Away from Home and Back: Coordinating (Remote) Workers in 1800 and 2020

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Abstract

We examine the future of remote work by drawing parallels between two contexts: The move from home to factory-based production during the Industrial Revolution and the shift to work from home today. In both cases, new technology induced new working arrangements, and this shift was associated with a similar trade-off in the past as it is today: productivity advantages and cost savings versus organizational barriers such as coordinating workers under the new workplace arrangement. Using contemporary data, we show that the COVID-19 pandemic moved even sectors with high organizational barriers to working from home. Without further technological or organizational innovations, this shift is likely to be reversed, and remote work may not be here to stay just yet.

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1 Introduction

For decades, observers have widely expected dramatic changes in working arrangements (Cairncross, 1997; Friedman, 2005). While the ‘revolution’ in information communication technology (ICT) has provided the equipment to make work from home (WFH) feasible for many occupations, take-up largely stagnated over the past decade (Mas and Pallais, 2020) – until the COVID-19 pandemic brought about dramatic changes in the spring of 2020.[1,2]

The disruptions to existing working arrangements caused by COVID-19 have led to a major increase in WFH. As the gradual roll-out of vaccines has brought the end of the pandemic in sight in some countries, many firms are preparing for a more permanent shift to WFH with workers continuing to work off-site at least some days.[3] If the pandemic has changed the office for good, perhaps the entire structure of central business districts (CBD-s) may need to reconfigure to adapt to a post-pandemic world.[4] Thus, whether the pandemic-induced increase in WFH is indeed permanent is of vital importance to policymakers.

A predominant reliance on production from home is not novel in economic history. Before the rise of factories during the First Industrial Revolution around 1800, most production took place at home. In this paper, we ask what lessons can be learned from the rapid change opposite to today’s direction – when workers moved from their homes to the factory floor. We argue that the two episodes share important similarities. While new technologies (mechanized machinery in the 19th century or ICT today) increase productivity in the long run, organizational barriers – such as the need to coordinate workers in the new setting – make a switch to the novel working arrangement costly. Whether (and when) an industry switches to the new working arrangement depends on a trade-off between the (potential) productivity advantage of the new setting and the organizational cost associated with reaching the frontier.[5] During the Industrial Revolution, it took a long time to

[1]According to Gallup, among all U.S. workers, the average number of telecommuting days per month was 2.4 in 2019. This number had been largely unchanged since 2015. In 2006, it was 2.0. Source: Gallup article ‘U.S. Remote Workdays Have Doubled During Pandemic’ (August 31, 2020).

[2]In this paper we focus on work from home. More generally, many of the issues we discuss apply to a newer phenomenon: ‘work from anywhere’ (WFA) – an arrangement that offers both temporal and geographic flexibility. See Choudhury, Foroughi, and Larson (2021) for a recent contribution.

[3]See the PWC report “It’s time to reimagine where and how work will get done.”

[4]See, for example The Economist article “The future of work: Is the office finished?” (September 12, 2020).

[5]We think of organizational barriers that reduce productivity relative to the frontier as “costs.” For example, uncoordinated workers on a production chain effectively raise the cost per unit of output, relative to the production possibility of the technology.

develop organizational innovations that reduced the cost side, and this was one reason for the slow economy-wide transition to factory-based production. In this paper, we use contemporary data to argue that similar challenges exist in terms of coordinating employees who work remotely today. Based on these insights, we hypothesize that WFH may not be here to stay just yet.

2 Re-Organizing Work during the First Industrial Revolution

The rise of the factory system during the Industrial Revolution gave rise to one of the most dramatic changes in the organization of work. Prior to 1800, workers in manufacturing predominantly worked from home, on their own time. Throughout the 19th century, as factories became the dominant organizational form in manufacturing in Northwestern Europe, both the *location* and the *nature* of work changed. Work was moved from homes to centralized plants, and, under the mature factory system, it became very closely regulated: "the employer dictated when workers worked, their conduct on the job and that they steadily attend to their assigned tasks" (Clark, 1994, p. 128).

This was an extraordinarily lengthy and uneven process, taking the best part of a century to complete. In cotton textiles – the pioneer of the factory-system – the change took a few decades; factory-based production, relying on a highly synchronized organization of machines and workers, spread widely during the first half of the 19th century (Chapman, 1974, p. 470). In other industries, the change was even slower, and it was only by the turn of the 20th century that the factory system became the dominant organizational form.[6]

What gave rise to this transition, and why was it so lengthy? Scholars of economic history have described a number of factors. Part of the answer is surely technological: In most industries, mechanization – that is, the introduction of machinery powered by inanimate sources such as water or steam – gave rise to economies of scale and made it necessary to concentrate workers under one roof. The more expensive machinery and increased standardization of products also raised monitoring problems that could be more efficiently solved if workers were located in one place and supervised by a foreman (Williamson, 1980; Szostak, 1989). In addition, the increasing complexity of mechanized production meant that a single person could not master them easily. Knowledge became more specialized, and experts were needed continuously on site (Mokyr, 2001, 2002). As mechanization arrived at different times in different industries, it is unsurprising that the

[6] Mokyr (2010, p. 339) estimates that two-thirds of the industrial workers in Britain were employed in factories by 1900.

process was uneven and lengthy.

However, there is also growing evidence that technology is only part of the story. Organizing production in one location (i.e., a plant) led to a host of new challenges for workers and firms (Pollard, 1965).[7] One distinguishing feature of the factory-system was the development of 'flow-production' – that is, the production of highly standardized goods at low unit cost by "arranging machines and equipment in line sequence to process goods continuously through a sequence of specialized operations" (Chapman, 1974, p. 470). This required both an extensive division of labor and *coordination* across employees working on different parts of the production process (Clark, 1994). The need to coordinate workers is illustrated vividly by Karl Marx, who quoted a large cotton manufacturer, Henry Ashworth, noting that "When a laborer lays down his spade, he renders useless for that period, a capital worth eighteen pence. When one of our people leaves the mill he renders useless a capital that cost *£100,000*" (Clark, 1994, p. 129).

The move to factory production initially proceeded without basic organizational knowledge (Pollard, 1965). Instead, organizational innovations were developed through a long process of trial and error that took generations to converge to best-practice methods.[8] Labor managements practices are a case in point. Workers moving from home production to factories were not accustomed to the rhythm and discipline that factory work required. Employers first responded by using disciplinary tools. Factory workers were fined or dismissed for minor infractions such as arriving to work a few minutes late, being away from their machine, or talking or eating at work (Clark, 1994, p. 131). Over time, however, employers learned that disciplinary measures led to inefficiently high turnover rates. It took half a century for the cotton textile industry to move away from discipline as the main labor management practice and settle instead on efficiency wages in the 1840s (Huberman, 1996).

Why would these organizational challenges hamper the transition to factory-based production?

[7] We focus on organizational challenges related to employees working efficiently in the factory system. A more complete discussion of the wider set of organizational challenges caused by the move to the factory system can be found in Pollard (1965) and Mokyr (2010). In Juhász, Squicciarini, and Voigtländer (2021), we discuss the organizational challenges faced in mechanized cotton spinning.

[8] The historical literature suggests that there were two main classes of challenges that early cotton spinning mills faced. First, they had to deal with the mill layout and design. As Allen (2009) writes: "The cotton mill, in other words, had to be invented as well as the spinning machinery per se." Second, there was a set of labor management innovations that were required for setting up and operating spinning mills at a scale not seen elsewhere before (Pollard, 1965). In this paper, we will focus on labor management challenges. For more details on mill designs challenges, see Juhász et al. (2021).

One implication of the lack of organizational knowledge was that many early factories were not operating efficiently. Consistent with this, in Juhász et al. (2021), we show that the productivity distribution of mechanized cotton spinning plants at the early stage of the Industrial Revolution in France (circa 1800) was remarkably dispersed with a strikingly fat lower tail. We show that the fat lower tail was driven by the fact that many early adopters of the new cotton spinning technology were not operating it efficiently, as knowledge about complementary organizational innovations had not yet diffused across the economy. By 1840, when much of this diffusion had taken place, the fat lower tail in the cotton spinning productivity distribution largely disappeared.

Our results imply that initially, many plants adopted the new technology despite the fact that organizational costs reduced their productivity. What explains this decision? In sectors such as cotton spinning, where the productivity advantage of moving to the new, mechanized technology was strikingly large (Allen, 2009), adoption was profitable even at the cost of large organizational inefficiencies. However, in sectors where the productivity advantage of the new technology was smaller, adoption was delayed until organizational knowledge about factory production had advanced sufficiently.

3 Re-organizing Work Today

Our hypothesis is that the two opposing forces that influenced the move to factory-based production are also at work today. New technologies (ICT in particular) may make it increasingly viable to move workers off-site for several reasons. First, capital costs are lower due to a reduced need for office space (Bloom, Liang, Roberts, and Ying, 2015). Second, Bloom et al. (2015), Angelici and Profeta (2020), and Harrington and Emanuel (2020) show well-identified evidence for important productivity benefits from moving some employees to remote working. Third, recent evidence points to the fact that some – although by no means all – workers value alternative working arrangements (Katz and Krueger, 2019; Mas and Pallais, 2020).[9] Most relevant for our context, Mas and Pallais (2017) show experimental evidence that the average worker applying to a national call center would be willing to give up 8% of their wages to work from home.[10]

[9] Alternative working arrangements encompass those employed through temporary help agencies, on-call workers, contract company workers, and independent contractors or freelancers (Katz and Krueger, 2019, p.383).

[10] In subsequent work, Mas and Pallais (2020) note that workers with particularly high willingness to pay for flexibility sort into jobs with employers who have relatively low cost of offering flexible arrangements. They estimate that the *marginal* worker would be willing to give up 21% of their wages for the option to work from home.

However, working even part of the time at a distance from co-workers and supervisors may also lead to significant costs. Challenges include how to coordinate, monitor, and incentivize co-workers when they are not continuously co-located with one another (Spreitzer, Cameron, and Garrett, 2017). Siebradt, Hoegl, and Ernst (2009, p. 64) list "difficulties in communication and coordination, reduced trust, and an increased inability to establish a common ground" as some of the major issues in managing virtual teams. Battiston, Blanes i Vidal, and Kirchmaier (2017) find that in-person communication is more efficient than electronic communication for emergency room operators. Work by Andres (2012) suggests that technologically-mediated collaboration across workers creates lags in information exchange, more misunderstandings, fewer attempts at seeking information, and incoherent messages. That is, the organizational and management practices developed for managing workers on-site may not work as well when many employees are working off-site.

In what follows, we examine modern-day data for evidence of the two forces at work: benefits and organizational costs. Sectors that are technologically more suited to remote work should see a higher share of employees working from home, as this is where the productivity advantage of WFH will be large. As a proxy for this force, we use the Dingel and Neiman (2020) measure, designed to capture the technological feasibility of work from home. However, in sectors heavily reliant on management practices developed for on-site work, the switch to WFH may be particularly costly. We focus on a central challenge that our historical discussion highlighted: the need for coordination across specialized workers. We now introduce a measure designed to capture this second force.

3.1 A Measure for Dependence on Coordination

We construct an industry-level variable indicating the importance of interpersonal cooperation (which we call the 'coordination measure'). This indicator is based on an occupation-level classification of cooperation-reliance from O*Net survey data.[11] We classify an occupation into being reliant on inter-personal cooperation if any of the responses to questions about needing to coordinate or communicate with other workers are on average (across all participants) rated as "very

[11]More precisely, the data are from two surveys in release 24.2 of the dataset. We use the 'Generalized Work Activities Survey') questions 26, 28, 31, 33, 34, 35, and 38 and the 'Work Context Survey' questions 7 and 9. Overall, these data are available for 968 occupations. Dingel and Neiman (2020) use the same surveys to construct a proxy for occupation-specific and industry-specific technological feasibility to work from home. None of the survey questions that we use overlap with any of the questions used by Dingel and Neiman (2020).

important” (at least 4 on a 1-5 scale):

- Communicating with supervisors, peers, or subordinates
- Establishing and maintaining interpersonal relationships
- Resolving conflicts and negotiating with others
- Coordinating the work and activities of others
- Developing and building teams
- Training and teaching others
- Providing consultation and advice to others
- Interactions that require to work with or contribute to a workgroup or team
- Interactions that require to coordinate or lead others in accomplishing work activities (not as a supervisor or team leader)

Consider the first item. If respondents from a given occupation indicated, on average, that communicating with supervisors, peers, or subordinates is (at least) “very important” in their job, we classify the occupation as being reliant on coordination. Note that our definition does not capture whether a particular aspect of interpersonal coordination can be conducted at a distance, as that is endogenous to the current technological and organizational frontier. We then follow Dingel and Neiman (2020) and aggregate the coordination measure to the industry level using BLS data on the employment share for each occupation in given industries. The resulting measure has an intuitive interpretation. For each industry, it shows the share of employees working in occupations that rely on inter-personal cooperation. We aggregate to the industry level both for 4-digit NAICS industries and for 2-digit industries (i.e., the industries used in the RPS survey by Bick, Blandin, and Mertens, 2020), depending on the level of detail at which our various analyses can be run. Table 1 shows the summary statistics. At the 2-digit industry level, the average industry employs 83% individuals in occupations classified as reliant on inter-personal cooperation, with the 10th and 90th percentiles being 61% (Transportation/Warehousing) and 95% (Finance/Insurance), respectively. At the 4-digit industry level, the mean is 80%.

Table 1: Interpersonal Cooperation: Summary Statistics

Data set	N	Mean	St.Dev.	Median	p10	p90
2 digit	17	.83	.12	.87	.61	.95
4 digit	250	.80	.17	.87	.54	.96

Notes: The table reports the summary statistics for the share of individuals in occupations classified as reliant on interpersonal cooperation.

3.2 Distinct Occupations and the Need for Coordination

This section presents a plausibility check, examining the relationship between our coordination measure and the number of occupations in industries. Arguably, having more distinct occupations within an industry is an indicator for specialization in specific tasks.[12] In turn, we expect industries with higher specialization to also have a stronger need for coordination among employees. Column 1 in Table 2 reports the raw correlation between the log number of occupations and our coordination measure for 4-digit industries. The statistically highly significant coefficient indicates that a doubling in the number of occupations is associated with an increase by 8.5 percentage points (p.p.) in the need for coordination (relative to a mean of 80 percent). Since this relationship could be mechanically driven by the size of the different sectors, column 2 controls for log employment. We also add fixed effects for five aggregate industries.[13] If anything, the relationship between the number of occupations and the need for coordination becomes even stronger. In the remaining columns of Table 2, we show that this result also holds within aggregate industries. The coefficient on the number of occupations is particularly large for agriculture/mining/construction and for manufacturing. In these sectors, doubling the number of occupations is associated with 25-30 p.p. higher need for coordination. In particular, the large (and highly significant) coefficient in manufacturing is reassuring for drawing parallels with the Industrial Revolution, where the need for coordination became a bottleneck in this sector. For the remaining industries (trade and services), the coefficient is similar to our finding for all industries combined (column 2).

[12] The average number of occupations for 4-digit industries is 148, ranging between 17 and 590, with a standard deviation of 89.

[13] These are Agriculture, Building & Mining, Trade & Transportation, Services, and Public Administration.

Table 2: Need for Coordination and Number of Occupations

Dependent variable: Sector-specific need for coordination

	(1)	(2)	(3)	(4)	(5)	(6)
	All Industries		Agric, Mining, Construction	Manu-facturing	Trade & Transp.	Services & Public
log(# of occupations)	0.085	0.119	0.249	0.295	0.083	0.112
	(0.020)	(0.039)	(0.086)	(0.091)	(0.066)	(0.054)
log(total employment)		-0.024	-0.036	-0.072	-0.027	-0.023
		(0.014)	(0.022)	(0.036)	(0.025)	(0.021)
Industry FE		✓				
Mean Dep. Var.	0.80	0.80	0.83	0.73	0.79	0.85
R^2	0.09	0.18	0.46	0.24	0.03	0.08
Observations	250	250	21	69	62	98

Notes: The table shows that (4-digit) industries with a higher number of distinct occupations have a stronger need for coordination among their employees. Robust standard errors in parentheses. See text for data sources and construction of variables.

3.3 Coordination and Working from Home

How do technological feasibility and the need for coordination affect work from home? We examine the association between the share of respondents working from home and i) Dingel and Neiman's proxy for the technological feasibility to work from home, and ii) our coordination measure.[14]

We first focus on the 'steady state,' examining the relationship in February 2020, prior to COVID-19 disrupting existing working arrangements in the US. We then examine data from May 2020 – a time by which many employees had moved to WFH as a consequence of COVID-19. The data for both exercises are from Bick et al. (2020).[15] In particular, we estimate equations of the form:

$$WFH_i = \beta \cdot TF_i + \gamma \cdot NC_i + \varepsilon_i \,, \tag{1}$$

[14]Dingel and Neiman's (2020) measure is designed to capture the technological *feasibility* of WFH, while our coordination measure proxies for some of the organizational challenges to re-organizing work. Both measures were constructed using a very similar methodology and both vary between 0 and 1.

[15]Bick et al. included questions on WFH in the Real-Time Population Survey (RPS) in May 2020. This representative survey collected information on nearly 5,000 working age adults who report their employment in one of 17 sectors, and it also includes retrospective questions about the working situation in February 2020. We aggregate both our coordination measure and the feasibility measure by Dingel and Neiman (2020) to these 17 sectors.

where WFH_i is the share of employees working from home in industry *i*, TF_i represents the technological feasibility of working from home, NC_i is our need-for-coordination measure, and ε_i is the error term.

Table 3 shows our results. Consistent with our hypothesis, we find that the propensity to work from home in February is positively associated with the technological feasibility of working from home and negatively with our coordination measure. A one-standard deviation (s.d.) increase (0.26) in the technological feasibility to work from home is associated with 1.8 p.p. more work from home. Similarly, industries with a one s.d. (0.12) higher need to coordinate experienced 1.25 p.p. less working from home in the pre-pandemic steady state, relative to a sample mean of 8.4%.[16]

Table 3: Work from Home in February and May 2020

Dep. var.: Share of employees working from home

	(1) Feb 2020	(2) May 2020
Technological Feasibility	0.070	0.612
	(0.039)	(0.053)
Need for Coordination	-0.104	0.050
	(0.055)	(0.169)
Mean Dep. Var.	0.084	0.317
R^2	0.20	0.80
Observations	17	17

Notes: The table shows that both technological feasibility and the need for coordination were associated with working from home before the COVID pandemic (in February 2020). By May 2020, technological feasibility became the predominant factor, while the need for coordination ceased to matter. Robust standard errors in parentheses. Data are for 17 U.S. industries. See text for data sources and construction of variables.

Next, we perform the analysis using data from May 2020, when the pandemic-related lockdown was in full force. Column 2 in Table 3 reports the results (with partial scatterplots shown in Figure 2). The Dingel and Neiman (2020) measure is strongly positively associated with WFH during this time period (as has also been shown by Bick et al., 2020). However, strikingly, the need to

[16] A natural concern given the small sample size is that these results may be driven by outliers. This is not the case: Figure 1 shows that our findings reflect a coherent pattern.

coordinate across workers is now uncorrelated with an industry's share of working from home – the coefficient is *positive*, statistically insignificant, and close to zero.[17]

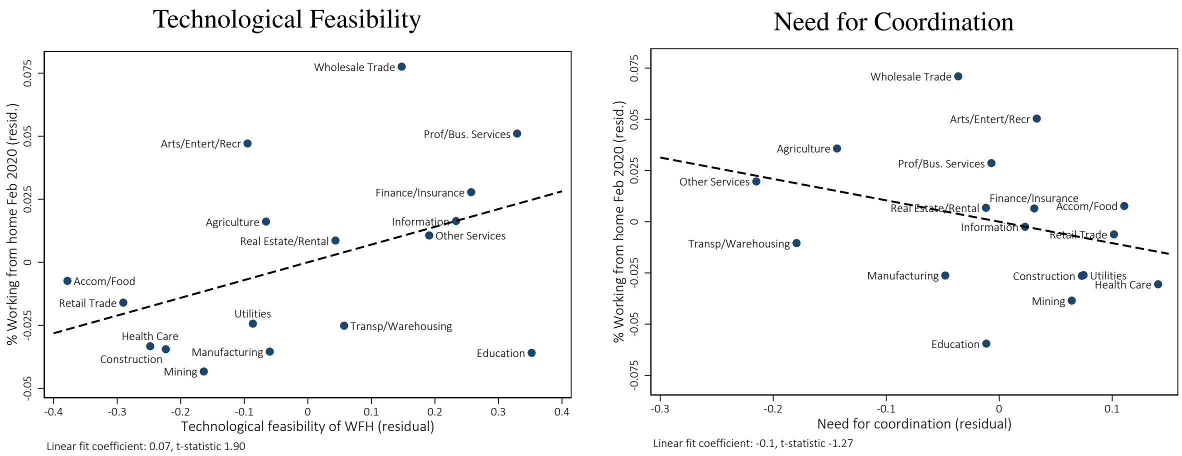

Figure 1: WFH, Coordination, and Technological Feasibility: February 2020

Notes: The figure shows the partial scatterplots corresponding to column 1 in Table 3, for the technological feasibility measure (left panel) and for our need-for-coordination measure (right panel). In both panels data are from February 2020.

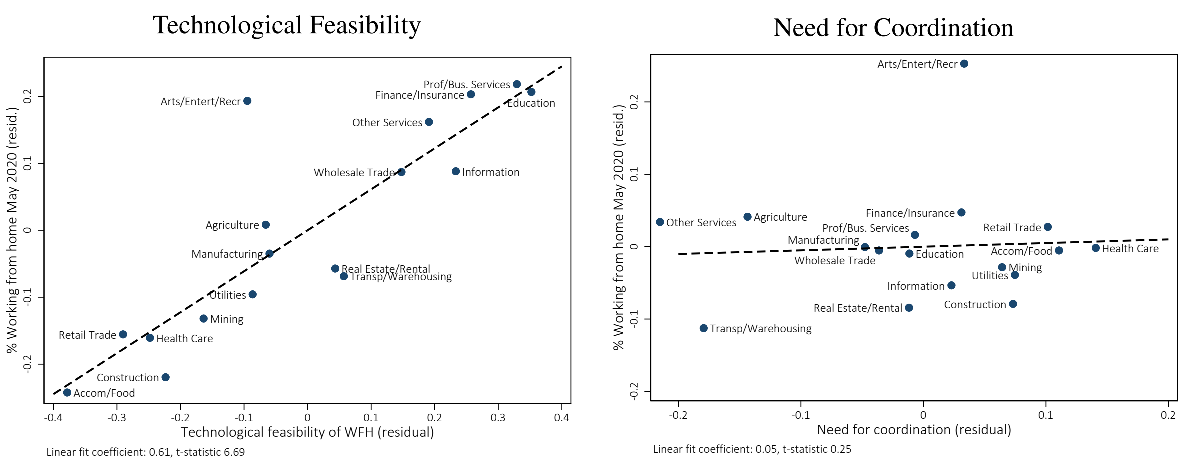

Figure 2: WFH, Coordination, and Technological Feasibility: May 2020

Notes: The figure shows the partial scatterplots corresponding to column 2 in Table 3 for the technological feasibility measure (left panel) and for our coordination measure (right panel). In both panels data are from May 2020.

[17]One concern with contrasting these results is that unemployment increased substantially between February and May. One may speculate that workers were laid off particularly strongly in sectors that heavily rely on coordination. However, this would work against finding a 'zero relationship,' because those occupations within a sector that could be performed from home were more likely to be retained. In other words, we would expect a *higher* share of working from home than before the pandemic in those industries that depend heavily on coordination.

We interpret the two results together in the following way. COVID-19 temporarily shifted the economy out of its long-run equilibrium. The 'social distancing' made necessary by the pandemic led to a mass movement to WFH, wherever it was technologically feasible: any job that could be done remotely was moved to a WFH setup without much regard for the coordination costs incurred (as the public health hazard was arguably too large). This suggests that as the public health motivation for keeping workers offsite subsides over time, more and more firms – particularly those in sectors heavily reliant on coordination – will re-evaluate the benefits and costs of working from home.

Of course, neither technology nor management practices are static. This suggests that the trade-off that governs the shift to WFH will change over time, depending on how the associated costs and benefits evolve. In much the same way that, during the Industrial Revolution, the breakthrough technologies in cotton textiles led to innovations that spilled over to other sectors and helped them move towards factory-based production, the pandemic may lead to technological and organizational innovations that make remote work profitable for an increasing number of firms and sectors. Patenting evidence suggests that innovation already shifted towards *technologies* facilitating remote work in early 2020 (Bloom, Davis, and Zhestkova, 2020). Moreover, Adams-Prassl, Boneva, Golin, and Rauh (2020) find that over the course of the pandemic, the share of workers who report being able to do all tasks from home has increased – although mostly for those starting from an initially high level, suggesting that important barriers (technological or organizational) remain.

In addition, the current technological and organizational frontier is still far from allowing remote work to be a perfect substitute for on-site work, particularly for those occupations requiring coordination across workers. Bailenson (2021) argues that 'Zoom fatigue' – the phenomenon that videoconferencing calls are more tiring than in-person communication, is due to non-verbal overload experienced during a call.[18] While it may be the case that a few years down the line, 'Zoom fatigue' will be seen as an example of a teething problem, it also closely echos the experience from the move to factory-based production during the Industrial Revolution. This experience suggests that revolutionary changes in working arrangements tend to proceed slowly, as it takes time for

[18]This results from a constant visual exposure to call participants' (and one's own) image during Zoom calls, in combination with a lack of non-verbal cues, which are important factors in in-person conversations. As a result, some companies are experimenting with cutting down on Zoom meetings for their workers (see for example the case of Citibank described on www.inc.com).

organizations to develop best-practice solutions to these types of novel challenges. As such, the dramatic shift to work from home seen in 2020 may not (yet) be permanent.

4 Conclusion

We examined the trade-off faced by firms as they consider moving workers more permanently to remote working arrangements. Informed by studying the monumental shift from home to factory-based work during the Industrial Revolution, we have argued that firms face a trade-off. While new technologies may give a productivity advantage to novel working arrangements, such a drastic reorganization of production is costly in the absence of best-practice organizational techniques. Using contemporary survey data, we have shown evidence consistent with firms facing organizational challenges to moving workers off-site. Our results also suggest that the mass movement to remote working witnessed during the pandemic ignored these organizational barriers because of the extraordinary public health hazard of onsite work. However, based on the lessons from the Industrial Revolution, as well as the pre-pandemic results for February 2020, we expect organizational barriers to matter in the foreseeable future. An intriguing question beyond the scope of this paper is whether the past year of remote work has already led to some organizational innovations that have eased the costs of WFH. We leave this for future research.

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