a set of promotion, bonus, and dismissal practices (human resources) and a set of monitoring and targeting practices (non-human resource management) and examine how different management practices impact the adoption of telework differently.

Bloom et al. (2015) examine the experimental data on the employees of a Chinese travel agency and document that working from home is a management practice for raising productivity. This productivity improvement comes from the flexibility and convenience of working from home, such as flexible working time and styles. According to the study by Kawaguchi et al. (2021), firms that arranged remote work environments prior to the onset of the COVID-19 pandemic were able to substantially mitigate the negative impacts on their sales, and firms that increased workers who worked from home during the pandemic were also able to cope with the crisis. Telework can be considered one of the management practices that have a significant impact on firm performance. Given that management practices tend to be complementary to each other, our study can be viewed as examining whether telework requires other complementary management practices.

3. Data

This study focuses on management and technology factors and examines whether and how these two factors prompt establishments to arrange and promote telework environments. To answer this question, we construct empirical measures of telework, management, and technology from the 2020 JP MOPS. This survey was conducted between January 25th and March 12th of 2021 by adopting a similar survey protocol employed in the previous waves of the JP MOPSs (See Kambayashi et al., 2021 for the results from the previous JP MOPSs). Survey questionnaires were mailed to 40,000 manufacturing establishments with at least 30 workers, and 4,344 establishments responded to the survey questions by mail or online. The response rate of this survey is 10.9 percent.

Survey respondents were instructed to answer most survey questions as of January 2020, December 2020, and 2015, respectively. COVID-19 infection was not widespread in Japan as of January 2020, whereas various preventive measures were imposed on social and economic behaviors and activities as of December 2020¹. Thus, the January 2020 part of the survey answers provides information on establishments prior to the onset of the COVID-19 pandemic, and the December 2020 part provides this piece

¹ The first victim of covid-19 in Japan was discovered on 13th Feb. 2020.

of information posterior to the onset of the COVID-19 pandemic. This allows us to follow changes in establishment choices and behaviors before and after the pandemic as well as to examine management and organizational issues related to the COVID-19 pandemic.

Our key dependent variable is the establishment's adoption of telework. The 2020 JP MOPS contains information on the telework arrangements of each establishment. Survey respondents were asked to answer what percentage of workers work from home at least once a week for each of the five worker categories (managers, IT and data specialists, other specialists, full-time workers, and part-time workers). We use this piece of information to construct two empirical measures that capture the adoption and implementation of telework at the establishment level. One measure is a dummy variable indicating whether an establishment adopts some form of telework or not at a given point in time. This variable takes the value of 1 if some workers in at least one worker category work from home, and the value of 0 if no workers in all the five categories work from home. The other measure is a dummy variable indicating whether an establishment increases the percentage of workers who work from home in at least one category of workers between two reference time points. This variable takes the value of 1 if an establishment increases the percentage of workers who work from home, and the value of 0 otherwise.

The quality of management is one of our key independent variables in this study. In the 2020 JP MOPS, survey respondents were instructed to answer a total of 16 management questions regarding monitoring, targeting, bonuses, promotion, and dismissal practices. We follow the procedure employed in the management survey literature (Bloom et al., 2019, for US MOPSs; Kambayashi et al., 2021, for JP MOPSs) and use this piece of information to construct a measurement of management quality for each establishment. More specifically, we evaluate a respondent's answer to each of these management questions on a scale of 0 to 1 from the viewpoint of incentives and production efficiency and calculate a simple average of scores from the 16 questions. This average score is called the "management score" and is intended to capture the quality of management. Past studies have shown that management scores are positively associated with establishment/firm performances such as productivity, survival, and profitability (Bloom and Van Reenen, 2007; Bloom et al., 2019; Kambayashi et al., 2021). In this study, we interpret a high management score as indicating that an establishment is managed well.

We also use the information on each establishment's technology in the 2020 JP MOPS. Survey respondents were instructed to choose to what extent their establishment introduces and uses the Internet of Things devices (IoT), Artificial Intelligence (AI), and

3D CAD/CAM, respectively. For example, for the Artificial Intelligence survey question, they were asked to choose one answer from the following four alternatives: “1. An establishment has not yet introduced AI and does not plan to introduce AI,” “2. An establishment has not yet introduced AI but plans to introduce AI,” “3. An establishment has already introduced AI in some process,” and “4. An establishment has already introduced AI in most processes.” From such information, we construct a dummy variable indicating whether an establishment has already introduced each of these technologies or not. We also construct a “technology score” by evaluating the usage of each technology on a scale of 0 to 1 and taking their simple average. A high technology score is interpreted as indicating that establishments introduce and utilize IoT, AI, and 3D CAD/CAM in their production process to a great extent.

4. Results

4.1 Summary Statistics

We first use the telework dummy variable to see how prevalent telework arrangements are in our sample of Japanese manufacturing establishments. Table 1A presents the percentages of the establishments where some workers work from home at least once a week for January 2020, December 2020, and 2022. Note that the 2020 JP MOPS was conducted in early 2021 and telework data for 2022 are regarding establishments’ plans for arranging telework environments in 2022.

Two features are noteworthy in Table 1A. First, most establishments in our sample did not adopt telework at all in January 2020 and December 2020, and they did not plan to do so in 2022. As of January 2020, less than 10 percent of the establishments arranged once-a-week telework in each of the five worker categories. As the telework dummy indicates, only about 10 percent of the establishments arranged once-a-week telework for workers in at least one worker category. Compared with other studies (Cabinet Office Japan, 2022; Kawaguchi and Motegi, 2021), the percentage of establishments adopting telework in our sample is low. One possible reason for this is that our sample comes from the manufacturing sector, where work-from-home is not as feasible and efficient as other sectors (Dingel and Nieman, 2020). Another possible reason is that our telework data are linked to establishments, not to individual workers. The second feature is that the percentage of establishments adopting once-a-week telework more than doubled in most worker categories from January 2020 to December 2020 and is expected to keep increasing in 2022. For example, this telework percentage for managers increased to 17.1 in December 2020 (after the onset of the COVID-19

pandemic) from 7.7 in January 2020 (before the onset of the COVID-19 pandemic), and it is expected to increase up to 19.5 in 2022.

Table 1B summarizes changes in each establishment's telework arrangements between January 2020 and December 2020. According to Table 1B, 9.7 percent of the establishments did not adopt telework for managers as of January 2020 but adopted it as of December 2020. This number ranges from 1.9 percent (part-time workers) to 9.7 percent (managers). We can thus see that the COVID-19 pandemic acted as a catalyst for the adoption of telework at the establishment level. This is consistent with other studies (Cabinet Office Japan, 2022; Kawaguchi and Motegi, 2021). Table 1B also reports the percentages of establishments that increased telework percentage for each worker category between January 2020 and December 2020.

[Table 1 here]

Table 1C reports the percentages of workers at each establishment who work from home, conditional on some form of telework arranged (i.e., the telework dummy takes the value of 1). As we can see, the average percentage of workers at each establishment who work from home increased between January 2020 and December 2020 in all the worker categories except the full-time worker category. Notice that this average percentage is affected by composition effects because the composition of establishments arranging telework differs between January 2020 and December 2020. Our close examination reveals that the percentage of workers who work from home is much smaller for the establishments that did not arrange telework in January 2020 but arranged telework in December 2020 than the establishments that arranged telework at both points in time. Even though the latter type of establishment, on average, increased the percentage of full-time workers who work from home, the composition effect from the former type of establishment is strong enough to drive down the overall average percentage of full-time workers who work from home. We see a similar pattern when using the median percentage of workers who work from home.

We next look at summary statistics on management scores and technology variables. Table 2A reports summary statistics on management scores, human resource management scores, and non-human resource management scores. As explained above, management scores are the overall average scores from the 16 management questions. We break management scores up into human resource management scores and non-human resource management scores. The former scores are the average scores from bonus, promotion, and dismissal practices questions, whereas the latter scores are the average

scores from monitoring and targeting practices questions. The average management score is 0.503, which can be interpreted as indicating that a typical establishment in the sample adopts about 50 percent of the “best” management practices that are evaluated on the basis of incentives and efficiency. The maximum management score is 0.901, and the minimum management score is 0. Consistent with the results from past studies, the management scores vary considerably across the establishments in the sample. The average human resource management score is 0.627, and the average non-human resource management score is 0.523. Both scores also vary considerably across the establishments in the sample.

Table 2B presents summary statistics on technology variables. As of 2015, 70.8 percent ($= 62.5 + 8.3$) of the establishments in the sample did not adopt IoT. This number falls to 59.3 percent as of January 2020 and 57.1 percent as of December 2020. While the main mode of IoT adoption was a client-server system throughout all the periods, the percentage of using a cloud system rose over time. We can see a similar pattern regarding the adoption and use of 3D CAD/CAM. Many of the establishments did not adopt 3D CAD/CAM throughout all the periods. When it was adopted, it was utilized in some parts of the process. Our data show that only a few establishments use AI. As of December 2020, less than 10 percent of the establishments in the sample adopted AI. To evaluate each establishment's overall technology adoption, we score each technology variable and convert the three technology variables into a single index, “technology score”. As of December 2020, the average technology score is 0.245 and the median technology score is 0.220. This also indicates that most establishments in the sample did not adopt advanced technologies.

[Table 2 here]

4.2 Analysis of the Relationship between Telework, Management, and Technology

We first examine the relationship between telework and management by using logit model estimations. In the first specification, the dependent variable is the telework dummy variable, and the main independent variable is the management score. Rather than taking the individual unobservable effects of establishments, in the second specification, we replace the dependent variable with a dummy variable indicating whether an establishment increases the percentage of workers who work from home between January 2020 and December 2020. The number of employees, a year established, a dummy for headquarters, and dummies for three-digit industry codes are also included as control variables in the estimation equation.

Table 3 reports the results from logit model estimations. The estimation result for the first specification shows that the coefficient on the management score is positive and statistically significant at the conventional significance level for all the reference time points. Thus, the telework dummy is positively associated with the management score. We have qualitatively the same result for the second specification. The coefficient on the management score is 2.16, and statistically significant at the one percent significance level. In this estimation, the telework dummy includes establishments that had already adopted telework as of January 2020 as well as establishments that had not yet adopted telework as of January 2020. When the sample is limited to establishments that did not adopt telework at all as of January 2020 (before the onset of the COVID-19 pandemic), the coefficient on management score shrinks to 2.05, and is statistically significant at the one percent significance level.

The estimation results above indicate that well-managed establishments are more likely to have telework arrangements in place at a given point in time and that well-managed establishments are more likely to introduce telework and expand the percentage of workers who work from home between January 2020 and December 2020. The need for telework had changed dramatically as the COVID-19 infection rapidly spread. It is thus a possible case that well-managed establishments responded to this need and that telework and good management are complementary relations (See also Table 5 and further discussion below).

[Table 3 here]

The management score may serve as a proxy variable for other establishment characteristics in our estimations. We are especially concerned that advanced technologies enable establishments to arrange telework relatively easily, and well-management establishments are more likely to adopt advanced technology than poorly managed establishments.

Table 4 presents estimation results for the relationship between management and advanced technologies. In this estimation, the dependent variables are dummies for the adoption of each technology and the technology score for December 2020. In all the specifications, the coefficient on the management score is positive and statistically significant at the one percent significance level. Indeed, well-managed establishments are more likely to adopt IoT, AI, and 3D CAD/CAM and have higher technology scores than poorly managed counterparts.

[Table 4 here]

Given that the management score is positively correlated with the technology variables, we estimate the relationship between telework and management by adding the technology score to the baseline estimation model. Table 5 presents estimation results from logit model estimations using the January 2020 and December 2020 data. The coefficient on management score is positive in all the specifications and statistically significant at the one percent significance level in all the specifications except January 2020. The positive correlation between management and telework still holds even after the technology factor is controlled for. The estimation results show that both the magnitude and statistical significance of the management score are larger for December 2020 than for January 2020. As we discussed above, this also renders support to the interpretation that well-managed establishments responded to the need for telework during the COVID-19 pandemic. The technology score is also positively correlated with the telework dummy, indicating that establishments with advanced technologies are more likely to adopt telework than establishments without them.

[Table 5 here]

What management practices matter for the positive relationship with the arrangement of telework? To answer this question, we decompose the management score into human resource management score and non-human resource management score and use them as the main independent variable in the estimation specification used in Table 5.

Table 6A presents estimation results for the human resource management score. While the coefficient on the management score is statistically insignificant for January 2020, it is positive and statistically significant at the conventional significance level for December 2022 and pooled data. Table 6B reports estimation results for the non-human resource management score and shows qualitatively the same results as the ones in Table 6B. Thus, both human resource and non-human resource management practices have positive impacts on the arrangement of telework. In both cases, the impact of the management score on the arrangement of telework is smaller, compared with the overall management score.

[Table 6 here]

We further investigate whether good management facilitates establishments to adopt telework by exploiting panel aspects of our data. For this purpose, the sample is restricted to establishments that had not yet adopted telework as of January 2020. The establishments in this subsample were likely to face similar needs for adopting telework, arising from the rapid spread of COVID-19 infection, and were markedly different from establishments that had already adopted telework before the COVID-19 pandemic. In this estimation, the dependent variables are telework dummies for December 2020 and 2022 (plan), and the main independent variable is a change in management scores over time.

Table 7 reports estimation results for the relationship between the telework dummies and management score. First, as consistent with the results from the full sample, the telework dummies are positively associated with the management score for this subsample. Second, the telework dummy variables are not associated with a change in management score between January 2020 and December 2020. This also applies to a change in technology score between January 2020 and December 2020. Finally, the coefficients on a change in management score between 2015 and January 2020 are positive and statistically significant at the conventional significance level.

The results above indicate that short-run improvement in management practices is not positively associated with the arrangement of telework, but long-run improvement in management practices is positively associated with the adoption of telework. Past studies about management reveal that a management structure is stable over time and is hard to improve continuously. One interpretation of this result is that an establishment's capability to build a structured management system and operate it smoothly has positive impacts on the adoption of telework (not management practices per se), although further investigation is required to test this hypothesis.

[Table 7 here]

5. Conclusion

We empirically examined what factors facilitate remote work arrangements by using the data from the 2020 JP MOPS. Our empirical investigation revealed several relationships between telework, management, and technology. First, well-management establishments tend to adopt and use telework. This relationship holds true even after technology factors are controlled for. Second, both human resource and non-human resource management practices have positive impacts on the arrangement of telework. Third, a long-run improvement in the quality of management is positively associated with telework adoption, but we do not observe such a relationship for a long-run improvement in the

quality of management. Finally, technology factors are strongly correlated with the adoption of telework.

These results provide several fresh insights into potential drivers for remote work arrangements. While past studies have examined the roles played by work environments in remote work arrangements, many of such studies have lacked systematic analyses mainly because a unit of analysis is not an establishment or a firm, but rather an individual or an occupation. This study exploited establishment-level variation in management and technology and showed that these factors had positive impacts on the arrangement of telework. This study thus points to the importance of establishment-level characteristics such as work environments in determining telework arrangements.

By the nature of our measure of management, a high management score indicates that an establishment employs objective goals and evaluations and it manages production processes and human resources efficiently. As discussed by Groen et al. (2018) and Kawaguchi and Motegi (2021), our result can be intercepted along with the hypothesis that objective management and reliable monitoring make output controls easily implementable, and this, in turn, facilitates telework arrangements. However, our measure of management is not linked directly to incentives and work environments designed for telework arrangements. In addition, only a long-run improvement in the quality of management has an impact on the adoption of telework. These findings lead us to infer that the organization's ability to design, build and implement good management practices is a critical factor for the adoption of telework. In other words, as Bloom et al. (2015) pointed out, telework is a good management practice and is complementary with other management practices.

It is also worthwhile to emphasize the strong positive association of the technology variables with the adoption of telework. Our result carries two interpretations, though they are not mutually exclusive. One interpretation is that our technology variables capture how easily workers can work from home. According to this interpretation, advanced technology is one of the establishment characteristics that enables workers to work from home easily. The other interpretation is that establishments with advanced technology possess a tendency and capability to arrange telework environments. This trait might allow establishments to respond timely to the need for telework caused by the spread of COVID-19 infection.

This study is descriptive in nature and is unable to disentangle one mechanism of telework arrangements from another one. Therefore, the findings from this study should be interpreted as suggestive, and further investigation is required to draw definitive conclusions. Nonetheless, this study exploits variation in establishment

characteristics and sheds light on the relationships between telework, management, and technology that past studies have not examined sufficiently. This study also shows that establishment heterogeneity regarding management and technology can explain an unexplained part of the variation in telework arrangement within a given occupation.

References

- Adams-Prassl et al., "Work that can be done from home: evidence on variation within and across occupations and industries," *Labour Economics*, 2022, Vol. 74, 102083.
- Bloom, N., E. Brynjolfsson, L. Foster, R. Jarmin, M. Patnaik, I. Saporta-Eksten and J. Van Reenen, "What drives differences in management practices? " *American Economic Review*, 2019, 109(5), pp.1648-1683.
- Bloom, N., J. Liang, J. Roberts, and Z. J. Ying, "Does working from home work? Evidence from a Chinese experiment," *Quarterly Journal of Economics*, 2015, 122(4), pp.1351-1408.
- Bloom, N. and J. Van Reenen, "Measuring and explaining management practices across firms and countries," *Quarterly Journal of Economics*, 2015, pp.165-218.
- Dingel and Nieman, "How many jobs can be done at home," *Journal of Public Economics*, 2020, Vol.189, 104235.
- Groen, B.A.C., S.P. van Triest, M. Coers, and N. Wtenweerde, "Managing flexible work arrangements: Teleworking and output controls," *European Management Journal*, 2018, 36, pp.727-735.
- Kambayashi, R., Ohyama, A., and N. Hori, "Management Practices and Productivity in Japan: Survey Evidence from Six Industries in JP MOPS," *Journal of the Japanese and International Economies*, 2021, Vol.61(Sep).
- Kawaguchi, D., S. Kitao and M. Nose, "The impact of COVID-19 on Japanese firms: Mobility and resilience via remote work," *International Tax and Public Finance*, forthcoming.
- Kawaguchi, D., and H. Motegi, "Who can work from home? The roles of job tasks and HRM practices," *Journal of the Japanese and International Economies*, 2021, Vol.62 (Dec).
- OECD, "Teleworking in the COVID-19 pandemic: Trends and prospects," *OECD Policy Responses to Coronavirus (COVID-19)*, 2021, OECD Publishing, Paris.

Tables

Table 1A: Percentages of establishments arranging telework by worker category

	January 2020		December 2020		2022 (plan)	
	No telework	Some telework	No telework	Some telework	No telework	Some telework
Managers	92.3	7.7	82.9	17.1	80.5	19.5
IT&Data specialists	96.3	3.7	91.2	8.8	88.5	11.5
Other specialists	96.4	3.6	91.1	8.9	89.2	10.8
Full-time workers	94.8	5.2	86.4	13.6	85.4	14.6
Part-time workers	97.2	2.8	95.3	4.7	94.6	5.4
Telework dummy	89.4	10.6	76.4	23.6	74.2	25.8

Note) Telework dummy takes “Some telework” (the value of 1) if some workers in at least one worker category work from home, and takes “No telework” (the value of 0) if no workers in all the five categories work from home.

Table 1B: Percentages of establishments that increase telework by worker category

	A change between January and December 2020	
	From no telework to some telework	Increase in telework percentage
Managers	9.7	10.9
IT&Data specialists	5.2	5.8
Other specialists	5.3	5.9
Full-time workers	8.2	8.6
Part-time workers	1.9	2.1

Table 1C: Average and median percentages of telework by worker category

	January 2020		December 2020		2022(plan)	
	Mean	Median	Mean	Median	Mean	Median
Managers	12.7	10.0	16.3	10.0	18.9	10.0
IT&Data specialists	11.1	4.0	22.8	7.0	23.5	10.0
Other specialists	18.2	8.5	20.3	10.0	21.6	10.0
Full-time workers	37.2	25.0	23.6	10.0	25.8	10.0
Part-time workers	18.3	10.0	18.1	10.0	19.2	10.0

Table 2A: Summary statistics on management score

	January 2020						
	Min	25th	Median	Mean	75th	Max	Observations
Management score	0.000	0.401	0.510	0.503	0.613	0.901	3,935
Human resource management score	0.000	0.417	0.627	0.578	0.750	1.000	3,935
Non-human resource management score	0.000	0.380	0.523	0.523	0.665	1.000	3,935
Technology score	0.000	0.000	0.220	0.227	0.387	1.000	4,190
	December 2020						
	Min	25th	Median	Mean	75th	Max	Observations
Management score	0.000	0.3969	0.505	0.500	0.611	0.901	3,939
Human resource management score	0.000	0.415	0.604	0.567	0.750	1.000	3,939
Non-human resource management score	0.000	0.380	0.529	0.524	0.666	1.000	3,939
Technology score	0.000	0.000	0.220	0.245	0.413	1.000	4,190

Table 2B: Summary statistics on technology

IoT	2015	January 2020	December 2020
Do not adopt, and do not plan to do so	62.5	47.8	43.0
Do not adopt, but plan to do so	8.3	11.5	14.1
Adopt stand alone peer-to-peer system	7.0	7.7	7.9
Adopt client server system	17.5	21.3	21.3
Adopt cloud system	4.8	11.7	13.7
AI	2015	January 2020	December 2020
Do not adopt, and do not plan to do so	90.7	80.1	75.3
Do not adopt, but plan to do so	5.6	11.9	15.7
Adopt in some processes	3.3	7.7	8.7
Adopt in most processes	0.3	0.3	0.3
3D CAD/CAM	2015	January 2020	December 2020
Do not adopt, and do not plan to do so	63.7	57.6	55.3
Do not adopt, but plan to do so	6.1	4.5	5.8
Adopt in some processes	25.8	32.4	33.2
Adopt in most processes	4.4	5.5	5.7

Table 3: Relationship between telework and management

	(1) Telework dummy			(2) Telework increase dummy from Jan. 2020 to Dec. 2020	
	January 2020	December 2020	2022	Increase in telework percentage	From no telework to some telework
Management Score	1.431***	1.938***	2.562***	2.160***	2.046***
	(0.404)	(0.300)	(0.294)	(0.364)	(0.404)
Controls	Yes	Yes	Yes	Yes	Yes
Observations	3,216	3,237	3,178	3,143	2,831

Notes: (i) The 2020 JP MOPS data are used. (ii) Coefficients are estimated by logit model. (iii) Numbers in parentheses are robust standard errors. (iv) The number of asterisks indicates the significance level in a t-test for coefficients; *<10% , **<5%, and ***<1%.

Table 4: Relationship between management and technology

	Dependent variables : Technology variables (December 2020)			
	IoT	AI	3D CAD/CAM	Technology score
Management score	3.176***	3.707***	1.790***	0.404***
	(0.249)	(0.426)	(0.268)	(0.023)
Model	Logit	Logit	Logit	OLS
Controls	Yes	Yes	Yes	Yes
Observations	3,937	3,801	3,808	3,822

Notes: (i) The 2020 JP MOPS data are used. (ii) Coefficients are estimated by logit model or OLS. (iii) Numbers in parentheses are robust standard errors. (iv) The number of asterisks indicates the significance level in a t-test for coefficients; *<10% , **<5%, and ***<1%.

Table 5: Relationship between telework, management, and technology

	Dependent variable : Telework dummy			
	(1) January 2020	(2) December 2020	(3) January and December 2020	
Management score	0.787* (0.420)	1.307*** (0.312)	1.032*** (0.269)	1.591*** (0.588)
Technology score	1.552*** (0.269)	1.622*** (0.201)	1.418*** (0.170)	3.103*** (0.414)
Model	Logit	Logit	Pooled logit	Random logit
Controls	Yes	Yes	Yes	Yes
Observations	3,209	3,226	5,900	5,900

Notes: (i) The 2020 JP MOPS data are used. (ii) Coefficients are estimated by logit model. (iii) Numbers in parentheses are robust standard errors. (iv) The number of asterisks indicates the significance level in a t-test for coefficients; *<10% , **<5%, and ***<1%.

Table 6A: Relationship between telework and human resource management

	Dependent variable : Telework dummy			
	(1) January 2020	(2) December 2020	(3) January and December 2020	
Human resource management score	0.312 (0.281)	0.675*** (0.204)	0.511*** (0.176)	0.680* (0.380)
Technology score	1.644*** (0.264)	1.747*** (0.197)	1.512*** (0.165)	3.268*** (0.409)
Model	Logit	Logit	Pooled logit	Random logit
Controls	Yes	Yes	Yes	Yes
Observations	3,209	3,226	5,900	5,900

Notes: (i) The 2020 JP MOPS data are used. (ii) Coefficients are estimated by logit model. (iii) Numbers in parentheses are robust standard errors. (iv) The number of asterisks indicates the significance level in a t-test for coefficients; *<10% , **<5%, and ***<1%.

Table 6B: Relationship between telework and non-human resource management

	Dependent variable : Telework dummy			
	(1) January 2020	(2) December 2020	(3) January and December 2020	
Non-human resource management score	0.412 (0.333)	0.775*** (0.251)	0.562*** (0.212)	0.967** (0.475)
Technology score	1.603*** (0.267)	1.678*** (0.199)	1.465*** (0.167)	3.182*** (0.416)
Model	Logit	Logit	Pooled logit	Random logit
Controls	Yes	Yes	Yes	Yes
Observations	3,209	3,226	5,900	5,900

Notes: (i) The 2020 JP MOPS data are used. (ii) Coefficients are estimated by logit model. (iii) Numbers in parentheses are robust standard errors. (iv) The number of asterisks indicates the significance level in a t-test for coefficients; *<10% , **<5%, and ***<1%.

Table 7: Effects of short-run and long-run management improvement

Dependent variable : telework dummy (December 2020)			
Management score (January 2020)	1.399*** (0.425)		
Management score difference between January 2020 and December 2020		0.245 (1.185)	
Management score difference between 2015 and January 2020			1.500** (0.624)
Technology score (January 2020)	1.668*** (0.266)		
Technology score difference between January 2020 and December 2020		1.219 (0.966)	1.064 (0.977)
Observations	2,826	2,820	2,778

Notes: (i) The 2020 JP MOPS data are used. (ii) Coefficients are estimated by logit model. (iii) Numbers in parentheses are robust standard errors. (iv) The number of asterisks indicates the significance level in a t-test for coefficients; *<10% , **<5%, and ***<1%.