The Effects of Temporal Distance on Communication Patterns in a Large Multinational: Evidence from Daylight Savings Time

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Abstract

We study how temporal distance affects communication patterns in a large multinational company by exploiting a natural experiment – the annual change of clocks from Daylight Savings Time (DST). We hypothesize that temporal distance constrains employees' ability to communicate synchronously (via calls, instant message chats, virtual meetings) but not asynchronously (via e-mail), and that this constraint is binding for employees engaged in globally distributed knowledge-production. Using the shift from DST as a discrete change in temporal distance and detailed data on employee function and communication patterns, we find that an increase in shared time between offices of one-to-two hours increases volumes of unscheduled Skype calls by 28 percent, while an equivalent decrease in shared time decreases chat- and scheduled call and meeting volumes by 9.5 and 9.0 percent, respectively. In contrast, asynchronous communication volumes (e-mail) are largely unaffected. We further show that the positive response to increased shared time is driven by R&D workers, while the negative responses are concentrated among workers in operational tasks (production and IT). We interpret our results as evidence that knowledge workers place a high value on shared time and discuss implications for the spatial organization of firms and the offshoring of work.

I. Introduction

Over the last two decades, multinational companies (MNCs) have increasingly offshored not only production but also knowledge-creation, engaging in cross-border collaborative innovation and R&D (Singh, 2005; Zhao, 2006; Alcácer & Zhao, 2012; Foley and Kerr, 2013; Choudhury, 2015, 2017; Branstetter, Glennon, & Jensen, 2018; Kerr & Kerr, 2018). Branstetter, Li, & Veloso (2014) document that MNCs from advanced industrial economies are largely responsible for the "exponential" growth in U.S. patents filed from China and India; Kerr and Kerr (2018) state that the share of R&D for U.S. MNCs conducted by foreign subsidiaries rose from 6 percent in 1982 to 14 percent in 2004. This trend has been facilitated by the widespread diffusion of the Internet and digital communication technologies such as e-mail and Skype which have significantly reduced the cost of cross-border communication. One measure carefully constructed by Altman, Ghemawat, & Bastian (2018) shows that the volume of cross-border telephone calls (including Voice over Internet Protocol calls) has nearly tripled from 2001 to 2017, rising from 2 to 7 percent of all calls.[1]

While a rich prior literature argues that coordination and communication within MNCs is key for knowledge flows and innovation (Prahalad & Doz, 1987; Bartlett & Ghoshal, 1998; Birkinshaw & Hood, 1998; Gupta & Govindarajan, 2000), we have relatively little empirical evidence regarding communication patterns between MNC units in the age of digital communication. It is important to pursue this line of research for multiple reasons, but crucially to understand whether digital communication technologies have helped multinational units circumvent various dimensions of distance. In a recent editorial, Alcacer, Kogut, Thomas, and Yeung (2017) state that *"… while advances in communication and transportation technology make the world ever smaller by facilitating transactions over larger distances … figurative "distances" between countries can help or hinder firms in their quest to create value" (*Alcacer

[1] In comparison, cross-border flows of capital, goods, and people increased by roughly one third during the same time period – a tenfold smaller growth increment.

et al., 2017; page 1*).* This insight builds on the prior literature, notably Hofstede (1980) and Ghemawat (2001), arguing that multiple dimensions of distance, i.e. geographic, cultural, political, administrative, etc., are relevant to the organization of multinational firms. Berry, Guillen and Zhou (2010) provide an excellent discussion of this literature and single out *geographic distance* as being relevant to global communication as "geographic distance increases the costs of transportation and communication" (Berry, Guillén, & Zhou, 2010; page 1468). It is conceivable that digital communication technologies such as email and Skype have at least partially mitigated the barrier of geographic distance by lowering the monetary costs of communication. At the same, time, the ongoing global distribution of knowledge work by MNCs may have *magnified* the relevance of other dimensions of distance.

In this paper we focus on the effects of a relatively understudied dimension of distance – *temporal distance*, which is the separation of two locations in the number of time zones – and study how it affects communication patterns within a multinational firm. To guide our analysis, we develop a stylized model that leverages two theoretical frameworks on information processing in organizations, the media richness framework of Daft and Lengel (1986) and the media synchronicity framework of Dennis, Fuller, & Valacich (2008). Temporally distant MNC units have few, if any, business hour overlap (BHO) – times that fall within both units' regular working hours (Bølerabc, Javorcik, Ulltveit-Moe, 2018). The lack of overlap, we argue, constrains employees' ability to communicate synchronously, so that the actual volumes of synchronous communication are below their theoretical first-best levels.[2] As a result, decreases in temporal distance – which release the constraint a little – will *increase* volumes of synchronous communication. In turn, increases in temporal distance – which effectively tighten the constraint – will *decrease* volumes of synchronous communication. In contrast, changes in temporal distance can have ambiguous effects on volumes of asynchronous

[2] While employees may work outside of regular business hours, doing so entails a higher opportunity cost due to foregone personal or family time (Perlow, 1999; Rothbard, 2001).

communication, which may both complement and substitute for synchronous communication but are not constrained by temporal distance directly.

We argue that the underprovision of synchronous communication resulting from temporal distance can have important consequences for the performance of globally distributed work, and especially, global knowledge production. Information used in complex problem solving is often tacit and "sticky" and, therefore, costly to transfer across locations (von Hippel, 1994; Szulanski, 2003). It is widely believed that knowledge transfer and co-production depend on synchronous, often spontaneous, interactions and communications (Allen 1977; Van den Bulte & Moenaert, 1998; Catalini, 2016). Multinational firms globally distribute a variety of work, from simple operational tasks (e.g. data entry, software maintenance, and raw material processing) to more complex tasks such as innovation and R&D. Because knowledge-production is more reliant on synchronous communication, we expect that workers engaged in co-production of knowledge will be *most* likely to increase communication volumes in response to decreases in temporal distance. For the same reason, we expect that they will be *least* likely to reduce communication volumes in response to increases in temporal distance.

Empirical evidence regarding the effects of temporal distance on communication and collaboration is limited[3] due to a number of empirical challenges. First, temporal distance is highly correlated with multiple other dimensions of distance which also affect the ease of communication, for example geographic, linguistic, cultural, and economic distance (Berry et al., 2010; Ghemawat, 2007). Second, all else equal, firms may co-locate units that need to collaborate within the same timezone, thus introducing reverse causality into the relationship between temporal distance and communication volumes. Finally, firms may select locations for a variety of unobserved factors (e.g.

[3] See O'Leary & Cummings (2007) and Espinosa, Nan, & Carmel (2015) for reviews of the literature.

the availability of talent) which may obscure the effect of temporal distance on communication. Therefore, to empirically isolate the effect of temporal distance on communication patterns requires a source of exogenous variation in temporal distance but no other dimension of distance between agents. To the best of our knowledge, the sole causal estimates of the effect of temporal distance on work performance come from an online laboratory experiment (Espinosa, Nan, & Carmel, 2015).

We propose a novel identification strategy to identify the casual effects of temporal distance on communication patterns in a real-world business setting. Specifically, we study how communication patterns inside a Fortune 100 multinational company respond to the annual change in clocks from Daylight Savings Time (DST). Because of different practices across countries and regions, this event creates increases and decreases of up to two hours in BHO between some MNC units, while for others, overlap does not change. The company is a large U.S.-based multinational with operations in 167 cities across 48 countries, a context that provides rich variation in Daylight Savings Time changes. We observe the volume and type of communication sent and received by all pairs of the firm's employees from September to November 2017, a period that is intercepted by the shift to Daylight Savings Time. This unique dataset reports time employees spent on synchronous communication (scheduled calls and meetings, unscheduled Skype calls, and instant message chats) and asynchronous communication (e-mail). Using a difference-in-differences approach with fixed effects for each office dyad, we estimate the effect of temporal distance by observing how the volumes and patterns of communication respond to changes in BHO in the post-Daylight Savings Time period, comparing office pairs that gain or lose overlapping business hours with those whose BHO remains unchanged.

We find statistically and economically significant responses in communication patterns to changes in temporal distance. Gaining one-to-two hours of overlap leads to a 28 percent increase in unscheduled Skype call minutes on average. Losing one-to-two hours in overlap, meanwhile, leads to a 9.5 percent decrease in instant message chat- and a 9.0 percent decrease in scheduled calls and meeting minutes. The significant responses of synchronous communication volumes to a change in temporal distance provide support for the view that for some collaborating offices, temporal distance is a binding constraint. Meanwhile, neither increases nor decreases in BHO have statistically significant effects on the volume of asynchronous communication (e-mail).

In order to explore the mechanisms driving these aggregate results, we decompose communication volumes by employee function, and find that the effects of *positive* changes in temporal distance are concentrated among employees engaged in knowledge-intensive collaboration. Specifically, we show that positive responses to more shared time are driven by increased communication between R&D workers, while workers in operational tasks (IT and production) show no significant responses to increased overlap. *Negative* responses to decreases in shared time, in contrast, are concentrated among workers in operational tasks. These findings support our hypothesis that knowledge-intensive workers place a high marginal value on synchronous communication and shared time and that for workers engaged in operational tasks, the value of synchronous relative to asynchronous communication is lower.

Our study contributes to several literatures, notably the literature on distance, communication patterns and knowledge production in multinational firms. This rich literature has generated several insights including three core insights relevant for our study: (1) there is increasing global knowledge co-production within multinationals (Singh, 2005; Zhao, 2006; Foley & Kerr, 2013; Choudhury, 2015, 2017; Kerr & Kerr, 2018); (2) intra-firm communication is key to transfer and exploit knowledge in the intrafirm context (Ghoshal, Korine, & Szulanski, 1994; Gupta & Govindarajan, 2000), and (3) figurative measures of distance prevent MNCs from creating value and engaging in cross-border economic activity (Berry et al., 2010; Ghemawat, 2011; Alcácer et al., 2017). We contribute to this literature by providing to the best of our knowledge, the first set of causal results showing how temporal distance affects intra-firm communication patterns within multinational units. Our results also contribute to the literature on distributed work (Allen, 1977; Hinds & Kiesler, 1995, 2002; Olson, Olson, & Venolia, 2009; Cummings, Espinosa, & Pickering, 2009; Edmondson, 2012; Espinosa et al., 2015) and the organizations literatures on information processing in organizations (Daft & Lengel, 1986) temporal structuring in organizations (Orlikowski & Yates, 2002) and remote work (Bloom, Liang, Roberts, & Ying, 2015; Choudhury, Foroughi, & Larson, 2019).

II. Theory and Related Literature

In this section, we describe a simple conceptual framework and generate hypotheses to examine the effects of temporal distance on patterns of communication and collaboration in the context of a global firm. Antràs, Garicano, & Rossi-Hansberg's (2006) model of global task offshoring provides a useful starting point for our theorizing. The model provides a compelling description of how falling cross-border communication costs enable increased offshoring and the vertical disintegration of knowledge work. Specifically, Antràs et al. (2006) model globally distributed workers who encounter problems of varying difficulty in the process of knowledge production. While lower-skilled workers can solve a range of easy problems, the most difficult problems are channeled to higher-skilled workers (managers), who then communicate the solution back to workers. Thus, work is completed collaboratively, with lower-skilled workers specializing in easier problems and higher-skilled workers specializing in solving the most difficult problems. The lower communication costs are, the greater the number of problems a higher skilled worker can solve, and the greater her span of control – i.e., the number of knowledge workers she can manage. When the costs of cross-border communication fall, as they have in recent years, this collaborative process can accelerate in globally distributed teams. Thus, firms can globally distribute a range of routine tasks involved in knowledge work to locations with lower costs of labor, while relying on collaboration with higher-skilled workers in higher-wage locations who specialize in solving the most knowledge-intensive, non-routine problems.

Consider now problems that rely on collaborative work but differ in their communication requirements. The literature on mediated communication has typically drawn a distinction between two modes of communication, *synchronous* and *asynchronous* (e.g., Daft & Lengel, 1986; Hinds and Kiesler, 1995; Dennis, Fuller, & Valacich, 2008), though recently, scholars have suggested that it is most appropriate to refer to *degrees* of synchronicity rather than a dichotomy (Jr., Turner, & Tinsley, 2008). For example, face-to-face meetings, virtual meetings, and calls are considered synchronous while e-mail and snail mail are asynchronous communication modes. Instant message chats are best described as a nearly synchronous, as there is some temporal delay, albeit a short one, involved in the act of sending and receiving messages.

A key insight of media richness and media synchronicity theories is that optimal work performance is achieved when agents match the mode of communication to the needs of the task at hand (Daft & Lengel, 1986; Dennis, Fuller, & Valacich 2008). Daft & Lengel (1986) distinguish tasks that require communication to reduce uncertainty from those that require it to reduce equivocality. Uncertainty is reduced through communication that *transmits* the maximum amount of information, for example, communication that reports production amounts, planned workflows, employee absenteeism, or machine downtime. Meanwhile, equivocality[4] is reduced by communication that *clarifyies* information, for example when a group of collaborators discuss complex problems to reach a shared understanding. A key proposition of media richness theory is that synchronous modes of communication are "richer" – defined as better able to change understanding within a time interval (Daft & Lengel, 1986) – and, therefore, are more important for tasks that require reduction of

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[4] To quote Daft and Lengel (1986), "Equivocality seems similar to uncertainty, but with a twist. Equivocality presumes a messy, unclear field. An information stimulus may have several interpretations. New data may be confusing, and may even increase uncertainty. New data may not resolve anything when equivocality is high. Managers will talk things over, and ultimately enact a solution. Managers reduce equivocality by defining or creating an answer rather than by learning the answer from the collection of additional data (Weick 1979)." (Daft and Lengel, 1986; page 1986). Hinds and Kiesler (1995:375) additionally state: "uncertainty means that data are missing; equivocality means that values, schema or meanings for interpreting events are ambiguous or conflictful."

equivocality.[5] Meanwhile, asynchronous modes are "leaner" and more appropriate for tasks requiring the transmission of large amounts of clear-cut information.

Dennis, Fuller, & Valacich (2008) further refine this perspective, proposing that all tasks involve *both* communication processes – information transmission (conveyance) and information processing (convergence) – and, therefore, task completion will call for *both* synchronous and asynchronous communication, albeit in different amounts. They propose that the greater the need for conveyance in the execution of a task, the more performance will be enhanced through a greater share of asynchronous communication. Conversely, the greater the need for convergence, the more task completion will benefit from a greater share of communication taking the synchronous form. This theoretical refinement is consentient with the empirical observation that people use a variety of communication modes when collaborating on a task. For example, often individuals work towards a shared understanding regarding the task on a phone call and follow the call with an e-mail which documents the agreed next steps.

We incorporate these insights from the mediated communication literature into a framework of global collaboration in the spirit of Antràs et al. (2006), by introducing the notion that the problems which arise in production have both synchronous and asynchronous communication requirements. Let us consider two geographically and temporally distributed workers in a global firm, who collaborate to solve problems. Assume that each worker is endowed with 10 hours[6] of work time per day and that solving a problem requires each to communicate for h hours with the other.[7] Problems with low h can be resolved quickly while those with high h require a longer time commitment. Thus,

[5] Synchronous communication media are considered richer because they allow for more immediate feedback, utilize more cues (e.g. tone, body language), are more personalized, and enable greater language variety (Daft & Lengel, 1986).
[6] We assume that each worker works for 10 hours per day, although the framework could be flexibly modified to accommodate other choices. The key is that there is at least some period of time in a worker's day (leisure or family time) during which the probability of working is less than the probability of working during regular business hours.
[7] For simplicity, we assume that all work requires some collaboration. The incorporation of individual work would effectively reduce an individual's total time endowment but would not affect our conclusions.

the maximum number of problems that the workers can solve in one day is $x \leq \frac{10}{h}$, which reflects the agents' *total work time constraint*.

Next, consider that problems differ in the optimal communication mode required to solve them. Specifically, let $0 \leq \alpha \leq 1$ denote the share of time h that agents need to communicate synchronously to solve a problem. Here, α may proxy for the complexity, or ambiguity of a problem which increases the need for convergence processes and synchronous communication.[8] $(1 - \alpha)$ is then the share of time spent on the problem during which agents communicate asynchronously. The need to communicate synchronously creates a second constraint, namely that total time spent communicating synchronously does not exceed the number of overlapping business hours, t, between the workers, where $0 \leq t \leq 10$. Therefore, the number of problems that the agents can solve also has to satisfy $x \leq \frac{t}{\alpha h}$, which reflects the agents' *temporal distance constraint*.

Assuming that the workers' objective is to maximize the number of problems solved in a workday, the problem is a simple maximization subject to two inequality constraints.[9] The solution characterizing the maximum number of problems the agents can solve in one day is given by x* = min[$\frac{10}{h}$, $\frac{t}{\alpha h}$], i.e. it is the lesser of the number allowed by the total work time constraint and the temporal distance constraint. At x*, either the work time constraint binds with $x^* = \frac{10}{h}$, or the temporal distance constraint binds, with $x^* = \frac{t}{\alpha h}$. Which of the two constraints binds will depend on the values of the

[8] This assumption is motivated by the following insight from Hinds and Kiesler (1995: 376): "Synchrony might be especially important in exchanging and discussing complex information such as the details of a technical plan, draft of a document, or interpretation of a statistical finding. Synchrony permits a great amount of information to be exchanged in a given unit of time, and ongoing feedback so that people can adjust what they say to one another, correct misunderstandings, and fill in details."

[9] It can be expressed with a Lagrangian given by $\mathcal{L}(x) = x + \lambda\left(\frac{10}{h} - x\right) + \mu\left(\frac{t}{\alpha h} - x\right)$, where λ represents the shadow price of additional work time and μ the shadow price of additional overlapping business hours at x*, i.e. the increase in the number of problems that the workers could solve if the respective constraint were relaxed by an infinitesimally small amount.[9]

parameters, specifically, on t and α. The temporal distance constraint will bind when $\frac{t}{\alpha} < 10$, and the total work time constraint otherwise. For example, if a problem takes one hour to solve $(h = 1)$ and half of that time the agents have to communicate synchronously ($\alpha = 0.5$), then for $t \geq 5$, the agents solve ten problems and are constrained by work time (not temporal distance). Meanwhile for the same values of h and α, if $t < 5$, the agents solve $2t$ problems and are constrained by temporal distance (not work time).

This simple framework allows us to derive a first hypothesis regarding the relationship between temporal distance and communication patterns between geographically and temporally distributed workers. It reflects the likelihood that is that at least some agents that collaborate inside the firm are constrained by temporal distance – i.e. that the shadow value of additional overlapping business hours, is positive for some collaborators. When this is true, increases in business hour overlap will lead to increases in observed volumes of synchronous communication. Synchronous communications which were previously not taking place due to lack of overlap will now take place.

Hypothesis 1a: An increase in business hour overlap will lead to an increase in synchronous communication volumes, on average.

Similarly, the existence of agents constrained by temporal distance implies that some collaborators are currently using all of their existing temporal overlap to communicate synchronously. If that overlap is reduced, we expect that there are at least some synchronous communications that would have taken place which no longer do.

Hypothesis 1b: A decrease in business hour overlap will lead to a decrease in synchronous communication volumes, on average.

Next, we consider the nature of work that is most likely to be constrained by temporal distance. We can observe from the expression x*=min[$\frac{10}{h}$, $\frac{t}{\alpha h}$], that the temporal distance constraint is more likely to bind, the higher the share of synchronous communication (α), which, according to mediated communication theories, is increasing the ambiguity of the task and the need for convergence processes. The literature on intra-firm knowledge creation and learning has long argued that knowledge creation is uncertain and ambiguous (Argote, Beckman, & Epple, 1990; Kogut & Zander, 1993; Grant, 1996). Hinds and Kiesler (1995) build on Perrow (1967) and Rice (1992) to also state that knowledge work involves "unanalyzable tasks" and involves informal consultation across knowledge workers. Knowledge transmission, also, tends to be localized, because knowledge is most appropriately transferred though face-to-face meetings and impromptu, synchronous interactions (e.g., Jaffe, Trajtenberg, & Henderson, 1993; Almeida & Kogut, 1999). Therefore, we expect that more knowledge-intensive work is more likely to give rise to problems that call for synchronous communication. Meanwhile, we expect that operational tasks are more likely to give rise to conveyance problems – those where solutions are less equivocal. Examples are overseeing the entry of data or reviewing the contents of memoranda. Such problems can be more effectively solved through asynchronous communication. Therefore, because of their higher need for synchronous communication, we expect that workers involved in knowledge-intensive tasks will be most responsive to increases in temporal distance.

Hypothesis 2a: Increases in business hour overlap will lead to the greatest increases in synchronous communication volumes among workers engaged in knowledge-intensive collaboration.

Note that the above hypotheses are less likely to hold if workers work outside of regular business hours and, therefore, the work time constraint and the temporal distance constraint are not "hard." [10] In the extreme case, when all agents work around the clock, and both the work time constraint and the value of temporal overlap are 24 hours, changes in temporal distance should have

[10] In fact, some firms purposefully create incentives and solutions to alleviate the relevance of temporal distance. For example, Accenture consulting operates certain Eastern European and Indian offices on time-shifted schedules to allow for more overlapping business hours with the United States.

no effect on communication patterns. In reality, while working outside of regular business hours is a possibility for some workers, doing so entails a higher opportunity cost because of foregone personal or family time. Prior literature has documented that workers experience "time famine", and Perlow (1999) advocates for individuals' interdependent work patterns to be integrated with larger firm level temporal contexts. The importance of time famine and the opportunity cost of time is especially relevant in context of workers trying to allocate time to manage both work and family responsibilities (Rothbard, 2001). Therefore, in the more realistic case where people may work outside of regular business hours but are less likely to do so than during business hours. Given the higher value they place on synchronous communication, we expect that knowledge workers will be more likely to work outside of regular business hours, if needed, in order to communicate synchronously. Because of their higher value of synchronous communication and a higher willingness to adjust by working outside business hours, we expect their communication volumes to be less sensitive to reductions in shared time.

Hypothesis 2b: Decreases in business hour overlap will lead to the lowest decreases in synchronous communication volumes among workers engaged in knowledge-intensive collaboration.

The effects of temporal distance on the volumes of asynchronous communication are more complex. Asynchronous communication volumes are not affected by temporal distance directly, since agents can dedicate the asynchronous communication time required for task completion, $(1-\alpha)h$, at any point in their schedule.[11] However, temporal distance may affect volumes of asynchronous communication *indirectly*, depending on the relationship between synchronous and asynchronous communication. If the two forms of communication are strict complements, as modeled above, then

[11] We assume that the work requiring asynchronous communication can be performed sequentially or simultaneously, i.e. there is no need for sequencing or "hand off" of the work.

changes in business hour overlap that increase or decrease synchronous communication may have a parallel effect on asynchronous communication. For example, for each additional problem that workers can now tackle on because they can communicate synchronously, they also devote the incremental amount of asynchronous communication.

A distinct possibility is that agents who are constrained in their ability to communicate synchronously use any remaining time in their day to communicate asynchronously to advance the work. Specifically, it may be that workers substitute for synchronous communication by communicating asynchronously but pay a cost in terms of efficiency. For example, consider the possibility that $K\alpha h$ units of asynchronous communication are required to substitute for αh units of synchronous communication, where $K > 1$. Because of its lower efficiency, workers will not choose the asynchronous option when synchronous options are available. However, when agents are constrained by temporal distance, some portion of their total work time is under-utilized; they cannot solve more problems without communicating synchronously. If substitution is possible, workers may use the remaining time on asynchronous communication to solve additional problems, though at a lower efficiently. In this case, if temporal distance decreases, enabling more synchronous communication, the volumes of asynchronous communication would fall. In general, the volumes of asynchronous communication would move in the opposite direction from the volumes of synchronous communication. As the theoretical effects are ambiguous, we do not present formal hypotheses regarding the direction of the effects of changes in temporal distance on volumes of asynchronous communication. We will keep in mind both theoretical possibilities – complementarity and substitution – as a possible interpretation of empirical patterns.

While we focus our theoretical predictions on the patterns and volumes of communication, the analysis has implications for the quantity and quality of the work performed in geographically distributed teams. Our theoretical discussion implies that, relative to a first-best solution with zero temporal distance, actual levels of synchronous communication will be below optimal levels, at least for some collaborators. The implication is that some problems may not be solved, or will solved less efficiently, than they would be otherwise. This will be reflected in a lower output per unit of time.

III. Empirical Context and Data

Our empirical context is the largest of four business divisions (the "Division") of a U.S. headquartered, multinational company (the "Firm"). We have access to two proprietary datasets from the Firm: i) a directory of Division employees, and ii) data on employees' daily communications during a twelve-week period, from September 2017 to December 2017. The following section describes the data and the construction of key variables.

Data and Measurement

The employee directory provides information on 12,089 individuals employed at the Division in the fall of 2017, including each employee's work address. Using the work address, we identify 253 different locations at which business is performed ("offices"), which are located in 167 cities across 48 countries. We geocode the longitude and latitude of each office and assign it to the time zone corresponding to its city.[12] We identify three offices, all in one U.S. state, as headquarter locations and the remainder as subsidiaries.[13] Figure 1 depicts the location of the Division offices and the corresponding time zones, and Table 1 shows the share of employees by continent. While 40 percent of the Division's employees are located in North America, Asia, the Middle East, and Europe, also account for sizeable percentage of total employment (Table 1). The directory also provides

[12] The city-level time zone data is provided by geonames.org. We use data from 2018 as for the 253 offices in our sample, none are located in an area that changed time zones between 2017 and 2018.
[13] We validate the Division offices and the headquarter locations with a Director of Operations affiliated with the Firm.

information on the business function of each employee. 88 percent of employees fall into one of the three largest categories – Production (55 percent), Information technology (IT) (18 percent), and Research and development (R&D) (15 percent). The remaining employees fall into one of more than 20 smaller categories, which we group into "Other"[14] (Table 1).

Our main measure of communication volume, termed *Attention Minutes*, estimates the time an individual spent communicating to others through three types of synchronous communication media (scheduled calls and meetings, unscheduled Skype calls, and instant message chats) and one asynchronous medium (e-mail) and are constructed from employees' daily Skype and Outlook records.[15] Time spent on scheduled calls and meetings is estimated using the beginning and end time stamps of shared Outlook calendar events. Therefore, scheduled calls and meetings include any calendar event shared among multiple employees, and therefore potentially capture scheduled synchronous interactions across multiple media types (e.g. Skype, Zoom, dial-in conference calls, in-person meetings).[16] Time spent on instant message chats and e-mails is estimated using the sent time stamps and word counts of Skype instant message chats and Outlook e-mail messages. The time spent on unscheduled Skype calls is estimated from the start and end time stamps of Skype calls that fall outside of any scheduled call or meeting.[17]

Each instance of communication is apportioned among the participants in the conversation. For example, if individual A sent an email of length 10 minutes to individuals B and C, then the

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[14] The median number of employees for these functions is 18 employees (<0.2% of the employees in the directory).

[15] The Firm, together with an external human analytics company, use a proprietary, multi-step process to construct four different measures of employee communication from these data. We describe here the main features of the algorithm.

[16] This is beneficial for our analysis in that we are able to observe the total volume of scheduled communication, some of which may be taking place outside of Skype and Outlook. While scheduled meetings may also include some face-to-face meetings, given the extent of geographic distance between most of the offices in our data, we expect the in-person component captured by the scheduled meeting variable to be small.

[17] Our definition of unscheduled calls is narrow, in that it focuses on Skype calls between individuals outside of any scheduled call or meeting, to prevent overlap with our definition of meetings. For our analysis, these definitions are appropriate in that we focus on shifts across synchronous and asynchronous communication – because meetings and calls are both synchronous, we are not theorizing about substitution effects between these types.

amount of time spent by the sender to compose the email (e.g. the amount of attention that they spent on this communication) is divided equally between both target participants. The directed dyads A-B and A-C each receive 5 minutes of e-mail communication.[18] Because of this procedure, any events or emails involving a large number of participants (e.g. a Firm-wide email announcement or conference call) contribute relatively little weight to the communication estimates. At the level of each worker, their daily time is apportioned to the conversations they participated in. One important aspect to note is that, to the extent that a worker participated in more than one conversation at the same time (i.e. multi-tasked), the algorithm allocates the time to only one conversation, with meetings prioritized. The objective is to produce an estimate how a worker allocated their daily "Attention Minutes" to conversations, which does not exceed a maximum of 24 hours per day.

Two limitations of the data are worth noting. One limitation, already mentioned, is that we do not observe multi-tasking behavior. We believe that this limitation, while it may understate the relevance of certain types of communication, should not affect our estimated effects due to the panel nature of the data and the fact that sudden shifts in multi-tasking behavior during the three-month observation window are unlikely. A second limitation is that we do not observe unscheduled communications outside a person's Skype and Outlook logs, for example an unscheduled call made via a personal telephone or Zoom. As such, the volumes of communication that we report via scheduled calls and meetings, unscheduled Skype calls, instant message chats, and e-mail can be interpreted as a lower bound of the actual volumes. This limitation also, is unlikely to affect our estimates, unless employees are systematically less likely to schedule their interactions that take place outside business hours than those during business hours and use different technologies when they

[18] E-mails and instant message chats are directed forms of communication. In contrast, the time spent on unscheduled Skype calls and scheduled calls and meetings involving multiple parties is undirected and evenly distributed between co-attendees. For example, if an individual A spends 10 minutes in a meeting with individuals B and C, the dyads A-B and A-C each receive 5 minutes of scheduled communication. In addition, because individuals B and C are also present and spending their attention on each other, dyads B-A, B-C, C-B, and C-A also are assigned the same weight.

communicate during and outside of regular business hours, for example making calls via Skype while at work but via Zoom when at home. In this scenario, some increases or decreases in total communication that we observe, may represent conversations shifting between observed and unobserved communication modes. However, given the Firm's focus on confidentiality and a culture heavily reliant on scheduled interactions over Outlook and Skype, we believe that this is unlikely.

Sample and Summary Statistics

Matching each employee to their office using the directory, we aggregate the daily, employee-level data to the level of office dyad-weeks in order to measure the total volume of communication (by mode) between each pair of offices in each week. With 253 offices and 12 weeks of data in our sample, this results in an undirected network of dyad weeks of length 382,536 (31,878 unique office dyads x 12 weeks).[19] However, even at the office dyad-week level, the communication network is extremely sparse. Most offices do not communicate with one another in a given week and, in fact, 80 percent of the office dyads do not communicate with one another during any week observed in our data. Hence, we construct our baseline sample by selecting the subset of office dyads which communicate at least once during the twelve-week period and observe them for the full 12 weeks. This results in a maximum baseline sample of 77,568 dyad weeks (6,464 unique office dyads x 12 weeks). All but two of the 253 offices are represented in the baseline sample.

Table 2 shows summary statistics of the communication variables at the office dyad-week level. Overall, the communication network is sparse. Across all office dyads, the median value of weekly communication volumes is zero for each media type – most office dyads do not communicate with one another in a given week. However, the mean values exhibit more variation in communication

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[19] We focus on communications between offices, hence within-office communications (office dyads where $i=j$) are not included in the analysis.

volumes across media types. Scheduled calls and meetings account for by far the highest volume of communication, with an average value of 208 minutes (3.47 hours) per dyad-week. The next largest mode of communication is e-mail, with an average of 56 minutes per dyad-week. The average volumes of unscheduled Skype calls and instant message chats are much lower by comparison – 1.5 and 16 minutes, respectively – though, some dyads record more than 1,000 minutes (17 hours) of unscheduled Skype calls and more than 6,000 minutes (100 hours) of instant message chats in a week. Table 3 shows correlations between the main variables. The four measures of communication are highly positively correlated, suggesting that offices which communicate with one another often do so across different types of media.

INSERT TABLES 2 AND 3

Descriptive Patterns of Communication and Temporal Distance

Next we describe the simple correlational patterns between distance and communication volumes. We measure temporal distance between each pair of offices as their business hour overlap (BHO), under the assumption that business hours take place from 8 am to 6 pm, local time. BHO is preferred to a raw time zone difference, as the latter may take negative values or may be greater than 12 hours. For example, Sydney, Australia is 16 hours ahead of Boston, USA. The minimum time zone difference between the cities is 8 hours (24-16). We calculate BHO by subtracting the minimum time zone difference from the maximum hours of BHO (10). Because BHO cannot be negative, we set its minimum level to zero. In the above example, Sydney and Boston have a BHO of two hours, corresponding to 4-6 pm Boston time and 8-10 am Sydney time.[20] The average BHO between offices before the end of Daylight Savings is 4.6 hours (Table 2).

Figure 2 shows a binscatter diagram of communication volumes, by type, and BHO in the cross-section of office pairs included in our baseline sample. The binscatter points to strong positive relationship between BHO and the volume of communication for each media type: more temporally proximate offices communicate more with each other, in each mode of communication. However, this simple relationship may overstate the role of temporal distance due to its high correlation with other dimension of distance, for example geographic distance (Table 3), but also cultural, economic, linguistic, and other differences between countries (Ghemawat, 2001; Berry Guillen and Zhao, 2010). At the same time, this simple relationship may understate the importance of temporal distance due to other unobserved factors determining communication volumes. For example, a large amount of the Firm's IT support functions are located in South-East Asian countries (e.g. India, Malaysia, etc.) due to their comparative advantage in talent in this area (Arora, Arunachalam, Asundi, & Fernandes, 2001). Although these countries are temporally distant, they may see high volumes of communication, given the large amount of work outsourced to these countries.

INSERT FIGURE 2

To probe deeper, we next visualize the cross-sectional relationship between BHO and the *share* of each office dyad's total communication taking a synchronous versus asynchronous form. Based on our conceptual framework, temporal distance will constrain the volumes of synchronous communication but not asynchronous communication. Moreover, we control for geographic distance

[20] Our sample includes a small number of city pairs that have overlaps that are fractional (e.g. 8.5 hours of time zone difference). In these cases, we round up so that BHO always takes on an integer value between zero (no overlap in business hours) and ten (complete overlap in business hours).

in this analysis, so that we effectively compare the communication patterns of equidistant office pairs, but which differ on the temporal distance dimension (e.g. pairs of offices 1,000 km apart, but one in the North-South and the other in the East-West direction).[21] The binscatter diagrams are shown in Figure 3. The patterns suggest a positive relationship between temporal distance and synchronous communication *shares*. Controlling for geographic distance, higher levels of BHO are associated with greater shares of unscheduled Skype calls and scheduled calls and meetings. Meanwhile, higher levels of BHO are associated with lower shares of e-mail. These descriptive patterns are consistent with our theoretical framework in which temporal distance leads constrains synchronous but not asynchronous communication.

INSERT FIGURE 3

Still, the patterns of the cross-sectional analysis cannot be interpreted as a causal effect of temporal distance, as it may be the case that the Firm purposefully co-locates offices which have a high need for synchronous, relative to asynchronous communication. Therefore, we next turn to the analysis of changes in communication patterns in response to changes in temporal distance caused by cities' transition from daylight savings time.

IV. Identification Strategy and Empirical Model

Our identification strategy takes advantage of the annual change of clocks from Daylight Savings Time. As a result of different practices across cities and countries, the event creates a discrete change in the business hour overlap of some office pairs but not others. This section describes our empirical strategy involving DST and research design in more detail.

[21] We calculate geographic distance (in kilometers) between offices by applying the Haversine formula to the longitude and latitude of each office location. The average geographic distance between offices is 8,470 kilometers.

The move from Daylight Savings Time that corresponds with our study occurred on November 5th, 2017. On that date, some cities around the world moved their clock backward by one hour, some forward, and others not at all. These practices created discrete changes of up to two hours, plus or minus, in temporal distance between the Division's offices. We quantify the effect of these changes on the BHO of each pair of offices in our sample. Specifically, we calculate the BHO for each office pair, first using each city's DST time zones and then using each city's GMT time zones, which are effective after the switch from DST. We create an indicator variable called $Increased\ BHO_{ij}$, which takes the value one if the BHO of office pair ij increased (by one or two hours) and zero if it experienced no change.[22] We define $Decreased\ BHO_{ij}$, similarly, with a non-zero value for office pairs that experienced a decrease in BHO (by one or two hours) and zero for those that experienced no change. Table 4 shows the distribution of the change in BHO for the office pairs in our baseline sample. Overall, 59 percent of pairs saw no change in their BHO, 28 percent of pairs saw a decrease (mostly of one hour), and 13 percent saw an increase (mostly of one hour). Our empirical model will compare the treated office dyads (increase or decrease, respectively) with the office dyads that did not experience a change in BHO (control group).

INSERT TABLE 4

We use a difference-in-differences research design to examine how the shift in temporal distance induced by DST affected communication volumes and patterns between offices. Specifically, we compare employee communication patterns taking place during the eight weeks before the shift

[22] Because we measure BHO for an 8 am – 6 pm working day, in some cases office dyads may experience a change in time zone difference but not in BHO. For example, the East Coast of the United States and Singapore have a time zone difference of 12 hours during DST and 11 hours after DST, but no change in business hour overlap, which remains at zero.

from DST (pre-period) to those taking place in the four weeks after the shift (post-period) (Figure 4). We estimate:

$$Comm_{ijt} = exp\left[\beta_1 Treated_{ij} * Post_t + \beta_2 Tot\_Comm_{it} + \beta_3 Tot\_Comm_{jt} + d_{ij} + \partial_t\right]\varepsilon_{ij} \quad (1)$$

where $Comm_{ijt}$ are different measures of total volumes of communication between office i and j in week *t* and $Treated_{ij} * Post_t$ is either $Increased\ BHO_{ij} * \ Post_t$ or $Decreased\ BHO_{ij} * \ Post_t$. The model includes office dyad fixed effects (d_{ij}), which control for heterogeneity among the dyads that affect the average communication levels of that office dyad over the 12-weeks, for example the intensity of their working relationship and all other time-invariant determinants of their communication levels (e.g. geographic distance, cultural distance, administrative distance, etc.). With the dyad fixed effect in place, we effectively identify the effect of temporal distance from *changes in communication volumes within each office dyad* before and after DST. The model also includes week fixed effects, ∂_t, which control for firm-wide temporal variation in communication levels, for example due to holidays or other events that affect all offices. Finally, we control for total weekly volume of intra-firm communication for each office i and j in the dyad, excluding communication with the focal counterparty, Tot_Comm_{it} and Tot_Comm_{jt}, to account for any week-specific variation in intra-firm communication of each office (e.g. local holidays). In Equation (1) the main parameter of interests is β_1, which estimates the average effect on weekly communication volume of an increase/decrease in BHO during the four-week post-period.

We estimate Equation (1) using a standard OLS model and a (pseudo) Poisson (PPML) model (Silva & Tenreyro, 2006). The PPML model has become widely used in the international trade literature to estimate gravity models of trade flows between countries after Silva & Tenreyro (2006) convincingly argued that log linear OLS models traditionally used for this purpse are inconsistent due to the high number of zeros in the trade data. Gravity models typically estimate bilateral trade flows based on time-varying country attributes (e.g. countries' GDP, existence of trade agreements) and country-pair fixed effects. There are clear similarities in our empirical model presented in Equation (1), in which communication flows are modelled as a function of the total communication of each office, time-varying temporal distance, and office dyad fixed effects. Moreover, like international trade flows, the communication flows network features a large number of zeros. We estimate the PPML model using the *ppmlhdfe* command in Stata, which was designed for this purpose (Correia, Guimarães, & Zylkin, 2019). We cluster standard errors at the level of each office dyad, which is also the level at which treatment is assigned.

While the PPML is our preferred model, we also estimate Equaiton (1) using OLS, albeit in levels. In an OLS model with logged dependent variables, dropping observations with zero values (that cannot be logged) can potentially lead to a sample selection bias, or to the extent that constants are added to the dependent variables, inconsistent estimates (Silva & Tenreyro, 2006). Therefore, we estimate the OLS model in levels, which and also has the benefit of showing efect sizes in an easy-to-interpret format (number of minutes), while the Poisson coefficients represent percentage changes. The coefficients of interest are on the variables *Increased BHO x Post* and *Decreased BHO x Post*, which estimate of the effect of a one-to-two hour increase or decrease, respectively, in BHO between offices on communication volumes by media type. Due to the inclusion of dyad fixed effects, all dyads that saw zero communication in both the pre- and post-period *within each mode* of communication, drop out of the analysis for that mode.[23]

[23] The PPML model drops the observations which have no variation on the dependent variable automatically. The OLS model does not drop them automatically but we condition the sample of the OLS models in each case on only the subset of dyads from the baseline sample which have non-zero communication in each communication media type during the 12-week period, therefore the number of observations in the two models is the same. The results, however, are not sensitive to the inclusion of all dyads (including those lacking variation on the dependent variable) in the OLS models.

V. Results

Tables 5a and 5b present the main results of our difference-in-differences analysis estimated per Equation (1) using the PPML (Table 5a) and the OLS (Table 5b). First, we examine synchronous communications – unscheduled Skype calls, instant message chats, and scheduled calls and meetings. The results provide evidence that an increase in BHO led to increases in synchronous communication volumes for the treated office pairs in the post period. Specifically, the estimate in Column (1) of Table 5a implies that office dyads which experienced an increase in BHO increased their volume of unscheduled Skype call minutes by 28 percent, on average. The effect is statistically significant at the 5 percent level. While the magnitude of the response is large, this can be explained by the low average levels of unscheduled calls in the data. The OLS estimates in Table 5b show that the effect translates into an approximate 3.2 minutes increase in unscheduled Skype call minutes per week, on average. We find no significant responses to increases in BHO for the other two synchronous communication modes, instant message chats and scheduled calls and meetings.

Turning to the effect of decreased BHO on synchronous communication, we find, in contrast, statistically significant negative effects on communication volumes. The estimates in Columns (5)-(7) of Table 5a suggest that instant message chat volumes fall by 9.5 percent and scheduled calls and meetings by 9.0 percent on average for dyads that experience a decrease in BHO. The effects are statistically significant at the 5 percent and 1 percent confidence level, respectively. The OLS estimates imply that offices which loose shared time experience a 7-minute drop in instant message chats and a 20-minute drop in scheduled calls and meetings per week, on average. Unscheduled Skype calls show no significant responses to decreases in BHO. Taken together the results support *Hypothesis 1a* and *1b*, showing increases in synchronous communication when BHO increases and decreases in synchronous communication when BHO decreases.

Turning to asynchronous communication, the estimates in Column (4) of Table 5a show a marginally significant, positive effect on email from increased BHO. The point estimate suggests that email volume increased by 5 percent per week, on average. The OLS models estimate shows a 7-minute increase in total weekly email volume, on average. Turning to the effects of decreased BHO on asynchronous communication volumes, Column (8) of Table 5a shows small and not statistically significant effects of decreased BHO on e-mail. Overall, these estimates provide some evidence that asynchronous communication (e-mail) functions as a complement for synchronous communication. We do not find evidence in the baseline results that office dyads that experience less shared time increase volumes of asynchronous communication to substitute for the lower levels of synchronous communication. Thus, with an increase in temporal distance, the total volume of communication falls.

INSERT TABLES 5a AND 5b

An important assumption of the difference-in-differences analysis is that the treated and control groups exhibit parallel trends in the pre-period. In our context, this assumption requires that there are no significant differences in the growth rates of communication volumes, conditional on controls, between the offices which saw increases or decreases in BHO and those that experienced no change. While we are somewhat limited in our ability to explore longer-term communication growth trends given the 12-week duration of our data, we validate this assumption by testing whether the treatment and control groups exhibit different trends in communication growth rates in the eight weeks leading up to the change from DST. Specifically, we estimate a model parallel to Equation (1) but with the $Treated_{ij} * Post_t$ variable replaced with $Treated_{ij} * Week_t$ where $Week_t$ is an indicator variable for each of the six bi-weekly periods in our data, of which four correspond in the pre-period and two in the post-period. We aggregate communications to the bi-weekly level because weekly communication volumes exhibit high degrees of volatility on a weekly level, i.e. most dyads do not communicate on a weekly basis. The analysis is presented in Table 6 and graphically in Figure 5.[24] Overall, we find no significant differences in the trends in communication between the treated and untreated groups – all except one coefficient estimated in the pre-period are not statistically significant. In the post period, the estimates of the bi-weekly analysis show significant differences, in line with our main results. This analysis lends support to the parallel trend assumption.

Heterogeneity of Effects by Employee Function

Next, we use information on employee function to test the hypotheses regarding the knowledge intensity of the work performed and the intensity of responses to increases and decreases in temporal distance. To do so, we decompose the total communication volume of each office dyad-week based on the functions of the sending and receiving employees. Specifically, for each of the three major functions in the Division – R&D, IT, and production – we define $Comm_{ijft}$ where f indicates the function and $Comm_{ijft}$ aggregates the communication volume only if both the sending and receiving employee is in that function. Thus, for example, $Email_{ijR\&Dt}$ is be the total e-mail volume between R&D employees of offices i and j in week t.[25] Almost 70 percent of the total inter-firm communication takes place between workers in the same function (Table 7), consistent with the high degree of functional homophily in organizational communication also noted by Kleinbaum, Stuart, & Tushman (2008). Due to the high degree of homophily, the functional subsamples account for the majority of total communications that we explored in the baseline analyses.[26]

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[24] We present he bi-weekly estimates of the PPML model, though the analysis using OLS models lead to the same conclusions.

[25] We do not include communications where only one of the communicating employees is in the focal function in this because in this case, the same conversations would be counted in more than one of the dependent variables.

[26] Table 7 shows that among the three major functions, communications involving R&D employees exbibit the lowest degree of homophily. Therefore, in the Appendix we present the functional results for R&D, also counting conversations involving any R&D employee. These results are consistent with the functional results involving conversations within the R&D function only. [TBA]

INSERT TABLE 7

Tables 8–10 present the results of the effect on changes in BHO on the communication between offices by employee function and Figure 6, summarizes all results, including the baseline results. These results show that the increases in volumes of unscheduled Skype calls among office dyads that saw increases in BHO are concentrated among R&D employees. They see a large and statistically significant increase in unscheduled Skype calls. The estimates in Column (1) of Tables 8a and 8b imply that the weekly volume of unscheduled Skype calls increase between R&D workers increase by 59 percent, or 12 minutes, on average when BHO increases. Meanwhile, employees in IT and production functions show no statistically significant response to increased BHO in any synchronous communication mode. These results are consistent with these workers having a lower shadow price on additional shared time – a release in the constraint does not affect their behavior. Overall, the results provide support for *Hypothesis 2a*, showing that workers in R&D functions respond most to increases in business hour overlap by increasing synchronous communication volumes.

Turning to decreases in BHO, we detect no statistically significant changes in communication volumes among R&D employees. In contrast, we show a statistically significant decrease in synchronous communication volumes among IT and production workers. Specifically, the estimates in Columns (5)-(7) of Tables 9a and 9b imply that IT workers experience a 13.5 percent, roughly 12 minutes per week, decrease in instant message chats with a decrease in BHO. Production workers show a 13.6 percent, roughly a 29-minutes decline in the volume of weekly scheduled calls and meetings, on average, following a loss in business hour overlap (Tables 10a and 10b). We find some evidence that among production workers, e-mail communication minutes potentially increase to make up for the fall in synchronous communication, though the estimates are not always statistically significant. Overall, these results support *Hypothesis 2b*, that knowledge-intensive workers are least likely to decrease synchronous communication volumes in response to a loss of shared time. These results lend support for the view that these workers place a high value on synchronous communication.

While not the main focus of our study, it was interesting to note that R&D workers and IT and production workers exhibit changes on *different types of synchronous media* when subject to changes in BHO. While R&D workers exhibited an increase in unscheduled calls, IT and production workers exhibited a decrease in use of instant message chats and scheduled calls and meetings, all of which are synchronous forms of communication. A plausible explanation of this pattern might relate to differences in "bandwidth" across these media choices. As Hinds and Kiesler (1995) state, bandwidth relates to the ability to exchange information from multiple human senses (e.g. calls reflect the intonation of voice, that IM chat does not) and is important to exchange social information needed to achieve complex tasks such as R&D tasks.

INSERT TABLES 8-10

Robustness

One of the weeks of our post period, week 11 in Figure 4, is the week of the Thanksgiving holiday, which occurred on November 23rd in 2017. Given the importance of the U.S.-based headquarters in the Division's communication network, one potential concern is that this major U.S. holiday may impact the volume of communication within the Division and may bias the results in our main analyses. While the inclusion of week fixed-effects in all models controls for aggregate trends in each week, as a robustness check of our baseline results, we drop all office dyads which involve the United States during Thanksgiving week. Table 11 shows that our results are robust to this exercise.

INSERT TABLE 11

VI. Discussion and Conclusion

This paper uses intra-organizational data from a real-world setting and exploits a natural experiment to present causal results on how temporal distance affects communication patterns between more than 250 offices of a multinational firm, located across 48 countries. Our novel identification strategy exploits the annual change of clocks from daylight savings time. This enables us to control for all other dimensions of distance between units of a multinational firm and present clean estimates for how changes in temporal distance affect communication patterns between units. In summary we have the following main findings: we observe a positive and statistically significant relation between an increase in business hour overlap (i.e. reduction in temporal distance) and unscheduled Skype calls; this positive effect is concentrated among workers engaged in knowledge-intensive tasks. We also document a negative and statistically significant relation between a decrease in business hour overlap (i.e. increase in temporal distance) and instant messages/scheduled meetings; this negative effect is concentrated among workers with operational (i.e. IT and production) tasks. Our results contribute to the literature on communication patterns within multinationals, the literature on distributed work, and three strands of the organizations literature: the literature on information processing in organizations, the literature on temporal structuring of organizations, and the literature on remote work.

Our paper has several limitations. Our analysis pertains to a single multinational firm and relates to communication patterns across a three-month period. While, to the best of our knowledge, our results pertain to the first natural experiment on how temporal distance affects communication patterns within a global firm, these patterns should be validated in real-world and laboratory settings across a wide variety of organizational contexts. We also acknowledge several limitations in our data: in a recent paper on temporal distance and communication, Espinosa, Nan and Carmel (2015) build on O'Reilly and Pondy (1979) and argue that "communication patterns" (measured using variables such as 'turn taking in communication') and "communication content" are relevant to how temporal distance relates to communication outcomes. However, given that our data comes from a real-world setting, confidentiality concerns prevent us from observing the content of communication and features of the data such as turn-taking. For similar reasons, we also only observe communications sent and received using the employees' work-related Skype and Outlook accounts. We do not observe communications employees may have engaged in using private accounts or other communication technologies. In particular, we have little ability to differentiate how employees communicated during their scheduled calls and meetings, which is the largest category of communication by volume in our data.

However, our paper makes a contribution to several literatures, notably how geography and distance affects communication patterns within multinational firms. This literature, starting with Tushman (1977) and Gupta and Govindrajan (2000) has posited the importance of "richness in transmission channels" on communication patterns within MNCs. A separate strand of the multinationals literature, including the editorial by Alcacer, Kogut, Thomas and Yeung (2017) had made a case for studying the impact of "figurative distances" in hindering value creation for MNCs and Ghemawat (2013:11) distance as to why "most types of economic activity that can be conducted either within or across borders are still quite localized by country." While an important paper by Berry, Guillen and Zhao (2010) documents nine different dimensions of distance relevant for MNCs, temporal distance is conspicuously missing from this list.[27] Yet, as our natural experiment indicates, controlling for all other dimensions of distance, temporal distance is correlated to communication patterns between units of a multinational firm. It is important to document the effects of temporal distance on communication patterns within multinationals given the recent literature documenting the

[27] The dimensions of distance outlined by the authors include economic, financial, political, administrative, cultural, demographic, knowledge (differences in patent and scientific production), connectedness (differences in tourism and internet use) and geographic.

increase in global knowledge co-production within MNCs (Singh, 2005; Zhao, 2006; Foley & Kerr, 2013; Choudhury, 2015, 2017; Kerr & Kerr, 2018).

Secondly, our study also contributes and is related to the literature on distributed work (Allen, 1977; Hinds and Kiesler, 1995, 2002; Cummings, Espinosa and Pickering, 2009; Olson, Olson and Venolia, 2009; Edmondson, 2012; Espinosa, Nan and Carmel, 2015). Time zones are often mentioned as a challenge in global work (Edmondson, 2012) and as Olson, Olson and Venolia (2009) have summarized difficulties in coordination when workers are on different time zones and are on different diurnal rhythms. Cummings, Espinosa and Pickering (2009) theorize that the likelihood of coordination delay for members on globally distributed projects is a function of temporal boundaries between them and use survey data to find that greater use of asynchronous email does not reduce coordination delay for pairs of members with nonoverlapping work hours. O'Leary and Cummings (2007) theorize that temporal distance reduces time for problem solving and decreases the likelihood of synchronous communication. In a more recent paper, Espinosa, Nan and Carmel (2015) posit that more temporal distance will be associated with more asynchronous communication and vice versa and test this using a laboratory experiment. To the best of our knowledge, this study represents the first set of causal results in a real-world setting. Our causal results are directionally related to the proposition forwarded by O'Leary and Cummings (2007) on synchronous communication for workers in knowledge intensive tasks; however, contrary to what Espinosa, Nan and Carmel (2015) posit, we do not find any correlations between changes in temporal distance and asynchronous communication. Our results documenting heterogeneous patterns in communication for workers involved in R&D and operational tasks mirrors the findings of Hinds and Kiesler (1995), who studied lateral communication patterns for technical and administrative workers; our unique contribution is to exploit the heterogeneity in job function to study how temporal distance affects communication patterns.

Thirdly, our study contributes to organizational literatures on information processing in organizations, temporal structuring and remote work. In the literature on information processing in organizations, Daft and Lengel (1986:560) argue that managers work under conditions of "time constraints" and define "information richness" as "the ability of information to change understanding within a time interval." Our empirical study studies how exogenous changes to time constraints affect communication patterns within global firms. In yet another organizations literature, Orlikowski and Yates (2002) posit that organizational actors, through their every action, produce and reproduce "temporal structures" which in turn shape the temporal rhythm of their ongoing practices. The authors also relate these organizational temporal structures to time management by individual workers and state the following: "Temporal structures, because they are constituted in ongoing practices, can also be changed through such practices. Like all social structures, they are ongoing human accomplishments, and thus provisional. They are always only "stabilized-for-now"" (Orlikowski and Yates, 2002: 687). Our contribution to this literature is to document how natural phenomenon such as the annual change of clocks from Daylight Savings time can impact the temporal structures and communication patterns of organizations. Our findings are also relevant for the organizational literature on remote work practices (Bloom et al., 2013; Choudhury, Foroughi and Larson, 2019). In this literature, Choudhury, Foroughi and Larson (2019) document a newly emerging form of remote work, i.e. 'work from anywhere', where the firm awards employees geographic flexibility to live in any chosen location; our study indicates that for R&D workers who self-select to geographically locate in an East-West continuum, greater temporal distance might act as a friction relevant to their synchronous communication patterns.

More broadly, our study highlights a friction in managing temporally distributed work that has broader implications for related literatures focusing on global outsourcing and online labor markets (e.g., Ghani, Kerr, & Stanton, 2014; Goldfarb et al., 2015; Stanton & Thomas, 2016). In fact, the effects that we uncover are likely to be magnified in inter-firm settings. In the intra-firm context, managers and employees have access to multiple coordination mechanisms, for example management by authority, tacit procedures, blueprints, or company directives (Srikanth & Puranam, 2011; Mani, Srikanth, & Bharadwaj, 2014). These mechanisms are largely unavailable between agents operating at arms-length, who are therefore likely more reliant on communication as the primary mechanism of coordination.

Our findings also have practical implications for managers of global companies and for firm location strategy. While "follow the sun" arrangements (Espinosa & Carmel, 2003), with global locations working sequentially around the clock, can be very effective for employees engaged in less complex, administrative, or predictable patterns of collaboration who can communicate asynchronously, this may not be the case for knowledge workers. Our results suggest that employees engaged in knowledge co-production place a strong premium on synchronous communication, and will benefit from being located in a way that minimizes temporal distance – that is largely in the North-South direction. For example, while Seattle and San Francisco or New York and Sao Paulo are geographically distant, workers in these two locations will experience complete business hour overlap. Overall, our study calls for more carefully weighting the benefits that locations offer as destinations of globally distributed or offshored work (e.g. access to human capital, lower wage rates) with the incremental coordination costs created by temporal distance frictions.

In conclusion, as multinational firms continue to engage in global collaborative patenting and firms more broadly, explore novel models of remote work, such as 'work from anywhere', our study identifies temporal distance, i.e. the distance in time zones and overlapping business hours, as an important friction that affects within-firm communication patterns. This study, to the best of our knowledge, provides the first set of causal results on how temporal distance affects intra-firm communication patterns and exploits data from a real-world setting and a natural experiment to present these results. Our findings contribute to literatures on communication patterns within multinationals, the literature on distributed work, three strands of the organizations literature: the literature on information processing in organizations, the literature on temporal structuring of organizations and the literature on remote work in organizations. Our results also have practical implications for managers and suggests 'north-south' geographic corridors (where there is *no* temporal distance between geographically dispersed units) might lead to efficient synchronous communication patterns for R&D workers within multinational firms.

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Tables and Figures

Table 1: *Division Employees by Office Location (left) and by Function (right)*

Office Location	Total	*Percent*
North America	4,883	40.4
Asia Pacific	2,646	21.9
Middle East / Africa	2,191	18.1
Europe	1,845	15.3
Central/ South America	524	4.3
Total	12,089	40.4

Function	Total	Percent
Production	6,648	55.0
IT	2,188	18.1
R&D	1,754	14.5
Other*	1,499	12.4
Total	12,089	100.0

Note: Observations represent 12,089 active employees included in the Firm's directory in November 2017. *"Other" groups more than 20 smaller functions.

Table 2. *Summary statistics*

	mean	s.d.	p50	min	max	N
Unscheduled Call (min)	1.547	16.997	0	0	1163	77,568
Inst. Message Chat (min)	15.921	138.653	0	0	6151.1	77,568
Scheduled Call & Mtg. (min)	207.991	2074.205	0	0	127085.6	77,568
E-mail (min)	56.133	463.139	0	0	23567.4	77,568
Increased BHO	0.181	0.385	0	0	1	55,836
Decreased BHO	0.322	0.467	0	0	1	67,488
Pre-DST BHO	4.614	3.450	4	0	10	77,568
Post-DST BHO	4.462	3.469	3	0	10	77,568
Post	0.333	0.471	0	0	1	77,568
Distance (km)	8469.815	5641.204	8916.112	0	19764.27	77,568

Note: Observations represent 6,464 office dyads over 12 weeks. Increased BHO is defined for dyads that do not have a change in BHO (the control group) and dyads that experience an increase in BHO due to the end of Daylight Savings Time. Decreased BHO is defined for dyads that do not experience a change in BHO and dyads that experience a decrease in BHO due to the end of Daylight Savings Time.

Table 3. *Table of Correlations*

	Unscheduled Call (min)	Inst. Message Chat (min)	Scheduled Call & Mtg. (min)	E-mail (min)	Increased BHO	Decreased BHO	Pre-DST BHO	Post-DST BHO	Post	Office 1 Comm. Volume (min)	Office 2 Comm. Volume (min)	Distance (km)
Unscheduled Call (min)	1.000											
Inst. Message Chat (min)	0.449	1.000										
Scheduled Call & Mtg. (min)	0.419	0.701	1.000									
E-mail (min)	0.514	0.722	0.922	1.000								
Increased BHO	-0.025	-0.014	-0.021	-0.023	1.000							
Decreased BHO	-0.029	-0.013	-0.027	-0.026	.	1.000						
Pre-DST BHO	0.071	0.055	0.037	0.039	-0.190	-0.114	1.000					
Post-DST BHO	0.071	0.053	0.037	0.040	-0.069	-0.250	0.979	1.000				
Post	-0.001	-0.005	-0.001	-0.005	0.000	0.000	0.000	0.000	1.000			
Office 1 Comm. Volume (min)	0.121	0.133	0.158	0.218	-0.025	-0.029	-0.048	-0.045	-0.015	1.000		
Office 2 Comm. Volume (min)	0.090	0.162	0.133	0.133	0.020	-0.010	-0.029	-0.025	-0.006	-0.045	1.000	
Distance (km)	-0.073	-0.063	-0.055	-0.054	0.211	0.181	-0.934	-0.921	0.000	0.040	0.022	1.000

Table 4. *Distribution of Treatment*

Change in BHO (hours)	Dyads	Percent
-2	125	1.9
-1	1686	26.1
0	3813	59.0
1	675	10.4
2	165	2.6
Total	6464	100.0

Note: This Table shows the distribution of the change in BHO attributed to the end of Daylight Savings Time for the 6,464 office dyads included in the baseline sample.

Table 5a: *Estimated Effect of Change in BHO, PPML Models.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Synchronous		Asynchronous		Synchronous		Asynchronous
	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail
Increased BHO x Post	0.282** (0.120)	0.059 (0.062)	-0.037 (0.080)	0.051* (0.028)				
Decreased BHO x Post					0.018 (0.083)	-0.095** (0.048)	-0.090*** (0.033)	0.019 (0.024)
Model	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
Dyads	515	1365	4369	2352	599	1570	5292	2781
Dyad-Weeks (N)	6180	16380	52428	28224	7188	18840	63504	33372

Note: Dependent variables are weekly attention minutes. The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of communication in each communication type. Estimation using Poisson Pseudo Maximum Likelihood model. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5b: *Estimated Effect of Change in BHO, OLS Models.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Synchronous		Asynchronous		Synchronous		Asynchronous
	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail
Increased BHO x Post	3.235* (1.877)	5.315 (3.860)	-10.093 (11.511)	7.037** (3.167)				
Decreased BHO x Post					-0.045 (1.113)	-6.610* (3.625)	-19.990*** (7.283)	2.732 (2.985)
Model	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
adj. R^2	0.853	0.909	0.948	0.978	0.849	0.908	0.951	0.977
Dyads	515	1365	4369	2352	599	1570	5292	2781
Dyad-Weeks (N)	6180	16380	52428	28224	7188	18840	63504	33372

Note: Dependent variables are weekly total attention minutes. The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of communication in each communication type. Estimation using OLS. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: *Bi-Weekly Differences in Trends*

	Increased BHO				*Decreased BHO*			
	(1) Unscheduled Call	(2) Inst. Message Chat	(3) Scheduled Call & Mtg.	(4) E-mail	(5) Unscheduled Call	(6) Inst. Message Chat	(7) Scheduled Call & Mtg.	(8) E-mail
Wks 3-4 X Treated	0.023 (0.160)	-0.060 (0.100)	0.002 (0.173)	-0.060 (0.044)	-0.115 (0.119)	-0.098 (0.066)	0.044 (0.050)	-0.061* (0.030)
Wks 5-6 X Treated	-0.042 (0.211)	0.009 (0.100)	-0.170 (0.111)	0.016 (0.048)	-0.136 (0.149)	-0.089 (0.064)	-0.025 (0.061)	-0.049 (0.031)
Wks 7-8 X Treated	-0.127 (0.167)	-0.005 (0.080)	-0.033 (0.147)	-0.063 (0.042)	-0.251 (0.129)	-0.032 (0.059)	0.082 (0.071)	-0.036 (0.037)
Wks 9-10 X Treated	0.067 (0.217)	-0.040 (0.109)	-0.055 (0.183)	-0.019 (0.040)	-0.057 (0.107)	-0.082 (0.061)	-0.068 (0.050)	-0.003 (0.040)
Wks 11-12 X Treated	0.436* (0.183)	0.144 (0.119)	-0.145 (0.153)	0.071 (0.065)	-0.186 (0.141)	-0.243* (0.103)	-0.065 (0.060)	-0.044 (0.041)
Model	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
Dyads	515	1365	4369	2352	599	1570	5292	2781
Dyad-Bi-weekly periods (N)	3090	8190	26214	14112	3594	9420	31752	16686

Note: Dependent variables are bi-weekly attention minutes. The omitted category are Weeks 1-2. The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of communication in each communication type. The number of observations corresponds to bi-weekly dyads. The reference group for this comparison is weeks 1-2 of the study. Treated is an indicator for a dyad that has a change in BHO due to the end of Daylight Savings in our study. In column (1) – (4), Treated stands for an increase in BHO. In columns (5) – (8), Treated stands for a decrease in BHO. Estimation using Poisson Pseudo Maximum Likelihood model. Controls include the bi-weekly communication volumes for each office minus the focal communication in a bi-week dyad observation, as well as dyad and bi-week fixed effects. Standard errors clustered at the dyad-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: *Within- and Between-Function Share of Communication*

	R&D	IT	Production	Total
Within-Function Comm. (min.)	1,244,386	5,479,277	9,963,674	18,589,211
Between-Function Comm. (min.)	2,130,254	2,350,786	2,505,415	8,298,512
Within-Function Comm. (percent)	0.369	0.700	0.799	0.691
Between-Function Comm. (percent)	0.631	0.300	0.201	0.309

Note: Within-function sums all recorded communication between two employees who are both in the same function. The Between-function sums all recorded communication where exactly one employee in the employee-dyad is assigned to the relevant function. The Between-Function measure is based on the volume of communication between employees who are in different functions. Numbers exclude within-office communication. The total column represents the sum of minutes for each of the three functions, as well as for employees who are in the "other" category.

Table 8a: *Estimated Effect of Change in BHO, R&D employees only.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Synchronous			Asynchronous	Synchronous			Asynchronous
	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail
Increased BHO x Post	0.594*** (0.160)	0.096 (0.177)	-0.150 (0.233)	-0.014 (0.118)				
Decreased BHO x Post					0.185 (0.239)	-0.218 (0.216)	0.010 (0.126)	0.096 (0.099)
Model	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
Dyads	43	100	319	172	49	127	405	221
Dyad-Weeks (N)	516	1200	3828	2064	588	1524	4860	2652

Note: Dependent variables are weekly attention minutes between employees within the R&D function. The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of intra-R&D employee communication in each communication type. The number of observations corresponds to dyad-weeks. Estimation using Poisson Pseudo Maximum Likelihood model. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 8b: *Estimated Effect of Change in BHO, R&D employees only.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Synchronous			Asynchronous	Synchronous			Asynchronous
	Scheduled Call & Mtg.	Inst. Message Chat	Unscheduled Call	E-mail	Scheduled Call & Mtg.	Inst. Message Chat	Unscheduled Call	E-mail
Increased BHO x Post	11.552** (5.009)	3.589 (5.567)	-29.667 (54.708)	-8.011 (11.715)				
Decreased BHO x Post					1.839 (2.911)	-2.592 (5.717)	-10.436 (16.849)	6.069 (9.017)
Model	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
adj. R^2	0.696	0.752	0.835	0.955	0.708	0.727	0.873	0.944
Dyads	43	100	319	172	49	127	405	221
N Dyad-Weeks (N)	516	1200	3828	2064	588	1524	4860	2652

Note: Dependent variables are weekly attention minutes between employees within the R&D function. The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of intra-R&D employee communication in each communication type. The number of observations corresponds to dyad-weeks. Estimation using OLS. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 9a: *Estimated Effect of Change in BHO, IT employees only.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Synchronous		Asynchronous		Synchronous		Asynchronous
	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail
Increased BHO x Post	0.280 (0.182)	0.015 (0.092)	0.005 (0.049)	0.067 (0.050)				
Decreased BHO x Post					-0.008 (0.147)	-0.135* (0.071)	-0.035 (0.057)	0.003 (0.032)
Model	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
Dyads	279	585	1958	978	315	677	2372	1138
Dyad-Weeks (N)	3348	7020	23496	11736	3780	8124	28464	13656

Note: Dependent variables are weekly attention minutes between employees within the IT function. The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of intra-IT employee communication in each communication type. The number of observations corresponds to dyad-weeks. Estimation using Poisson Pseudo Maximum Likelihood model. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 9b: *Estimated Effect of Change in BHO, IT employees only.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Synchronous		Asynchronous		Synchronous		Asynchronous
	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail
Increased BHO x Post	1.751 (1.231)	6.234 (6.828)	7.501 (8.194)	5.817 (3.881)				
Decreased BHO x Post					-0.223 (1.344)	-12.438* (7.158)	-5.735 (9.367)	-1.710 (3.130)
Model	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
adj. R^2	0.663	0.913	0.885	0.959	0.679	0.906	0.892	0.961
Dyads	279	585	1958	978	315	677	2372	1138
Dyad-Weeks (N)	3348	7020	23496	11736	3780	8124	28464	13656

Note: Dependent variables are weekly attention minutes between employees within the IT function. The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of intra-IT employee communication in each communication type. The number of observations corresponds to dyad-weeks. Estimation using OLS. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 10a: *Estimated Effect of Change in BHO, Production employees only.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Synchronous		Asynchronous		Synchronous		Asynchronous
	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail
Increased BHO x Post	-0.205 (0.324)	0.190 (0.149)	0.053 (0.109)	0.028 (0.067)				
Decreased BHO x Post					0.267 (0.199)	0.003 (0.083)	-0.136** (0.062)	0.051 (0.051)
Model	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
Dyads	138	536	1703	895	156	575	2022	1020
Dyad-Weeks (N)	1656	6432	20436	10740	1872	6900	24264	12240

Note: Dependent variables are weekly attention minutes between employees within the Production function. The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of intra-Production employee communication in each communication type. The number of observations corresponds to dyad-weeks. Estimation using Poisson Pseudo Maximum Likelihood model. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 10b: *Estimated Effect of Change in BHO, Production employees only.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Synchronous		Asynchronous		Synchronous		Asynchronous
	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail
Increased BHO x Post	-3.016 (3.596)	6.573 (5.110)	-13.278 (16.352)	11.737** (5.662)				
Decreased BHO x Post					1.126 (2.472)	0.190 (3.682)	-29.467** (12.435)	12.618*** (4.816)
Model	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
adj. R^2	0.865	0.895	0.965	0.979	0.866	0.900	0.970	0.978
Dyads	138	536	1703	895	156	575	2022	1020
Dyad-Weeks (N)	1656	6432	20436	10740	1872	6900	24264	12240

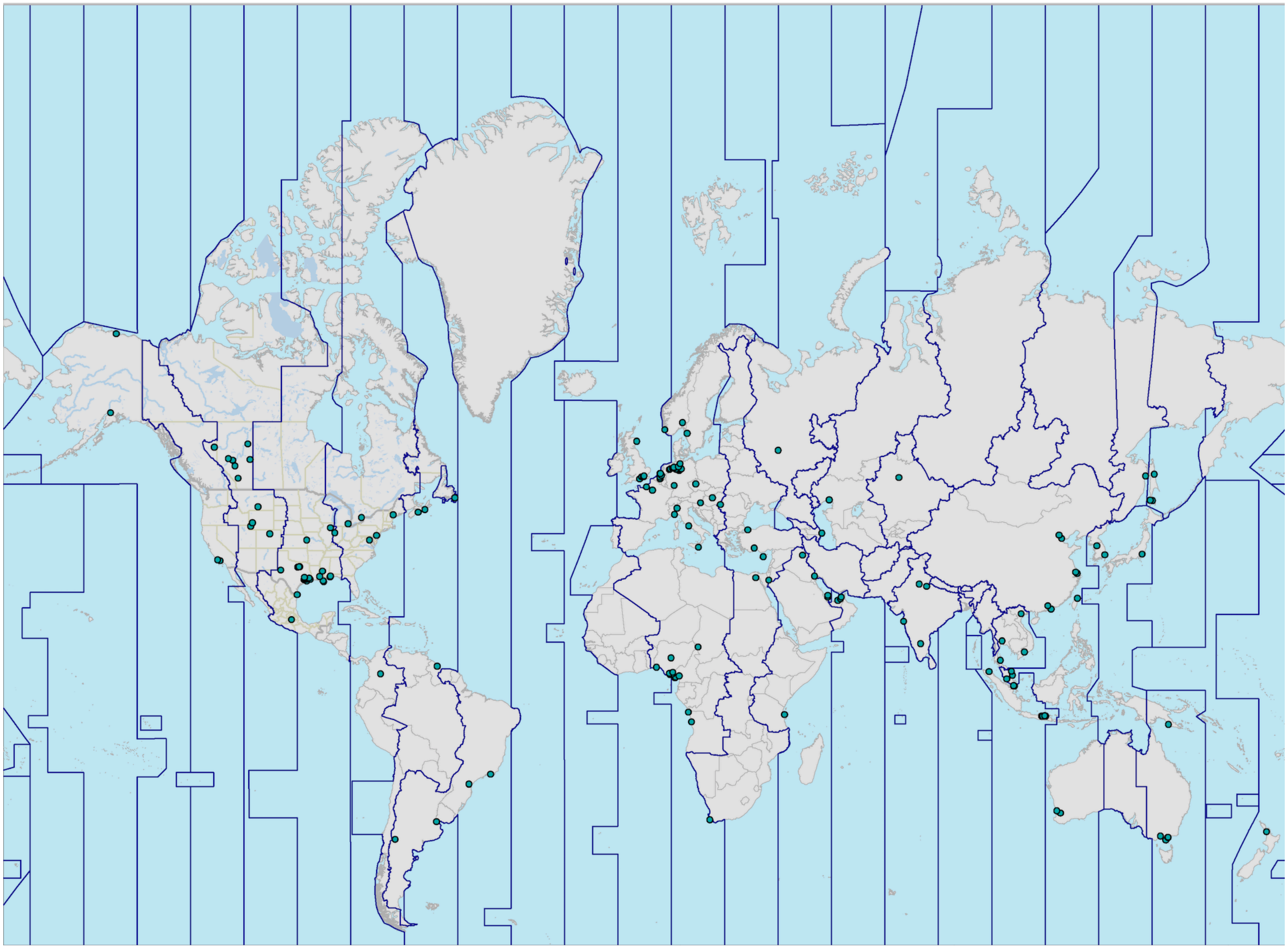
Note: Dependent variables are weekly attention minutes between employees within the Production function The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of intra-Production employee communication in each communication type. The number of observations corresponds to dyad-weeks. Estimation using Poisson Pseudo Maximum Likelihood model. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 11: *Estimated Effect of Change in BHO, Thanksgiving week robustness analysis*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Synchronous			Asynchronous	Synchronous			Asynchronous
	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail	Unscheduled Call	Inst. Message Chat	Scheduled Call & Mtg.	E-mail
Increased BHO x Post	0.271** (0.123)	0.003 (0.059)	-0.069 (0.071)	0.031 (0.028)				
Decreased BHO x Post					0.060 (0.079)	-0.051 (0.040)	-0.085** (0.034)	0.035 (0.022)
Model	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Dyad FE	Y	Y	Y	Y	Y	Y	Y	Y
Week FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
Dyads	515	1365	4369	2352	599	1570	5292	2781
N	5999	15828	50587	27259	6975	18224	61471	32312

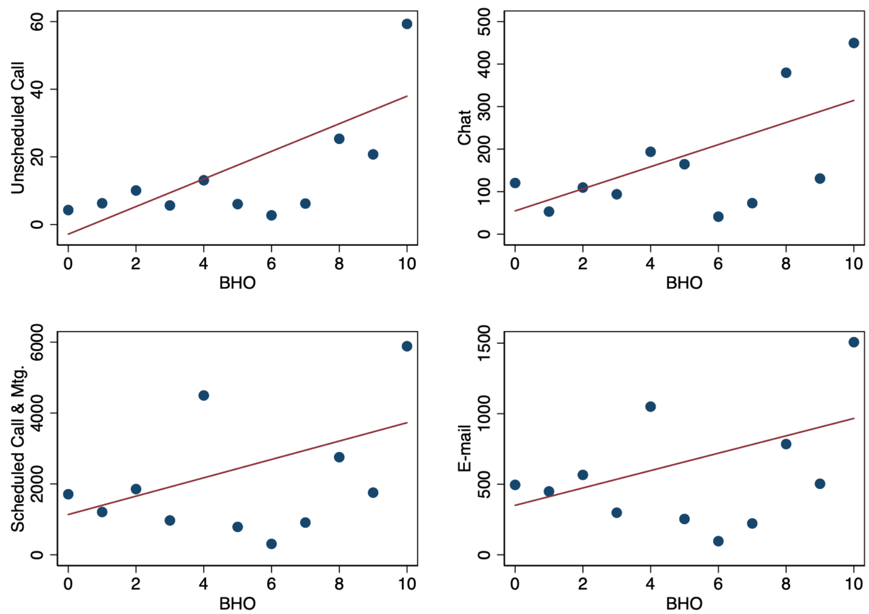
Note: Dependent variables are weekly total attention minutes. The number of dyads in each case corresponds to the office pairs that have non-zero and time-varying values of communication in each communication type. The number of observations corresponds to the number of dyad-weeks for dyads in our sample, excluding observations during the week of Thanksgiving that have at least one US office in the dyad. Estimation using Poisson Pseudo Maximum Likelihood model. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 1: Locations of Division Offices



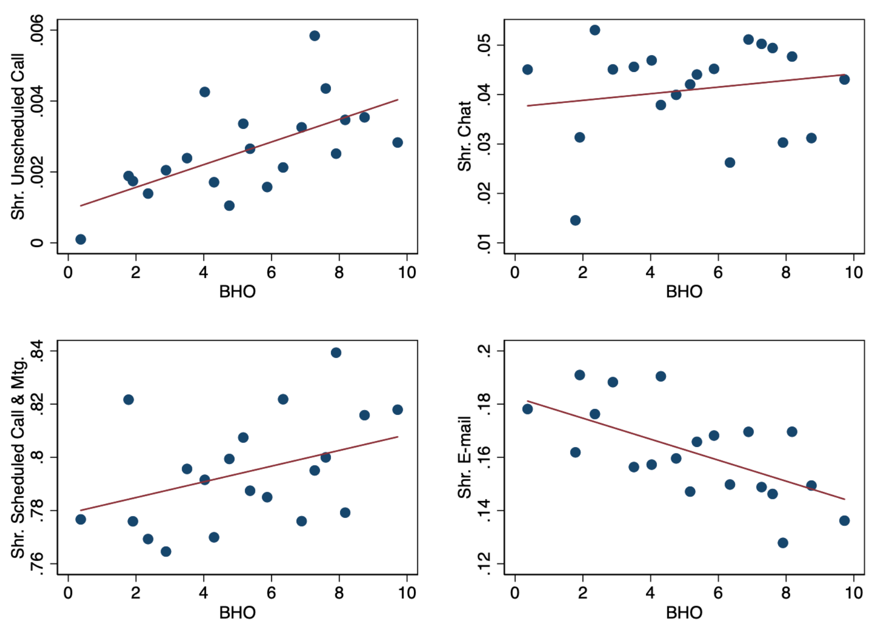
Note: Calculations by authors. Each marker represents one of 253 Division offices.

Figure 2. Binned Scatterplots of Communication Volumes and BHO



Note: Figure shows average total volumes of communication by media type during the 12-week period for each value of business hour overlap. Observations are all office pairs with non-zero total communication (N=6,464).

Figure 3. Binned Scatterplots of Communication Shares and BHO



Note: Figure shows the average values of the share of an office pair's total communication during the 12-week period in each media type for each value of business hour overlap. Models control for geographic distance between office pairs (in logs). Observations are all office pairs with non-zero total communication (N=6,464)

Figure 4: Timeline of events

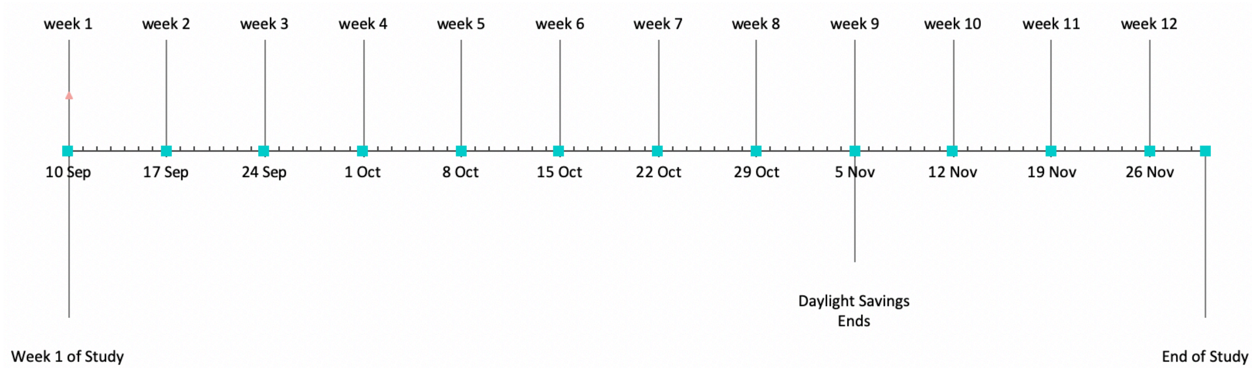
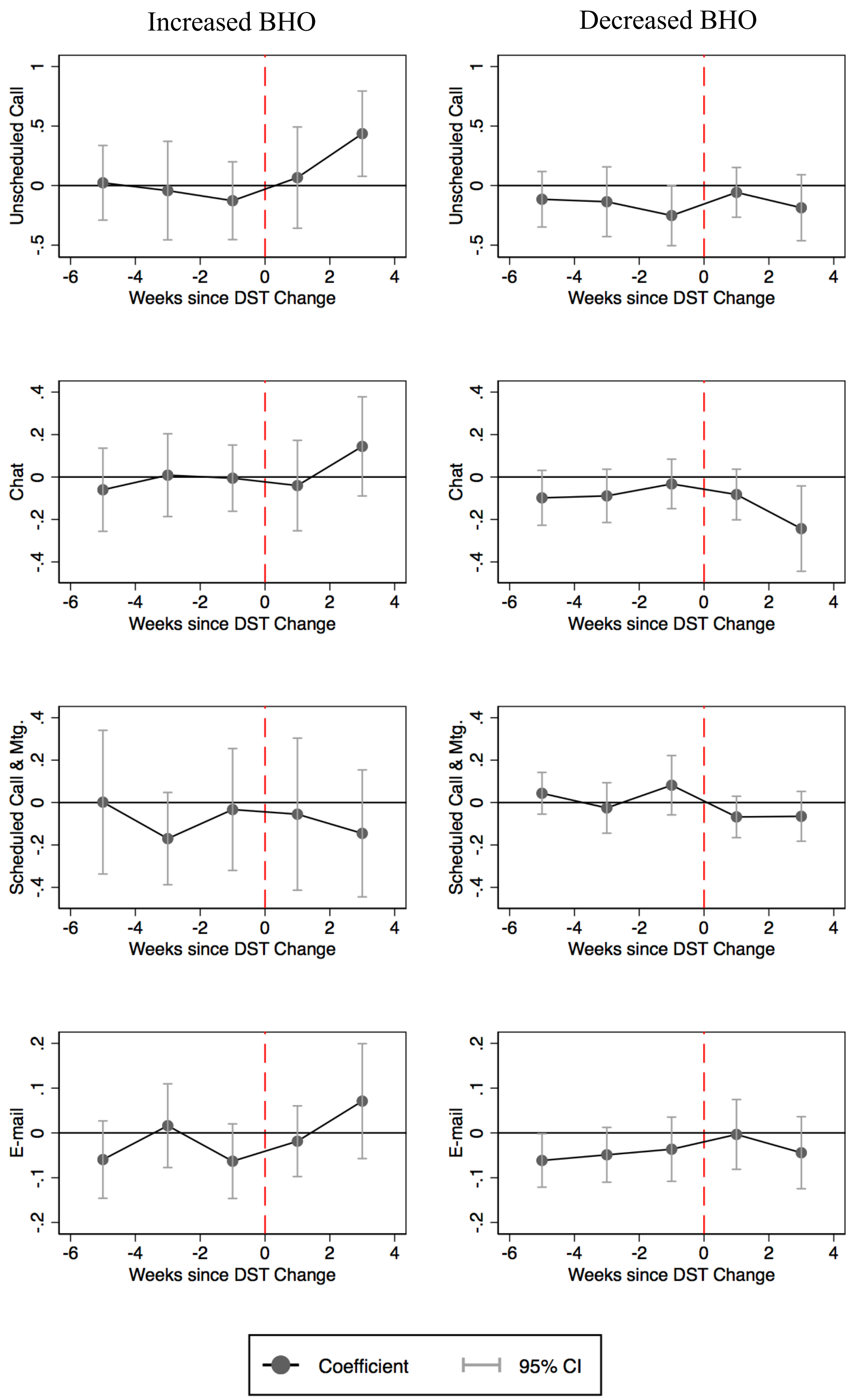


Figure 5: Trends in Communication Volumes in the Pre- and Post-Period



Note: This figure depicts the differences in each type of communication between treatment and control office dyads. Our sample of dyads corresponds to all office-pairs that have some communication of the relevant type in at least one period of the study. The number of observations corresponds to bi-weekly dyads. The left column compares dyads experiencing an increase in BHO due to the end of Daylight Savings Time office dyads experiencing no change in BHO. The right column compares office dyads experiencing a decrease in BHO due to the end of Daylight Savings Time with the dyads experiencing no change in BHO. The vertical axis on all panels is the percentage difference in attention minutes for each type of communication between treated and control dyads. The reference group for this comparison is weeks 1-2 of the study. Estimation using Poisson Pseudo Maximum Likelihood model. Controls include the weekly communication volumes for each office minus the focal communication in a dyad-week, as well as dyad and week fixed effects. Standard errors clustered at the dyad-level in parentheses. $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

Figure 6: Summary of Results

	Increased BHO	Decreased BHO

All conversations	• Synchronous
	  • Unscheduled call: ↑
	  • IM chat: *n.s.*
	  • Sched. call & mtg: *n.s.*
	• Asynchronous
	  • E-mail: *
		• Synchronous
		  • Unscheduled call: *n.s.*
		  • IM chat: ↓
		  • Scheduled call & mtg: ↓
		• Asynchronous
		  • E-mail: *n.s.*

Knowledge-intensive (R&D)	• Synchronous
	  • Unscheduled call: ↑
	  • IM chat: *n.s.*
	  • Sched. call & mtg:
	• Asynchronous
	  • E-mail: *n.s.*
		• Synchronous
		  • Unscheduled call: *n.s.*
		  • IM chat: *n.s.*
		  • Sched. call & mtg: *n.s.*
		• Asynchronous
		  • E-mail: *n.s.*

Less knowledge-intensive (IT & Production)	• Synchronous
	  • Unscheduled call: *n.s.*
	  • IM chat: *n.s.*
	  • Sched.call & mtg: *n.s.*
	• Asynchronous
	  • E-mail: *n.s.*
		• Synchronous
		  • Unscheduled call: *n.s.*
		  • IM chat: $*$
		  • Scheduled call & mtg: ↓
		• Asynchronous
		  • E-mail: *n.s.*

Note: Figure 6 summarizes our main results, showing how baseline communication volumes change in response to increased or decreased business house overlap. ↑ represent positive effects, statistically significant at the 1 or 5 percent level; ↓ represent negative effects, statistically significant at the 1 or 5 percent level; and *n.s.* stands for no statistically significant effects using our preferred model (Poisson). *These effects are statistically significant at the 10 percent level.