RIETI Discussion Paper Series XX-E-00X

How Good Managers Steer Their Projects: Using Value-Added Measures of Manager Quality

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December 5, 2020

Abstract

Using detailed project management records from the design department in a large Japanese architectural & engineering consultancy firm, we estimate the manager effects on the project profitability. One standard deviation increase in unobserved manager ability increases the profitability by 6 percentage points. Based on interviews with seven project managers, we hypothesize that managers improve team performance by better planning, better communication with both client and project members and better understanding of the client's needs and decision-making style, which all help to front-load design work, reduce waiting time, and avoid wasteful redesigning. We provide supporting evidence from the analyses of labor input data, and three-hundred-sixty-degree evaluation records. Especially, we find that the speed of project execution, quality of communication with subordinates, and degree centrality in the internal network could be important mediating factors.

Keywords: Team production, labor productivity, middle manager, communication, coordination

JEL classification: J24, M54

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1 Introduction

Team production is often found to be associated with higher productivity (Boning et al. (2007), Hamilton et al. (2003)). Most of the studies of team production, however, are limited to simple production environment where tasks are clearly defined and homogeneous, output is easy to measure, and processes are relatively stable. However, production in many high value-added services industries such as design, consulting, research, and financial service are carried out in a more complex environment: tasks are heterogeneous and need to be coordinated in a non-routine way, output is hard to measure, and processes need to adapt to uncertain and changing conditions. This implies that factors that make teams more productive are still under-investigated.

In this paper, we study a particular such factor, the effect of project managers, on the performance of teams of architectural designers. We first measure the productivity difference across project managers, then analyze how good project managers can raise productivity of their teams. As the representative of the firm, the manager participates in the negotiation with the client to determine the revenue and building design attributes. After the contract is signed, the manager forms the team to produce the required service and supervise the process. As the team leader, the manager is responsible for planning and allocating the production work, as well as monitoring the production process. Therefore, the manager affects project outcome both through better bargaining and better cost management. The manager typically manages multiple projects at the same time. The success of project management is thus dependent on how he prioritizes each task in each project. The main outcome measure of each design project is profitability. More precisely, the firm primarily uses the cost ratio, which is the ratio of variable cost and revenue, or one minus gross profit rate, to evaluate the performance of a project. Since the majority of variable costs are labor costs, our profitability measure captures the usual notion of productivity.

We use detailed project management records including project and client characteristics as well as labor inputs of individual project members over a decade. The data is merged with personnel records to obtain the worker characteristics. The dataset enables us to quantify the manager effects and verify the importance of cost management practices.

The main empirical challenge is the non-randomness of job assignment and heterogeneity of the projects. To correct the selectivity bias, we rely on a polychotomous Roy model introduced by Dahl (2002). The main restriction we impose is that selectivity bias depends on a flexible function of conditional assignment probability. That is, once we compare managers equally likely to be chosen, then difference in performance does not result from assignment choice.

In order to deal with heterogeneity in the work content, we restrict our analysis to the projects in the design department, and exploit detailed information on characteristics of architecture, clients and team members. Moreover, we control for unobserved complexity of projects by including as control the special outsourcing cost ratio, which is the share of costs for outsourcing tasks that require special capability the firm does not possess, and control for experience of managers by constructing detailed work experience measures based on the labor inputs in the past. To the extend to which the manager experience correlates with unobserved complexity of the project, including these experience variables also helps to mitigate selection problem.

According to our value-added measurement of manager effects, managers who are one standard deviation better increases the gross profit ratio by 6 percentage points after correcting for selectivity bias. Separately, standard deviation of the manager effect on costs is 6.8% of mean costs, whereas that on revenue is 10.4% of mean revenue. It is found that better managers tend to have longer tenure and higher salary although we include tenure as control. The coefficients of various manager experience variables can be interpreted as the return to specific human capital and are interesting on their own. We find that the 1000 increase in the hours spent for projects in a particular industry leads to 0.46% higher profitability for projects in the focal industry.

After estimating the manager effects, we examine how high-performing managers are different from other managers in terms of both behavior and other outcomes using time use records, evaluation records, the list of award-winning projects, and the list of projects whose managers were penalized for defective designs, and interviews. Based on the interviews, we first judge that important aspects of project management that are correlated with the performance include planning, early coordination, communication, and client relations. If the manager plans well, each member will be given clear targets on how many hours could be spent on each task. If the clients are given sufficient information about choices and roadmap early on, they can make timely decisions by coordinating well with all stake-holders and are unlikely to reverse early decisions. Communicating regularly with team members help managers to identify delay, obstacles, mistakes, and misunderstanding as soon as they arise, thus managers can intervene effectively if necessary. Knowing clients, especially their decision makers and decision making processes, is critical to better assist their decision making and bargaining well with them.

We find that one important mediating factor that leads to better outcome is smooth and timely execution of a project. We measure the speed of execution by the slope of cumulative labor input curve across time. It is found that front loading, namely quicker move to execute the project at early stage, is strongly associated with higher profitability. One standard deviation increase in our front loading measure increases profitability by 2.5 percentage points and decreases project's time length by 45 days, compared to average length of 634 days. And as is consistent with our measured manager effects, projects led by managers with better effects have faster speed of execution at the beginning of the projects. If the manager better plans, coordinates, and communicates with members and clients, members can start their design tasks quickly and the project will be completed as scheduled. Therefore this result is consistent with the hypothesis that better managers are more effective at planning well ahead and communicating with client and members.

Our detailed labor inputs data also allows construction of internal network of workers. In this network, each node represents one worker, and two nodes are connected if the pair of workers have worked together before. We found that the degree centrality of managers measured using this internal network is significantly positively associated with the project outcome, and the ranking of the manager effects from our estimation.

Our paper complements previous studies in team production by focusing on vertical communication, namely the communication between team leader and members, and adaptation to the needs of clients. This contrasts with other studies such as Boning et al. (2007), Chan et al. (2014a,b), Hamilton et al. (2003) and Mas and Moretti (2009), which focus on horizontal interactions (e.g. peer pressure, peer learning, problem solving, task coordination, etc.) using simple technology in a more stable environment.

Unlike some of other studies on team work, moral hazard does not play a crucial role in our case because of the following three reasons: First, each worker's contribution to the project is objectively measured as they can always claim which part of the design they did. Second, architects have strong intrinsic motivation to do high quality works as well as the reputation they can obtain by winning awards. Third, the firm's employees are consistently under time pressure to meet deadline and any shirking is easily identified and impose some consequences on the architect's career.

Our work also contributes to the literature of middle managers. Lazear et al. (2015) are the first ones to estimate the value-added model of middle managers. Their work finds that value added by the managers is mainly through training because the productivity of workers raised by good managers mostly remain after bosses change. Frederiksen et al. (2017) study how heterogeneity in performance evaluations across supervisors affects employee career and future earnings. Their analysis demonstrates that supervisor heterogeneity is at least partially attributed to real differences in managerial ability to raise worker productivity. But, these two studies shed light only on a part of managers' tasks. We believe that the manager has three roles: "problem-solver" who identify problems and issues, find solutions, and negotiate effectively with clients and other stakeholders; "coordinator" who plan effectively, and share information with employees, clients and stakeholders in a timely and comprehensive manner; and "trainer" who assign developmental tasks to subordinates, and effectively teach and motivate subordinates. Our study focuses more on the managers' role as problem-solver and coordinator rather than trainer.

Additionally, our study is closely related to the management literature that investigates determinants of team performance. Huckman et al. (2009) and Huckman and Staats (2011) study the effect of role experience, experience diversity and team familiarity in an Indian software company. Gardner and Staats (2012) explores how a professional service team can integrate knowledge among members. Differing from these studies, our paper utilizes a richer dataset and therefore is able to construct more detailed measure of work progress and task specific experience for managers.

Finally, this paper focuses on the value of middle managers, therefore complements the literature on CEO's productivity (e.g. Bertrand and Schoar (2003), Bandiera et al. (2011), Bandiera et al. (2017)). Like CEOs studied by the papers, project managers in our sample also allocate time over various activities and make complex decisions that affect firm performance although their decisions have more direct consequences on front-line workers. But unlike CEOs, project managers deal with more detailed problems arising from production site.

The rest of the article is organized as follows. Section 2 presents our theoretical framework, 3 documents the interview with project managers, 4 explains the dataset and 5 explains our empirical strategy. Section 6 explains the results. Section 7 conclude with a brief discussion of our future plan on extension.

2 Theoretical Framework

In this section, we provide a framework for analyzing project managers. Before production begins, the firm selects manager i who manages project j. Some points are worth noting at the beginning. First, the manager's human capital H_{it} is the most important determinant of the project outcome and includes both general and specific components. For example, a project for a client in a certain industry is likely to be assigned to a manager with rich experience in the same industry because the knowledge about the business domain and the typical decision making style in the industry will help the manager to negotiate and coordinate well with the client. Client-specific knowledge is also important, since it takes time to build trust and learn the needs of specific client. Moreover, the relation-specific human capital is also valuable because the ability to form an effective team and communicate well with team members should be correlated with the past experience in working with a broad group of employees.

Second, each manager has a time constraint and thus even the most capable manager will have poor performance when the workload is too heavy. Importantly, this implies that projects managed by the same manager will have negative externalities because they compete for manager's time. Therefore, the workload of manager i at time t, W_{it}, plays an important role in both the assignment and production stages. Finally, the potential outcome depends on the match between the manager's experience and the job characteristics. We let x_j be the observed project characteristics and ε_j be the unobserved job complexity and uncertainty.

We consider the process backward. After project j is assigned to manager i, the negotiation between the firm and the client starts to determine the revenue and building design attributes. As a representative of the firm, manager i influences the bargaining outcome. After the contract is signed, the manager forms the team to produce the required service and supervise the process. Therefore, the manager affects project outcome both through better bargaining and better cost management. The manager typically manages multiple projects at the same time. It is thus important how he prioritizes each activity in each project. To capture this idea, we model the behavior of the manager as time allocation among different tasks.

We presume that manager i affects the profit through the time he spends on each activity. Specifically, the revenue depends on how much time the manager spends to communicate with client, denoted by t_{ij}^C, and how much time is spent on planning and information collection, which is denoted by t_{ij}^P. The idea is that knowing the information like the clients' needs and their organizational structures would facilitate negotiation process. The cost also depends on how much time manager spends on planning, which adds more value through a more precise working schedule, or prediction of other shocks that affect costs. What's more, communication with team members, denoted by t_{ij}^M, is likely to raise the effectiveness of team effort E_j. Finally, the effectiveness of time spent on each activity probably depends on manager's experience and talent. To summarize, the final profit y_j will depend on $(H_{it}, x_j, \varepsilon_j)$ and the actual time allocation and team effort $(E_j, t_{ij}^C, t_{ij}^M, t_{ij}^P)$:

$$y_j = f\left(H_{it}, x_j, \varepsilon_j, E_j, t_{ij}^C, t_{ij}^M, t_{ij}^P\right) \tag{1}$$

Note that each manager faces a time constraint

$$\sum_{j \in J_{it}} \left(t_{ij}^C + t_{ij}^M + t_{ij}^P\right) \leq T \tag{2}$$

where J_{it} is the set of jobs that manager i manages at some point of time. We view the outcomes in the data as a result of optimization effort of managers given the constraint:

$$\max_{\left\{t_{ij}^C, t_{ij}^M, t_{ij}^P\right\}} \sum_{j \in J_{it}} E\left[y_j | H_{it}\right] \tag{3}$$

where manager i's human capital H_{it} is likely to affect the effectiveness of planning and communication. For example, experience of dealing with the same client offers some knowledge of its needs. When $\left\{t_{ij}^C, t_{ij}^M, t_{ij}^P\right\}$ is optimally chosen, team effort E_j is endogenously determined by the manager's time allocation and the team members' human capital. Then, the outcome becomes the function of

$(H_{it}, W_{it}, x_j, \varepsilon_j)$:

$$
\begin{aligned}
y_j^* &= f^* \left(H_{it}, W, x_j, \varepsilon_j\right) \\
&= f\left(H_{it}, x_j, \varepsilon_j, E_j^*, t_{ij}^{C*}, t_{ij}^{M*}, t_{ij}^{P*}\right), \qquad (4)
\end{aligned}
$$

where E_j^*, t_{ij}^{C*} , t_{ij}^{M*} , t_{ij}^{P*} are functions of $(H_{it}, W_{it}, x_j, \varepsilon_j)$. We assume that the assignment decision is made only to maximize the current profit when each project arrives. Namely, manager d_j who manages project j is chosen from the set of available managers I_t at time t to maximize the profit:

$$
d_j = \arg\max_{k \in I_t} E\left[f^*\left(H_{kt}, W_{kt}, x_j, \varepsilon_j\right)\right]
$$

In reality, it is plausible that the firm trades off current profits by taking into account long-term benefits like giving young managers learning opportunities, or saving the work capacity of experienced managers for future projects. We could assume, however, that f^* also captures changes in the option value–dynamic consideration of the decision's consequence on the future opportunities.

3 Data

In this section we describe the dataset and definition of key variables constructed from the data. We use project management data and personnel records from a large Japanese construction management firm.

Project management data

For the fiscal years of 2004-2016, the dataset contains detailed project management records. A typical project may consist of several phases, from initial planning, to schematic design, structural design, detailed design, technical design and engineering, and supervision of the construction process. The unit of observation in project management data is at the phase level, which is called a job. For each job, we observe revenue, costs, and other characteristics. Costs can be classified into labor costs and non-labor costs. And for non-labor costs, we further observe components including material/traveling costs and outsourcing costs. Outsourcing decisions are made by managers, it typically happens when the work can not be done within the firm, either due to resource/capability constraint or efficiency consideration. Project management data also contains detailed information about the projects and the clients including client ID, client's industry, type and size of the building, location, phase of the work, contractor selection method, etc.

We select a sample of jobs that represent the main operation of the firm. Because short-term profitability is occasionally sacrificed for long-term benefits such as public relations value or investment in future opportunities. As a result, some jobs have unusually high cost ratio (i.e. money-losing). Since a financial loss due to strategic bidding will not reflect the true capability of project managers, we exclude jobs with cost ratio higher than 2 (e.g. the total cost amounts to more than double the revenue) [1]. Also, employees serving multiple phases of the same project may not precisely allocate

[1] This excludes 23 jobs from the sample. In a robustness check, we verify that including these observations do not affect the results qualitatively. The estimated manager effects with and without including these observations lie closely on the 45 degree line.

hours across phases and under-reporting to jobs with small revenue is more common. Since the cost ratio is more likely to be biased for jobs with small revenue, we omit those that have less than 10 million yen revenue. Finally, we restrict our analysis to the design department where projects are more standardized in terms of structure, technology and pricing, compared with engineering and urban development. After the above sample restrictions, our final sample contains 2678 jobs, still accounting for more than a half of the design department's revenue. Table 1 contains summary statistics of job level variables that are going to be used in the paper. Some points are worth noting. The variable month length shows that average job lasts about 2 years. All jobs are performed by teams, and as shown by the variable team size which typically have about 20 people. Outsource ratio is the portion of the costs that is not completed within the firm. Group outsource ratio is the share of costs that is outsourced to companies within under the same parent firm, special outsource ratio is the share of costs that can not be completed due to technical reason, and ordinary outsource ratio contains the routine work that is more efficient to be done outside the firm. Area, whose unit is m^2, measures building size of each job. Rev_chief_other is the sum of revenue of others jobs managed by the chief manager at the start year-month of the job. Similarly, no_job is the number of jobs managed by the chief manager at the start year-month of the job. Exp_industry and exp_job_content are the amount of past working hours of the chief manager for jobs that have the same industry and job content respectively. Finally, general experience is measured by years after graduation of the chief manager at the start year of each job.

Worker personnel data

For each worker during 2011-2016, we obtain personal records containing educational background, salary level, and job rank. Job ranks are classified into three job levels: manager, senior architect, and junior architect. Each job is assigned to a manager, who manages the job and becomes responsible for all consequences of the job. Under the manager, at least one senior architect is assigned to the team as leader and junior architect join teams to produce service. Some managers may join teams as experts to provide technical guidance.

Labor inputs produced from project management data

Using project management data, we created labor inputs measured in hours for each worker on each job in each month during the period of 2004-2016. This data enables us to construct several interesting variables. First, we can measure how fast labor inputs accumulate over the course, namely the speed of executing a job. This measure reflects how managers organize their design operations. Second, it provides detailed work experience for each worker during the thirteen-year period. By counting labor inputs over years in jobs with particular dimension of characteristics, we can measure work experience in a particular domain (industry), job content (design phase) or location. Third, we can also construct a measurement of internal network that describes the relationships defined by co-working experience among all workers. For example, the relationship may be defined by how many hours two team members have worked together before the start of a new job.

Progress curve

As discussed in the section of theoretical background, it is critical how manager allocates his time. Details of manager time use are not directly observed in our data, but we can see how labor inputs, which are the most important inputs in the service production, are expended over time. By investigating this relationship, which we call progress curve, the quality of manager's time management may be inferred. We first define progress curve in the data and then discuss why we think it is an useful measure of management quality. An example and more details of how we calculate progress curve can be found in the appendix.

Normalize both total labor input and total time length to the unit interval. Then let $P_j(t)$, a function mapping $[0, 1]$ to $[0, 1]$, represent the relationship between passage of time t and the progress measured by accumulated labor inputs in job j at time t. For example, $P_j(0.5) = 0.5$ means that after the passage of 50% of time, 50% of the actual total labor inputs have been expended to produce service. Our data allows observation of $P_j(t)$ for each month. As the labor input variable, we can use either working hours, or labor costs, which might be proper labor input assuming that wage captures productivity differences. For every job that started and ended between 2004 and 2016, we can calculate unweighted labor inputs by simply adding up total hours spent in each month. And for those jobs between 2011 and 2016, since job rank information is also available for each worker, we can further weight hours by hourly wage.

$P_j(t)$ captures the speed of execution up to every point in time over the course. For example, at an early stage, say when only 20% of time have passed ($t = 0.2$), an above-average value of $P_j(t)$ would indicate that the project is moving rather quickly. The slope of $P_j(t)$ at the beginning probably reflects the speed of decision-making of the client and coordination among stakeholders, which depends on the manager's ability as coordinator. On the other hand, if the progress tends to be backloaded, namely, labor inputs fall more on the later stage of the project period, $P_j(1) - P_j(0.8)$ takes a higher value implying that this project probably ended in a rush before the deadline. Moreover, slopes at different parts of $P_j(t)$ may be correlated. A smooth start at the beginning may provide more slack for correcting mistakes at a later stage while a rush at the end may be a result of bad coordination at the beginning.

Progress curve $P_j(t)$ would also depend on characteristics of job j. For instance, we learned from the interviews that big projects tend to start slow because there are more parameters to choose with the client and more stakeholders to deal with. This relationship is vivid in Figure 1, where we divide jobs between 2011 and 2016 into ten revenue deciles–ten equal groups divided according to the distribution of revenue–and plot the average progress curve in each decile. The progress curves have a clearly ordered pattern: small jobs start quicker. And as expected from the previous discussion, progress curve has non-trivial curvature that probably contains information about the underlying quality of cost management.

Predict standard progress curve

Progress curve may be used to understand team performance. As seen in Figure 1, progress naturally differs depending on the revenue size. Our interviews with managers also revealed that the standard speed of project execution may also depend on other job characteristics such as design phase. We therefore calculate the standard progress curve for each set of job characteristics in order to facilitate comparison across jobs. We use logit regression with continuous dependent variable, which is equivalent to ordinary least squares regression taking the logit transformation of progress curve $log(\frac{P_j(t)}{1-P_j(t)})$ as dependent variable. The regression is weighted by job revenue and conducted separately for each t at $t = 0.1, 0.2, ..., 0.9$. Independent variables used include design phase, client and building type, revenue (log, also up to quadratic term) and total floor area (up to quadratic term). Predicted value, denoted by $\hat{P}_i\,(t)$, is interpreted as the standard progress curve for projects with similar characteristics to job i and used as a benchmark for comparison.

Measurement of experience

Experience, or more broadly human capital of managers and team members are important determinants of team performance. Here we discuss how experience is calculated from our data. Our measure of manager experience consists of two parts: general experience and task specific experience. General measures include age, tenure and years of schooling. Specific measures are working hours expended by each project manager on specific type of jobs up to the time since 2004 including the time period before becoming a manager. We focus on two dimensions of specificity. One is domain, equivalent to the client industry, and job-content, equivalent to design phase. For example, the domain-specific experience is calculated as accumulated hours spent by the project manager on the jobs from the same industry.

Internal network

Familiarity among workers can be important for project outcome for at least two reasons. First, managers play an important role in selecting team members. Co-working experience in the same team helps managers to understand the strength and the weakness of each team member candidate and thus should enable them to form effective teams. Second, familiarity may facilitate coordination among team members. To measure familiarity among employees, we select all senior architects and managers as nodes, and connect two nodes if the pair of workers have co-working experience in the past. Note that this network changes each year as new relationships are built, some new workers enter and some old workers leave the firm.

Other data

As a mean of human resource development, the firm conducts an upward feedback every year. The upward feedback is a process through which every manager receives feedback on seven questions from both subordinates and peers. The questions rate the effort of the manager in seven areas including assignment efficiency, health management, communication with subordinates, fair evaluation, coaching young employees, and client relationship management. Details can be found in the appendix.

As quality measures of job, for more recent jobs from 2011 to 2016, we have the list of awards won by projects from architecture related organizations, and the record of occurrence of penalty imposed on managers due to design defects. A survey of time use is conducted during the 2 weeks of November 15, 2017-November 28, 2017. 116 managers participated. For every half hour during the survey period, the data records the type of activity (meeting, guiding subordinates, etc.), and includes an indicator showing whether the activity is regular or not. The graphs below show the distribution of share of time spent on each type of activities among managers. Communication accounts for a large share of their time.

4 Empirical framework

Correcting selectivity bias

The equation that we would like to estimate is

$$y_{ij} = x'_{1j}\beta_1 + x'_{2j}\beta_2 + x'_{3i}\beta_3 + \psi_i + u_{ij} \tag{5}$$

where y_{ij} is outcome variable for job j managed by manager i, which is mainly cost ratio. In the robustness section we also show results using revenue and cost as outcome, in order to assess the idea that managers may influence revenue and cost separately.

We divide control variables into three groups: characteristics of job, composition of team, and manager-specific variables. x_{1j} is the vector of basic characteristics of job j, including industry, content, location, size, dummy indicating the client is private or public organization, and special outsourcing cost ratio. These variables control for heterogeneity of profitability that is out of manager's control. If, for example, markups differ across industry because of differences in the intensity of competition, not including industry dummy leads to omitted variable bias. Special outsourcing cost ratio, which is the share of costs for outsourcing tasks that require special capability the firm does not possess, is included to control for complexity.

x_{2j} is vector of characteristics of team members of job j. It includes number of workers for each job rank group, average schooling, age and experience of team members. Team size is probably an indicator of difficulty in coordination and affects profitability. Since team members are chosen by managers, the effect of team composition on profitability may also reflect manager's influence.

x_{3i} is vector of observed manager specific variables. It includes measure of manager workload, which is total number of jobs and amount of revenue (excluding job j) managed by manager i at the start of job j, and experience measure. The calculation of experience measure is discussed in more detail in the data section. The purpose of including these variables is two-fold. First, we expect positive return to manager experience, and omitting it confounds effects of experience and ability. Second, to the extend that firms assign more difficult projects to more experienced managers, including experience also helps control for unobserved complexity. Similar logic applies to workload of manager. Controlling for workload of manager also helps to control for externalities among jobs managed by the same manager. Namely, overloaded managers may not spend enough time in each of the jobs they manage thus lowering the performance of the jobs

Finally, given that we have controlled for observed experience, manager fixed effect ψ_i captures intrinsic ability of manager. u_{ij} is the error term.

Projects that come from old client are automatically assigned to previous manager. For other projects, an internal meeting is held to decide who should be the chief manager. Therefore the company does not assign managers randomly to projects. This leads to concerns about selection bias, namely that u_{ij} is correlated with observed variables. For example, if capable managers tend to be assigned to a particular industry, the model will mistakenly attribute manager ability to industry effect, thus underestimating manager ability. In order to account for this selection bias, we adopt the framework of Dahl (2002), which combines the insight of Lee (1983) and semi-parametric literature (e.g. Ahn and Powell (1993)). We assume that potential utility/profit of assigning manager i to job j is

$$y_{ij}^* = V_{ij} + e_{ij},\ \ i = 1, ..., M$$

where V_{ij} is conditional expectation of reward, e_{ij} is conditional independent error. V_{ij} may contain elements that affect profits, like how manager's experience and ability match with current project.

In this model, assignment decision $d_j = i$ if and only if for any $s \neq i$,

$$V_{sj} - V_{ij} + e_{sj} - e_{ij} \leq 0$$

or equivalently,

$$\max_{s \neq i} \left(V_{sj} - V_{ij} + e_{sj} - e_{ij} \right) \leq 0$$

Denote the $M - 1$ vector V as

$$V = \left(V_{1j} - V_{ij}, ..., V_{Mj} - V_{ij} \right)$$

and

$$\epsilon_{ij} = \max_{s \neq i} \left(V_{sj} - V_{ij} + e_{sj} - e_{ij} \right)$$

The selectivity bias now can be written as

$$E \left[u_{ij} | d_j = i, V \right] = E \left[u_{ij} | \epsilon_{ij} \leq 0, V \right] \neq 0$$

The dimension of this conditional expectation depends on the number of candidates M, which can be as big as 100 in our case. In order to reduce dimension, we impose the following index sufficiency assumption

$$g \left(u, \epsilon | V \right) = g \left(u, \epsilon | p_{ij} \right)$$

where $g \left(\cdot \right)$ is the conditional joint distribution of errors, and

$$p_{ij} = Pr \left(\epsilon_{ij} \leq 0 | V \right)$$

is the conditional probability of choosing manager i for job j. This assumption means that p_{ij} contains all the information about how V affects joint distribution of u_{ij} and ϵ_{ij}. Under general invertibility condition (e.g. Hotz and Miller (1993)),

$$g \left(u, \epsilon | V \right) = g \left(u, \epsilon | p_{1j}, ..., p_{Mj} \right)$$

So that our assumption can be understood as further restriction that $p_{sj}, s \neq i$ can be dropped. This also suggests that one way to relax our assumption is to include more conditional choice probabilities of candidate managers.

The index sufficiency assumption implies that outcome equation can be written as

$$y_{ij} = x'_{1j}\beta_1 + x'_{2j}\beta_2 + x'_{3i}\beta_3 + \psi_i + \lambda\left(p_{ij}\right) + v_{ij} \tag{6}$$

where $E\left[v_{ij}|d_j = i, x_{1j}, x_{2j}, x_{3i}\right] = 0$, $\lambda\left(p_{ij}\right)$ is unknown function that corrects selectivity bias. To correctly take into account first step estimation, we use the 2-step procedure in Murphy and Topel (1985) to calculate variance covariance matrix. More details about the implementation can be found in the appendix.

Estimate manager effect

One of our target parameters is the standard deviation of ψ_i. In order to separate variance of manager effect from sampling error , we use mixed effect model (see e.g. Abowd et al. (2006)) to estimate individual manager effect, while report results from fixed effect model as well. In matrix notation, model specification is

$$Y = X\beta + D\psi + v \tag{7}$$

where Y denotes outcome, X is matrix of control variable, D is assignment matrix, ψ is vector of manager effect. Stochastic assumptions for mixed effect model are:

$$\psi \sim N\left(0, \sigma_\psi^2 I_J\right) \tag{8}$$

$$E\left[\psi|X\right] = E\left[v|D, X\right] = 0 \tag{9}$$

$$Cov\begin{bmatrix} \psi & \\ v & |X \end{bmatrix} = \begin{bmatrix} \sigma_\psi^2 I_J & 0 \\ 0 & \sigma^2 I_N \end{bmatrix} \tag{10}$$

Note that unlike traditional random effect estimator, we allow arbitrary correlation between D and X.

Estimate p_{ij}

We estimate choice probability in two ways. In the first approach, we use logit model. Besides usual caveats about logit model, however, we face a greater difficulty in specifying variables included in V_{ij}. Some variables like expected team composition are likely to be important but impossible to measure. As an alternative, we also use the share of projects assigned to manager i among those similar to job j as an estimate of p_{ij}. The idea is that if we fix the pool of manager candidates, as more projects with the same type are assigned, the share of projects each manager receives will approach the true assignment probability p_{ij}. This requires modeling the type of projects instead of variables contained in V_{ij}.

In both ways of estimating p_{ij}, it is important to determine the group of candidate managers for each job j. Since we have more than a hundred managers in the data, simply including every manager would make the computation very demanding. Moreover, we don't want to include managers that specialize in different type of jobs into the same group, as the comparison may be misleading. On the other hand, if we include too few candidates, the effect of bias correction may be weakened. In the following estimation of p_{ij}, we classify jobs into cells defined by a triple of district-industry-start year, where district is the geographic area where the responsible office is located, industry refers to the client industry. As shown in Figure 3, there is a low mobility across geographic districts: most of the managers manage jobs coming from one district. We include client industry in the definition of cells because the experience in relevant industries is an important consideration when select chief manager. Including start year reflects the availability of managers in the time dimension [2].

Fitted probability using logit

We estimate the following equation using logit regression

$$d_{ij}^{*} = \alpha_0 + \alpha_1 z_{1ij} + \alpha_2 z_{2ij} + \varepsilon_{ij}, \tag{11}$$

where d_{ij}^{*} is the latent variable of a dummy d_{ij} representing whether manager i is selected to manage job j.

z_{1ij} includes variables that also appear in the outcome equation: the experience, workload of manager i at the time of arrival of job j. We include both tenure and experience specific to industry or job content measured in hours and include the number of jobs and the amount of revenue as the measures of workload. In addition, we also include industry, district, year fixed effects to control for heterogeneity across those categories.

In z_{2ij}, we put variables that move the assignment probabilities but does not affect outcome. The inclusion of such variables ensure that the identification in the outcome equation does not come only from functional form restriction. Specially, we use the shares of manager i's specific experience among all candidate managers. There are several sources of change in the experience share that affects the assignment probability. For example, retirement, sickness, turnovers of potential candidates change the denominator of the revenue share, but is unlikely to affect the outcome in the second stage. On the other hand, since managers work similar amount of hours, gradual change in the numerator is less likely to affect assignment probability significantly.

Assignment share of similar projects

In this way of estimating p_{ij}, we assume that jobs in the same district, industry, and year have the same type. That is, these categorical variables contain sufficient information to determine the expected benefits V_{ij}. For each district-industry-year triple, the probability p_{ij} is calculated as the share of revenue assigned to manager i over total revenue. We use revenue because it is a better measure of the amount of work involved.

5 Value-Added Model Estimation Results

Table 2 shows the first stage estimation of p_{ij}.The first column shows parametric estimation of p_{ij} from logit regression. It shows that the probability of getting a new job has a non-linear relationship

[2] We also classify jobs intro private/public, design/non-design, or above/below median revenue and examine the specialization patterns of managers in each way of classification, but do not find a clear evidence of specialization along these dimensions.

with current workload: as the number of jobs keep increasing, the probability of getting new job decreases. The experience in the corresponding industry significantly increases the probability of getting assigned. *Rev_Past* is the weighted average of revenue of past jobs for each candidate, which controls for the potential specialization in terms of revenue size. Importantly, our excluded variables, the shares of experience among candidate managers, are significant predictor of d_{ij}. In the second column of Table 2, we report results regressing revenue share, which is non-parametric estimate of p_{ij}, to the same control variables as in the first column. While the signs and significance of the coefficients of experience variables are similar between the two columns, which might show that our two approaches are consistent with each other, there are also some notable differences. For example, tenure is a significant predictor for only revenue shares and the estimated slopes of the number of jobs, one of the workload measures we use, are different.

We find the manager effect to be economically significant. As shown in Table 3, the standard deviation of manager effects is between 5.8%-10.7% depending on the model and whether controlling for selection bias. Mixed effect models controlling for selection bias in columns 2-3 are our preferred model specifications and their results show that one standard deviation increase in manager effect leads to 5.8-6.2 percentage point increase in profitability, which is quite large.

Table 4 shows the estimation results of (5). Outsource ratios are significantly associated with higher cost ratio. In particular, the special outsourcing cost ratio strongly increases cost ratio, supporting our claim that it serves as a proxy for underlying complexity. The coefficient of Rev_chief_other_adj shows that one standard deviation increase of revenue of other jobs under management increases cost ratio by 1.4%, which supported that too much workload of the chief manager is harmful to profitability. In the mixed effect model, the estimated coefficient implies that 10000 hours more industry specific experience increase profitability by about 4.5%. The insignificance between industry specific experience and cost ratio in the fixed effect model may indicate that experience across industries are substantially convertible, which we couldn't correctly measure in our experience variable. Finally, in both ways of selection bias correction, having higher general experience, as measured by longer tenure, significantly helps to decrease cost ratio or equivalently increase profitability.

6 Interview Summary: What Do "Good" Managers Do

We have shown that the standard deviation of manager effect, unobserved manager ability, is about 6%. What explains the difference in manager performance? In order to explore what differences in ability, behavioral characteristics or management styles are causing differences in project performance, we have interviewed seven project managers who are among the top 15 percent in terms of the manager effect from March 27th to April 2nd, 2018. The main purpose of these interviews is to hypothesize about what make them better than the others rather than to test any predictions. We summarize here what we find relevant in characterizing "good" managers as well as the actual comments from the interviews.

Good planning

When setting a target profit, all "good managers" develop detailed plan on the allocation of necessary resources such as how many junior architect members are needed, how many hours will be needed for each task, which tasks need to be outsourced, etc.. They also instruct members to complete assigned tasks within the pre-specified target hours so that labor costs are controlled.

- *"It is important to share the same expectation with the client when signing the contract at the beginning.... In order to control costs, you need to foresee what problems might arise in the course and present to the clients what solutions are applicable to each of the problems in advance."*
- *"I am making efforts to understand what the client is expecting as early as possible. Also, when negotiating the contract, I always have the break-even point clearly in mind so that I can effectively negotiate the price."*
- *"I always make time schedule of work backward from the goal and stick to the planned schedule. I avoid adding forward from the start because you will fail in soft-landing because there are too many parameters in this thought process."*
- *"I negotiate the price myself. You need to make sure that the revenue and cost are balanced in advance. Since the time span of our project is typically very long, you need to check the progress from time to time."*
- *"In my department, I always tell my people what target of cost ratio we want to achieve, so they work bearing in mind how many hours they can spend in each of the project. This may not be always the case for other project manager. Especially in large ones, employees may not be aware how many hours they can spend. Unless the project manager's calculation is fully shared with the members, each of them may end up spending more and more without limit."*

Additionally, we have learned from the interviews that young designers, motivated by their career concerns, tend to put too many hours and end up over-investing in quality, which may not be desirable from the firm's point of view. Therefore, managers should make their members be aware of their time limit on each task.

Frontloading efforts

"Good managers" provide clients with sufficient information including pros and cons of each option they have in order to facilitate early decisions. They also present to their clients a roadmap that shows future events and decisions to expect in order to prepare them for timely decision-making. Such efforts to share information helps to avoid wasteful waiting.

- *"In order to facilitate early coordination, it is necessary to show 'roadmap'—what decisions will need to be made in the course of project—to clients in advance.... It is also important to help the client to decide on basic policy at the beginning by showing the options, say plan A vs. plan B. Once the choice set is narrowed down and fixed, you don't have to expand it later."*
- *"I always keep in mind that I should share daily work schedule with the client"*
- *"Target cost is determined by the number of project members multiplied by hours (from 9AM to 6PM) over the scheduled period. Overtime work may be needed If there are any changes in design, but I advise my junior architect not to be swayed by the speed of the designer.*

- *"For most of the clients, requesting the design work is the experience they never have before. So, it is important to ensure that they understand the process and the decision maker with the formal authority is fully informed about the agreement. We even judge when the formal decision maker will be asked to make a decision and schedule an appointment far ahead. For example, if the client is a bank and the decision maker with formal authority is the CEO, we will notify the client that we make a proposal three months later and make an appointment with the CEO at the timing. Such efforts significantly reduce the waiting time."*

Communication

"Good managers" communicate with their subordinates once a week by setting weekly department/project meetings or by exchanging emails in order to stay informed of the progresses made and offer effective advice. Whenever they find delay or trouble, they step in to help eliminate any obstacles the subordinates face. They also communicate well with other project managers to coordinate over resources, especially employees who serve both of them as project members.

- *"I hold weekly department meeting with my subordinates. I share information from the management and discuss experience and knowhows from a particular project or on a particular theme."*

- *"I check time input of all junior architect in each job every week. If there is any difference between total inputs and the actual working hours, I ask them why. It may be the case that there are not sufficient number of junior architect assigned. Then, I may need to assign more people or do something else."*

- *"Communication among structural design, facilities, and supervision is also necessary. Managers lend and rent team members across department. Therefore, managers need to communicate with each other in order to know the work load their subordinates are assigned."*

- *"I am trying to create a friendly atmosphere that makes my subordinates feel comfortable with talking to me. This helps me to gather information. I want to receive a timely report as soon as the project encounters any difficulties."*

- *"I hold my department meeting every Monday from 9:30am. I check with each one of my ten members on whether they are making progress as scheduled. I also ask everyone what they plan to do in the week."*

Understanding of client

"Good managers" make efforts to learn their clients' business models, needs, and decision-making process in order to make precise estimates of the budget, do effective bargaining and coordination, and avoid wasteful re-do and delay. Note that it will be very costly if an initial design that the team spent several months producing is rejected by the client, in which case the work has to start all over again.

- *"Projects are very different depending on the type of building. Each of our junior architect has his or her strong area. Even in urban development, for example, someone is strong in projects in Shibuya or Minato ward, another one has a strength in projects with A Real Estate, etc.*

Experience and personal connections employees developed in the past through the projects they were assigned help them to work effectively in related projects in the future. So, it is important what kind of team members you combine to form a team. We don't change the leader, a position for senior architects, but junior architects can be replaced. Some of the big projects could take more than ten years. In such projects, it is often the case that we, designers, know better than the clients about the past history and background."

- *"The most important skill among all is the ability to foresee what will happen in the future. This ability may partly depend on the manager's comprehension about what decision-making style the client has. Say, does the client have bottom-up or top-down decision-making style? The authorization styles differ significantly among organizations."*
- *"I listen to my clients very well. I try to understand what kind of buildings they want to build, how much budget they have, what kind of organizational structure they have, who is the final decision maker, etc.."*

7 How "Good" Managers Behave Differently

How is the progress curve related to the manager effect?

If "good managers" are generally good at planning and put forth more front-loading efforts through sufficient information sharing, those projects managed by the "good managers" should start moving forward more quickly and experience less redo's than others. As a result, they would experience less rush toward the end than others. Note that the average time length of jobs is 22.5 months and making uniform progress at each point of time is not a trivial task. The team managed by less capable managers would have to rush at the end and be apt to make mistakes when a project is running late.

In order to find out how progree patterns are different dependent on the manager quality, we divide managers into 2 groups based on ranking in the manager effect. Figure 4 plots the weighted average relative progress curve,with 95% confidence intervals, of two groups of managers at $t = 0, 1, ...0.9$. More specifically, for red line, we plot

$$\sum_{i\in\Omega_G} r_i \frac{P_i(t)}{\hat{P}_i(t)}$$

for $t = 0.1, 0.2, ...0.9$, where G is a set of managers ranked top 20% based on the result from the mixed effect model, $\hat{P}_i(t)$ denotes predicted progress. Similarly, blue line is the corresponding weighted average for managers rank bottom 20%. It is clear in Figure 4 that better managers have been able to move the project forward significantly more quickly at the beginning of job. Note that ranking of managers are estimated from regression model that does not use variation of labor inputs across time, whereas relative progress measure is constructed solely from the speed of project execution in terms of labor inputs without using cost information, so there is no reason to expect that these two measures will correlate beforehand. Therefore the pattern shown in Figure 4 provides strong support for the claim that our estimated manager effect captures real differences in management practices that impacts productivity.

Figure 4 shows that the speed of project execution at different phases ($t = 0 - 0.2; 0.3 - 0.6; 0.6 - 0.9$) has different effects on the job outcome. We let F_i, M_i, B_i be front loading, mid loading and back loading measure, respectively, as follows:

$$F_i = \frac{P_i\left(20\right)}{\hat{P}_i\left(20\right)}$$

$$M_i = \frac{P_i\left(60\right) - P_i\left(30\right)}{\hat{P}_i\left(60\right) - \hat{P}_i\left(30\right)}$$

$$B_i = \frac{P_i\left(90\right) - P_i\left(60\right)}{\hat{P}_i\left(90\right) - \hat{P}_i\left(60\right)}$$

Front loading measure compares progresses during the first 20% of time among jobs with similar characteristics, and similarly for mid and back loading measures.

How large is the effect of front loading? We measure it by running weighted least square regressions, controlling for other covariates. As shown in Table 5, it is found that frond loading is significantly associated with lower cost ratio and shorter time length of job. Although not obvious from previous plots, back loading is found significantly associated with higher cost ratio and longer time length. To interpret the magnitude of the coefficient, one standard deviation increase in front loading measure leads to around 2.5% decrease in cost ratio and 45 days decrease in time length. It is also significantly correlated with higher chance of winning awards. Similarly, one standard deviation increase in back loading measure leads to 3.3% increase in cost ratio, 50 days increase in time length. Meanwhile, progress in the middle is significantly associated with more defects. In order to further understand this result, we run the regression for each phase of job, and it is found that it is the contract administration jobs that are driving the correlation between mid loading and defect rate, therefore this result may only reflect some special consideration in this kind of jobs.

Internal communication

Our interview results generally support the view that good managers communicate and share information well with their team members and subordinates. One caveat with this result is that what matter may not be simple total hours you spend with your subordinates but rather communication style as one of the interviewee suggests (*i.e. a friendly atmosphere that makes subordinates feel comfortable with talking*).

In order to examine this implication, we take a look at the upward feedback the firm conducts every year. Details of each feedback question are explained in the appendix. The respondents are subordinates of the focal manager in the formal hierarchy, thus the fact should be noted that they comprise a smaller set than that of employees working in the jobs led by the manager. We report the rank correlation between manager effect ranking (lower numbers indicate batter managers) and average feedback question score (higher numbers indicate better managers) in Table 6. Since we only have data for upward feedback from 2011, we restrict our sample for estimation of manager effect to this smaller sample in order to better match the upward feedback data. Also we don't control for manager experience variables in order to let estimated manager effect to contain both observed and unobserved effects. According to the table, managers with better ranking in the manager effect on the cost ratio tend to have higher score in question 3, "Does the manager make efforts to share common goals and expectations by communicating closely with subordinates?" supporting our claim. Better managers also get significant higher scores on question 2, "Does the manager pay attention to the health status of subordinates and make appropriate time management?", and question 6, "Is the manager capable of managing projects effectively?".[3]

Degree centrality and outcomes

Although we did not ask specifically about team formation effectiveness during the interview, managers generally support a recent change in the firm's policy that allows managers more freedom to recruit project members from the pool of employees who are not direct reports in the chain of command. Since designers have different skills and experience as one of the interviewee stated, managers who have large internal networks through co-working experience may be able to form their teams more effectively. Thus, we next examine if good managers tend to have larger internal networks.

This argument does not necessarily claim the causal relationship. Although a large network will help a manager to form a better team, a capable manager will end up knowing many people because he/she will manage more projects and other people will want to work with him/her.

Specifically, we calculate degree centrality for each manager-year, which is defined as the share of managers and senior architects with whom each manager has coworking experience in all of managers and senior architects. Figure 5 show the distribution of the degree centrality of all managers and senior architects. We can see from it that most of the managers and senior architects have worked with less than 40% of other managers and senior architects within the firm before.

In order to examine the effect of degree centrality on our main project performance measure, the cost ratio, we run the following regression:

$$y_{ij} = x'_{1j}\beta_1 + x'_{3i}\beta_3 + \gamma d_{ij} + u_{ij}$$

where ψ_i in (5) is replaced with d_{ij} which is the degree centrality of manager i at the time when job j started. The vector of team member characteristics,x_{2j}, is not included as control because the efficacy of team member composition should be the primary mediator of the effect of degree centrality, which we hope to capture by d_{ij}. However, team size in x_{2j} is controlled for in the second specification because managers who manage large teams should tend to have high degree centrality. The results in Table 7 show that the degree centrality of manager is significantly negatively associated with the cost ratio. Moreover, when we control for team size, the significance of the effect declines reflecting the fact that managers with high degree centrality tend to be the ones who are assigned large jobs but team size explains only part of the effect in the first specification. While it may be consistent with our claim, more evidence is required to make this claim. In the last two columns of the same table, we see that degree centrality of manager does not correlate with front loading measure, but significantly reduces back loading measure, which may imply that appropriate team

[3] We also examine the responses to the time use survey the firm conducted in late 2017 after the observation period and find that the time they spend with their subordinates is negatively correlated with the manager effect on the cost ratio but this relationship is not statistically significant. We decided not to include the result in the study because of our concern about the bias due to self-sorting and attrition. Only less than a half of the managers in our sample responded to the survey.

formation helps to avoid delay. Finally, we also run the regression

$$d_{ij} = \alpha\psi_i + \gamma_2 T_{it} + \gamma_3 T_{it}^2 + year_j + v_{ij}$$

where we control for quadratic function of tenure T_{it}, to examine the partial correlation between the degree centrality and the manager effect. Table 8 shows that managers with greater manager effect on the cost ratio tend to have higher degree centrality.

Decomposition of the Manager Effect

As we have discussed earlier, managers influence outcome through both revenue creation and cost management. Therefore, in an attempt to separate the manager effect, we put revenue and cost in place of cost ratio on the left hand side and report measured standard deviation divided by the mean of outcome variable. Table 9 shows that, one standard deviation increase in manager effect leads to 6.8% decrease in cost and 10.4% increase in revenue. Table 10 shows rank correlation among manager effects on three outcome variables. As can be seen in Figure 6, where we plot the rank of manager effect in cost ratio, against rank of manager effect in revenue and cost, the capability to raise revenue and that to reduce cost are correlated but there are definitely someones who are strong only on one dimension.

Manager effect at different phases

As a feature of the knowledge intensive business service industry, the ability to solve non-routine tasks is one of the key values of project managers. In order to test this idea, we divide samples according to different phases of a typical project. The initial phases include planning & develop management, and schematic design. This stage likely requires the most creativity, because the concept of the design needs to be initialized based on client's request, relevant information regarding the condition of the land, and government regulations. The middle phases, which include design development and contract documentation, involves writing down the details of design and is probably more standard. The final phase, contract administration, does not require creativity but is rather demanding on ability of coordination since the construction side is also involved and original designs might need to adapt to local conditions. 11 shows that consistent with the intuition, manager effects are higher at the initial and final stage, while smaller at the final stage.

Other Measures of Manager Quality

Next we characterize "good" managers by comparing estimated manager effects on cost ratio with other individual level measures. In Table 12, we show rank correlation between the manager effects and other measures of manager quality. Again, good performers are those have smaller effect on cost ratio or cost, but higher effect on revenue. All three ways of calculating manger effect show that good performers tend to have shorter tenure and less records of punishment. In addition, good performers in terms of the cost ratio also tend to have higher salary, more records of award, and better peer evaluation score. Good performers in cost reduction tend to have higher peer evaluation scores.

Annual Manager Effect

As another way to measure manager effect, we change the unit of observation from job to manager-year. That is, total revenue and cost of jobs managed by a manager is calculated for each year. If a job spans across more than a year, then its revenue is split according to number of days spent in each year, and its cost is split according to number of working hours expended in each year. As can be seen in Table 13, the standard deviation of the manager effect is even larger. The rank correlation between annual manager effect on cost ratio and job manager effect on cost ratio is 0.33 and significant at 1% level, showing that different ways of ranking managers are consistent with each other.

8 Conclusion

In this paper, we provide new evidence on how managers affect productivity in a complex team work environment that require creativity. We first quantify the manager effect using mixed effect model, then based on the interview results, attempt to explain how good managers improve their performance. Specifically, we hypothesize that managers improve team performance by better planning, better communication with both client and project members and better understanding of the client's needs and decision-making style, which help to front-load design work, reduce waiting time, and avoid wasteful redesigning. We show that good managers are different in several dimensions. We provide supporting evidence from the analyses of labor input data, and three-hundred-sixty-degree evaluation records (namely the upward feedback). Especially, we find that the speed of project execution, quality of communication with subordinates, and degree centrality in the internal network could be important mediating factors.

Our study contributes to a large literature of productivity differences across and within firms. In this paper we provide new work-group level evidence that management practices lead to substantial productivity differences. Another important question as discussed in Gibbons and Henderson (2012) is that, why these practices are not readily diffused? Although our current paper can not directly speak to this question, there might be information barriers to good management practices. Our research is part of the firm's effort of reforming human resource management. We are hopeful that our evaluation of the firm's policy to diffuse good practices among project managers can shed light on this question.

There are other interesting questions worth exploring. For one thing, the detailed labor inputs can be viewed as a measurement of task specific human capital. Therefore we can study how these specific skills are learned across time for each workers. Interesting questions include: how should jobs be sequenced; who should be promoted as manager; what is the return to these skills; and, how would composition of team affects productivity? Our detailed labor input data also allow us to measure the degree of delegation from project managers to the employees in the senior architect level. We can examine what determine the degree of delegation, and how good managers are different in the delegation strategy. We look forward to answering these questions in our future study.

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	count	mean	std	min	25%	50%	75%	max
Revenue	2678	87,551,946.79	118,221,815.20	10000000.00	21,898,448.25	45,000,000.00	95,150,000.00	1,148,320,000.00
Month length	2678	22.24	16.15	2.00	11.00	17.00	30.00	134.00
Cost	2678	54,913,690.89	78,799,412.15	106,250.00	14,143,940.00	29,323,583.50	62,509,154.25	1,041,541,717.00
Cost ratio	2678	0.68	0.29	0.00	0.48	0.66	0.84	1.97
Team size	2678	24.44	15.22	1.00	13.00	21.00	33.00	116.00
Group_outsource_ratio	2678	0.06	0.16	-0.14	0.00	0.00	0.02	1.00
Special_outsource_ratio	2678	0.07	0.15	-0.07	0.00	0.00	0.07	0.99
Ordinary_outsource_ratio	2678	0.16	0.13	0.00	0.06	0.13	0.22	0.96
Area	2678	54420.84	110375.14	0.00	3575.36	13446.00	50000.00	1000000.00
Rev_chief_other	2678	1,271,322,032.57	819,598,189.91	0.00	666,948,791.75	1,130,273,042.50	1,776,557,033.00	4,395,472,593.00
No_job	2678	27.90	21.86	1.00	15.00	24.00	34.00	176.00
Exp_industry	2678	2208.75	3249.91	0.00	150.50	834.00	2624.00	20067.50
Exp_job_content	2678	1971.39	2182.25	0.00	423.00	1216.75	2798.00	13420.00
General Exp	2678	24.88	5.73	9.00	21.00	24.00	28.00	42.00

Table 1: Summary statistics of jobs

Outcome Variable	d^*_{ij}		Rev share	
$General\ Exp$	-0.1261	(0.1295)	0.0016^{***}	(0.001)
$General\ Exp^2$	0.0031	(0.0025)	$-3.8 \times 10^{-5***}$	(1.02×10^{-5})
No. job	0.1361^{***}	(0.0146)	-0.0002^{***}	(6.4×10^{-5})
$No.job^2$	-0.0007^{***}	(0.0001)	2.6×10^{-7}	(4.7×10^{-7})
Amount of Rev.	1.1728^{***}	(0.1881)	0.0222^{***}	(0.0007)
$Amount of Rev.^2$	-0.2400^{**}	(0.0932)	-0.0018^{***}	(0.0004)
$\ln Rev\_Past$	-0.6235^{***}	(0.1836)	0.0008	(0.0007)
Exp. Industry	3.0615^{***}	(0.3103)	0.0366^{***}	(0.001)
Exp. Job content	1.1247^{**}	(0.5409)	-0.0005	(0.002)
Exp. Share Industry	21.2234^{***}	(3.3401)	0.6288^{***}	(0.0192)
Exp. Share Job content	19.0180^{***}	(3.4857)	0.2753^{***}	(0.0193)
No. Obs	54270		54270	
R^2	0.13		0.45	

Note: Both regressions control for industry, year and district fixed effects. Unit of experience is 10,000 hours. The marginal effects times 100 at mean value of independent variables are reported for logit regression. Standard errors are included at the brackets.

Table 2: Parametric estimation of p_{ij}

Outcome Variable	Cost Ratio	Cost Ratio	Cost Ratio	Cost Ratio	Cost Ratio	Cost Ratio
σ_ψ	6.0%	5.8%	6.2%	10.2%	10.4%	10.7%
Model	Mixed	Mixed	Mixed	Fixed	Fixed	Fixed
No. of Managers	105	105	105	105	105	105
Control for selection	No	Rev share	Logit	No	Rev share	Logit

Note: Standard deviations of the manager effect in fixed effect model are weighted by revenue. Quadratic function of p_{ij} is controlled.

Table 3: Estimation of Manager Effect

Variable	Fixed Effect		Mixed Effect	
Group_outsource_ratio	0.3705^{***}	(0.0465)	0.3169^{***}	(0.0386)
Special_outsource_ratio	0.2872^{***}	(0.0402)	0.3337^{***}	(0.0358)
Ordinary_outsource_ratio	0.0647	(0.0584)	0.0986^{**}	(0.0426)
$Area\_adj$	-0.0448^{***}	(0.0147)	-0.0245^{***}	(0.0102)
$Area\_adj^2$	0.0052^{***}	(0.0021)	0.0013^{***}	(0.0014)
Rev_chief_other_adj	0.0241^{**}	(0.0095)	0.0141^{**}	(0.0063)
No_job	-0.0001	(0.0006)	-0.0003	(0.0004)
Exp_industry_adj	-0.0065	(0.0297)	-0.0450^{**}	(0.0189)
Exp_job_content_adj	0.0535	(0.0411)	-0.0312	(0.0248)
$Team\_size\_adj$	0.1486^{***}	(0.0299)	0.1543^{***}	(0.0188)
$Team\_size\_adj^2$	-0.0229^{***}	(0.0073)	-0.0245^{***}	(0.0041)
$Team\_size\_adj^3$	0.0012^{**}	(0.0005)	0.0014^{***}	(0.0003)
$\hat{p}_{ij}$	-0.4675^{***}	(0.1632)	-0.3103^{***}	(0.1302)
$\hat{p}_{ij}^2$	0.4172^{***}	(0.1474)	0.2772^{***}	(0.1179)
$General\ Exp$	-0.0176^{***}	(0.0029)	-0.0074^{***}	(0.0014)
No. Obs	2678		2678	

Note: Exp_industry_adj and Exp_job_content_adj are the corresponding variables divided by 10,000. Team_size_adj is the original variable divided by 10. Area_adj and rev_chief_other_adj are the corresponding variables normalized by standard deviations. Standard deviations are adjusted for the measurement errors in the first stage estimation. The dummies of industries, job content, broad category, and foreign or not are also controlled.

Table 4: Second stage estimation

Outcome Variable	Cost Ratio	Time Length	Awards	Defects
Front Loading	-0.0316^{***}(0.000)	-44.9433^{***}(0.006)	0.073^{**} (0.05)	0.0043 (0.398)
Mid Loading	0.0302 (0.163)	3.2251 (0.932)	-0.043 (0.443)	0.0166^{***} (0.001)
Back Loading	0.0328^{**}(0.041)	50.4209^{**}(0.029)	-0.033 (0.476)	-0.0108^{*} (0.091)

Note: First row shows estimated effects of front loading on each outcome variable; similarly for second and third row. Bracket contains estimated p-value

Table 5: Effect of Relative Progress

	Mixed Effect		Fixed Effect	
Question 1	-0.08	0.33	-0.01	0.92
Question 2	-0.20^{***}	0.01	-0.23^{***}	0.00
Question 3	-0.21^{***}	0.01	-0.21^{***}	0.01
Question 4	-0.03	0.66	-0.08	0.27
Question 5	-0.05	0.54	-0.04	0.63
Question 6	-0.16^{**}	0.03	-0.22^{***}	0.00
Question 7	-0.04	0.58	-0.14	0.06

Note: Rank correlation is reported in each grid, with p-value in the bracket

Table 6: Manager Effect and upward Questions

	Cost ratio	Cost ratio	Front loading	Back loading
Degree centrality	-0.2787^{**}	-0.2191^{*}	0.7617	-0.6989^{**}
	(0.142)	(0.127)	(0.478)	(0.348)
Control for team size	No	Yes	Yes	Yes
Clustered by project	Yes	Yes	Yes	Yes

Note: The table shows the correlation between degree centrality of the chief manager and other variables shown in the columns. Besides team size, job characters are also controlled.

Table 7: Cost ratio and manager centrality

	Degree centrality	Degree centrality
Manager effect	-0.2271^{*}	-0.2333^{***}
	(0.124)	(0.041)
Quadratic function of tenure	Yes	Yes
Year fixed effect	Yes	Yes
Model	Mixed effect	Fixed effect

Note: The table shows the correlation between degree centrality and estimated manager effect from different models. Quadratic function of tenure and year fixed effects are also controlled.

Table 8: Degree centrality and manager effect

Outcome Variable	Cost	Revenue
SD of Manager Effect	6.8%	10.4%
Model	Mixed Effect	Mixed Effect
Number of Managers	105	105
Number of Observations	2678	2678

Note: the table shows the standard deviation of manager effects, using cost and revenue as the outcome measures.

Table 9: Estimation of Manager Effect

	Cost Ratio	Cost	Revenue
Cost Ratio	1	0.67	-0.84
Cost	0.67	1	-0.57
Revenue	-0.84	-0.57	1

Note: the table shows the rank correlation between the manager effects estimated using different outcome measures.

Table 10: Rank Correlation of Manager Effects

	Standard Deviation of Manager Effect
Planning & develop management	13.3%
Schematic design	11.6%
Design development	4.2%
Contract documentation	6.9%
Contract administration	9.7%

Note: The table reported standard deviation of manager effect estimated using sub-sample of jobs of different phases. Job characteristics and logit assignment probability are controlled.

Table 11: Manager effects at different phases

	Tenure	Salary	Award	Punishment	Peer Evaluation
Manager Effect on Cost Ratio	0.22^{***}	-0.10^{**}	-0.11^{**}	0.16^{***}	-0.09^{*}
	(0.00)	(0.05)	(0.01)	(0.00)	(0.08)
Manager Effect on Cost	0.15^{***}	-0.06	0.03	0.12^{***}	-0.13^{***}
	(0.00)	(0.22)	(0.51)	(0.01)	(0.01)
Manager Effect on Revenue	-0.19^{***}	0.01	0.07^{*}	-0.14^{***}	0.06
	(0.00)	(0.89)	(0.09)	(0.00)	(0.23)

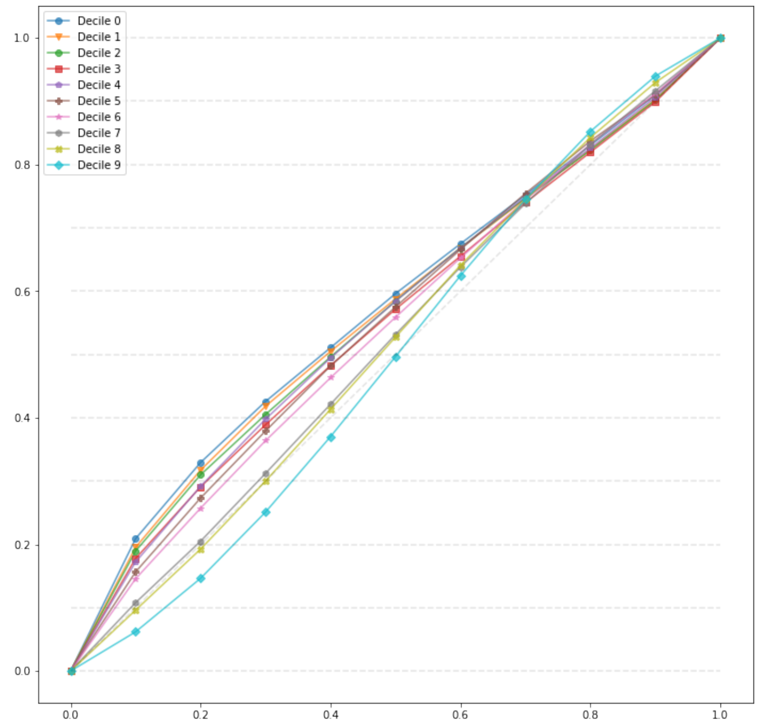
Note: Rank correlation is reported in each grid, with p-value in the bracket

Table 12: Manager Effect and Worker Character

Outcome Variable	Cost Ratio	Cost	Revenue
SD of Manager Effect	9.9%	9.3%	11.4%
Model	Mixed Effect	Mixed Effect	Mixed Effect
Number of Managers	102	102	102
Number of Observations	664	664	664

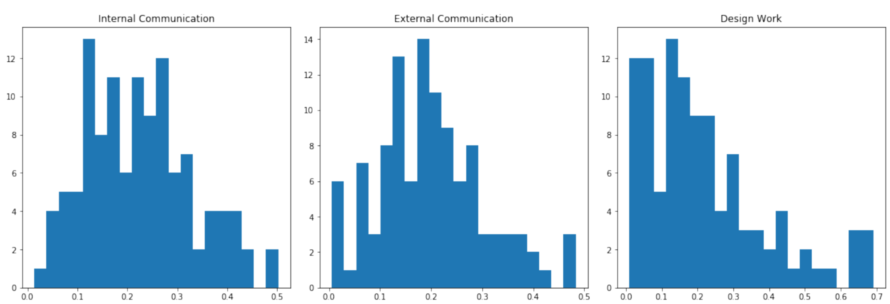
Note: Year fixed effect and number of jobs managed by each manager in each year is controlled.

Table 13: Manager Effect by Year-Manager



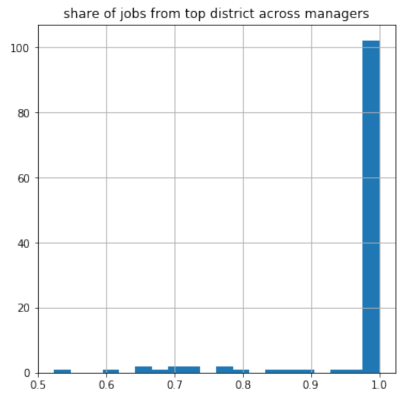
Note: The figure plots average progress curve for jobs across ten equally sized revenue bins. Labor input is measured as labor costs (hours times hourly wages)

Figure 1: Average Progress Curve across Revenue Decile



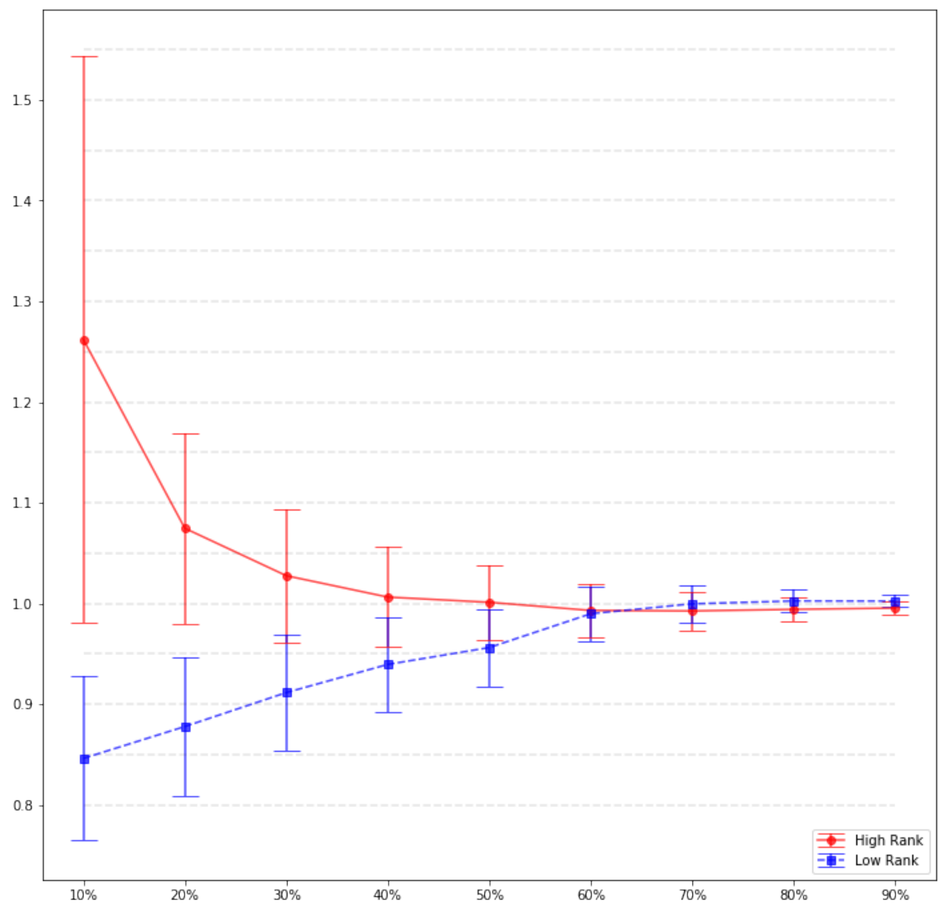
Note: From left to right, the panel plots the distribution of share of manager's time allocated to internal communication, external communication and design work respectively.

Figure 2: Manager time allocation



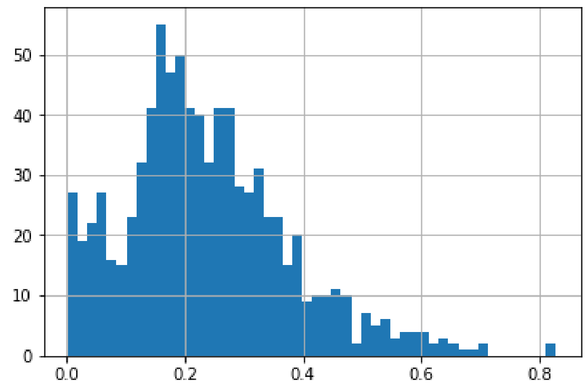
This figure shows the distribution of share of jobs from the top district across managers. It shows that most of the managers do not move across districts, since the top district tends to account for 100% of jobs.

Figure 3: Distribution of share of job from top district



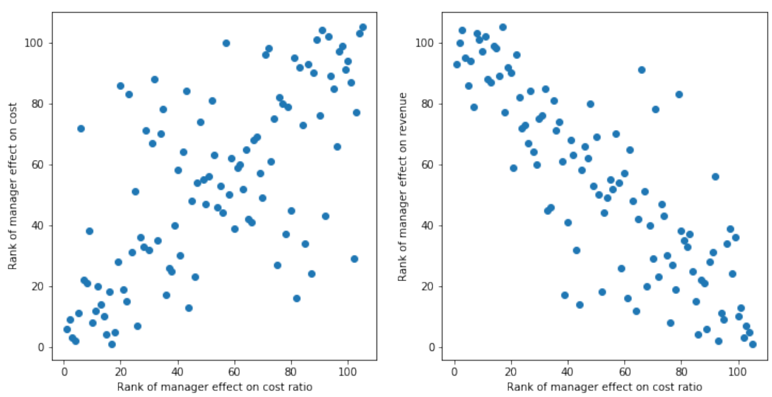
Note: The figure shows the average relative progress of groups of high and low rank managers.

Figure 4: Difference in Relative Progress



Note: The figure shows the distribution of degree centrality across managers.

Figure 5: Distribution of degree centrality



Note: the left (right) panel plots the rank correlation between the manager effects estimated using cost (revenue) as outcome.

Figure 6: Comparison of three manager effects

Appendix

A More explanation on data

Items of upward feedback

There are 7 questions in upward feedback:

1. Does the manager adjust junior architect assignment appropriately in accordance with the difficulty and the current progress of the project?
2. Does the manager pay attention to the health status of subordinates and make appropriate time management?
3. Does the manager make efforts to share common goals and expectations by communicating closely with subordinates?
4. Does the manager evaluate subordinates in a fair manner?
5. Does the manager make efforts to guide and develop young employees and hand down expertise and skills to them?
6. Is the manager capable of managing projects effectively?
7. Does the manager respond appropriately to clients and other parties outside firm?

Example of progress curve

Here an example is given to illustrate how speed of progress is measured. Say some job i has start date is 2014.4.24, end date is 2014.6.30 (i is dropped in the following notation for simplicity). For each year-month m, define t_m as number of days between m and start date, normalized by number of days between start and end date, and P_m is number of working hours in m divided by total number of working hours between start and end year-month. Say in total this job lasts 68 days, and in total 18.5 hours are used as inputs. Then t_m and $P_m$will be calculated from data as follows:

- $t_0 = P_0 = 0$ as start point
- When m is 2014.4, there is no input at all, then $t_m = 7/68$, $P_m = 0/18.5$
- When m is 2014.5, 4 hours are spent on this job, then $t_m = 38/68$, $P_m = 4/18.5$
- When m is 2014.6, rest of the hours are spent, and job ends, then $t_m = 68/68$, $P_m = 18.5/18.5$
- Connecting these points, we have a piece-wise linear function $P_m(t_m)$, from which we can calculate progress at each time points.

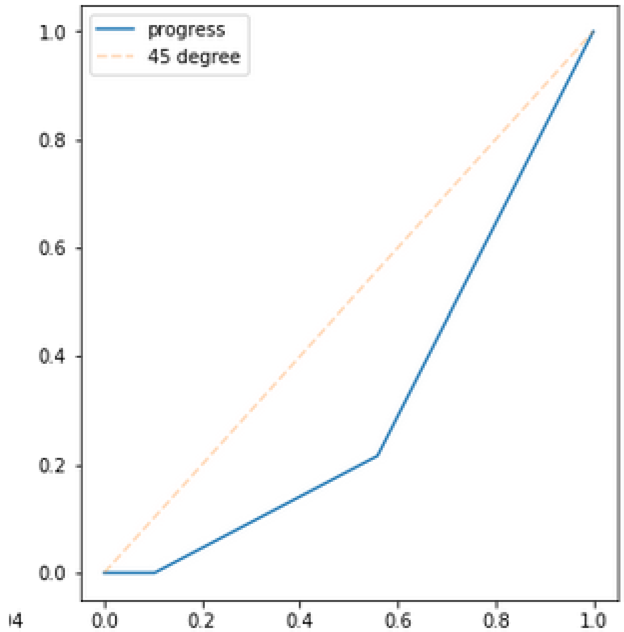


Figure 7: An example of progress curve

- Note that this example is simplified, in a typical case both input and time length will be larger and hours are weighted by hourly wage

B Correction of variance

We follow the procedure outlined in Murphy and Topel 1985. Since we estimate p_{ij} at the first step, we need to correct for the variance at the second step. The equation we estimate at second step is

$$y_{ij} = x'_{1j}\beta_1 + x'_{2j}\beta_2 + x'_{3i}\beta_3 + \psi_i + \lambda\left(\hat{p}_{ij}\right) + \left[\lambda\left(p_{ij}\right) - \lambda\left(\hat{p}_{ij}\right)\right] + v_{ij}$$

where $\left[\lambda\left(p_{ij}\right) - \lambda\left(\hat{p}_{ij}\right)\right]$ represents the source of variation resulted from using estimated $\hat{p}_{ij}$ instead of true value. Effectively it is like adding an additional mean zero error term. Using the first order approximation of the term $\left[\lambda\left(p_{ij}\right) - \lambda\left(\hat{p}_{ij}\right)\right]$, we can correct estimated variance using the formula

$$\left(X'X\right)^{-1} X'F^{*}V\left(P\right)\left(X'F^{*}\right)'\left(X'X\right)^{-1}$$

where $V\left(P\right)$ is variance-covariance matrix of all estimated p_{ij}, F^{*} is the derivative of polynomial $\lambda\left(p_{ij}\right)$ wrt estimated p_{ij} and coefficient, and X is matrix of regressors in the second stage. Next we describe more details of how these matrix are calculated in both parametric and nonparametric estimation of p_{ij}.

Implementation in parametric model

Since we predict p_{ij} by logit model for each job in second step, $V(P)$ is of size $n \times n$, where n is number of observations in the second step. The values in $V(p)$ are calculated from delta method (an alternative is to use bootstrap), using partial derivative of predicted probability w.r.t. parameter

$$\frac{\partial p_{ij}}{\partial \theta} = p_{ij}(1 - p_{ij}) z_{ij}$$

where z_{ij} is the vector of regressors, θ is vector of parameters in the first step. And

$$V(P) = \Delta P \hat{V}(\theta) \Delta P'$$

Implementation in nonparametric model

For revenue share, $V(P)$ is of size $J \times J$, where J is number of different cells that defined by chief and categories. The elements of $V(P)$ can be estimated from formula of multinomial distribution:

$$Var(p_{ij}) = \frac{p_{ij}(1 - p_{ij})}{n}$$

$$Cov\left(p_{ij}, p'_{ij}\right) = -\frac{1}{n} p_{ij} p'_{ij}$$

if p_{ij} is within the same category; uncorrelated otherwise.