RIETI Discussion Paper Series 24-E-044

The Management of Knowledge Work

DESSEIN, Wouter
Columbia University

LO, Desmond (Ho-Fu)
Santa Clara University

SHANGGUAN, Ruo
Jinan University

OWAN, Hideo
RIETI

RIETI
Research Institute of Economy, Trade & Industry, IAA

The Research Institute of Economy, Trade and Industry
https://www.rieti.go.jp/en/

RIETI Discussion Paper Series 24-E-044
April 2024

The Management of Knowledge Work*

Wouter Dessein, Columbia University
Desmond (Ho-Fu) Lo, Santa Clara University
Ruo Shangguan, Jinan University
Hideo Owan, RIETI and Waseda University

Abstract

We explore the role of management in knowledge-intensive work. Our theory posits that the manager's function in a project mainly consists of ex ante coordination, specifying and delegating tasks to the project team, and ex post coordination of the team's execution of those tasks as the project unfolds. Consistent with the predictions generated from this view, our micro-level data from architectural design teams show a clear pattern of coordinated time use: (i) the involvement of both the manager and the project team is significantly higher ex ante than ex post; notably, this time pattern is more potent for more knowledge-intensive projects and projects subject to more information frictions, and (ii) the timing of the peak hours of the manager precedes those of the team. We also find that the team takes up the slack when the manager reduces ex-ante hours because of a heavier workload. Finally, projects in which managerial attention deviates from our predicted involvement correlate with higher team hours and lower overall profitability. Our study highlights the importance of managerial coordination and rational inattention in organizing knowledge workers.

Keywords: manager, project management, coordination, managerial attention, profitability.
JEL classification: D24, D83, M11, M54

*This study is conducted as a part of the Project "Productivity Effects of HRM Policies and Management Quality" undertaken at the Research Institute of Economy, Trade and Industry (RIETI). The draft of this paper was presented at the DP seminar for this paper at the Research Institute of Economy, Trade and Industry (RIETI). We thank seminar and workshop participants at Columbia Business School, the University of Padova, Paris Dauphine University, HEC Lausanne, Waseda University, Enhancing Sales Productivity Conference, SIOE, RIETI, and Einaudi Institute of Economics & Finance, Rome for their helpful comments. We are grateful to the anonymous firm for providing the internal data and insightful comments.

1 Introduction

Knowledge firms have become a cornerstone of the modern economy (Drucker 1999; Foss 2005). These firms frequently assemble collaborative teams of employees designed to carry out multiple projects and tasks concurrently. Teams are usually directed by managers who orchestrate and delegate responsibilities to specialized knowledge workers, effectively leveraging their unique expertise (Becker and Murphy 1992; Bolton and Dewatripont 1994; Garicano and Hubbard 2016). However, a significant challenge arises due to the intangible nature of knowledge work, which makes the tasks and collaborations of knowledge workers less delineated compared to their counterparts in conventional industrial firms. This raises a couple of important research questions.

First, what is the role of management and its economic impact on knowledge work? The literature has emphasized the role of monitoring and motivating employees in traditional industries (Alchian and Demsetz 1972; Holmstrom 1982; Hermalin 1988). However, it is not clear how the non-repetitive and intangible nature of knowledge work affects this role. Second, knowledge work is typically team- and project-based, with each project presenting unique requirements, having a start and completion date, and workers often concurrently involved in multiple projects. How do senior managers - as team leaders - and their teams coordinate their time use across different projects and stages of a given project? Coordination and allocating managerial time are crucial in organizing teamwork in knowledge firms (Dessein, Galeotti, and Santos 2016).

This paper provides a theory of how the manager and her team allocate time to knowledge-intensive work. We posit that the role of the manager is coordination, i.e., aligning the activities of her team of specialists in a project, or ”a job” in our context (Foss 2005, pp.139-140; Dessein and Santos 2006, p.961; Jost 2011, p.15; Lazear and Gibbs 2017, pp.140-142). This mainly consists of (i) ex-ante coordination - that is, delineating which tasks must be completed as well as how and by whom, and (ii) ex-post coordination of her team’s execution of those tasks as events such as a change in project specifications unfold. The more ”knowledge intensive” and ”less routine” a job is, the more time a manager needs to devote to ex ante coordination: delegation and specification of tasks. Hence, in more knowledge-intensive jobs, we predict the manager’s involvement to be more upfront and decrease faster over time than less knowledge-intensive jobs. However, we predict this time pattern to be less pronounced when the manager has better ex ante information about the job. The attention allocated by the manager's team is predicted to exhibit the same time pattern. However, since the team is also involved in project execution, relatively more team attention is allocated to later parts of the jobs than the manager. The model further predicts that larger jobs require more attention and that when the manager reduces her hours on a given job (e.g., because of a heavier workload), the team puts in more hours to pick up the slack, increasing overall project costs. Together, these theoretical results shed light on the issues of coordination and organizational attention among knowledge workers.

To test our theory, we obtained micro-level data on the time spent by employees and the characteristics of architectural design jobs in one of the business service firms in Japan. The firm hires hundreds of architects, and our data covers the firm's design jobs recorded from 2004-2016. Since project coordination is a major issue in the architectural and construction business (Ghazimatin, Mooi, and Heide 2022), this context is appealing to test our theory for the following reasons. First, knowledge workers such as architects tend to be more autonomous and rewarded based on outputs (e.g., job completion) rather than effort provision, and monitoring and motivating task execution is a minor part of the manager's time. Second, architects are involved in many design tasks that are not well-specified during formal contracting due to the tacit nature of knowledge and clients' idiosyncratic requirements. This requires substantial communication with clients and coordination among team members, particularly in the early stages of a design job. For example, developing initial concepts requires design imagination and creativity while paying attention to cost calculations. In this process, architects are required to think outside of the box, link previously disconnected concepts, or view things in fresh ways to meet client requirements (Pressman 2014). Third, although parametric modeling using computer-aided design (CAD) systems allows for many changes to be made quickly, ex-post coordination is still needed in a design job due to client specification changes, schedule changes in response to human resource constraints, or the discovery of design defects. Indeed, a company survey shows that their managers spend most of their time on client- and internal-related coordination work. Fourth, the manager mostly assumes the coordination role, whereas her team focuses on executing an architectural job. This clear and distinctive division of labor facilitates the interpretation of our empirical results.

Our empirical results, in general, support our theory. The manager and her team spend more time initially at a job but decrease their time involvement as the job progresses toward completion. Crucially, the initial time spent is more pronounced, and the decrease after that is more rapid, for more knowledge-intensive jobs such as design (versus, e.g., construction documentation), as well as jobs with more informational barriers: we find that the manager and the team log more hours on new clients and jobs that are farther away from their offices during the initial phases of a job when compared to later phases.

In addition, we find that the peak hours of the manager precede the timing of those of her team in a given job. This is consistent with sequential coordination in which the manager's ex ante coordination is a critical input to the team's ex post execution (Castaner and Ketokivi 2018). An increase in the manager's workload decreases her ex ante involvement relative to her team in a given job. A larger architectural job, and hence a bigger design team, receives more attention from the manager as well. Coordinated time use in architectural work between the leader and the team members becomes evident through the above results.

Finally, we analyze the economic significance of managerial attention. Assuming the predicted total time spent by managers for a job is at the optimum, our analysis shows that the absolute deviation of the actual number of hours from the optimal number of hours positively correlates with higher variable costs for a job (i.e., wages and traveling expenses). In fact, regardless of whether the manager spends more ("over-run") or less time ("under-run") than predicted, such deviations prolong team hours and are detrimental to job profits as well.[1]

In sum, our paper investigates the coordination and timing of manager and team involvement in knowledge work. We consider the management of those jobs as a production function in which the quality of work depends on ex-ante coordination of the manager, task execution, and ex-post coordination. The empirical analysis is consistent with the notion of coordinated time use in teamwork. In this way, our study integrates

[1] The difference between revenue and variable cost is known as the contribution margin, a measure of short-term profit. In our institutional context, the revenue of a job is pre-determined when the contract is signed.

organizational architecture and managerial attention into a novel, coherent framework.

Related literature. Little is known about employees' *coordinated time use* and its economic impact on knowledge firms. Our study is the first to document and analyze those patterns of middle managers and their worker teams using monthly records of employee hours. This analysis extends the work on middle managers in knowledge firms (Roberts and Shaw 2022) and contributes to several strands of literature. First, regarding time use, Faraj and Xiao (2006)'s study of trauma centers makes anecdotal observations of temporal, coordinated actions among medical specialists, yet it lacks a record of time spent. By examining the time spent on various tasks, Bandiera et al. (2020) identify two types of executives - "leaders" and "managers." However, their study focuses exclusively on the time use of CEOs and does not consider it in conjunction with their subordinates' time use. Ogura (2010) summarizes a national survey of middle managers' time use in Japan. Lo et al. (2022) show how retail managers in Japan and Chile judiciously allocate their attention across tasks and products based on the interplay of expertise and time pressure. Friebel, Heinz, and Zubanov (2022) show that the time spent on human-resource activities by middle managers at a retail chain reduces worker turnover but sacrifices attention on customers. The last three papers also leave out the analysis of the temporal nature of time use between the managers and their teams (Marks, Mathieu, and Zaccaro 2001).

Second, we provide much-needed empirical evidence on organizational coordination. Both management and economics scholars agree on the important role of firms in coordinating interdependent sub-units or specialists (Thompson 1967; Becker and Murphy 1992; Castaner and Ketokivi 2018). Formally, coordination requires the aggregation of dispersed information but may be ineffective because of physical communication constraints (Aoki 1986; Hart and Moore 2005; Cremer et al. 2006, and Dessein and Santos 2006) or because specialized agents are biased and communicate strategically (Alonso et al. 2008, 2015; Rantakari 2008; Dessein et al. 2010; Friebel and Raith 2009). Two key insights are that, first, while task specialization by employees is limited by the need for coordination (Becker and Murphy 1992), this depends on the need for task adaptation to a changing external environment (Dessein and Santos 2006). Second, centralization typically performs better in coordinating decisions, while decentralization tends to adapt decisions to local circumstances better (Alonso et al. 2008; Rantakari 2008). However, only a few empirical studies directly examine organizational coordination. For instance, Zhou (2013) finds that more internal hierarchy is used when tasks are more complex or interdependent in manufacturing firms, presumably because of coordination needs. The increasing trend of centralization is also attributed to the use of functional managers to coordinate activities across business units (Guadalupe, Li, and Wulf 2014). Garicano and Hubbard (2016) find hierarchies in knowledge firms reduce coordination costs and boost productivity. These studies, however, do not have information on individual managers. Dessein, Lo, and Minami (2022), analyzing middle managers at a large retailer, demonstrate that the extent of task centralization/delegation depends on the interaction between local volatility and coordination needs across sub-units in a store. While our paper focuses on analyzing vertical coordination between the leader and her team (and its temporal nature), Dessein et al. (2022) emphasize the importance of horizontal coordination among peer managers. Besides the above work using data from companies, Englmaier et al. (2021) find that relative to the control group in an experimental setting, having a leader in the treatment group improves coordination among team members in escape games.

Our paper is further related to the literature on hierarchies and the organization of knowledge in production (Garicano 2000; Garicano and van Zandt 2012). As argued in Garicano (2000)'s canonical model, a manager in knowledge-based hierarchies deals with more complex/exceptional problems than workers. In line with this, our model and evidence point to a division of labor between managers and workers in the coordination and execution of design projects. Our paper also illustrates the economic significance of team performance with the "right amount of managerial attention." This complements evidence by Lazear, Shaw, and Stanton (2015), who show that superior managers matter for team productivity in technology-based service jobs. Similarly, using personnel data from a high-tech company, Hoffman and Tadelis (2020) find that managers' social skills lead to higher performance ratings and earnings but lower employee turnover, whereas Deming (2017) shows how high social skills reduce coordination costs, enhance teamwork, and generate higher worker wages.

2 Institutional Context

Our data is obtained from a large business service firm that has an architectural design business in Japan ("the firm"). The firm maintains an exemplary reputation in the industry and has its own sales team to reach clients who seek consulting work on their buildings, structures, and construction sites. The firm has headquarters in Tokyo but has several regional offices in the country. A complete architectural design project encompasses several phases, including initial planning, schematic design, design development, construction documentation, and the supervision of the construction process.[2] It is not uncommon that the design and construction supervising work required by clients only include a subset of such phases. For instance, for standard buildings like a small factory, the requirement for creativity is low, and the first stages may be skipped. The firm views a phase as the basic unit of its design jobs and organizes teams around different phases. We follow the firm's practice by calling a phase a "job" and treating it as our unit of analysis.

When a client contacts the firm and the negotiation process starts, an executive panel consisting of the most senior executives assigns "the job" to an employee who is at the rank of "Manager" as "the job manager." Factors affecting a job assignment include expertise, tenure, current workload, and the nature of the client. Job revenue is largely predetermined at the beginning of the job and written in the contract. Therefore, once the job starts, the manager aims to minimize cost, especially its major components of labor and incidental costs, while maintaining quality work.[3]

Once the job contract is decided, the job manager organizes a design team to work on their buildings and structures. A design team typically consists of up to ten members, all of whom are architectural specialists at lower ranks (i.e., Senior and Junior Architect) than the job manager.[4] Since each architect has different skills and experience, the

[2]As a secondary source of revenue, the firm also provides consulting services for the specific problems the client wants to solve. For example, a client might want to explore enhancing the strength against the potential risk of earthquakes or other natural disasters.

[3]An exception to cost minimization is when a job participates in an industry competition that awards the design of, for instance, a monumental building. In this case, cost minimization may affect the chance of awards or reputation, so other metrics are involved.

[4]The firm classifies its employees into Manager, Senior Architect, and Junior Architect. There are multiple grades within each rank. In our data, job managers at the rank of Manager make up more than

manager attempts to optimize the talent mix to achieve a high-quality output with reasonable labor costs. Moreover, the size and composition of the design team may adapt to evolving needs as the job progresses. As mentioned earlier, the manager typically performs coordination functions. Her coordination work includes- but is not limited to - determining designs and material with clients, scheduling progress, assigning tasks to team members, solving conflicts and quality problems, negotiating with clients on specification changes, adjusting for delays, and mentoring team members. She often delegates the execution of the plan and tasks to her team members.[5] The firm also conducts job rotations for its employees to develop experience with various managers and clients (Aoki 1990).

Most managers we interviewed informed us that understanding client needs and their decision-making process and conscientious planning and coordination helps ensure smooth operations and on-schedule job completion. Our interviews revealed that most project managers are specialized in a particular client industry, implying that industry-specific knowledge is important. At the same time, a manager at the firm has to concurrently handle multiple jobs, ranging from a few to over 100. Often working under time constraints, the attention each manager and her team pay to each job varies substantially depending on various factors. Usually, the manager and the team spend more time on jobs that generate higher revenue because there are more parameters to decide on and more scrutiny in decision-making. The design team pays more attention to jobs involving new clients and creativity. Managerial attention also depends on the experience of the leader and the members. For instance, more senior managers are more likely to delegate developmental job assignments to advance team members' careers in the firm.

We do not view moral hazard as a primary concern in our context for the following three reasons. First, the division of labor in such close-knit relationships facilitates observable and measurable contributions of each team member to the job. Any architect can easily show and prove the part of the design and documentation they crafted. Sec-

99.6%

[5]The firm's compensation policy has two components related to the reporting lines and internal hierarchy issues: fixed salary and bonus. Salary is adjusted every year depending on the merit evaluation by his supervisor within the range set for each rank grade. The bonus pool is proportional to the firm's profit and divided based on the salary. No part of the compensation is directly linked with the individual performance.

ond, architects in reputable firms are intrinsically motivated to strive for quality work. Winning external awards for one's work further provides a strong extrinsic motivation (MacLeamy 2020). Third, time pressure to meet a deadline is often present. Since the skills of the team members are complementary in nature, an architect's shirking and other malfeasances are easily detected by professional team members, and they would adversely impact the architect's career in the firm.[6] The limited need for monitoring is also reflected in the pattern of time allocation shown in the later analysis, where the manager's time allocation always precedes that of the team members, and managers do not synchronize their time allocations.

3 A Model of Project Management

3.1 Model

Since moral hazard is not a major concern in the architectural firm, we consider a team-theoretic model in which production depends in a multiplicative way on (i) the quality of ex ante coordination and delegation of tasks, Q^D, by a manager and a team of workers (ii) the quality of the task execution by workers, Q^E, and (iii) the quality of ex post coordination of tasks, Q^C, by a manager an a team of workers. Concretely, total output is given by

$$Q = \mu^{1-(\alpha+\beta+\gamma)} \cdot \left(Q^D\right)^\alpha \left(Q^E\right)^\beta \left(Q^C\right)^\gamma \tag{1}$$

where μ is the size of the project and $\alpha + \beta + \gamma < 1$.

Quality of ex ante coordination & task delegation. As noted in Section 2, understanding client needs, as well as conscientious planning and coordination, is essential to ensure smooth operations and on-schedule job completion. The manager has to specify which tasks must be completed and how and by whom. The team of workers needs to

[6]This is not to say that the firm's and the employee's interests are perfectly aligned. For example, some employees might spend more time on the job than the company would like to win an external award. Another employee might design from scratch instead of using an existing blueprint in the archives to gain experience. These can result in some loss to the firm, at least in the short run. However, these issues are minor compared to the coordination problem we focus on in this paper.

know ”what to do” and ”what to do” must correspond to the client’s needs.

Whereas the manager is essential in the process of ex ante coordination, she can use a team of workers to assist her in this effort (e.g., collecting information, writing out instructions, filling in details, etc.).[7] We further posit that the quality of ex ante coordination, Q^D, depends on the time the manager spends in the early stages of the project, as well as the familiarity of the manager with the project. Formally,

$$Q^D = A^D \left(\frac{t_M^D}{\rho}\right)^{\rho} \left(\frac{t_T^D}{1-\rho}\right)^{1-\rho} + \mu \cdot (1 + k_c x_c + k_r x_r + k_d x_d) \tag{2}$$

where t_M^D and t_T^D are the time devoted to ex ante coordination and task specification by, respectively, the manager and a team of workers who support her.

The parameter ρ captures how essential the manager’s role (and time) is in this process. The larger the value of ρ, the less the manager can rely on workers (or assistant managers) to support her in this process.

The parameter x_c reflects how many jobs with common clients are under the supervision of the same manager. We assume $k_c > 0$, so that less time is required to achieve the same level of ex ante coordination for projects with a common client. The parameter x_r reflects how routine the job is. Conversely, $1/x_r$ reflects how “knowledge intensive” it is. Intuitively, we anticipate that $k_r > 0$ so that the less routine a job is (e.g., creative design vs. construction documentation), the more need there is for ex ante coordination and task delegation. Finally, the parameter x_d reflects the distance of the project from the headquarters of the firm. We assume $k_d < 0$, so more time is required for more remote projects.

Quality of task execution. How well do workers execute the delegated tasks and task instructions? We posit that

$$Q^E = A^E \cdot t_T^E \tag{3}$$

where t_T^E is the effort/time put in by the workers. Note that execution of tasks is, by definition, only a function of worker input. Anything that requires the involvement of

[7]This work is different from delegation in that the work of the manager and subordinates are complements and not substitutes.

the manager ex post will be captured by the quality of ex post coordination.

Quality of task coordination (ex post coordination). Unforeseen circumstances arise and new client needs may emerge that require a re-juggling or re-organization of tasks. In other words, ex post coordination may be needed. Again, the manager plays a key role in this "ex post" coordination, though a team of workers may assist her. In particular,

$$Q^C = A^C \left(\frac{t_M^C}{\rho}\right)^{\rho} \left(\frac{t_T^C}{1-\rho}\right)^{1-\rho} \tag{4}$$

where t_M^C and t_T^C are the time devoted to ex post coordination.

Labor cost. While output is given by (1), the cost of production equals

$$L = t_M^D \lambda_M + t_M^C \lambda_M + t_T^D \lambda_T + t_T^E \lambda_T + t_T^C \lambda_T$$

where λ_M and λ_T are the wages of managers and workers (or, alternatively, opportunity cost). Intuitively, both the manager and the workers are involved with multiple project and λ_M and λ_T are the marginal value of one unit of attention.

Timing. We assume there are two periods. In period 1, there is ex ante coordination. In period 2, there is task execution and ex post task coordination. In period 1, we denote

$$t^1 = t_M^1 + t_T^1 = t_M^D + t_T^D$$

In period 2, we denote

$$t^2 = t_M^2 + t_T^2 = t_M^C + t_T^E + t_T^C$$

We further denote $t = t^1 + t^2$ and $t_l = t_l^1 + t_l^2$ for $l = M, T$.

3.2 Optimal Allocation of Attention

Assume first that managerial and worker attention, $t_M^D, t_M^C, t_T^D, t_T^E$, and t_T^C, are allocated to maximize total value

$$Q - L = \mu^{1-(\alpha+\beta+\gamma)} \cdot \left(Q^D\right)^{\alpha} \left(Q^E\right)^{\beta} \left(Q^C\right)^{\gamma} - (t_M^D + t_M^C)\lambda_M - (t_T^D + t_T^E + t_T^C)\lambda_T \tag{5}$$

As we show in Appendix 1, the first-order conditions with respect to managerial and worker attention t_T^k and t_D^k, for $k = D, C$, imply that $t_T^{k^*} = \kappa \cdot t_M^{k^*}$ where the optimal span of control κ for the manager is given by

$$\kappa = \frac{(1-\rho)\lambda_M}{\rho\lambda_T} \tag{6}$$

Intuitively, the larger is ρ, that is the more essential is the manager in the process of ex ante or ex post coordination, the lower is the span of control of the manager κ. Similarly, the larger is the wage premium of the manager, λ_M/λ_T, the larger is κ.

By substituting the expression for the optimal span of control in (5) and then taking the first-order conditions, Appendix 1 shows that the optimal levels of ex ante coordination, ex post coordination, and project execution are given by

$$\begin{aligned} Q^{D^*} &= \alpha A^D \left(\frac{\lambda_T}{\lambda_M}\right)^{\rho} \left(\frac{1}{\lambda_T}\right) Q^* \\ Q^{C^*} &= \gamma A^C \left(\frac{\lambda_T}{\lambda_M}\right)^{\rho} \left(\frac{1}{\lambda_T}\right) Q^* \\ Q^{E^*} &= \beta A^E \left(\frac{1}{\lambda_T}\right) Q^* \end{aligned}$$

Importantly, observe that $Q^{D^*}, Q^{E^*}, Q^{C^*}$ and, hence, Q^*, are (i) independent of the ex ante information parameters x_c, x_r and x_d and (ii) linear in the size parameter μ. Intuitively, at the optimum, the marginal return to managerial attention must be equalized across ex ante and ex post coordination, pinning down the optimal level of Q^D and Q^C independently of x_c, x_r and x_d. In other words, for given project characteristics and labor costs, the same quality of ex ante coordination Q^{D^*} must be achieved *regardless* of the routineness of the project x_r, the distance of the job site x_d, or the number of common projects x_c.

This observation, together with the expressions (2), (3), and (4) that give Q^D,Q^E, and Q^C as a function of managerial and worker attention, yields the following lemma:

Lemma 1. • *$t_M^D, t_T^D, t^1/t$ and t_M^D/t_M are decreasing in x_c, x_r and $(-x_d)$. On the other hand t_M^D/t_T^D is unaffected*

- *The ratios $Q^{D^*}/Q, Q^{C^*}/Q$ and Q^{E^*}/Q are independent of x_c, x_r, x_d, and μ.*

Proof See Appendix 1.

Using the fact that ex ante coordination occurs in period 1, whereas execution and ex post coordination occurs in period 2, we obtain the following comparative static results:

Proposition 1. *Assume time is allocated to maximize total value Q-L, then:*

1. *The share of the manager's time is larger in period 1 (t_M^1/t^1) than in period 2 (t_M^2/t^2).*
2. *The more jobs come from a common client in the manager's portfolio (x_c), the more routine the project (x_r), or the smaller the distance from the job site (x_d), the less time the manager and the team spend in period 1 (t_M^1, t_T^1), and proportionally more time the manager and the team spend in period 2 (t_M^2/t_M and t_T^2/t_T).*
3. *In a larger job (μ), the manager and the team spend more time both in period 1 (t_M^1 and t_T^1) and period 2 (t_M^2 and t_T^2).*

The intuition for these results can be understood as follows. The first result states that the manager decreases her relative involvement as the job progresses. Intuitively, in both periods 1 and 2, the manager and her team are involved in coordinating work (ex ante coordination in period 1, ex post coordination in period 2). While managerial attention devoted to ex ante coordination may be higher (or lower) when compared to ex post coordination, the ratio of managerial-to-worker attention devoted to coordination will be identical in both periods as it is solely determined by the parameters ρ, λ_M,and λ_T. In Period 2, however, the team must also execute the tasks specified and delegated in period 1, whereas the manager is not involved in task execution. Hence, the manager's relative involvement drops in period 2 compared to period 1.

The second result concerns the impact of the availability of ex ante information on manager and team attention. When the manager already has more ex ante information about a job (i.e., a more routine job, a nearby job) or a client (i.e., a common client), she is more efficient in ex ante coordination and task delegation.

Thirdly, the manager and the team spend more hours, both *ex ante* and *ex post* , in larger jobs because of higher returns to (or need for) attention.

3.3 Cost Minimization and Managerial Workload

Cost minimization. In our analysis above, we have assumed that the time allocated to a project is optimized to maximize total output minus wage costs. In our empirical setting, however, the total revenues associated with a job are contracted up in advance. Hence, the firm may instead be allocating manager and worker attention to a job in way that minimizes its wage costs subject to achieving a minimum (contracted) output level.

Our analysis can easily accommodate a cost-minimization framework. Let Q^c be the contracted upon output level. The firm then chooses $t_M^D, t_M^C, t_T^D, t_T^E$, and t_T^C, to minimize

$$L = (t_M^D + t_M^C)\lambda_M + (t_T^D + t_T^E + t_T^C)\lambda_T \tag{7}$$

subject to

$$Q = \mu^{1-(\alpha+\beta+\gamma)} \cdot \left(Q^D\right)^{\alpha} \left(Q^E\right)^{\beta} \left(Q^C\right)^{\gamma} \geq Q^c \tag{8}$$

where Q^c may be smaller or larger than Q^* from the previous section.

As we show in the Appendix, the above minimization problem is equivalent to the maximization problem studied previously, but where both λ_M and λ_T are divided by the same factor λ_Q given by

$$\lambda_Q^{\frac{\alpha+\beta+\gamma}{1-(\alpha+\beta+\gamma)}} = Q^c/Q^* \tag{9}$$

The factor λ_Q is the shadow cost associated with the output constraint (8). Note further that $\lambda_Q = 1$, and the manager and team time allocations are identical to the ones obtained in the previous section, if and only if $Q^c = Q^*$.

It follows that regardless of the contracted output level Q^c, the optimal span of control κ for the manager remains given by (6) and our results carry through:

Proposition 2. *Under cost minimization, the results of Proposition 1(1) and Proposition 1(2) hold. Propostion 1(3) holds if we replace project size μ by contracted output level Q^c.*

The impact of a higher managerial workload. Cost minimization is a useful framework to study the impact of changes in the workload of a manager. Formally, λ_M can be interpreted as the opportunity cost of a unit of managerial attention. When managers are involved in multiple projects, this opportunity cost of attention will be affected by the portfolio of jobs assigned to a manager.

Let us, therefore, denote by $\lambda_M(S)$ the opportunity cost of attention when the manager is involved in jobs $j \in S = \{1, 2, ..., m\}$, where $\lambda_M(S') > \lambda_M(S)$ whenever $S \subsetneq S'$. Any administrative burdens imposed on a manager or other non-client related tasks can also be interpreted as a (non-revenue generating) job which affects λ_M. We obtain the following result:

Proposition 3. *Assume manager and team time are allocated to minimize costs subject to minimum job output levels Q_j^c. Consider an increase in the workload of a given manager from S to S' where $S \subsetneq S'$. Then for any job $j \in S$, the increase in workload to S'*

- *reduces period 1 and 2 managerial time allocated to job j.*
- *increases period 1 and 2 team time allocated to job j.*
- *increases the total labor cost L of job $j \in S$ (even if t_M is evaluated at cost $\lambda_M(S)$)*

The intuition is straightforward: as the opportunity cost of the manager increases, it is optimal to use more team time and less managerial time to achieve the same minimum output level. Assume first that managerial labor cost is evaluated at the old opportunity cost $\lambda_M(S)$. Since the original time allocation minimized costs given $\lambda_M(S)$, it must be that the new time allocation results in a higher labor cost L. Evaluating managerial labor at a cost $\lambda_M(S') > \lambda_M(S)$ then only further increases L.

The impact of time deviations on cost. Consider, finally, what happens when a manager "deviates" from the optimal time allocation in period 1 or 2, and team attention is subsequently adjusted to achieve the contracted upon output level Q^c. It is immediate that any time deviation - upward or downward - by the manager will result in a higher total labor cost.

3.4 Senior and junior managers

We now incorporate senior and junior managers in our analysis. We assume that a senior manager can save time and be involved in more projects by working with an assistant manager on a project. The junior manager, in contrast, can only work independently.

Abusing notation, let t_M be labor output of a senior manager when assisted by an assistant manager. We posit that

$$t_M = \left(\frac{t_{sM}}{\phi}\right)^{\phi} \left(\frac{t_{aM}}{1-\phi}\right)^{1-\phi} \tag{10}$$

where t_{sM} is the time contributed by the senior manager and t_{aM} the time contributed by the assistant manager.[8] In contrast, the labor output of a junior manager simply equals

$$t_M = t_{jM}$$

where t_{jM} is the time contributed by the junior manager. Finally, Q^D and Q^C are a function of t_M as in our baseline mode. We denote the wages of junior managers, senior managers, and assistant managers respectively by $\lambda_{jM}, \lambda_{sM}$, and λ_{aM}, where we posit that

$$\lambda_{aM} < \lambda_{jM} \equiv \lambda_M$$

The wage of the senior manager λ_{sM} will be determined in equilibrium as follows:

Assumption 2 The wage of the senior manager, λ_{sM}, is such the managerial wage cost of a project led by a senior and assistant manager is identical to the wage cost of a project led by a junior manager.

In Appendix 1, we show the following result:

[8] As we will show below, this production function is such that if another senior manager were to take the role of an assistant manager, then the firm would be indifferent to having a senior manager working by himself or in a team with another senior manager (both managers are paid the same hourly wage λ_{sM} in the latter case).

Proposition 4. *Compared to the junior manager, the senior manager spends less time on both ex ante and ex post coordination ($t_{sM}^{1*} < t_{jM}^{1*}$, $t_{sM}^{2*} < t_{jM}^{2*}$).*

Proof. See Appendix 1.

This result captures the idea that a senior manager has more responsibilities, being assigned larger teams and also delegates part of her coordination role to the junior manager.

4 Data and Measures

4.1 Data

Our analysis uses project management, personnel, and labor input data provided by the firm. In the project management data, contract terms for each phase of any project from 2004 to 2016 are observed. We refer to such a phase as "a job." A project may consist of several phases and some related jobs. For example, designing a large sports stadium involves five stages or jobs: (i) planning, (ii) schematic design, (iii) design development, (iv) construction documentation, and/or (v) construction supervision. There will be more jobs if it also involves the construction of, for instance, a connected shopping arcade and its peripheral roads and parking structure. Many times, however, a project is composed of a single job. The firm organizes its activities based on jobs. Following this, our unit of analysis is a job. We know each job's revenue, costs, and detailed categorical classification, such as client industry and building type. As we stated earlier, job revenue is predetermined by between the firm and the client before production. Personnel records are available from 2011 to 2016. It includes each worker's basic information, such as the year of birth, the year of entering the firm, etc.

The labor input data contain detailed records of working hours for each worker on each job each month. We index job and month by j, and t, respectively. These time records are not used for billing the client; instead, they are mainly for cost control. Although workers self-report the number of hours, the managers and the firm closely monitor the records to ensure compliance. After the client signs the contract, each job is assigned to a job manager as the team leader, who is responsible for all the subsequent actions. Managers typically manage multiple jobs concurrently. Therefore, how managers allocate their limited time is key to the firm's success. For our analysis, jobs that receive zero attention from their chief manager throughout the job period are excluded. For those jobs, the manager's coordination role is fully delegated to a seasoned senior architect in a second-in-command role.[9] We also exclude jobs with revenue less than one million Japanese Yen (about US$9000 during our data period). This restriction excludes failed jobs that do not generate meaningful revenue for the firm. We also exclude the first three months since the starting month for each job. This is because we use whether there is any positive labor input in the first three months of a job as an instrumental variable for time progress, an issue that we discuss further below.

4.2 Variables and measurement

We use the following variables in our empirical analysis.

- $ManagerHour_{jt}$ ("manager hours") is the number of hours recorded for the job manager j in month t. We use "manager" and "team leader" interchangeably.
- $TeamHour_{jt}$ ("team hours") is the number of hours recorded for all team members on job j in month t, excluding the manager.
- $t\_progress_{jt} \in [0.1]$ ("job progress") is the ratio of the cumulative number of days from the start of job j until the first day of the following month $t+1$, to the total duration of job j (in days). Its value ranges from 0 (job start) to 1 (job completion), measuring the progress of the current job.
- $C_{jt} \in [0, 1]$ ("common client") is defined as follows: For each job j in the job portfolio of manager i in month t, count the number of other jobs in the portfolio having the same client as job j, and then divide the count by the total number of jobs under manager i minus 1. The more jobs from the same client under the manager's responsibility, the more the manager understands the client's business. This is one of our two measures of (lack of) information friction.

[9] Even for the selected jobs, managers need not spend positive time during the project period every month. Zero hours may happen because the manager has higher priority in other jobs or the team waits for the client to decide on design details.

An example of C_{jt} : there are 10 jobs in month t for the manager. Suppose 5 are with the same client, and the other 5 are different. For job j sharing clients with 4 other jobs, C_{jt} is 4/9. For job j not sharing clients with other jobs, C_{jt} is 0.

- $Prox_j \in [0, 1]$ ("proximity") captures how close the site of job j is to the firm. It is measured as $1/(Dist_j+1)$, where $Dist_j$ is the geographical distance between the job site and the firm's responsible office in kilometers. $Dist_j$ is calculated as follows. For the job sites that are located in Japan, we calculate the distance between the responsible regional office (in four prefectures) and the job site prefecture using data from the Geospatial Information Authority of Japan [10]. For jobs outside Japan, we use country-level distance measure from CEPII [11]. The longer the distance, the more information asymmetry is between the manager and the headquarters office (Kalnins and Lafontaine 2013; Huang et al. 2017). This is our second measure of (lack of) information friction.

- $NoJob_{jt}$ ("workload") is the total number of jobs the manager of job j is in charge of in month t.

- Rev_j ("job revenue") is the revenue of job j. It is determined before the start of production. We use its standardized logarithm value with mean zero and unit standard deviation in our regressions.

- $Tenure_{jt}$ ("tenure") is the number of years since the manager of job j, at the year indicated by time t, joined the firm. We use its standardized logarithm values in our regressions.

- $TeamSize_{jt}$ ("team size") is the number of workers contributing positive hours to job j in month t, excluding the manager. Team size varies with time due to the changing need for labor as a job progresses.

- $JobType_j$ ("job type") denotes a categorical variable (with 22 categories) that controls for the type of service in each job j. [12]

[10] https://www.gsi.go.jp/KOKUJYOHO/kenchokan.html

[11] http://www.cepii.fr/CEPII/en/publications/wp/abstract.asp?NoDoc=3877

[12] The top 10 categories of $JobType_j$ cover 90.0% of the number of jobs and 97.1% of revenue in the sample. Ordered in terms of revenue, they are: Construction documentation (34.2%), Design/Construction

- $Industry_j$ denotes a vector of 39 dummies indicating the industry in which a job is classified. Industries include real estate, education, finance/insurance, transportation, municipal government, and others.

Table 1 provides the summary statistics for these variables. We note that the monthly average hours spent on a job are 9.4 for the manager and 290.1 for the team. With the average team having 7.2 members, a team member spends an average of 40 hours per month on a job. The mean value of the manager's share of hours to that of her entire team is 8.8%. A typical manager has worked for the firm for about 25 years and carries a monthly workload of about 17 jobs. Finally, the average revenue of a job is 95 million Japanese Yen (=USD807,500 at the exchange rate recorded at the year-end in 2016).

<insert Table 1 about here>

4.3 Stylized Facts

Before examining our regression analysis, we document some facts about managerial time use and selective attention in Appendix 2. We summarize the key observations as follows.

Managerial time use. According to the firm's survey on managers' time use,[13] over 78% of an average manager's working time covers design work (26%), client meetings (23%), and internal meetings (29%). Working time is the time after removing "dead time" such as rest and transition between offices or work places. While a manager may use design work to implement her technical knowledge on architectural jobs, such technical engagement also inevitably helps her understand the job better, facilitating coordination and guiding the team on involved tasks. As such, the vast majority of managerial time use appears to be coordination in nature.

supervision (22.2%), Design development (14.3%), Construction supervision (13.8%), Other (3.2%), Schematic design (3.0%), Planning management (2.0%), Other planning (1.9%), Basic planning (1.4%), Commercial Planning (1.0%).

[13]The firm conducted this survey not directly related to our study. Yet, we find the findings relevant enough to report them. See details in the Appendix.

Selective attention. The longitudinal labor-input data described in the previous subsection show clear patterns of selective attention: managers often pay little attention to a significant number of tasks at a given time (Dessein et al. 2016). Most managers spend only a positive number of hours in a given month on one out of four jobs. Among a manager's jobs, the first and second most attentive jobs incur about 20 and 12 hours per month, respectively. And only the first five or six jobs receive meaningful amounts of attention. These patterns are consistent with the idea that managers must prioritize time use such that their primary task of coordination is done efficiently.

5 Econometric Specifications

Our empirical analysis aims to examine the effect of job progress, information frictions, and managerial workload on the following outcome variables: manager hours, team hours, and team size. We describe the econometric setup for each of those three analyses below.

5.1 Effect of job progress

To study the effect of job progress on manager hours, team hours, and team size of job j in a given month t, we use the following regression as our baseline setup:

$$y_{jt} = \beta_0 + \beta_1 t\_progress_{jt-1} + \beta_2 t\_progress^2_{jt-1} + \gamma_1 \ln(Tenure_{jt}) + \gamma_2 \ln Rev_j + \phi X_j + \epsilon_{jt}, \quad (11)$$

where y_{jt} is the outcome variable (either $\ln(ManagerHour_{jt}+1)$, $\ln(TeamHour_{jt}+1)$, or $\ln(TeamSize_{jt}+1)$), X_j is a vector of manager, industry, and job-type fixed effects, and ϵ_{jt} is the error term that is clustered by job type and year.

Using $t\_progress_{jt-1}$, our regression examines the effect of the job progress accomplished in the previous month on the outcome variables.[14] The pre-determined $t\_progress_{jt-1}$ helps to avoid contemporaneous correlations between the error term and job progress. Regression (11) enables us to see the evolution of time spent by the manager, her team,

[14] We add a value of 1 to the raw value of those variables with logarithms because their raw value may involve zeros.

and team size as a job progresses. In this and other regressions, we treat ln$(Tenure_{jt})$ and ln Rev_j as control variables.

By industry practice, the contract pre-specifies the starting date of a job before a design team is compiled because this date is often determined by client needs. However, the ending date of a job is correlated with the characteristics of the manager and/or his team; hence $t\_progress_{jt-1}$ and its squared term in (11) are endogenous. For instance, omitted variables such as the changing composition and quality of the team members may affect both the time of job completion (and hence $t\_progress_{jt-1}$) and our outcome variables. Note that the pre-determined starting time of the project does not relate to the missing information about the specific composition and quality of the design team. This eliminates - or at least mitigates - the relevant omitted-variable bias.

To correct the endogeneity of $t\_progress_{jt-1}$ and its squared term, we follow the procedure proposed by Wooldridge (2010, p. 939). Specifically, we use an "extended" version two-stage-least-square (2SLS) regression to estimate (11). The procedure outlined in Wooldridge (2010) requires the generation of predicted values of $t\_progress_{jt-1}$ and the squared term of the predicted values as the instrumental variables for the original variables as the first step. To accomplish this, we obtain the predicted values of $t\_progress_{jt-1}$ by estimating the fractional probit function (Wooldridge 2010, pp.750-751):

$$E(t\_progress_{jt-1}|\mathbf{x}, \mathbf{z}) = \Phi[\alpha_1 ln(Tenure_{jt}) + \alpha_2 lnRev_j + \lambda z_j, \quad (12)$$

where $\mathbf{x}$ is the vector of the included variables in (11), and ln$(Tenure_{jt})$, lnRev_j, and $\mathbf{z}$ are the excluded variables. The second step is to use the standard 2SLS to estimate (11) by treating the predicted values of $t\_progress_{jt-1}$ and its squared term as instruments for $t\_progress_{jt-1}$ and $t\_progress^2_{jt-1}$ respectively in the base-line regression (11).

The excluded variables, $\mathbf{z}$, in the fractional probit model (12) take advantage of the exogenous nature of the starting date of job j. They are:

- $InactiveFirstThree_j$: a categorical variable representing the number of inactive months (identified in data as no labor input from anyone) in the first three months after job j's start date. The inactivity is typically caused by unanticipated situations of the client, licensing, or other administrative issues. The longer the initially inactive period is, the more likely some idiosyncratic problems and issues may slow down the job progress.

- $StartYear_j$, $StartMonth_j$: two dummy variables representing the start year and start month of job j. Certain years may experience external shocks (e.g., government policy, the occurrence of natural disasters) while certain months may have fewer working days because of national and regional holidays. These peculiarities may impact the formation of the team and the manager's initial, essential tasks of delegation and coordination effort.

- For each job in each month except the first month, we calculate $DayStart_{jt-1}$ - the number of days to the end of the previous month since start - by using the first day of the next month minus the start date (e.g., if a job starts on June 15th, then the $DayStart_{jt-1}$ in June is calculated as July 1st minus June 15th, or 15 days). Other things constant (e.g., job size, manager's experience), a job that has an earlier starting date and has logged more days of working, ought to have an earlier ending date as well.

Our data, unfortunately, lacks a job's completion date stipulated in the original contract - if any - that the firm signed with its clients. The fractional probit in (12), nonetheless, provides a helpful way to estimate the expected job progress and, thus, the date of job completion.

As discussed in Wooldridge (2010), it is incorrect to directly use the excluded variables in estimating (11) by conventional 2SLS. This is because the endogenous variable $t\_progress_{jt-1}$ is not linear but has a range of $[0, 1]$. As such, generating its predicted values as an instrumental variable becomes necessary.

5.2 Effect of information frictions

We add C_{jt} (common client) and $Prox_j$ (geographic proximity) to the base-line regression (11) to examine the effect of information frictions on our outcome variables:

$$\begin{aligned} y_{jt} = \beta_0 + \beta_1 t\_progress_{jt-1} + \beta_2 t\_progress^2_{jt-1} \\ + \beta_3 C_{jt} + \beta_4 C_{jt} \cdot t\_progress_{jt-1} + \beta_5 Prox_j + \beta_6 Prox_j \cdot t\_progress_{jt-1} \\ + \gamma_1 \ln(Tenure_{jt}) + \gamma_2 \ln\, Rev_j + \phi_j + \epsilon_{jt}, \quad (13) \end{aligned}$$

To estimate (13) by 2SLS, all terms involving $t\_progress_{jt-1}$ are instrumented by its predicted value from estimating (12) and its derived terms in the information friction regression. We again follow the procedure proposed by Wooldridge (2010, p. 939) as in the previous subsection.

5.3 Effect of managerial workload

To examine the effect of managerial workload, we add $NoJob_{jt}$ to the base-line regression (11) above:

$$\begin{aligned} y_{jt} = \beta_0 + \beta_1 t\_progress_{jt-1} + \beta_2 t\_progress^2_{jt-1} \\ + \beta_7 \ln(NoJob_{jt}) + \beta_8 \ln(NoJob_{jt}) \cdot t\_progress_{jt-1} \\ + \gamma_1 \ln(Tenure_{jt}) + \gamma_2 \ln Rev_j + \gamma_3 \ln RevDep_{jt} + \phi_j + \epsilon_{jt}, \quad (14) \end{aligned}$$

In addition to $t\_progress_{jt}$ and its squared term, $NoJob_{jt}$ in (14) is also endogenous. To see this, the manager's workload may be affected by unobserved "supply" factors such as the specialist teams the manager can amass and "demand" factors such as the overall job arrivals to her department that also impact the outcome variables of time spent and team size. To control for unobserved "demand" factors, we include ln$RevDepRet_{jt}$, the aggregate job revenues of the department to which the manager belongs, as an explanatory variable in (14). To correct for the "supply" endogeneity, we use ln$PeerYRet_{jt}$ ("peer's time to retire") as the instrumental variable for ln$NoJob_{jt}$ in the 2SLS regression to estimate (14). The firm has a mandatory retirement age of sixty. $PeerYRet_{jt}$ is the average years until retirement for the peer managers of the focal manager of job j in the year indicated by time t. The peers are other job managers who work in the same department as the focal manager. This instrumental variable is relevant to the number of jobs of the focal manager because the focal manager will be assigned more jobs if other managers in the same department are relatively younger. This variable also meets the exclusion condition because peer managers' time to retire does not directly affect the focal manager or the team's monthly time spent on a given job.

To estimate (14) by 2SLS as prescribed in the Wooldridge procedure (2010, p. 939), we first obtain the predicted values from the fractional probit model but with $\ln RevDepRet_{jt}$ and $PeerYRet_{jt}$ as the additional variables in (12). Then the endogenous variables are instrumented by $PeerYRet_{jt}$, the predicted $t\_progress_{jt-1}$, its squared term, and its interactions with $PeerYRet_{jt}$.

6 Main Result

In this section, we review the results of the impact of job progress, knowledge intensity, information frictions and managerial workload on managerial and team attention to a given job, as well as their robustness checks.

6.1 Time trend of manager hours, team hours and team size

Predicted job progress. As discussed in Section 5.1, we use the predicted values of job progress to study the trend of managerial time allocation (and that of her team) to a given job. Table 2 shows the results on predicted job progress, obtained from the fractional probit regression in (12). While inactivity during the first month after the starting date has a positive effect on job progress (estimate=0.038), any further inactivity and delay leads to increasingly slower job progress (estimates are -0.053 and -0.087 for two and three months delay, respectively). In addition, jobs starting earlier, having smaller revenue, or jobs that are managed by more senior managers, show faster progress. A majority of the start years (9 out of 13) and a significant portion of the start months (4 out of 12) dummies are statistically significant at the 10%-level or smaller (not shown in the table).

<insert Table 2 about here>

Time trend of manager hours, team hours, and team size. Table 3 shows the key results on the time trend of manager hours, team hours, and team size as a function of job progress, obtained from estimating regression (11).[15] Columns 1, 2, and 3 look at manager hours, team hours, and team size, respectively. The positive coefficients of $t\_progress_{jt-1}$ and the negative coefficients of $t\_progress^2_{jt-1}$ in columns 1 and 2 on the manager and the team hours imply their inverted U-shape relation with job progress. That is, their hours initially increase but decrease after reaching a peak. Based on the estimates of those two terms, it is straightforward to recover the point of the job progress at which the peak hours of the manager and the team occur. The first-order ("FOC") and second-order ("SOC") conditions of the maximum hours of the regression equation in column 1 are $(\beta_1 + 2\beta_2 t\_progress_{jt-1}) = 0$ and $\beta_2 < 0$ respectively. The SOC is satisfied with the negative estimate on $t\_progress^2_{jt-1}$ in column 1. Substituting $\widehat{\beta}_1 = 1.03$ and $\widehat{\beta}_2 = -2.22$ into the FOC yields $t\_progress^*_{jt-1} = 0.23$ for the manager's peak hours. Similarly, using the two estimates in column 2, we find $t\_progress^*_{jt-1} = 0.35$ for the team's peak hours. It is instructive to notice that the timing of a typical manager's peak hours (at the 23% mark of job completion) precedes that of her team (at the 35% mark). This is the first-ever evidence showing the leading role played by the manager in sequential coordination (e.g., Castaner and Ketokivi 2018). These results also show that both the manager and the team concentrate their effort on the earlier part of jobs, likely to specify and coordinate the tasks involved in the job. After that, the manager and the team decrease their involvement in the execution stage. The result on team size in column 3 shows a similar pattern.[16]

[15] Column 1 in Table A3-1 in Appendix 3 shows the corresponding first-stage results. The coefficients of the predicted values of job progress and its squared term show high statistical significance. Tables A3-2 to A3-8 in Appendix 3 include the results of all first-stage regressions of other analyses in the paper. All first-stage regressions' results in our analyses pass the relevance condition with a partial-F statistic larger than 10 (Staiger and Stock 1997).

[16] Table A3-9 in Appendix 3 has the results on the time trend of our outcome variables, including only $t\_progress_{jt-1}$ but not its squared term. Those results show that the marginal effect of job progress on all outcome variables is negative.

<insert Table 3 about here>

Figure 1 visually shows the trend of hours spent and team size as a job progresses from start to completion by assuming the control variables at their mean values. The first graph shows that a typical manager initially devotes relatively plenty of time to a new job - more than 3.5 hours in a month. As shown above, their time increases to a peak at the 23% mark into the job, but then it monotonically decreases to only 0.5 hours per month when the job concludes. The second graph shows a similar time trend for her architect teams: team hours start with about 80 hours per month, peak at over 140 hours just at the 35% mark, and then monotonically decrease to about Twenty hours when the job is completed. Those temporal patterns clearly demonstrate coordinated time use between the managers and their design teams. Similar to team hours, team size in the third graph follows a similar inverted-U shape with the maximum size of just above six members at the 38% mark of job progress. [17]

<insert Figure 1 about here>

Lastly, we discuss briefly our two control variables in Table 3. First, larger jobs - measured by predetermined revenue Rev_j - have a large positive scale effect on manager hours (estimate=0.45) and team hours (estimate=1.06). That larger jobs have bigger teams is intuitive too. This supports our Proposition 1(3). Second, the seniority of the manager has opposite effects on managerial and team involvement. Column 1 shows that more senior managers spend less time on their jobs (estimate=-0.12) by having larger teams that spend more hours. These may be explained by the facts that more senior managers have "assistants" in their teams, as we hypothesized in Proposition 4.

Time trend of knowledge-intensive jobs. As we mentioned in our introduction, the key features of knowledge-intensive work is its non-repetitive, intangible nature. In architectural jobs that require high creativity, one would expect that the involvement of the manager and the team should be higher, especially in the beginning. The more creative types of jobs in our contexts are planning and development, schematic design, and

[17] Figure A3-1 in Appendix 3 shows the time trend results using only observations where $ManagerHour_{jt}$ are strictly positive. The results show that the decreasing time trend holds when the samples exclude the months when the manager does not spend any time.

design development, whereas the less creative types are construction documentation and construction supervision. We classify the jobs in the first category as "knowledge-intensive" jobs and the second category as "less knowledge-intensive" jobs. To examine the difference in job progress, the baseline model includes a dummy variable $KnowInten_j$ of the two job categories, where $KnowInten_j = 1$ for knowledge-intensive jobs and 0 otherwise, and its interaction with $t\_progress_{jt-1}$ as the following:

$$y_{jt} = \beta_0 + \beta_1 t\_progress_{jt-1} + \beta_2 t\_progress^2_{jt-1} + KnowInten_j + KnowInten_j \times t\_progress_{jt-1} + \gamma_1 \ln(Tenure_{jt}) + \gamma_2 \ln Rev_j + \phi_j + \epsilon_{jt}. \quad (15)$$

Table 4 shows the regression results on the outcome variables specified in (15) and Table A3-2 in Appendix A3 tabulates the first-stage result. The positive coefficients of the dummy variable $KnowInten_j$ in column 1 (=0.82), column 2 (=0.77), and column 3 (=0.25) imply that manager hours, team hours, and team size all get increased in the initial stages for more knowledge-intensive jobs. This matches our idea that ex ante coordination of creative jobs is more intensive. Other explanatory variables in (15) have the same directional effects as those in the baseline model in (11).

<insert Table 4 and Figure 2 about here>

Figure 2 plots the three graphs on time spent and team size evolution. The bold lines denote high- versus less-knowledge intensive jobs and the thin lines represent their confidence intervals. The first graph shows that the typical manager spends significantly more time early in the process on knowledge-intensive work than less knowledge-intensive work. The difference in time spent remains almost throughout the job, although the difference later on is not statistically significant. Similar patterns are shown in the second graph on team hours. As such, the first two graphs imply that knowledge-intensive jobs are more attention-demanding and coordination-intensive (Drucker 1999), especially in the initial stages of the job. The timing of the peak hours in those two graphs again shows the temporally leading role of the manager.

6.2 Impact of information frictions: common clients and proximity

Next, we analyze the impact of information frictions, using common clients and proximity to job sites, on the time trend of manager and team hours. With two additional explanatory variables - C_{jt} and $Prox_j$ - in the outcome regression in (13), the Wooldridge procedure requires their inclusion in the fractional probit model in (12) as well. Table 5 shows the results. Nearby job sites correlate with slower progress (estimate=-0.004) whereas common clients who have multiple concurrent jobs under the supervision of the same manager correlate with faster progress (estimate=0.016). However, the counter-intuitive negative effect of proximity on job progress disappears once we use quarterly averages, as shown in the next subsection.

Table 6 shows the results of the outcome regression of the 2SLS specified in (13).[18] As both variables measure (a lack of) information frictions, it is reassuring that common client and proximity show the same directional effects. Both variables yield negative main effects but positive interaction effects in the three columns on manager hours, team hours, and team size. These results are intuitive. Ex ante coordination involves mainly information acquisition - learning about client needs and job-specific requirements. When the manager handles more jobs from the same client or the job site is closer to the firm, information frictions become smaller, allowing employees to economize their efforts on ex ante coordination. In other words, the manager and her team spend more of their limited attention on ex ante information acquisition, coordination, and task delegation when the client is new or the job is far away. These results are consistent with Proposition 1(2). In contrast, and consistent with our theory, information frictions have no such effect (or a much smaller one) for the later stages of a job that mainly involve job execution and ex post coordination. With the same range of $[0, 1]$ of the two variables, we note that common client has a larger main effect. In comparison, job proximity has a larger interaction effect (except that the magnitudes of manager hours' interaction are very close).

<Insert Tables 5 and 6 about here>

Using the results in Table 6, we plot the corresponding graphs in Figure 3 by dis-

[18] In Table A3-3 in Appendix A3, we tabulate all the corresponding first-stage regressions on information friction and its robustness checks in the subsection.

tinguishing between jobs that have higher versus low information frictions. High and low information frictions are constructed by letting C_{jt} and $Prox_j$, respectively, be one standard deviation below and above their means. The three graphs show, respectively, that more manager and team hours and larger team sizes particularly occur in the first phases of those jobs for which information frictions are high. This supports the view that more ex ante work is needed due to a lack of information.

<Insert Figure 3 about here>

Robustness checks: quarterly average and job fixed effects. We conduct two sets of robustness checks. First, by replacing ϕ_j, job fixed effects are used. This eliminates any endogeneity caused by correlations between time-invariant job, manager, or team characteristics and the error term. Table A3-11 in Appendix 3 shows the fractional probit regression where the effects of the remaining time-varying variables are qualitatively the same as in Table 6. On our outcome regressions in Table A3-12, the main and interaction effects of common client in the second stage are also similar to those obtained from the original regression in (13). The two coefficients in the last column on common client are statistically significant: the manager spends more time in ex ante coordination when more jobs are coming from repeat customers.

Second, given rational inattention, manager and team hours may not move smoothly from one month to another during a job's duration. If so, using a quarterly average of the outcome variables is more suitable. Tables A3-13 and A3-14 in Appendix 3 show the job progress prediction and the second-stage results, respectively. Again, the results are qualitatively similar to our monthly regressions. Notice that the negative effect of job proximity on job progress in Table A3-13 becomes tiny and is no longer statistically significant.

6.3 The impact of a manager's workload

We now turn to our results on the effect of the manager's workload. As shown in Table A3-5 in the Appendix, both peer managers' time to retire and departmental job revenues have a highly significant and positive impact on the focal manager's workload, as shown in the first-stage workload regression results of (14). This confirms their relevance to the number of jobs assigned to the focal manager. Specifically, managers face a heavier job workload when demand is higher and when their peers are more junior.

Table 7 shows the results of using the fractional probit model to generate the predicted value of $t\_progress_{j,t-1}$. Higher departmental job revenues in a given month slow down the progress of the focal job, possibly because of a tighter supply of workers. The tiny positive estimate of ln$PeerYRet_{jt}$ implies that peer managers' time to retire has little impact on the job progress of the focal manager.

The second stage results in Table 8 show how the predicted workload, ln($NoJob_{jt}$), has a negative main effect on manager hours, although the coefficient is not statistically significant. The interaction effect with job progress is also negative. However, the main and interaction effects on team hours are positive and negative, respectively. These results imply that the manager spends less time ex ante under a heavier workload, but the team still concentrates its hours upfront. One can verify that the peak team hours happen at the 18.4% mark of a job when we take the manager workload one standard deviation above the mean. This is much earlier than the 35% mark in the original analysis.[19] This is in sharp contrast with our previous analyses where we obtained *positive* main effects of knowledge-intensive jobs and jobs with less information friction for *both* manager and team hours. In other words, the team tends to increase its share of time spent - especially ex ante hours - when the manager's workload becomes heavier, which is consistent with our model. Departmental revenue, however, yields statistical non-significant coefficients across the three outcome variables.

Figure 4 plots the graphs on manager and team hours and team size using the 2SLS workload results. High and low levels are constructed by letting ln($NoJob_{jt}$) be one standard deviation above and below their mean, respectively. Unlike previous analyses in which both the manager and her team have heightened ex ante hours when jobs are less routine or informative, the first two graphs here show that the manager's ex ante hours are at low levels under high workload; in contrast, the team's ex ante hours are at high levels. As such, our results suggest the team has to substitute for the manager's

[19] We do so by substituting the estimates in the second column in Table 8 in the FOC and by assuming a workload that is one standard deviation above the mean. Peak team hours are then reached when $-1.304 + 2.870 - 2 \times 4.159 \times t\_progress_{jt-1} = 0$ or still when $t\_progress_{jt-1} = 18.4\%$.

lack of attention when she has more jobs to work on. These results support Proposition 3, which states the substitution effect between the manager hours and the team hours when the team moves along an "isoquant" in the cost minimization problem. The result is also consistent with our discussion that a senior managers can save time by working with an assistant manager (Proposition 4).

<Insert Tables 7 and 8, and Figure 4 about here>

Robustness checks: job fixed effects and quarterly average. We conduct two robustness checks for the workload regressions using (i) job fixed effects and (ii) the quarterly average of the outcome variables. Using job fixed effects yields similar results for the effect of workload on predicted job progress and the three outcome variables. Tables A3-15 and A3-16 in Appendix 3 show the results. In addition, quarterly averages also continue to generate robust results, as seen in Tables A3-17 and A3-18 in the Appendix.

7 Economic significance

In our theoretical model, managerial attention is optimally allocated to ensure both ex ante and ex post coordination. Deviations from the optimal time spent reduce profitability. Labor and related incidental costs (e.g., travel expenses) are arguably the most significant portion of variable costs in knowledge work. The difference between the gross revenue of a job, which is predetermined, and its variable cost is known as the contribution margin. The contribution margin is an important measure of short-term profits for the firm. If the model successfully captures a significant part of the desired balance in manager's time allocation, time deviations by the manager should reduce the contribution margin of the design jobs under her supervision.

To visualize the impact of managerial time deviations on total costs, we first use model 1 in Table 6 to calculate predicted hours, $Manag\hat{e}rHour_{jt}$. We then define the difference between the observed and the predicted hours as

$$HourDiff_j = \sum_t \left(ManagerHour_{jt} - Manag\hat{e}rHour_{jt} \right),$$

and transform $HourDiff_j$ by using the following logarithm function to reduce its dispersion and improve visualization:

$$g(x) = \begin{cases} \ln x + 1 & x \geq 1 \\ x & -1 < x < 1 \\ -(\ln(-x) + 1) & x \leq -1 \end{cases},$$

where $g(x)$ is continuous at $x = \pm 1$. Denote $FlatHourDiff_j = g(HourDiff_j)$.

We then run the following regression, including quadratic and cubic terms of $FlatHourDiff_j$, to estimate the nonlinear effects of time deviations (as measured by hour differences):

$$\ln Cost_j = \beta_0 + \sum_{k=1}^{3} \beta_{1,k} FlatHourDiff_j^k + \beta_2 \ln Rev_j + Industry_j + JobType_j + \epsilon_j,$$

where $Cost_j$ is the variable cost of job j.

Figure 5 plots the implied polynomial cost curve using the estimated values of $\beta_{1,k}$. It shows that the minimum cost almost coincides with our predicted hours spent. Deviations to either direction are associated with higher costs (and hence lower short-run profit) than under our predicted hours.

<Insert Figure 5 about here>

In the above analysis, a lack of managerial hours in one month can be offset by excess hours in the next month. A more appropriate measure of time deviations for a given job is arguably to calculate the (sum of the) *absolute value* of hour deviations from predicted hours spent in each period. To do so, we use the following formula:

$$HourDeviation_j = \sum_t |ManagerHour_{jt} - \hat{ManagerHour}_{jt}|.$$

We then estimate the regression in which the cost-to-revenue ratio is a primary measure of job performance:

$$\ln\left(\frac{Cost_j}{Rev_j}\right) = \alpha_0 + \alpha_1 \ln\ HourDeviation_j + \phi_j + e_j.$$

We also use the logarithm value of the original cost, ln($Cost_j$), as an alternative dependent variable, but that regression includes ln(Rev_j) as a control variable. The OLS regressions in the first two columns in Table 9 show a high *positive* correlation between manager hour deviations and costs. Nonetheless, the manager's hour deviations can be endogenous. Other factors may be causing correlated movements between the manager's hour deviations and the cost that should not be interpreted as causal. The project may have unobserved characteristics that make it particularly difficult or challenging. To resolve this, we again use peers' time to retire as its instrumental variable in the 2SLS regressions in the last two columns. This is because a (relatively) more senior job manager may get more unobserved distractions from her leading role in the company, such as non-project-based administrative and external obligations, or may be overburdened being assigned too many projects as indicated in Section 6.3. The estimates of hour deviations in the 2SLS regressions in Table 9 remain directionally robust but have a more profound impact than those obtained from the OLS on the cost-to-revenue ratio and costs. Table A3-8 in Appendix 3 shows the high relevance of peers' time to retire as the instrument for hour deviations. Together, the 2SLS method appears to be valid and useful in showing the detrimental effect of deviations in managerial attention. In unreported regressions, we further confirm that hour deviations are correlated with higher costs and cost-to-revenue ratio when we exclude the manager's costs from the total costs incurred by the team.

But what is the reason for these higher costs? First, it is intuitive that the team increases its hours (and hence costs) when the manager spends more time than predicted. For instance, a manager may try to micromanage her team and spend too much time communicating the progress of each task. Second, we previously found (in the workload analysis) that a lower involvement by the manager, caused by a heavy workload, results in a higher involvement by the team. As such, we hypothesize that the manager's hour deviations cause higher team hours.

To examine whether the higher costs in the presence of (high) time deviations by the manager are caused by more hours spent by her team, we regress team hours on (managerial) hour deviations. We do so by both OLS and 2SLS, with the latter using peers' time to retire as the instrument. Table 10 reports the results. We find that team hours increase in (managerial) hour deviations in both regressions. Note, however, that the more legitimate 2SLS result shows a much larger positive effect on team hours. In addition, we find that the correlations of project costs with the manager's hour deviations and team hours are 0.56 and 0.55, respectively. Our analysis then supports the idea that the manager's deviations from the optimal time spent are harmful to team hours and profitability.

<Insert Tables 9 and 10 about here>

8 Conclusion

Scholars in economics and management have long recognized the importance of coordinating specialized, knowledge workers (e.g., Thompson 1967; Bolton and Dewatripont 1994; Dessein et al. 2016). In contrast to the pivotal role of monitoring in administering traditional industries, the unique, non-repetitive, and intangible characteristics of knowledge work underscore the importance of effective managerial coordination. This is especially true when employees are organized in teams and work under time scarcity on multiple projects. As team leaders, middle managers often engage in ex ante coordination, such as defining, specifying, and assigning tasks to their team members, and in ex post coordination of their teams' task execution as projects progress. Our study provides the first, much-needed evidence on the temporal nature of knowledge-work coordination. Specifically, our data on design teams in an elite business service firm show clear patterns of coordinated time use of the managers and their teams. Time spent by the manager and the team is higher in earlier stages of a job than in later ones, and this pattern is more pronounced for more knowledge-intensive jobs and jobs susceptible to more information frictions. We also find that deviations in managers' time spent from our predicted optimal hours correlate with higher team hours and lower profitability.

Our analysis has managerial implications for coordination and time use in knowledge firms. First, the observation that the manager's peak working hours precede those of her team underscores the sequential and temporal character of team processes (Castaner and Ketokivi 2018; Marks et al. 2021). The front-loaded time spent on ex ante coordination helps the manager to evaluate customer needs, identify project objectives, lay down the course and timeline of actions, and assign tasks. Only after that can her team efficiently execute the project. This is particularly important when ex ante information about the customer is lacking or for projects involving more knowledge-intensive elements such as design and creativity. Otherwise, if a manager's time allocation is suboptimal, it may lead to a significant surge in team hours and an escalation of the overall project costs. Second, our evidence on manager workload demonstrates that the team must spend relatively more time (both ex ante and ex post) to compensate for a lack of manager hours devoted to ex ante coordination. Although we do not have data on customer satisfaction or the number of design errors of completed jobs, it is reasonable to presume that the lack of managerial attention and coordination may also cause lower job quality. Together, this shows that firms should give their managers sufficient time and space to conduct ex ante coordination activities. In sum, we believe archival panel data on both leaders and their teams will yield new insights on topics such as task assignments, dynamics, and changes in team composition. We hope that subsequent studies will further explore these promising avenues.

References

[1] Aoki, Masahiko. 1990. *Information, Incentives, and Bargaining in the Japanese Economy.* Cambridge, UK: Cambridge University Press.

[2] Alonso, Ricardo, Wouter Dessein, and Niko Matouschek. 2008. When Does Coordination Require Centralization? *American Economic Review* 98(1): 145–179.

[3] Argyres, Nicholas, Janet Bercovtiz, and Giorgio Zanarone. 2019. The Role of Relationship Scope in Sustaining Relational Contracts in Interfirm Networks. *Strategic Management Journal* 41: 222-245.

[4] Bandiera Oriana, Prat Andrea, Hansen Stephen, and Sadun Raffaella Sadun. 2020. CEO Behavior and Firm Performance. *Journal of Political Economy* 28(4):1325-1369.

[5] Bartel, Ann P., Brianna Cardiff-Hicks, and Kathryn Shaw. 2017. Incentives for Lawyers: Moving Away from 'Eat What You Kill.' *Industrial and Labor Relations Review*. 70 (2): 336–358.

[6] Becker, Gary S., and Kevin M. Murphy. 1992. The Division of Labor, Coordination Costs, and Knowledge. *Quarterly Journal of Economics* 107(4): 1137-1160.

[7] Bolton, Patrick, and Dewatripont Mathias. 1994. The Firm as a Communication Network. *Quarterly Journal of Economics* 109(4): 809-839.

[8] Castaner, Xavier, and Mikko Ketokivi. Toward a Theory of Organizational Integration. *Organization Design* 23(December): 53-80.

[9] Cyert, Richard M., and James G. March. 1963. A Behavioral Theory of the Firm. Englewood, Cliffs, NJ: Prentice Hall

[10] Deming, David. 2017. The Growing Importance of Social Skills in the Labor Market. *Quarterly Journal of Economics* 132(4): 1593-1640.

[11] Dessein, Wouter, Andrea Galeotti, and Tano Santos. 2016. Rational Inattention and Organizational Focus. *American Economic Review* 106 (6): 1522-1536.

[12] Dessein, Wouter, Luis Garicano, and Robert Gertner. 2010. Organizing for Synergies. *American Economic Journal: Microeconomics* 2(4): 77-114.

[13] Dessein, Wouter, Desmond Lo, and Chieko Minami. Coordination and Organization Design: Theory and Micro-evidence. *American Economic Journal: Microeconomics* 14(4): 804-843.

[14] Dessein, Wouter, and Tano Santos. 2006. Adaptive Organizations. *Journal of Political Economy* 114 (5): 956-995.

[15] Drucker, Peter F. 1999. Knowledge-worker Productivity: the Biggest Challenge. *California Management Review* 41(2): 79-94.

[16] Edmondson, Amy C. 2012. *Teaming: How Organizations Learn, Innovate, and Compete in the Knowledge Economy.* San Francisco: Jossey-Bass.

[17] Englmaier, Florian, Stefan Grimm, Dominki Grothe, David Schindler, and Simeon Schudy. 2021. The Value of Leadership: Evidence from a Large-Scale Field Experiment. *CESifo Working Paper* No. 9273.

[18] Faraj, Samer, and Yan Xiao. 2006. Coordination in Fast-Response Organizations. *Management Science* 52(8): 1155-1169.

[19] Foss, Nicolai J. 2005. *Strategy, Economic Organization, and the Knowledge Economy* Oxford University Press.

[20] Frederiksen, Anders, Lisa B. Kahn, and Fabian Lange. 2020. Supervisors and Performance Systems. *Journal of Political Economy* 128(6): 2123-2186.

[21] Friebel, Guido, Matthias Heinz, and Nikolay Zubanov. 2022. Middle Managers, Personnel Turnover, and Performance: A Long-Term Field Experiment in a Retail Chain. *Management Science* 68(1): 211-229.

[22] Garicano, Luis. 2000. Hierarchies and the Organization of Knowledge in Production. *Journal of Political Economy* 108(5): 874-904.

[23] Garicano, Luis, and Thomas N. Hubbard. 2016. The Return of Knowledge Hierarchies. *Journal of Law, Economics, and Organization* 32(4): 653-684.

[24] Geanakoplos, John, and Paul Milgrom. 1991. A Theory of Hierarchies Based on Limited Managerial Attention. *Journal of the Japanese and International Economies* 5: 205-225.

[25] Ghazimatin, Elham, Erik A. Mooi, and Jan B. Heide. 2022. Business-to-Business Projects, Task Configuration, and Innovation. *Journal of Marketing Research* 60(1): 72-91.

[26] Guadalupe, Maria, Hongyi Li, and Julie Wulf. 2014. Who Lives in the C-Suite? Organizational Structure and the Division of Labor in Top Management. *Management Science* 60(4): 824-844.

[27] Hoffman, Mitchell, and Steven Tadelis. 2021. People Management Skills, Employee Attrition, and Manager Rewards: An Empirical Analysis. *Journal of Political Economy* 129(11): 243-285.

[28] Huang, Zhangkia, Lixing Li, Guangrong Ma, and Lixin Colin Xu. 2017. Hayek, Local Information, and Commanding Heights: Decentralizing State-Owned Enterprise in China. *American Economic Review* 107(8): 2455-78.

[29] Jost, Peter-J. 2011. *The Economics of Organization and Coordination* Northampton, MA: Edward Elgar.

[30] Kalnins, Arthus, and Francine Lafontaine. 2013. Too Far Away? The Effect of Distance to Headquarters on Business Establishment Performance. *American Economic Journal: Microeconomics* 5(3): 157-179.

[31] Lazear, Edward P., and Michael Gibbs. 2017. *Personnel Economics in Practice* Hoboken, New Jersey: Wiley.

[32] Lazear, E. P., Kathryn L. Shaw, and C.T. Stanton. 2015. The Value of Bosses. *Journal of Labor Economics* 33(4): 823-861.

[33] Lo, Desmond, Francisco Brahm, Wouter Dessein, and Chieko Minami. 2022. Managing with Style? Micro-evidence on the Allocation of Managerial Attention. *Management Science* 68(11): 8261-8285.

[34] MacLeamy, Patrick. 2020. *Designing a World-Class Architecture Firm* Hoboken, New Jersey: Wiley.

[35] Marks, Michelle A., John E. Mathieu, and Stephen J. Zaccaro. 2001. A Temporally Based Framework and Taxonomy of Team Processes. *Academy of Management Review* 26(3): 356-376.

[36] Ogura, Kazuya. 2010 Managerial Working Hours and Heavy Workloads. *Japan Labor Review* 7(4): 45-71.

[37] Pressman, Andrew. 2014. *Designing Relationships: The Art of Collaboration in Architecture* Routledge.

[38] Rantakari, Heikki. 2008. Governing Adaptation. *Review of Economic Studies* 75 (4): 1257–1285.

[39] Roberts, John, and Kathryn L. Shaw. 2022. Managers and the Management of Organizations. *NEBR Working Paper 30730.*

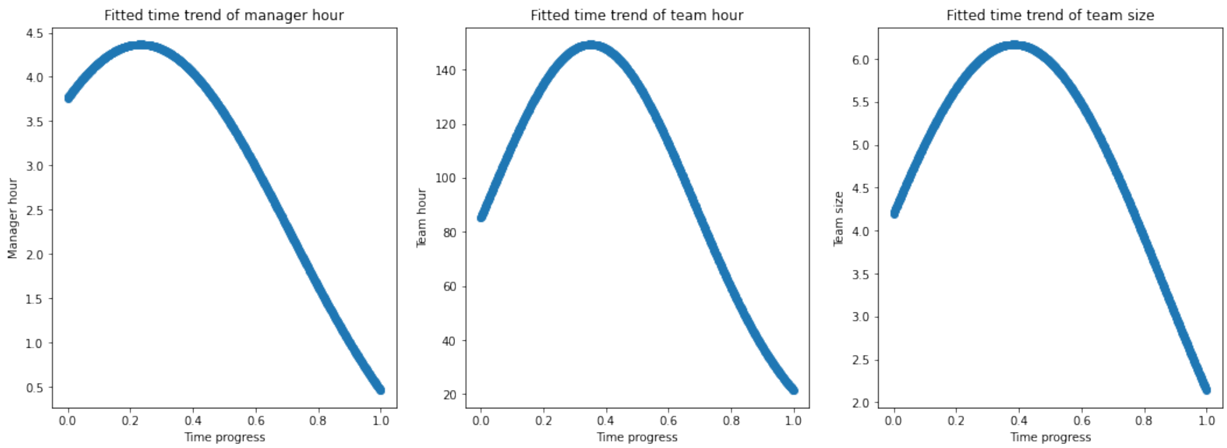
[40] Simon, Herbert A. 1947. Administrative Behavior. New York, NY: Free Press.

[41] Staiger, Douglas, and James H. Stock. 1997. Instrumental Variables Regression with Weak Instruments. *Econometrica* 65(3): 557-586.

[42] Thompson, J. D. 1967. *Organizations in Action: Social Science Bases of Administrative Theory*. New York, NY: McGraw-Hill.

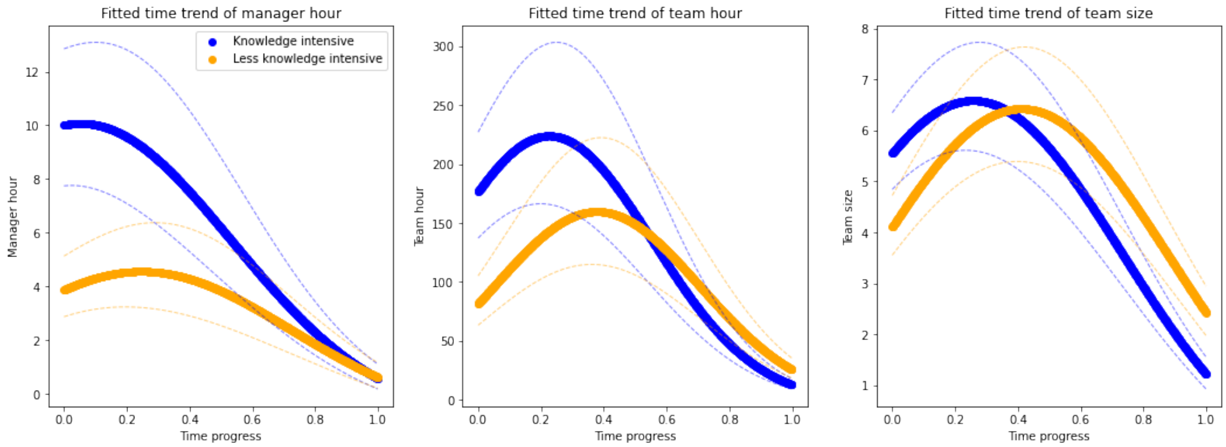
[43] Wageman, Ruth, Heidi Gardner, and Mark Mortensen. 2012. The Changing Ecology of Teams: New Directions for Teams Research. *Journal of Organizational Behavior* 33(3): 301-315.

[44] Zhou, Yue Maggie. 2013. Designing for Complexity: Using Divisions and Hierarchy to Manage Complex Tasks. *Organization Science.* 24(2): 339-355.



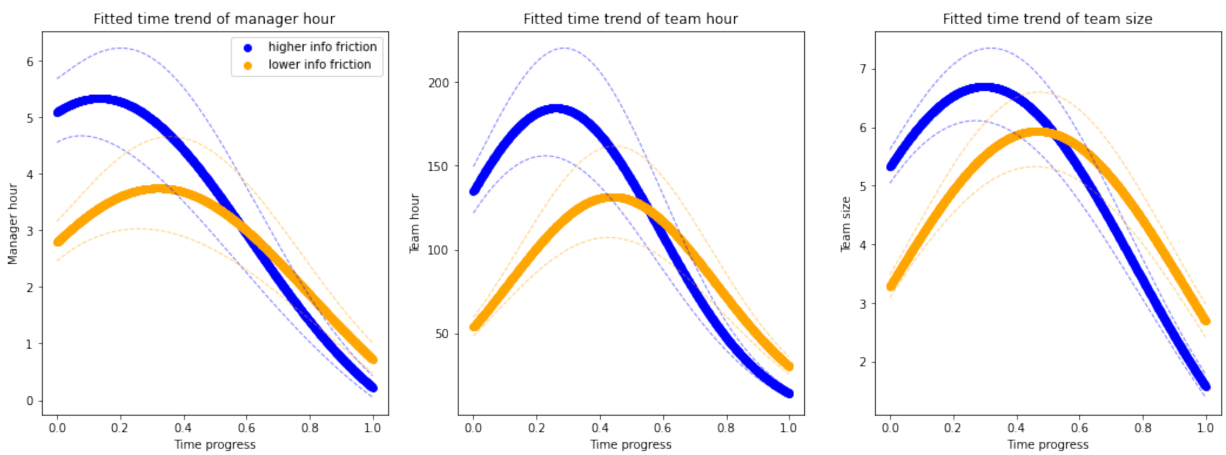
Fitted curves against $t\_progress_{jt-1}$. Control variables are taken at the mean.

Figure 1 – Time trend of hours



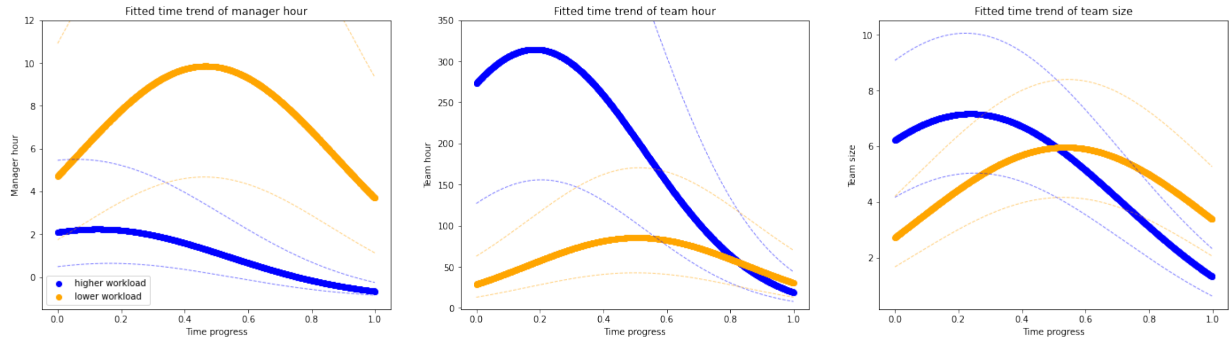
Classification by job types. Knowledge-intensive types include Planning & development management, Schematic design, and Design development. Less knowledge-intensive types include Construction documentation and Construction supervision. Controls are taken at the mean.

Figure 2 – Time trend of hours by job types



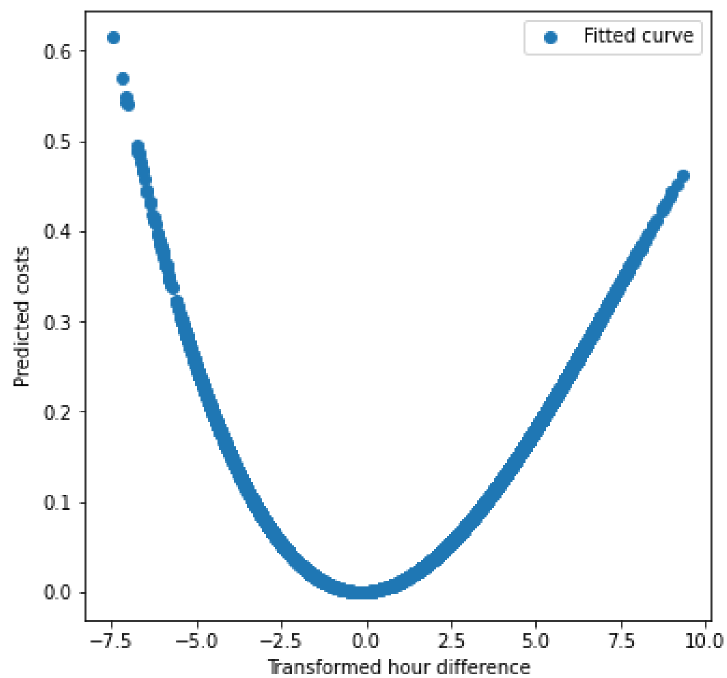
Curves of high (low) information friction are calculated by letting C_{jt} and $Prox_j$ one standard deviation lower (higher) than their means. Controls are held at mean values.

Figure 3 – Time trend of hours by information barriers



Curves of high (low) workload are calculated by letting $\ln NoJob_{jt}$ one standard deviation higher (lower) than then its mean. Controls are held at mean values.

Figure 4 – Time trend of hours by workload



Note: The figure plots the polynomial implied by the estimated values of $\beta_{1,k}$. Benchmark hours are predicted from the 2SLS model.

Figure 5 – Fitted curve between cost-revenue ratio and flatted hour difference, 2SLS model

	count	mean	std	min	25%	50%	75%	max
$ManagerHour_{jt}$	53654	9.384	18.534	0.000	0.000	2.500	11.000	304.500
$TeamHour_{jt}$	53654	290.109	438.576	0.000	37.500	134.000	364.000	9832.000
$TeamSize_{jt}$	53654	7.168	6.268	0.000	2.000	6.000	10.000	76.000
$ManagerHourShare_{jt}$	53654	0.088	0.205	0.000	0.000	0.013	0.062	1.000
$t\_progress_{jt}$	53654	0.582	0.237	0.030	0.393	0.592	0.783	1.000
C_{jt}	53654	0.067	0.124	0.000	0.000	0.000	0.077	1.000
$Prox_j$	53654	0.539	0.493	0.000	0.006	1.000	1.000	1.000
$NoJob_{jt}$	53654	17.036	11.771	1.000	9.000	15.000	22.000	87.000
Rev_j	53654	94950113.550	137212543.003	1000000.000	15060000.000	43700000.000	108459048.000	1148320000.000
$Tenure_{jt}$	53654	24.577	5.898	2.000	21.000	24.000	28.000	43.000

There are 184 unique managers and 5,133 unique jobs in the sample.

Table 1 – Summary stats

	$t\_progress_{jt-1}$	std
$InactiveFirstThree_j = 1$	0.038	0.012
$InactiveFirstThree_j = 2$	-0.053	0.013
$InactiveFirstThree_j = 3$	-0.087	0.013
$\ln DayStart_{jt-1}$	0.725	0.003
$\ln Rev_j$	-0.235	0.003
$\ln Tenure_{jt}$	0.153	0.014
Model	Fractional Probit	
No. Obs	53654	
Pseudo R^2	0.134	
Fixed Effect	W+I+J+Y+M	
No. of Start Years	13	
No. of Significant Start Year Effects	9	
No. of Start Months	11	
No. of Significant Start Month Effects	4	

Note: Start year or start month effects are regarded as significant if the p-value is lower than 0.1. $\ln Rev_j$, $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table 2 – Predict job progress

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
$t\_progress_{jt-1}$	1.032	0.330	3.178	0.363	1.675	0.161
$t\_progress^2_{jt-1}$	-2.218	0.329	-4.529	0.371	-2.182	0.164
$\ln Rev_j$	0.488	0.016	0.980	0.017	0.402	0.008
$\ln Tenure_{jt}$	-0.169	0.035	0.266	0.034	0.179	0.015
Model	2SLS		2SLS		2SLS	
Fixed Effect	W+I+J		W+I+J		W+I+J	
No. Obs	53654		53654		53654	
Adj. R^2	0.206		0.450		0.502	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$MH_{jt} = ManagerHour_{jt}$, $TH_{jt} = TeamHour_{jt}$, $TS_{jt} = TeamSize_{jt}$. $t\_progress_{jt-1}$ is instrumented by the predicted value. $t\_progress^2_{jt-1}$ is instrumented by the squared predicted value. $\ln Rev_j$ and $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table 3 – Time trend of hours

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
$t\_progress_{jt-1}$	1.076	0.338	3.521	0.377	1.828	0.166
$t\_progress^2_{jt-1}$	-2.184	0.334	-4.657	0.384	-2.229	0.169
$KnowInten_j$	0.815	0.117	0.765	0.128	0.249	0.058
$KnowInten_j \times t\_progress_{jt-1}$	-0.842	0.222	-1.420	0.259	-0.684	0.118
$\ln Rev_j$	0.447	0.015	1.062	0.015	0.449	0.007
$\ln Tenure_{jt}$	-0.121	0.035	0.225	0.034	0.151	0.015
Model	2SLS		2SLS		2SLS	
Fixed Effect	W+I		W+I		W+I	
No. Obs	53654		53654		53654	
Adj. R^2	0.191		0.433		0.483	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$MH_{jt} = ManagerHour_{jt}$, $TH_{jt} = TeamHour_{jt}$, $TS_{jt} = TeamSize_{jt}$. The table shows a linear time trend. $t\_progress_{jt-1} the predicted value instruments$. $t\_progress^2_{jt-1}$ is instrumented by the squared predicted value. $\ln Rev_j$ and $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error. Knowledge-intensive types include Planning & development management, Schematic design, and Design development. Less knowledge-intensive types include Construction documentation and Construction supervision.

Table 4 – Time trend of hours, knowledge intensity

	$t\_progress_{jt-1}$	std
$InactiveFirstThree_j = 1$	0.036	0.012
$InactiveFirstThree_j = 2$	-0.056	0.013
$InactiveFirstThree_j = 3$	-0.090	0.013
$\ln DayStart_{jt-1}$	0.725	0.004
C_{jt}	0.016	0.002
$\ln Prox_j$	-0.004	0.002
$\ln Rev_j$	-0.235	0.003
$\ln Tenure_{jt}$	0.154	0.014
Model	Fractional Probit	
No. Obs	53654	
Pseudo R^2	0.134	
Fixed Effect	W+I+J+Y+M	
No. of Start Years	13	
No. of Significant Start Year Effects	9	
No. of Start Months	11	
No. of Significant Start Month Effects	4	

Note: Start year or start month effects are regarded as significant if p-value is lower than 0.1. C_{jt}, $\ln Prox_j$,$\ln Rev_j$, $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table 5 – Predict job progress for information friction regression

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
C_{jt}	-0.178	0.032	-0.257	0.036	-0.113	0.016
$C_{jt} \times t\_progress_{jt-1}$	0.268	0.056	0.338	0.066	0.153	0.029
$\ln Prox_j$	-0.059	0.035	-0.199	0.037	-0.082	0.017
$\ln Prox_j \times t\_progress_{jt-1}$	0.140	0.062	0.486	0.069	0.221	0.031
$t\_progress_{jt-1}$	0.998	0.328	3.223	0.357	1.693	0.159
$t\_progress^2_{jt-1}$	-2.195	0.326	-4.611	0.365	-2.218	0.162
$\ln Rev_j$	0.486	0.016	0.976	0.017	0.401	0.008
$\ln(Tenure_{jt})$	-0.170	0.035	0.264	0.034	0.179	0.015
Model	2SLS		2SLS		2SLS	
Fixed Effect	W+I+J		W+I+J		W+I+J	
No. Obs	53654		53654		53654	
Adj. R^2	0.207		0.454		0.506	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$MH_{jt} = ManagerHour_{jt}$, $TH_{jt} = TeamHour_{jt}$, $TS_{jt} = TeamSize_{jt}$. $t\_progress_{jt-1}$ is instrumented by the predicted value. $t\_progress^2_{jt-1}$ is instrumented by the squared predicted value. $\ln Rev_j$, $\ln Tenure_{jt}$, C_{jt}, $\ln Prox_j$ are standardized to have zero mean and unit standard error. $Prox_j = 1/(Dist_j + 1)$ is a proximity measure.

Table 6 – Time trend of hours, information friction

	$t\_progress_{jt-1}$	std
$InactiveFirstThree_j = 1$	0.037	0.012
$InactiveFirstThree_j = 2$	-0.054	0.013
$InactiveFirstThree_j = 3$	-0.089	0.013
$\ln DayStart_{jt-1}$	0.724	0.004
$\ln (PeerYRet_{jt})$	-0.004	0.029
$\ln Rev_j$	-0.234	0.003
$\ln Tenure_{jt}$	0.148	0.015
$\ln RevDep_{jt}$	-0.065	0.006
Model	Fractional Probit	
No. Obs	53654	
Pseudo R^2	0.135	
Fixed Effect	W+I+J+Y+M	
No. of Start Years	13	
No. of Significant Start Year Effects	9	
No. of Start Months	11	
No. of Significant Start Month Effects	4	

Note: Start year or start month effects are regarded as significant if p-value is lower than 0.1. $\ln Rev_j$, $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table 7 – Predict job progress for workload regression

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
$\ln NoJob_{jt}$	-0.306	0.375	1.109	0.389	0.331	0.171
$\ln NoJob_{jt} \times t\_progress_{jt-1}$	-1.009	0.284	-1.340	0.311	-0.649	0.131
$t\_progress_{jt-1}$	1.746	0.463	2.870	0.478	1.685	0.212
$t\_progress^2_{jt-1}$	-2.955	0.483	-4.159	0.495	-2.174	0.220
$\ln Rev_j$	0.449	0.024	1.003	0.024	0.404	0.011
$\ln(Tenure_{jt})$	-0.069	0.084	0.076	0.084	0.130	0.037
$\ln RevDep_{jt}$	0.044	0.036	-0.028	0.037	-0.006	0.017
Model	2SLS		2SLS		2SLS	
Fixed Effect	W+I+J		W+I+J		W+I+J	
No. Obs	53654		53654		53654	
Adj. R^2	0.091		0.395		0.461	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$MH_{jt} = ManagerHour_{jt}$, $TH_{jt} = TeamHour_{jt}$, $TS_{jt} = TeamSize_{jt}$. $t\_progress_{jt-1}$ is instrumented by the predicted value. $t\_progress^2_{jt-1}$ is instrumented by the squared predicted value. $\ln NoJob_{jt}$ is instrumented by $\ln(PeerYRet_{jt})$. The interaction term is instrumented by the interaction term of corresponding instruments. Standard errors are clustered by job-year. $\ln Rev_j$, $\ln Tenure_{jt}$, $\ln NoJob_{jt}$ are standardized to have zero mean and unit standard error.

Table 8 – Workload and time allocation

	$\ln \frac{Cost_j}{Rev_j}$	std	$\ln Cost_j$	std	$\ln \frac{Cost_j}{Rev_j}$	std	$\ln Cost_j$	std
$\ln(HourDeviation_j + 1)$	0.023	0.006	0.099	0.008	0.828	0.254	0.455	0.088
$\ln Rev_j$			0.873	0.009			0.614	0.065
Model	OLS		OLS		2SLS		2SLS	
Fixed Effects	W+I+J		W+I+J		W+I+J		W+I+J	
No. Obs	5021		5021		5021		5021	
Adj. R^2	0.169		0.898		-3.031		0.853	

Table 9 – Costs and attention deviation

	$\ln(TH_{jt} + 1)$	std	$\ln(TH_{jt} + 1)$	std
$\ln(HourDeviation_{it} + 1)$	0.144	0.016	0.763	0.174
$\ln Rev_j$	0.863	0.018	0.411	0.128
Model	OLS		2SLS	
Fixed Effects	W+I+J		W+I+J	
No. Obs	5021		5021	
Adj. R^2	0.735		0.652	

$TH_{jt} = TeamHour_{jt}$.

Table 10 – Team hour and attention deviation

Appendix 1: Mathematical Proof

Optimal Allocation of Attention

Proof of Lemma 1

Lemma 1

- $t_M^D, t_T^D, t^1/t$ and t_M^D/t_M are decreasing in x_c, x_r and $(-x_d)$. On the other hand t_M^D/t_T^D is unaffected
- The ratios $Q^{D^*}/Q, Q^{C^*}/Q$ and Q^{E^*}/Q are independent of x_c, x_r, x_d, and μ.

Proof. The firm chooses $t_M^D, t_M^C, t_T^D, t_T^E$ and t_T^C to maximize

$$Q - L = \mu^{1-(\alpha+\beta+\gamma)} \cdot \left(Q^D\right)^\alpha \left(Q^E\right)^\beta \left(Q^C\right)^\gamma - (t_M^D + t_M^C)\lambda_M - (t_T^D + t_T^E + t_T^C)\lambda_T$$

We provide the proof for the more general case where

$$Q^C = A^C \left(\frac{t_M^C}{\upsilon}\right)^\upsilon \left(\frac{t_T^C}{1-\upsilon}\right)^{1-\upsilon} \tag{16}$$

We later set $\rho = \upsilon$

Denote $h^D(t_M, t_T) = A\frac{t_M^\rho t_T^{1-\rho}}{\rho^\rho(1-\rho)^{1-\rho}}$ and $h^C(t_M, t_T) = A\frac{t_M^\upsilon t_T^{1-\upsilon}}{\upsilon^\upsilon(1-\upsilon)^{1-\upsilon}}$. Optimizing $Q - L$ over t_M^D, t_M^C we have that

$$\begin{aligned} \mu^{1-(\alpha+\beta+\gamma)}\alpha h_1(t_M^{D*}, t_T^{D*})\frac{Q}{Q^D} &= \lambda_M \\ \mu^{1-(\alpha+\beta+\gamma)}\gamma h_1(t_M^{C*}, t_T^{C*})\frac{Q}{Q^C} &= \lambda_M \end{aligned}$$

Similarly, optimizing $Q - L$ over t_T^D, t_T^E and t_T^C, we have that

$$\begin{aligned} \mu^{1-(\alpha+\beta+\gamma)}\alpha h_2(t_M^{D*}, t_T^{D*})\frac{Q}{Q^D} &= \lambda_T \\ \mu^{1-(\alpha+\beta+\gamma)}\gamma h_2(t_M^{C*}, t_T^{C*})\frac{Q}{Q^C} &= \lambda_T \\ \mu^{1-(\alpha+\beta+\gamma)}\beta h_2^E\frac{Q}{Q^E} &= \lambda_T \end{aligned}$$

We further have that

$$\begin{aligned} h_1^D(t_M, t_T) &= \frac{1}{\rho^\rho(1-\rho)^{1-\rho}} \frac{\rho A t_M^\rho t_T^{1-\rho}}{t_M} &(17)\\ h_1^C(t_M, t_T) &= \frac{1}{\upsilon^\upsilon(1-\upsilon)^{1-\upsilon}} \frac{\upsilon A t_M^\upsilon t_T^{1-\upsilon}}{t_M} &(18) \end{aligned}$$

and

$$h_2^D(t_M, t_T) = \frac{1}{\rho^\rho(1-\rho)^{1-\rho}} \frac{(1-\rho) A t_M^\rho t_T^{1-\rho}}{t_T} \quad (19)$$

from which

$$\frac{h_1^D(t_M, t_T)}{h_2^D(t_M, t_T)} = \frac{\rho}{1-\rho} \frac{t_T}{t_M}$$

$$\frac{h_1^C(t_M, t_T)}{h_2^C(t_M, t_T)} = \frac{\upsilon}{1-\upsilon} \frac{t_T}{t_M}$$

From the FOC wrt to t_M^k and t_T^k, $k = C, D$, we must also have that

$$\frac{h_1^k(t_M^k, t_T^k)}{h_2^k(t_M^k, t_T^k)} = \frac{\lambda_M}{\lambda_T}$$

it follows that at the optimum

$$\frac{t_T^{D*}}{t_M^{D*}} = \frac{(1-\rho)\lambda_M}{\rho \lambda_T} \equiv \kappa_D$$

and

$$\frac{t_T^{C*}}{t_M^{C*}} = \frac{(1-\upsilon)\lambda_M}{\upsilon \lambda_T} \equiv \kappa_C$$

Substituting $t_T^{k*} = \kappa_l t_M^{k*}$, $l = C, D$, in (17) and (19), we obtain

$$\begin{aligned} h_1^D(t_M^{D*}, t_T^{D*}) &= A^D \frac{\rho}{\rho^\rho(1-\rho)^{1-\rho}} (\kappa_D)^{1-\rho} = A^D \left(\frac{\lambda_M}{\lambda_T}\right)^\rho \\ h_1^C(t_M^{C*}, t_T^{C*}) &= A^C \frac{\upsilon}{\upsilon^\upsilon(1-\upsilon)^{1-\upsilon}} (\kappa_C)^{1-\upsilon} = A^C \left(\frac{\lambda_M}{\lambda_T}\right)^\upsilon \end{aligned}$$

and

$$h_2^D(t_M^{D*}, t_T^{D*}) = A^D \frac{1}{\rho^\rho(1-\rho)^{1-\rho}} \frac{1-\rho}{\kappa_D^\rho} = A^D \frac{(1-\rho)}{\rho^\rho(1-\rho)^{1-\rho}} \left(\frac{\rho\lambda_T}{(1-\rho)\lambda_M}\right)^\rho = A^D \left(\frac{\lambda_T}{\lambda_M}\right)^\rho$$

From the FOC wrt to t_M^D and t_M^C, we further have that

$$\frac{h_1^D(t_M^{D*}, t_T^{D*})}{h_1^C(t_M^{C*}, t_T^{C*})} = \frac{\gamma}{\alpha}\frac{Q^D}{Q^C}$$

from which

$$\frac{Q^D}{Q^C} = \frac{\alpha A^D}{\gamma A^C}\left(\frac{\lambda_M}{\lambda_T}\right)^{\rho-\upsilon}$$

From the FOC wrt to t_E^T and t_C^T, we have that

$$\gamma h_2^C(t_M^{C*}, t_T^{C*})\frac{Q}{Q^C} = \beta h_2^E \frac{Q}{Q^E}$$

or still

$$\gamma A^C \frac{(1-\upsilon)}{s_C^\upsilon}\frac{Q}{Q^C} = \beta A^E \frac{Q}{Q^E}$$

or still

$$\frac{\gamma A^C \left(\frac{\lambda_T}{\lambda_M}\right)^\upsilon}{\beta A^E} = \frac{Q^C}{Q^E}$$

Moreover, from the FOC, we know that

$$\gamma h_1^C(t_M^{C*}, t_T^{C*})\frac{Q}{Q^C} = \lambda_M$$

from which

$$\begin{aligned} Q_C &= \frac{1}{\upsilon^\upsilon(1-\upsilon)^{1-\upsilon}}\frac{\gamma A^C \upsilon (s_C)^{1-\upsilon}}{\lambda_M} = \frac{1}{\upsilon^\upsilon(1-\upsilon)^{1-\upsilon}}\frac{\gamma A^C \upsilon}{\lambda_M}\left(\frac{(1-\upsilon)\lambda_M}{\upsilon\lambda_T}\right)^{1-\upsilon} \\ &= \gamma A^C \left(\frac{1}{\lambda_M}\right)^\upsilon \left(\frac{1}{\lambda_T}\right)^{1-\upsilon} Q \end{aligned}$$

or still

$$\begin{aligned} Q_C &= \gamma A^C \left(\frac{1}{\lambda_M}\right)^\upsilon \left(\frac{1}{\lambda_T}\right)^{1-\upsilon} Q \\ Q_D &= \alpha A^D \left(\frac{1}{\lambda_M}\right)^\rho \left(\frac{1}{\lambda_T}\right)^{1-\rho} Q \end{aligned}$$

and

$$\begin{aligned}Q^E &= \frac{\beta A^E \gamma A^C}{\gamma A^C \left(\frac{\lambda_T}{\lambda_M}\right)^{\upsilon}} \left(\frac{1}{\lambda_M}\right)^{\upsilon} \left(\frac{1}{\lambda_T}\right)^{1-\upsilon} Q \\ &= \frac{\beta A^E}{\lambda_T} Q\end{aligned}$$

Hence,

$$\begin{aligned}Q &= \mu^{1-(\alpha+\beta+\gamma)} \cdot \left(Q^D\right)^{\alpha} \left(Q^E\right)^{\beta} \left(Q^C\right)^{\gamma} \\ &= \mu^{1-(\alpha+\beta+\gamma)} \cdot \left(\alpha A^D \left(\frac{1}{\lambda_M}\right)^{\rho} \left(\frac{1}{\lambda_T}\right)^{1-\rho}\right)^{\alpha} Q^{\alpha} \left(\frac{\beta A^E}{\lambda_T}\right)^{\beta} Q^{\beta} \left(\gamma A^C \left(\frac{1}{\lambda_M}\right)^{\upsilon} \left(\frac{1}{\lambda_T}\right)^{1-\upsilon}\right)^{\gamma} Q^{\gamma}\end{aligned}$$

or still

$$Q^* = \mu \cdot \left(\alpha A^D \left(\frac{1}{\lambda_M}\right)^{\rho} \left(\frac{1}{\lambda_T}\right)^{1-\rho}\right)^{\frac{\alpha}{1-(\alpha+\beta+\gamma)}} \left(\beta A^E \frac{1}{\lambda_T}\right)^{\frac{\beta}{1-(\alpha+\beta+\gamma)}} \left(\gamma A^C \left(\frac{1}{\lambda_M}\right)^{\upsilon} \left(\frac{1}{\lambda_T}\right)^{1-\upsilon}\right)^{\frac{\gamma}{1-(\alpha+\beta+\gamma)}}$$

Note that if $\rho = \upsilon$, then this is equal to

$$Q^* = \mu \cdot \left(\left(\frac{1}{\lambda_M}\right)^{\rho} \left(\frac{1}{\lambda_T}\right)^{1-\rho}\right)^{\frac{\alpha+\gamma}{1-(\alpha+\beta+\gamma)}} \left(\alpha A^D\right)^{\frac{\alpha}{1-(\alpha+\beta+\gamma)}} \left(\beta A^E \frac{1}{\lambda_T}\right)^{\frac{\beta}{1-(\alpha+\beta+\gamma)}} \left(\gamma A^C\right)^{\frac{\gamma}{1-(\alpha+\beta+\gamma)}} \tag{20}$$

And

$$\begin{aligned}Q^{D^*} &= \alpha A^D \left(\frac{\lambda_T}{\lambda_M}\right)^{\rho} \left(\frac{1}{\lambda_T}\right) Q^* \\ Q^{C^*} &= \gamma A^C \left(\frac{\lambda_T}{\lambda_M}\right)^{\rho} \left(\frac{1}{\lambda_T}\right) Q^* \\ Q^{E^*} &= \beta A^E \left(\frac{1}{\lambda_T}\right) Q^*\end{aligned}$$

and

$$Q^* = \mu \cdot \left(\alpha A^D\right)^{\frac{\alpha}{1-(\alpha+\beta+\gamma)}} \cdot \left(\gamma A^C\right)^{\frac{\gamma}{1-(\alpha+\beta+\gamma)}} \cdot \left(\beta A^E\right)^{\frac{\beta}{1-(\alpha+\beta+\gamma)}} \cdot \left(\left(\frac{1}{\lambda_M}\right)^{\rho}\left(\frac{1}{\lambda_T}\right)^{1-\rho}\right)^{\frac{\alpha+\gamma}{1-(\alpha+\beta+\gamma)}} \left(\frac{1}{\lambda_T}\right)^{\frac{\beta}{1-(\alpha+\beta+\gamma)}}$$

It follows that the optimal time allocation of the manager and her team are given by

$$t_M^{D^*} = \rho\frac{\mu}{A^D}\left(\frac{\lambda_T}{\lambda_M}\right)^{1-\rho}\left[\frac{Q^{D^*}}{\mu} - (1 + k_c x_c + k_d x_d)\right]$$

$$t_T^{D^*} = \frac{(1-\rho)\lambda_M}{\rho\lambda_T} \cdot t_M^{D^*}$$

and

$$t_M^{C^*} = \rho\frac{\mu}{A^C}\left(\frac{\lambda_T}{\lambda_M}\right)^{1-\rho}\frac{Q^{C^*}}{\mu}$$

$$t_T^{C^*} = \frac{(1-\rho)\lambda_M}{\rho\lambda_T} \cdot t_M^{C^*}$$

We can further show that[20]

$$t_T^{E^*} = \frac{\beta}{(1-\rho)\gamma} t_T^{C^*}$$

Note that Q^*, Q^{D^*}, Q^{E^*} and Q^{C^*} are (i) independent of x_c and x_d and (ii) linear in μ. The lemma now follows directly from the arguments in the main text. **QED**.

Cost Minimization and Managerial Workload

Proof of Proposition 2. The Lagrangian associated with the constrained cost minimization problem of Section 3.3 is given by

$$\mathcal{L} = L + \lambda_Q \left[Q^c - Q\right] \tag{21}$$

[20]Indeed, $t_T^{E^*} = \frac{Q^{E^*}}{A^E} = \beta\left(\frac{1}{\lambda_T}\right)Q^*$ and $t_T^{C^*} = \frac{(1-\rho)}{A^C}\left(\frac{\lambda_T}{\lambda_M}\right)^{-\rho}Q^{C^*} = (1-\rho)\gamma\left(\frac{1}{\lambda_T}\right)Q^*$.

where $\lambda_Q > 0$ is the Langrange multiplier,

$$L = \left(t_M^D + t_M^C\right)\lambda_M + (t_T^D + t_T^E + t_T^C)\lambda_T$$

and

$$Q = \mu^{1-(\alpha+\beta+\gamma)} \cdot \left(Q^D\right)^{\alpha}\left(Q^E\right)^{\beta}\left(Q^C\right)^{\gamma}.$$

At the optimum, the output constraint must be binding, otherwise costs can be further reduced by lowering managerial and/or team hours. Hence, at the optimum, $Q^c - Q = 0$ and $\lambda_Q > 0$. We denote the cost minimizing attention allocations for the manager by $t_M^k(Q^c)$ with $k = D, C$, and for the team by $t_T^k(Q^c)$ with $k = D, E, C$.

Consider now the original maximization problem of Section 3.2, but where the wage of the manager and her team are respectively $\lambda_M^c \equiv \lambda_M/\lambda_Q$ and $\lambda_T^c \equiv \lambda_T/\lambda_Q$ instead of λ_M and λ_T. Note that the first-order conditions of the Lagrangian associated with the cost minimization problem are identical to the first-order conditions of this modified maximization problem. It follows that $(t_M^D(Q^c), t_M^C(Q^c), t_T^D(Q^c), t_T^E(Q^c), t_T^C(Q^c))$ are the solution to the corresponding value maximization problem, but with labor costs λ_M^c and λ_T^c. Since $\lambda_M^c/\lambda_T^c = \lambda_M^c/\lambda_T^c$, the optimal span of control of the manager, κ, remains the same at the optimum (and is independent of Q^c).

Let us denote by $Q^*(\lambda_M, \lambda_T)$ the output level that maximizes $Q - L$ given labor cost λ_M and λ_T, then we must have that

$$Q^c = Q^*(\lambda_M^c, \lambda_T^c),$$

or still, using (20),

$$Q^c = \lambda_Q^{\frac{\alpha+\beta+\gamma}{1-(\alpha+\beta+\gamma)}} \cdot Q^*(\lambda_M, \lambda_T). \tag{22}$$

Recall that $Q^*(\lambda_M, \lambda_T)$, $Q^{D^*}(\lambda_M, \lambda_T), Q^{C^*}(\lambda_M, \lambda_T)$ and $Q^{E^*}(\lambda_M, \lambda_T)$ are all independent of x_c, x_r, x_d. Since Q^c is exogenously fixed, it follows from (22) that also λ_Q is independent of x_c, x_r, x_d. Hence, the comparative statics wrt x_c, x_r, x_d in the cost minimization problem are identical to those in the profit maximization problem with wages $\lambda_M^c \equiv \lambda_M/\lambda_Q$ and $\lambda_T^c \equiv \lambda_T/\lambda_Q$. Lemma 1 and Proposition 1, parts (1) and (2) follow directly.

Finally, consider an increase in the output objective from Q^c to $Q^{c'} > Q^c$. Denoting by $(t_M^{D'}(Q^c), t_M^{C'}(Q^c), t_T^{D'}(Q^c), t_T^{E'}(Q^c), t_T^{C'}(Q^c))$ and λ'_Q the solution to this new cost-minimization problem, then $(t_M^{D'}(Q^c), t_M^{C'}(Q^c), t_T^{D'}(Q^c), t_T^{E'}(Q^c), t_T^{C'}(Q^c))$ is also the solution to the profit-maximization problem with wages $\lambda_M^{c'} \equiv \lambda_M/\lambda'_Q$ and $\lambda_T^{c'} \equiv \lambda_T/\lambda'_Q$. Moreover, at the optimum, from (22), we must have that $\lambda'_Q > \lambda_Q$. It follows that an increase in the output objective from Q^c to $Q^{c'} > Q^c$ is equivalent to the impact of a proportional wage decrease in the profit-maximization problem: it increases the time spent by the team and the manager in both period 1 (ex ante coordination) and period 2 (execution and ex post coordination). QED

Proof of Proposition 3. At the optimum, the ratio of team time and manager time spent on both ex ante coordination and ex post coordination equals $\lambda_T/\lambda_M(S)$ before the increase in workload, and $\lambda_T/\lambda_M(S') > \lambda_T/\lambda_M(S)$ after the increase in workload. At the optimum, Q^{E^c} only depends on Q^c and λ_T. Hence, both Q^{E^c} and $t_T^{E^c}$ are not affected by a change managerial workload. Similarly, Q^{D^c} and Q^{C^c} are not affected. It follows that following an increase in managerial workload, the organization will achieve the same levels of ex ante and ex post coordination, but this level will be achieved by a higher absolute and relative level of team time, and by a decrease in manager time. This proves part (1) and (2). As costs were minimized previously given $\lambda_M(S)$, this must increase total labor costs when evaluated at $\lambda_M(S)$. Labor costs will be further increased when evaluated at $\lambda_M(S') > \lambda_M(S)$. QED

Senior and junior managers

Proof of Proposition 4. Optimal managerial time allocation implies that

$$t_{aM} = \frac{(1-\phi)\lambda_{sM}}{\phi\lambda_{aM}} t_{sM}$$

Substituting t_{aM} in (10), we obtain that

$$t_M = \frac{1}{\phi}\left(\frac{\lambda_{sM}}{\lambda_{aM}}\right)^{1-\phi} t_{sM}$$

Hence, for a given managerial labor output t_M, the optimal labor input from the senior and assistant manager equal

$$t_{sM}^{*} \equiv \phi \left(\frac{\lambda_{aM}}{\lambda_{sM}} \right)^{1-\phi} t_M$$

and

$$t_{aM}^{*} \equiv (1-\phi) \left(\frac{\lambda_{sM}}{\lambda_{aM}} \right)^{\phi} t_M$$

Given Assumption 2, we must have that

$$\lambda_{sM} t_{sM}^{*} + \lambda_{aM} t_{aM}^{*} = \lambda_{jM} t_M$$

Substituting t_{sM}^{*} and t_{aM}^{*}, it follows

$$\lambda_{jM} = \lambda_{aM}^{1-\phi} \lambda_{sM}^{\phi}$$

Hence, $\lambda_{aM} < \lambda_{jM}$ implies that

$$\lambda_{jM} < \lambda_{sM}$$

Without loss of generality, let $\lambda_{jM} \equiv \lambda_M$. Then t_M^{C*} and t_M^{D*} will be exactly as before – regardless of whether a team is led by a junior or a senior manager – but with the time devoted by the senior manager satisfying

$$t_{sM}^{k*} = \phi \left(\frac{\lambda_{aM}}{\lambda_{sM}} \right)^{\mathbf{1-\text{Œ}}} t_M^{k*} < t_M^{k*} \text{ for } k = D, C$$

and the time devoted by a junior manager satisfying

$$t_{sM}^{k*} = t_M^{k*} \text{ for } k = D, C.$$

QED

Appendix 2: Stylized Facts

Managerial time use. In the two weeks of November 15 to 28, 2017, the firm surveyed 116 managers about their time use for daily activities. Although this survey was not directly related to the longitudinal data used in our regressions, it provides useful information on how managers spend their day. Table A2-1 summarizes the statistics. It shows that the top five activities, in descending order, are design work, move (i.e., transition from one place to another), rest, non-project-related work, and inside-firm meetings. After removing the "dead time" of rest and moving around, Table A2-2 shows that a significant portion - 78.2% - of the managers' useful time spent falls into design work, client/external meetings, and internal meetings. Naturally, managers use the two kinds of meetings to coordinate tasks among workers and clients, which make up 52.6% of the useful time (Table A2-3). While a manager may use design work to implement the technical aspects of a job by herself, such engagement inevitably also involves understanding of the work to facilitate coordination and guide the team on involved tasks. All in all, this survey provides evidence that most of the managerial time use appears to be coordination in nature, whether it is internally or externally.

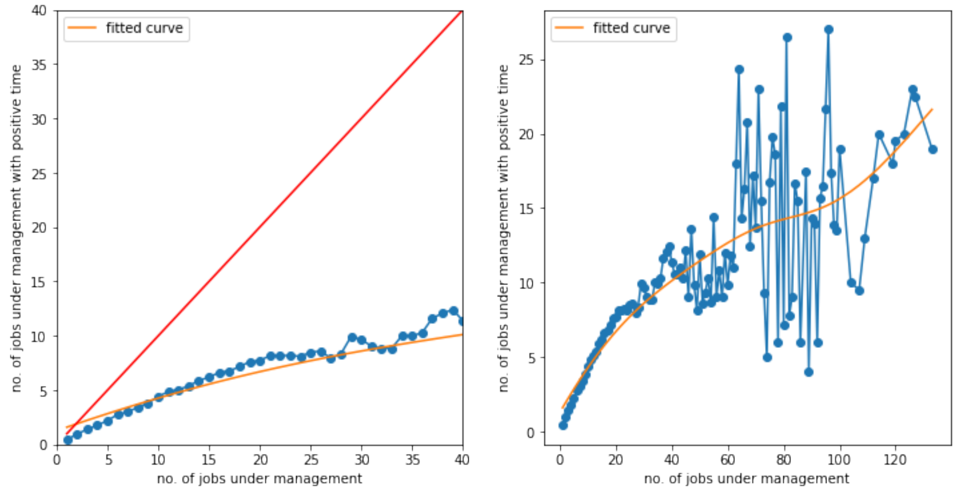
<Insert Tables A2-1, A2-2, and A2-3 about here>

Selective attention. Our formal, longitudinal data from the business service firm show strong evidence of selective attention of knowledge workers. The general pattern corroborates the highly selective attention phenomenon in which managers often choose to pay little attention to a significant number of tasks at any selected time (Dessein et al. 2016). Both panels in Figure A2-1 show a positive correlation between the number of jobs on which a manager spends positive time and the number of jobs under her management. However, the increase in jobs to which the manager devotes positive attention is much smaller than the increase in the number of jobs assigned to her portfolio. When we limit the number of assigned jobs to 40, the left panel shows a ratio of approximately 1/4: only 1 out of 4 jobs receives positive managerial attention in a given month. The standard errors increase as the samples in our data for managers with more than 40 jobs become fewer. Still, the right panel that uses our full samples shows the average between the number of jobs with positive attention to that of inattentive ones decreases to about only 1/8. This pattern is consistent with the idea that managers must efficiently prioritize their time use.

<Insert Figure A2-1 about here>

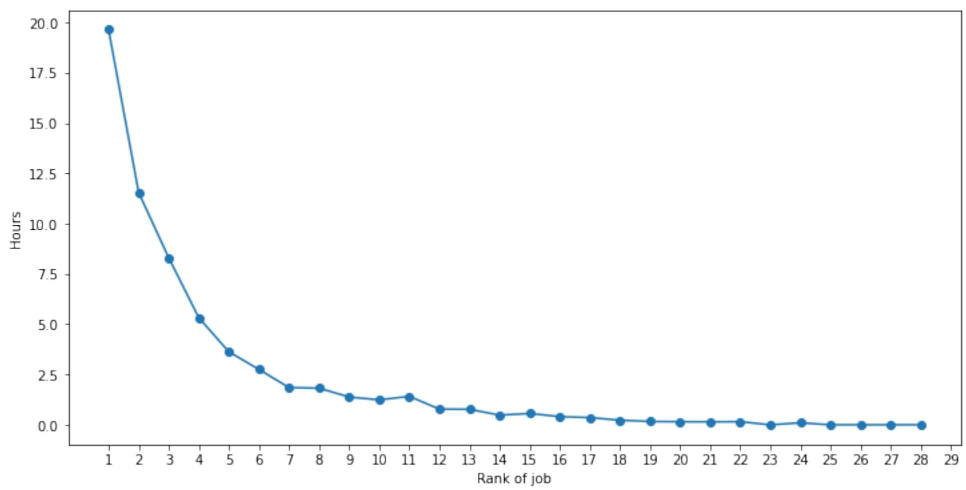
In Figure A2-2, we plot the average number of hours that managers spend on a job against the rank of the job in terms of hours. For instance, the jobs to which the managers allocate the most attention (rank=1) occupy about 20 hours of their time per month, and the 2nd job is about 12 hours, and so on. This figure displays that managerial hours allocated to jobs exponentially decrease in the hour rank of jobs. Only jobs ranked sixth or higher receive meaningful hours managers spend in the firm.

<Insert Figure A2-2 about here>



Note: The figure plots the average number of jobs allocated positive time, conditional on the number of jobs under management. The fitted curve is estimated from a nonparametric kernel regression.

Figure A2-1 – Number of jobs with positive attention and number of jobs assigned



Note: The figure plots the average number of hours spent on each job, conditional on rank in terms of hours.

Figure A2-2 – Average attention conditional on the rank of job

	Activity Type	Hour (Mean)	Hour (Std)	Hour (Median)
1	Claim Solving	5.724	10.581	1.000
2	Client Meeting	17.569	18.388	11.000
3	Committee Activity	5.466	9.663	0.000
4	Department Meeting	6.595	7.795	3.000
5	Design Work	40.526	33.985	34.500
6	Firmwise Meeting	0.276	1.368	0.000
7	Group Meeting	3.948	4.305	3.000
8	Guide Subordinates	12.216	12.707	10.000
9	Inside-firm Meeting	22.793	16.154	21.000
10	Move	30.716	25.266	24.000
11	Non-project	25.483	21.218	19.000
12	Outside Activity	3.121	7.607	0.000
13	Outside-firm Meeting	12.862	13.111	9.000
14	Rest	27.629	70.414	15.000

The tables show the average hours spent on each kind of activity across managers during the survey period. The hours during the two-week survey period are multiplied by two to infer the monthly working hours.

Table A2-1 – Distribution of hours over activities

Group	Mean	Std	Mean Share
Design Work	40.526	33.985	0.255
Clients/third Party Meetings	36.155	23.391	0.234
Working with Other Department	22.793	16.154	0.146
Guidance	12.216	12.707	0.079
Department/Group Meetings	10.543	9.622	0.068
Firm Meeting Unrelated to Job	5.741	9.701	0.037
External Professional Activity	3.121	7.607	0.020

Note: external professional activities include participating in architectural institute, giving public lectures to schools, etc. The Mean Share column reports the average share out of the total hours.

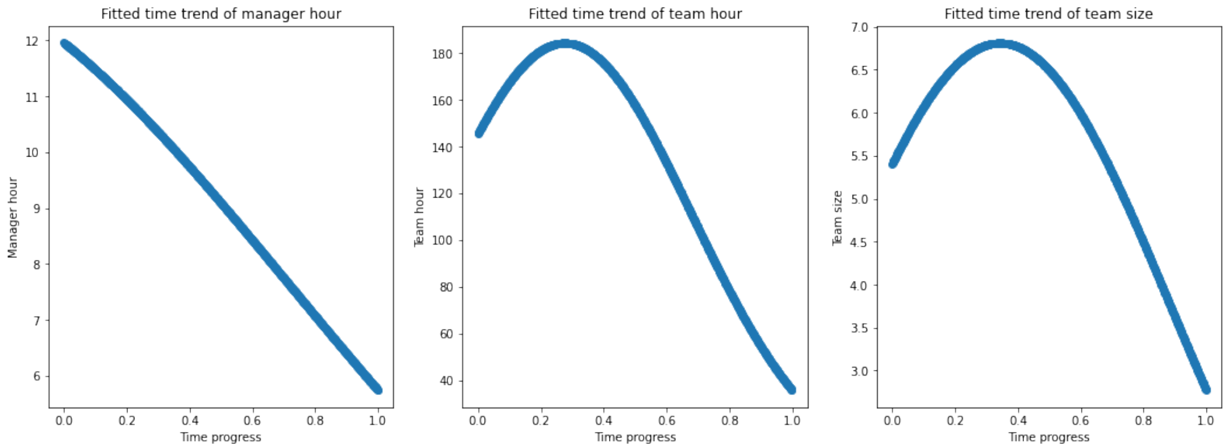
Table A2-2 – Summary statistics by groups of activities

Group	Mean	Std	Mean Share
Internal Related Coordination/delegation	45.552	21.723	0.292
Clients/third Party Meetings	36.155	23.391	0.234

Note: Internal-related coordination/delegation includes department/department group meetings, design work, guidance, and working with other departments. The Mean Share column reports the average share out of the total hours.

Table A2-3 – Summary statistics by groups of activities, continued

Appendix 3: Additional and Supplementary Empirical Results



Fitted curves against $t\_progress_{jt-1}$. Control variables are taken at mean.

Figure A3-1 – Time trend of hours, positive observations

	$t\_progress_{jt-1}$	std	$t\_progress^2_{jt-1}$	std
$t\_\hat{progress}_{jt-1}$	1.059	0.030	0.244	0.036
$t\_\hat{progress}^2_{jt-1}$	-0.054	0.032	0.763	0.039
$\ln Rev_j$	-0.000	0.002	0.004	0.002
$\ln Tenure_{jt}$	-0.001	0.004	-0.001	0.005
Fixed Effect	W+I+J		W+I+J	
No. Obs	53654		53654	
Adj. R^2	0.620		0.569	
Standard error	Cluster by job-year		Cluster by job-year	
Partial F stat	20403.774		14790.093	

Table A3-1 – First stage results of job progress

	$t\_progress_{jt-1}$	std
$t\_progr\hat{e}ss_{jt-1}$	1.080	0.030
$t\_progr\hat{e}ss^2_{jt-1}$	-0.045	0.032
$\ln Rev_j$	-0.000	0.002
$\ln Tenure_{jt}$	-0.002	0.004
$KnowInten_j$	0.105	0.011
$KnowInten_j \times t\_progr\hat{e}ss_{jt-1}$	-0.206	0.021
Fixed Effect	W+I+J	
No. Obs	53654	
Adj. R^2	0.623	
Standard error	Cluster by job-year	
Partial F stat	21783.574	

Table A3-2 – First stage results of job progress, knowledge-intensity

	$t\_progress_{jt-1}$	std	$t\_progress_{jt-1}$	std	$t\_progress_{jt-1}$	std
$t\_progr\hat{e}ss_{jt-1}$	1.053	0.030	0.268	0.006	1.078	0.032
$t\_progr\hat{e}ss^2_{jt-1}$	-0.047	0.032	0.929	0.009	-0.072	0.033
$\ln Rev_j$	-0.000	0.002			0.000	0.002
$\ln Tenure_{jt}$	-0.001	0.004	-0.184	0.009	-0.001	0.005
C_{jt}	-0.014	0.004	-0.003	0.001	-0.016	0.004
$C_{jt} \times t\_progr\hat{e}ss_{jt-1}$	0.027	0.006	-0.000	0.001	0.032	0.007
$\ln Prox_j$	-0.010	0.004			-0.013	0.004
$\ln Prox_j \times t\_progr\hat{e}ss_{jt-1}$	0.019	0.007			0.025	0.007
Fixed Effect	W+I+J		Job		W+I+J	
No. Obs	53654		33031		21792	
Adj. R^2	0.621		0.991		0.614	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	
Partial F stat	20432.950		83412.896		19857.501	

The table shows the first-stage results related to information friction. The first column corresponds to the main result. The second set of results control for job fixed effects. The third set of results uses the quarterly average.

Table A3-3 – First stage results of job progress, information friction

	$t\_progress_{jt-1}$	std	$t\_progress_{jt-1}$	std	$t\_progress_{jt-1}$	std
$t\_\hat{progress}_{jt-1}$	1.065	0.030	0.276	0.020	1.091	0.031
$t\_\hat{progress}^2_{jt-1}$	-0.060	0.032	0.928	0.008	-0.086	0.032
$\ln Rev_j$	-0.000	0.002			0.000	0.002
$\ln Tenure_{jt}$	-0.001	0.006	-0.137	0.008	-0.000	0.006
$\ln (PeerYRet_{jt})$	0.001	0.023	0.273	0.017	0.001	0.022
$\ln RevDep_{jt}$	0.000	0.005	0.058	0.002	-0.000	0.005
Fixed Effect	W+I+J		Job		W+I+J	
No. Obs	53654		33031		21792	
Adj. R^2	0.621		0.991		0.614	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	
Partial F stat	20414.772		106158.256		19738.192	

The table shows the first-stage results related to workload. The first column corresponds to the main result. The second set of results control for job fixed effects. The third set of results uses the quarterly average.

Table A3-4 – First stage results of job progress, workload

First Stage	$\ln NoJob_{jt}$	std
$\ln (PeerYRet_{jt})$	0.512	0.108
$t\_\hat{progress}_{jt-1}$	0.644	0.151
$t\_\hat{progress}^2_{jt-1}$	-0.703	0.157
$\ln Rev_j$	-0.052	0.008
$\ln (Tenure_{jt})$	0.301	0.031
$\ln RevDep_{jt}$	0.051	0.021
Fixed Effect	W+I+J	
No. Obs	53654	
Adj. R^2	0.682	
Partial F stat	45.053	

The table shows the first stage results of workload regression, using $\ln NoJob_{jt}$ as the dependent variable.

Table A3-5 – First stage of workload regression, number of jobs

First Stage	$\ln NoJob_{jt}$	std
$\ln(PeerYRet_{jt})$	0.724	0.296
$t\_progr\hat{e}ss_{jt-1}$	1.203	0.472
$t\_progr\hat{e}ss^2_{jt-1}$	-0.579	0.103
$\ln(Tenure_{jt})$	0.973	0.083
$\ln RevDep_{jt}$	0.295	0.049
Fixed Effect	Job	
No. Obs	33031	
Adj. R^2	0.855	
Partial F stat	81.743	

The table shows the first stage results of workload regression, using $\ln NoJob_{jt}$ as the dependent variable. Job fixed effects are controlled.

Table A3-6 – First stage of workload regression, job fixed effect

First Stage	$\ln NoJob_{jt}$	std
$\ln(PeerYRet_{jt})$	0.511	0.100
$t\_progr\hat{e}ss_{jt}$	0.790	0.152
$t\_progr\hat{e}ss^2_{jt}$	-0.810	0.155
$\ln Rev_j$	-0.048	0.008
$\ln(Tenure_{jt})$	0.284	0.029
$\ln RevDep_{jt}$	0.047	0.020
Fixed Effect	W+I+J	
No. Obs	21792	
Adj. R^2	0.693	
Partial F stat	55.871	

The table shows the first stage results of workload regression, using $\ln NoJob_{jt}$ as the dependent variable. A quarterly average is used.

Table A3-7 – First stage of workload regression, quarterly average

	$\ln(HourDeviation_j + 1)$	std	$\ln(HourDeviation_j + 1)$	std
$\ln(PeerYRet_j)$	0.608	0.169	1.041	0.134
$\ln Rev_j$			0.735	0.012
Fixed Effect	W+I+J		W+I+J	
No. Obs	5021		5021	
Adj. R^2	0.300		0.612	
Partial F stat	12.985		60.140	

$PeerYRet_j$ is the peer years to retire, averaged across months for job j.

Table A3-8 – Hour deviation effect on costs, first stage

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
$t\_progress_{jt-1}$	-1.182	0.062	-1.344	0.066	-0.503	0.030
$\ln Rev_j$	0.475	0.016	0.952	0.016	0.389	0.008
$\ln Tenure_{jt}$	-0.173	0.035	0.260	0.035	0.175	0.015
Fixed Effect	W+I+J		W+I+J		W+I+J	
No. Obs	53654		53654		53654	
Adj. R^2	0.209		0.450		0.500	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$MH_{jt} = ManagerHour_{jt}$, $TH_{jt} = TeamHour_{jt}$, $TS_{jt} = TeamSize_{jt}$. The table shows a linear time trend. $t\_progress_{jt}$ is instrumented. $\ln Rev_j$ and $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table A3-9 – Time trend of hours, linear term only

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
$t\_progress_{jt-1}$	-0.346	0.249	1.700	0.430	1.156	0.195
$t\_progress^2_{jt-1}$	-0.308	0.247	-3.088	0.443	-1.687	0.201
$\ln Rev_j$	0.453	0.012	1.052	0.021	0.444	0.010
$\ln Tenure_{jt}$	-0.270	0.024	0.297	0.041	0.195	0.018
Model	2SLS		2SLS		2SLS	
Fixed Effect	W+I+J		W+I+J		W+I+J	
No. Obs	32181		32181		32181	
Adj. R^2	0.390		0.538		0.586	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$MH_{jt} = ManagerHour_{jt}$, $TH_{jt} = TeamHour_{jt}$, $TS_{jt} = TeamSize_{jt}$. $t\_progress_{jt-1}$ is instrumented by the predicted value. $t\_progress^2_{jt-1}$ is instrumented by the squared predicted value. $\ln Rev_j$ and $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table A3-10 – Time trend of hours, positive observations

	$t\_progress_{jt-1}$	std
$\ln DayStart_{jt-1}$	1.032	0.004
C_{jt}	0.007	0.003
$\ln Tenure_{jt}$	0.738	0.017
Model	Fractional Probit	
No. Obs	33031	
Pseudo R^2	0.231	
Fixed Effect	Job	

Note: Due to computational reasons, only jobs that have more than 12 observations across time are included. C_{jt}, $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table A3-11 – Predict job progress for information friction regression, job fixed effect

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
C_{jt}	-0.238	0.036	-0.359	0.042	-0.152	0.018
$C_{jt} \times t\_progress_{jt-1}$	0.181	0.043	0.396	0.053	0.159	0.023
$t\_progress_{jt-1}$	-0.240	0.187	1.423	0.231	0.949	0.101
$t\_progress^2_{jt-1}$	-0.322	0.172	-1.766	0.212	-1.062	0.094
$\ln(Tenure_{jt})$	0.091	0.173	0.297	0.168	0.247	0.072
Model	2SLS		2SLS		2SLS	
Fixed Effect	Job		Job		Job	
No. Obs	33031		33031		33031	
Adj. R^2	0.541		0.595		0.654	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$MH_{jt} = ManagerHour_{jt}$, $TH_{jt} = TeamHour_{jt}$, $TS_{jt} = TeamSize_{jt}$.Due to computational reasons, only jobs that have more than 12 observations across time are included. $t\_progress_{jt-1}$ is instrumented by the predicted value. $t\_progress^2_{jt-1}$ is instrumented by the squared predicted value. $\ln Tenure_{jt}$, C_{jt} are standardized to have zero mean and unit standard error.

Table A3-12 – Time trend and information friction, job fixed effects

	$t\_progress_{jt-1}$	std
$InactiveFirstThree_j = 1$	0.032	0.019
$InactiveFirstThree_j = 2$	-0.085	0.021
$InactiveFirstThree_j = 3$	-0.116	0.021
$\ln DayStart_{jt-1}$	0.716	0.006
C_{jt}	0.014	0.004
$\ln Prox_j$	-0.002	0.004
$\ln Rev_j$	-0.238	0.004
$\ln Tenure_{jt}$	0.181	0.024
Model	Fractional Probit	
No. Obs	21792.000	
Pseudo R^2	0.141	
Fixed Effect	W+I+J+Y+M	
No. of Start Years	13	
No. of Significant Start Year Effects	8	
No. of Start Months	12	
No. of Significant Start Month Effects	2	

Note: Start year or start month effects are regarded as significant if p-value is lower than 0.1. C_{jt}, $\ln Prox_j$,$\ln Rev_j$, $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table A3-13 – Predict job progress for information friction regression, quarterly average

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
C_{jt}	-0.176	0.030	-0.263	0.037	-0.123	0.016
$C_{jt} \times t\_progress_{jt-1}$	0.269	0.053	0.354	0.067	0.168	0.029
$\ln Prox_j$	-0.088	0.034	-0.197	0.040	-0.077	0.017
$\ln Prox_j \times t\_progress_{jt-1}$	0.173	0.062	0.497	0.074	0.220	0.032
$t\_progress_{jt-1}$	2.165	0.341	4.200	0.391	2.020	0.170
$t\_progress^2_{jt-1}$	-3.251	0.337	-5.518	0.394	-2.518	0.172
$\ln Rev_j$	0.496	0.016	1.010	0.017	0.416	0.008
$\ln(Tenure_{jt})$	-0.175	0.034	0.255	0.035	0.176	0.015
Model	2SLS		2SLS		2SLS	
Fixed Effect	W+I+J		W+I+J		W+I+J	
No. Obs	21792		21792		21792	
Adj. R^2	0.223		0.466		0.519	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$t\_progress_{jt-1}$ is instrumented by the predicted value. $t\_progress^2_{jt-1}$ is instrumented by the squared predicted value. $\ln Rev_j$, $\ln Tenure_{jt}$, C_{jt}, $\ln Prox_j$ are standardized to have zero mean and unit standard error.

Table A3-14 – Time trend and information friction, quarterly average

	$t\_progress_{jt-1}$	std
$\ln DayStart_{jt-1}$	1.024	0.004
$\ln (PeerYRet_{jt})$	-0.786	0.061
$\ln Tenure_{jt}$	0.572	0.018
$\ln RevDep_{jt}$	-0.175	0.010
Model	Fractional Probit	
No. Obs	33031	
Pseudo R^2	0.231	
Fixed Effect	Job	

Note: To include job fixed effects, only jobs that have more than 12 observations across time are included. $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table A3-15 – Predict job progress for workload regression, job fixed effect

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
$\ln NoJob_{jt}$	-0.144	0.684	0.897	0.737	0.506	0.321
$\ln NoJob_{jt} \times t\_progress_{jt-1}$	-0.797	0.240	-0.512	0.263	-0.345	0.111
$t\_progress_{jt-1}$	-0.068	0.204	1.553	0.250	1.031	0.114
$t\_progress^2_{jt-1}$	-0.434	0.262	-1.555	0.316	-0.950	0.145
$\ln(Tenure_{jt})$	0.087	0.559	-0.567	0.643	-0.255	0.290
$\ln RevDep_{jt}$	0.141	0.225	0.033	0.238	-0.052	0.105
Model	2SLS		2SLS		2SLS	
Fixed Effect	Job		Job		Job	
No. Obs	33031		33031		33031	
Adj. R^2	0.501		0.548		0.592	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$MH_{jt} = ManagerHour_{jt}$, $TH_{jt} = TeamHour_{jt}$, $TS_{jt} = TeamSize_{jt}$. To include job fixed effects, only jobs that have more than 12 observations across time are included. $t\_progress_{jt-1}$ is instrumented by the predicted value. $t\_progress^2_{jt-1}$ is instrumented by the squared predicted value. $\ln NoJob_{jt}$ is instrumented by $\ln(NoReC_{jt}+1)$ and $\ln(NoReC_{jt-1}+1)$. The interaction term is instrumented by the interaction term of the corresponding instruments. $\ln Tenure_{jt}$, $\ln NoJob_{jt}$ are standardized to have zero mean and unit standard error.

Table A3-16 – Time trend and workload, job fixed effects

	$t\_progress_{jt-1}$	std
$InactiveFirstThree_j = 1$	0.033	0.019
$InactiveFirstThree_j = 2$	-0.083	0.021
$InactiveFirstThree_j = 3$	-0.115	0.021
$\ln DayStart_{jt-1}$	0.716	0.006
$\ln (PeerYRet_{jt})$	-0.008	0.044
$\ln Rev_j$	-0.238	0.004
$\ln Tenure_{jt}$	0.172	0.024
$\ln RevDep_{jt}$	-0.063	0.010
Model	Fractional Probit	
No. Obs	21792	
Pseudo R^2	0.141	
Fixed Effect	W+I+J+Y+M	
No. of Start Years	13	
No. of Significant Start Year Effects	8	
No. of Start Months	11	
No. of Significant Start Month Effects	2	

Note: Start year or start month effects are regarded as significant if p-value is lower than 0.1. $\ln Rev_j$, $\ln Tenure_{jt}$ are standardized to have zero mean and unit standard error.

Table A3-17 – Predict job progress for workload regression, quarterly average

	$\ln(MH_{jt}+1)$	std	$\ln(TH_{jt}+1)$	std	$\ln(TS_{jt}+1)$	std
$\ln NoJob_{jt}$	-0.093	0.353	1.301	0.406	0.415	0.171
$\ln NoJob_{jt} \times t\_progress_{jt-1}$	-1.165	0.272	-1.671	0.329	-0.756	0.135
$t\_progress_{jt-1}$	3.029	0.489	3.929	0.554	2.063	0.236
$t\_progress^2_{jt-1}$	-4.077	0.499	-5.136	0.559	-2.513	0.240
$\ln Rev_j$	0.469	0.021	1.037	0.024	0.421	0.010
$\ln(Tenure_{jt})$	-0.124	0.074	0.043	0.083	0.113	0.035
$\ln RevDep_{jt}$	0.037	0.034	-0.037	0.038	-0.004	0.017
Model	2SLS		2SLS		2SLS	
Fixed Effect	W+I+J		W+I+J		W+I+J	
No. Obs	21792		21792		21792	
Adj. R^2	0.110		0.382		0.455	
Standard error	Cluster by job-year		Cluster by job-year		Cluster by job-year	

$MH_{jt} = ManagerHour_{jt}$, $TH_{jt} = TeamHour_{jt}$, $TS_{jt} = TeamSize_{jt}$. $t\_progress_{jt-1}$ is instrumented by the predicted value. $t\_progress^2_{jt-1}$ is instrumented by the squared predicted value. $\ln NoJob_{jt}$ is instrumented by $\ln(NoReC_{jt}+1)$ and $\ln(NoReC_{jt-1}+1)$. The interaction term is instrumented by the interaction term of corresponding instruments. $\ln Tenure_{jt}$, $\ln NoJob_{jt}$ are standardized to have zero mean and unit standard error.

Table A3-18 – Time trend and workload, quarterly average