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Optimal Allocation of Decision-Making Authority and the Provision of Incentives under Uncertainty

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Optimal Allocation of Decision-Making Authority and the Provision of Incentives under Uncertainty

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Abstract

Incentives for managers are often provided by offering them performance-based compensation schemes. The efficiency of such monetary compensations, however, depends on several factors, among them the quality of the employed performance measures, the information available for contracting purposes, and the allocation of decision-making authority which translates into either more centralized or more decentralized organizational structures. This article investigates a firm's decision whether to delegate or retain the authority to decide on a specific job design in a moral hazard environment with asymmetric information on effort costs. It provides conditions under which decentralization is the preferred organizational form. Moreover, it derives the result that the relation between incentives and the delegation of decision-making authority is not univocal, but depends on the quality of the employed performance measure. In this regard, it contributes to explaining the mixed empirical evidence on the relation between incentives and decision-rights.

Keywords: *Job Design, Incentive Contracts, Decentralization, Delegation, Decision-Making Authority*

1 Introduction

To motivate managers, firms frequently offer them performance-based compensation contracts. The effective provision of incentives, however, depends on more than just the monetary compensation scheme. Brickley et al. (2009) postulate the idea that performance evaluation, rewards, and decision rights assignment are like three legs of a stool that a firm needs to balance. Examples from corporate practice indicate that a change in a firm's organizational structure, which is usually accompanied by the reallocation of decision rights, indeed often entails an adaptation of the firm's performance evaluation and compensation schemes. When *GlaxoSmithKline* restructured their R&D department in order to increase efficiency, performance measurement and incentives were accordingly adjusted (Garnier 2008). At *RoyalDutch/Shell Group*, massive changes in their industry environment forced them to change their organizational structure, and they also redesigned the incentive system (Grant 2007). When *Citibank* changed their organizational structure in order to put more emphasis on customers rather than regions, they also adjusted corporate incentives (Baron and Besanko 2001).

In order to implement an incentive scheme that aligns the interests of managers and firm owners, a firm needs to consider that its accounting system typically delivers performance measures that do not perfectly reflect how the firm's value is affected by a manager's effort choices across different tasks. Rewards based on such performance measures have to be designed with caution because otherwise they can lead managers to misallocate their efforts (e.g., Holmström and Milgrom 1991; Baker 1992; Feltham and Xie 1994; Hughes et al. 2005). Incentives also interact with the allocation of decision rights (e.g., Athey and Roberts 2001;

Holmström and Milgrom 1994). While keeping decision rights at the top level is associated with a greater centralization of authority, delegation of authority to lower hierarchical levels involves a tendency towards decentralized organizational structures. Because decentralization involves a loss of control for the firm owners, it is fundamental that the manager in charge is provided with incentives to act in the best interest of the firm. If this is accomplished, a key advantage of decentralization is the efficient use of specific knowledge and information located on lower hierarchical levels (e.g., Dessein 2002).

Incentives, performance measurement, and decision rights are all closely related to job design, i.e., the allocation of tasks within the firm. For example, problems of effort misallocation due to incongruent performance measurement can be mitigated by assigning conflicting tasks to different employees (e.g., Holmström and Milgrom 1991; Kragl and Schöttner 2014). Moreover, firm owners are typically not informed about the exact costs of effort that managers face when providing effort on various tasks (e.g., Puschke 2009). In this situation, it might be beneficial if an informed manager has the authority to decide whether he performs a task himself or assigns it to another employee with potentially lower effort costs.

The present article analyzes the interaction of delegating decision rights with respect to job design and providing monetary incentives depending on the quality of performance measurement. We consider an environment in which the firm (principal) contracts with two managers (agents), whose effort choices are unobservable. Moreover, the effort costs of one agent are private information to that agent.¹ The managers are responsible for performing effort on three productive tasks. Two tasks naturally match the agents' abilities, training

¹The agent costlessly acquires his private information after the contract is signed and cannot communicate it to the principal. Baker (1992) and Raith (2008) analyze similar settings but do not study the allocation of decision rights.

or experience, that is, each agent is specialized in one of the tasks. The third task can be performed by either agent with equal quality. The principal can choose between two organizational forms: With centralization, the firm retains the right to allocate the third task to one of the agents. With decentralization, the decision about job design is delegated to the informed manager. The tasks jointly affect an aggregate performance measure that may be incongruent in the sense that it does not perfectly reflect the true productivity of effort in the different tasks.² Incentive contracts can condition on the realization of the performance measure but not on the assignment of the third task. We thus follow an incomplete contracting approach, reflecting that real-world employment contracts usually do not cover all parts of an employment relationship, e.g., because certain parts are non-verifiable by third parties or the contracting parties are unable to foresee and plan for all possible contingencies (e.g., Milgrom and Roberts 1992).

We find that with a perfectly congruent performance measure, the delegation of decision-making authority and the provision of incentives are complements, that is, there is a positive relation between both. The firm delegates the job design to the informed agent when his potential cost advantage over the other agent is sufficiently strong. In this situation, the firm either achieves the first-best solution or provides the manager with decision authority with more than first-best incentives. Such strong incentives are required to ensure that the manager does not abuse his authority to implement a task assignment that maximizes his own utility but not the firm value.

If the performance measure is incongruent, the firm faces an additional control problem with respect to effort. Nevertheless, depending on the congruity problems induced by the

²We provide an example when we present the details of the model in Section 2.

two feasible job designs, delegation can still be optimal. For example, the firm delegates the decision authority to the informed agent if he is likely to have higher costs than his colleague and therefore will probably not multitask, but in case he does, the congruity problem is rather small. To mitigate potential congruity problems, the firm may lower the incentives for the informed agent when he obtains decision-making authority. That is, under imperfect performance measurement, delegation and incentives can be substitutes.

Our analysis contributes to the explanation of the mixed empirical evidence regarding the interaction of delegated authority and incentives. For instance, Wulf (2007) finds a significant positive relation between a division manager's authority (measured by officer status) and his compensation based on global performance measures, such as firm sales growth. Nagar (2002) investigates the delegation of authority to lower-level branch managers in retail banks and how incentive compensations should be designed to ensure that managers do not misuse their discretion. He finds a positive relation between branch managers' authority and their compensation. Using survey data on British establishments, DeVaro and Kurtulus (2010) also establish a positive relation between the delegation of authority and the provision of incentives. Focussing on non-managerial occupations, DeVaro and Prasad (2015) can confirm a positive correlation between authority and incentives for simple jobs such as clerical, craft, or sales occupations. However, for complex jobs in professional, technical, or scientific occupations, they document that authority and incentives are negatively correlated. They develop a model showing that such a negative relationship can emerge when a risk-averse agent is assigned the right to choose between tasks that have a positive risk-return tradeoff for the principal, and there is only one performance measure to affect task selection and effort. In such a situation, combining delegation with high-powered incentives may not be

optimal because it can induce the agent to excessively choose low risk-return task.³ We study a different setting and our result that delegation and incentives can be substitutes is derived independent of risk considerations. However, presuming that performance measurement is more difficult in complex than in simple jobs, our model also predicts that a negative relationship between delegation and incentives should be observed more often for complex jobs.

Jia and van Veen-Dirks (2014) provide further empirical evidence that the relationship between delegation and incentives depends on the quality of performance measurement. Using survey data on production managers, they demonstrate that decision rights assignment and incentive pay are substitutes. They argue that more decision authority entails increased multitasking, which in combination with imperfect performance measurement calls for lower incentives to avoid distortion of effort across tasks. Because performance measurement is more involved for production managers than for higher-level managers, whose effort is more closely related to global performance measures, a negative relationship between delegation and incentives is more likely to occur for the former group. Our theoretical results partly verify their argument. In one instance of our model, the informed manager indeed obtains lower incentives when he can choose the job design and, as a consequence of delegation, performs the allocatable task more often. However, this is only true when the efficient incentives for the allocatable task are lower than the incentives for the manager's specialized task. Due to imperfect performance measurement, the principal then mutes the manager's second-best incentives in favor of the low-incentive task. We thus demonstrate that imperfect performance measurement is not sufficient for delegation and incentives being substitutes.

³Lando (2004) constructs an example with a similar tradeoff.

Moreover, we also show that increased multitasking under delegation is neither necessary nor sufficient for a negative correlation between decision authority and incentives. The type of correlation crucially depends on the ratios of the tasks' true productivities and their performance measure sensitivities, which determines the efficient incentives for each task in a single-task job.

By deriving conditions under which the delegation of job design is beneficial for a firm, we contribute to the large literature that examines a principal's choice whether to assign decision authority to an agent (see, e.g., Bolton and Dewatripont (2013) for an overview). As in Dessein (2002), we model delegation as a way to improve the informational content of decision making. While he analyzes strategic communication, we consider an environment where communication is too costly for the contracting parties. Another important advantage of delegation can be enhanced employee motivation (e.g., Aghion and Tirole 1997; Baker et al. 1999; Shin and Strausz 2014). The motivational effects of delegation depend, however, on the nature and sequence of tasks to be performed (Bester and Krähmer 2008). In our setting, agents are primarily motivated by incentive contracts, whose effectiveness is affected by the assignment of decision rights.

Finally, our analysis contributes to the literature on job design, pioneered by Holmström and Milgrom (1991) and Itoh (1994). To the best of our knowledge, we are the first to analyze the optimality of delegating job design decisions. We show that the delegation of task assignments can be optimal under asymmetric information on effort costs and may even lead to the first-best solution when centralization does not. In our setting, the right to offer contracts rests with the principal. Complementary to our study, Melumad et al. (1995) and Macho-Stadler and Pérez-Castrillo (1998) analyze situations in which contracting authority

is delegated to agents, but the principal remains responsible for the job design. Similar to our model, Reichmann and Rohlfing-Bastian (2014) investigate a situation in which the principal delegates the job design to one of two agents. However, in their setting, the delegation decision is exogenously given. Moreover, and contrary to our setting, the principal in their model has full information on the agents' effort costs.

The remainder of the article is structured as follows. Section 2 presents the model and characterizes the first-best solution as a benchmark. Section 3 analyzes the case of centralization, whereas Section 4 focuses on decentralization. Section 5 sheds light on the optimal job design with a perfect and an imperfect performance measure. Finally, Section 6 concludes.

2 Basic Model and First-Best Solution

We follow the approach of Reichmann and Rohlfing-Bastian (2014) and consider a single-period setting in which a principal (firm owner) contracts with two agents indexed by $i = 1, 2$ to provide unobservable effort on three productive tasks indexed by $\ell = 1, 2, 3$. Each agent is specialized in one task, e.g., due to ability, experience, or specific training. Without loss of generality, we assume that Agent 1 is specialized in task 1 whereas Agent 2 is specialized in task 2, implying that only Agent 1 can perform task 1 and only Agent 2 can carry out task 2. The third task, however, can be performed by either agent. Splitting this task between the two agents is not feasible. Effort in task ℓ is $e_\ell \geq 0$.

The agents' contribution to the firm value is $Y \in \{0, 1\}$, with

$$\Pr[Y = 1|e_1, e_2, e_3] = f_1e_1 + f_2e_2 + f_3e_3,$$

where $f_\ell > 0$ denotes the marginal productivity of effort in task ℓ for $\ell = 1, 2, 3$. Because Y is non-verifiable, incentives have to be based on the verifiable aggregate performance measure $P \in \{0, 1\}$,

$$\Pr[P = 1|e_1, e_2, e_3] = g_1e_1 + g_2e_2 + g_3e_3,$$

with sensitivities $g_\ell > 0$ for $\ell = 1, 2, 3$. The productivity and performance measure sensitivity of task 3 are task-related and therefore do not vary with the agent performing the task. Agents incur a cost of effort when working on their specialized tasks which is given by $\kappa(e_\ell) = \frac{1}{2}e_\ell^2$ for $\ell = 1, 2$. With respect to the third task, the two agents differ in their costs. Agent 2 incurs standard effort costs of $\frac{1}{2}e_3^2$, whereas Agent 1's effort costs in task 3 are $\frac{1}{2}ce_3^2$. Ex ante, c is a random variable with $c \in \{c_L, c_H\}$, $0 < c_L < 1 < c_H$, and $\Pr[c = c_L] = p \in [0, 1]$. Accordingly, ex post, Agent 1 can have higher or lower effort costs for performing task 3 than Agent 2. We assume that the parameter c is private information of Agent 1. He observes c after he has signed the contract and entered the firm. There is no costless and credible way to communicate this information to either the principal or the other agent. All parties are risk neutral and reservation utilities are zero. We further assume that the functional forms are such that the above probabilities for the realizations of Y and P remain strictly below one at the first- and second-best solution.

In summary, we have three contractual frictions arising from our model. First, the

agents' actions are unobservable, which gives rise to a moral hazard problem. Second, the performance measure is incongruent if the productivities f_ℓ do not match appropriately with the performance measure sensitivities g_ℓ , that is, whenever $\Delta_{\ell n} \equiv (f_\ell g_n - f_n g_\ell)^2 \neq 0$ for (at least) two tasks ℓ and n ($\ell, n = 1, 2, 3, \ell \neq n$) (Feltham and Xie 1994). An equivalent definition of an incongruent performance measure, which will be useful later on, is that $\frac{f_\ell}{g_\ell}$ is not constant for all ℓ . This noncongruity potentially imposes a loss on the principal from an inefficient effort allocation of the multi-tasking agent, i.e., the agent who performs the third task in addition to his specialized task. Finally, there is an information asymmetry with respect to Agent 1's effort costs c for the third task.

Figure 1 illustrates the timing of the model.

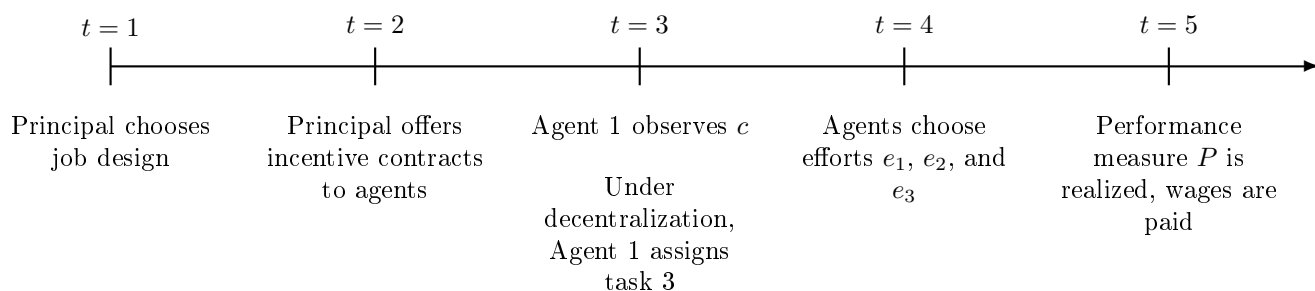


Figure 1: Timing of the Model

At $t = 1$, the principal chooses between a centralized or a decentralized organizational structure by an appropriate design of the workplace. Under centralization, the workplace is designed such that either Agent 1 or Agent 2 is able to perform task 3, i.e., the principal fixes the job design ex ante. This implies that he can base his decision only on expectations about Agent 1's cost parameter c . Under delegation, the workplace design ensures that either agent can carry out task 3 and that Agent 1 can assign the task ex post, i.e., when he has learned

c .⁴ We provide an example below. At $t = 2$, the principal offers an incentive contract to each agent. The incentive contract for Agent i specifies a bonus b_i to be paid when $P = 1$ and a fixed wage s_i . Each agent observes the organizational design and also the contract of the other agent. At $t = 3$, given that the agents accepted the contracts, Agent 1 observes his effort cost parameter c . Under decentralization, Agent 1 then assigns task 3. The task assignment is non-verifiable, that is, the contract cannot condition on it.⁵ At $t = 4$, the agents choose their efforts. Finally, at $t = 5$, the performance measure P is realized and wages are paid. Afterwards, the firm value Y is realized.

To illustrate this setup, consider the following example: The two agents are working for a specific product line in a company. Agent 1 is specialized in task 1 which is production management of the product line. Agent 2 is specialized in task 2, namely the marketing activities related to the product line. The third task is dealing with potential customer complaints or requests regarding the specific product line. The performance measure P reflects short-term profits. Since Agent 1 sometimes has to deal with unforeseen problems on the production floor, his costs for performing task 3 are unknown ex ante. Under centralization, the principal chooses one agent, say Agent 1, the production manager, to deal with these requests. The agents work in different offices and only Agent 1's telephone number is published on the website or printed on the company's products for directing customer complaints. Agent 1 has no possibility to redirect a call. By contrast, under decentralization, the agents share an office and a telephone. When the telephone for customer complaints rings, Agent 1 de-

⁴We omit the possibility of delegating the job design to Agent 2 as this agent has the same information as the principal on effort costs. Consequently, the principal derives no benefits from delegating to Agent 2 compared to centralization, but incurs a loss due to an additional control problem.

⁵If the contract could condition on the task assignment, the delegation outcome is identical to a situation where the principal can observe c . Hence, delegation would dominate centralization.

cides whether he picks up the phone himself or redirects the call to Agent 2. As it would be too costly to identify who actually answered the phone and performed task 3, the final assignment decision of Agent 1 is non-contractible.

Under decentralization, we assume that, if Agent 2 refuses to perform task 3 if it is assigned to him (e.g., does not answer the phone), the opportunity to perform the task is foregone (e.g., the customer’s request does not get answered) and the impact on the firm value Y and the performance measure P is zero. This assumption will imply that Agent 2 prefers to perform the task if Agent 1 assigns it to him.

The first-best solution to the present problem is provided as a benchmark. Assume that there is no asymmetric information, i.e., Agent 1’s effort cost parameter c and the effort levels e_ℓ ($\ell = 1, 2, 3$) are observable. The first-best job design depends on the realization of c . If $c = c_L$, Agent 1 performs task 3 and first-best effort levels are $e_1 = f_1$, $e_2 = f_2$, and $e_3 = \frac{f_3}{c_L}$. Otherwise, Agent 2 should perform task 3 and the respective effort levels are $e_\ell = f_\ell$ for all ℓ . The principal just compensates the agents for their effort costs and, consequently, his first-best profit is

$$\Pi^{FB} = \begin{cases} \frac{1}{2} \left(f_1^2 + f_2^2 + \frac{1}{c_L} f_3^2 \right) & \text{if } c = c_L \\ \frac{1}{2} (f_1^2 + f_2^2 + f_3^2) & \text{if } c = c_H. \end{cases}$$

3 Centralization

We first analyze the case of centralization, i.e., where the principal assigns task 3 at the first stage. This setting is comparable to Reichmann and Rohlfig-Bastian (2014), however, an additional component needs to be considered: Agent 1’s effort cost parameter c is unknown

to the principal. The principal only knows that c either equals c_L (with probability p) or c_H (with probability $1 - p$). The game is solved by backward induction. First, consider the situation where Agent 1 performs task 3. At stage 4, Agent 2 then chooses his effort e_2 in his single task 2 such that his expected personal net utility from compensation and effort is maximized:

$$e_2 = \arg \max_{\hat{e}_2} s_2 + (g_1 e_1 + g_2 \hat{e}_2 + g_3 e_3) b_2 - \frac{\hat{e}_2^2}{2} \Leftrightarrow e_2 = g_2 b_2.$$

Analogously, Agent 1 chooses the effort levels (e_1, e_3) such that:

$$(e_1, e_3) = \arg \max_{(\hat{e}_1, \hat{e}_3)} s_1 + (g_1 \hat{e}_1 + g_2 e_2 + g_3 \hat{e}_3) b_1 - \frac{\hat{e}_1^2}{2} - c \frac{\hat{e}_3^2}{2} \Leftrightarrow e_1 = g_1 b_1, e_3 = \frac{g_3}{c} b_1.$$

At stage 2, based on his expectations on c , the principal designs the agents' incentive contracts to maximize the expected firm value less the agents' wage payments subject to the agents' incentive compatibility and individual rationality constraints:

$$\begin{aligned} & \max_{\substack{s_k, b_k, e_\ell \\ k=1,2 \\ \ell=1,2,3}} E [(f_1 e_1 + f_2 e_2 + f_3 e_3) - s_1 - s_2 - (b_1 + b_2)(g_1 e_1 + g_2 e_2 + g_3 e_3)] \\ & \text{s.t. } e_1 = g_1 b_1, e_2 = g_2 b_2, e_3 = \frac{g_3}{c} b_1, \\ & E \left[s_1 + (g_1 e_1 + g_2 e_2 + g_3 e_3) b_1 - \frac{e_1^2}{2} - c \frac{e_3^2}{2} \right] \geq 0, \\ & E \left[s_2 + (g_1 e_1 + g_2 e_2 + g_3 e_3) b_2 - \frac{e_2^2}{2} \right] \geq 0. \end{aligned}$$

Here, $E[\cdot]$ denotes the expectation with respect to the random variable c . We denote the optimal bonus rates for Agent 1 and Agent 2 with $b_1^{C_1}$ and $b_2^{C_1}$, respectively, where the

superscript C_1 stands for centralization with Agent 1 as the multi-tasking agent. We obtain⁶

$$b_1^{C_1} = \frac{g_1^2}{g_1^2 + \gamma g_3^2} \frac{f_1}{g_1} + \frac{\gamma g_3^2}{g_1^2 + \gamma g_3^2} \frac{f_3}{g_3} \quad \text{and} \quad b_2^{C_1} = \frac{f_2}{g_2}, \quad (1)$$

with $\gamma := E\left[\frac{1}{c}\right] = p\frac{1}{c_L} + (1-p)\frac{1}{c_H}$. Accordingly, Agent 2's work incentives are efficient in the sense that his bonus induces first-best effort in his task, $e_2 = f_2$. By contrast, the optimal incentives for the multi-tasking Agent 1 compromise the incentives that would be efficient if task 1 and task 3 could be assigned to different agents, $\frac{f_1}{g_1}$ and $\frac{f_3}{g_3}$, respectively. As long as these incentives are different, $\frac{f_1}{g_1} \neq \frac{f_3}{g_3}$, a congruity problem exists and, therefore, the agent cannot be incentivized to provide the efficient effort in either of the tasks. The principal's profit can be computed as

$$\Pi^{C_1} = \frac{1}{2} \left(f_2^2 + \frac{(f_1 g_1 + \gamma f_3 g_3)^2}{g_1^2 + \gamma g_3^2} \right). \quad (2)$$

Due to the congruity problem, the principal does not necessarily benefit from lower expected effort costs of Agent 1. Intuitively, if the performance measure puts far too much weight on task 3 relative to task 1, high costs for task 3 can be beneficial because they counteract the congruity problem by making the agent exert less effort in task 3. Formally, Π^{C_1} is decreasing in γ and, therefore, also in the probability of low effort costs, p , if and only if $\gamma < \frac{g_1}{g_3} \left(\frac{f_1}{f_3} - 2\frac{g_1}{g_3} \right)$. However, if this condition holds, the principal can earn a higher profit than Π^{C_1} by excluding task 3 from the production process.⁷ We want to exclude such

⁶A sketch of the proof can be found in the Appendix.

⁷If the principal excludes task 3 from the production process, he earns the profit $\tilde{\Pi} = \frac{1}{2} (f_1^2 + f_2^2)$. Furthermore, $\lim_{\gamma \rightarrow 0} \Pi^{C_1} = \tilde{\Pi}$. Hence, if Π^{C_1} is initially decreasing in γ , Π^{C_1} is strictly smaller than $\tilde{\Pi}$ on an interval $[0, \tilde{\gamma}]$, where $\tilde{\gamma} > 0$.

extreme congruity problems from our analysis and henceforth focus on situations where Π^{C_1} is always increasing in γ and hence in p . We thus assume that $\frac{f_1}{f_3} \leq 2\frac{g_1}{g_3}$. Intuitively, this reflects a situation where the performance measure does not extremely overweight task 3 relative to task 1. In our illustrating example from Section 2, this means that short-term firm profits P are not overly sensitive to how Agent 1 deals with customer complaints.

If the principal assigns the third task to Agent 2, analogous to the above solution procedure, we obtain as optimal bonus rates and the principal's profit

$$b_1^{C_2} = \frac{f_1}{g_1}, \quad b_2^{C_2} = \frac{g_2^2}{g_2^2 + g_3^2} \frac{f_2}{g_2} + \frac{g_3^2}{g_2^2 + g_3^2} \frac{f_3}{g_3}, \quad \text{and } \Pi^{C_2} = \frac{1}{2} \left(f_1^2 + \frac{(f_2 g_2 + f_3 g_3)^2}{g_2^2 + g_3^2} \right). \quad (3)$$

Comparing the principal's profit functions from (2) and (3) gives us the following result.

Lemma 1 *Under centralization, the principal maximizes his profit by assigning task 3 to Agent 1 if and only if*

$$f_2^2 + \frac{(f_1 g_1 + \gamma f_3 g_3)^2}{g_1^2 + \gamma g_3^2} \geq f_1^2 + \frac{(f_2 g_2 + f_3 g_3)^2}{g_2^2 + g_3^2}, \quad (4)$$

leading to the profit

$$\Pi^C = \frac{1}{2} \max \left\{ f_2^2 + \frac{(f_1 g_1 + \gamma f_3 g_3)^2}{g_1^2 + \gamma g_3^2}, f_1^2 + \frac{(f_2 g_2 + f_3 g_3)^2}{g_2^2 + g_3^2} \right\}. \quad (5)$$

Assuming that $\frac{f_1}{f_3} \leq 2\frac{g_1}{g_3}$, the profit Π^C is weakly increasing in p .

If the performance measure is perfectly congruent (i.e., $\frac{f_\ell}{g_\ell}$ is constant for all ℓ), condition (4) can be simplified to $\gamma \geq 1$ or, equivalently, $p \geq \bar{p} := \frac{c_H - 1}{c_H - c_L} \frac{c_L}{c_H} \in (0, 1)$. Hence, the

optimal task assignment is exclusively determined by cost considerations: Agent 1 should perform task 3 if his probability for low effort costs is sufficiently high.⁸ By contrast, if the performance measure is incongruent, the congruity problem generated by the different task assignments becomes an additional determinant for the optimal task assignment. The principal may then trade off higher effort costs with a potential lower loss from noncongruity. However, because Π^{C_1} is increasing in p , he still assigns task 3 to Agent 1 when p is above a certain threshold $p_C \in [0, 1]$. Depending on the congruity problems under the different task assignments, this threshold is smaller or larger than \bar{p} .

Comparing Π^C and Π^{FB} , we find that centralization leads to the first-best effort choices and profit if and only if Agent 1's cost parameter is certain, and, at the same time, there is no congruity problem if the agent with the lower costs performs two tasks. This is the case if either (i) $p = 0$ and $\frac{f_2}{g_2} = \frac{f_3}{g_3}$ or (ii) $p = 1$ and $\frac{f_1}{g_1} = \frac{f_3}{g_3}$.

4 Decentralization

In this section, we analyze the case of delegated job design, where Agent 1 is in charge of assigning task 3. We first consider stage 3 of the model in order to determine under what circumstances Agent 1 decides to perform task 3 himself. Intuitively, this decision should be driven by the relative size of the bonuses offered by the principal and Agent 1's effort costs. The following Lemma confirms this intuition and identifies a threshold for Agent 1's effort costs that depends on the relation of the bonuses.

⁸Note that it is not necessarily optimal to have the agent with the lower expected effort costs perform task 3. There is a range of intermediate values of p where Agent 1's expected costs $pc_L + (1-p)c_H$ are larger than 1, but the agent still performs task 3 since $\gamma \geq 1$ still holds. This is due to the convexity of the effort cost function, which makes the principal overweight the possibility of low costs.

Lemma 2 *Given the incentive contracts offered by the principal, Agent 1 assigns task 3 as follows. (i) If $\frac{1}{2}\frac{b_1}{b_2} < c_L$, he always assigns task 3 to Agent 2. (ii) If $c_L \leq \frac{1}{2}\frac{b_1}{b_2} \leq c_H$, he performs task 3 himself if and only if $c = c_L$. (iii) If $c_H < \frac{1}{2}\frac{b_1}{b_2}$, he always performs task 3 himself.*

Lemma 2 indicates that Agent 1 will perform task 3 when his effort costs c are smaller than $\frac{1}{2}\frac{b_1}{b_2}$. Intuitively, the larger the bonus ratio $\frac{b_1}{b_2}$, the more motivated Agent 1 is to exert effort relative to Agent 2. Hence, ceteris paribus, Agent 1 decides to carry out task 3 himself if his own costs are sufficiently low or if he anticipates a relatively low motivation of his colleague. In cases (i) and (iii), Agent 1's task assignment is independent of his realized costs and the principal is thus weakly better off by assigning the task himself to Agent 2 and Agent 1, respectively, at the first stage. Centralization thus dominates decentralization in these situations. We therefore henceforth focus on case (ii), where Agent 1 performs task 3 if and only if his costs are low. This is the only candidate for a situation in which the principal can be strictly better off by choosing delegation rather than centralization. We now derive the incentive contracts that the principal should offer to the agents if he wants Agent 1 to perform task 3 when he has low costs.

Lemma 3 *Assume that the principal wants to induce Agent 1 to perform task 3 if and only if $c = c_L$. Define $\hat{c} := \frac{1}{2} \frac{f_1 g_1 + \frac{p}{c_L} f_3 g_3}{f_2 g_2 + (1-p) f_3 g_3} \frac{g_2^2 + (1-p) g_3^2}{g_1^2 + \frac{p}{c_L} g_3^2}$.*

(i) If $c_L \leq \hat{c} \leq c_H$, the optimal bonus rates are

$$b_1^D = \frac{g_1^2}{g_1^2 + \frac{p}{c_L} g_3^2} \frac{f_1}{g_1} + \frac{\frac{p}{c_L} g_3^2}{g_1^2 + \frac{p}{c_L} g_3^2} \frac{f_3}{g_3}, \quad b_2^D = \frac{g_2^2}{g_2^2 + (1-p) g_3^2} \frac{f_2}{g_2} + \frac{(1-p) g_3^2}{g_2^2 + (1-p) g_3^2} \frac{f_3}{g_3} \quad (6)$$

and the principal's profit is

$$\Pi^D = \frac{1}{2} \left(\frac{\left(f_1 g_1 + \frac{p}{c_L} f_3 g_3 \right)^2}{g_1^2 + \frac{p}{c_L} g_3^2} + \frac{(f_2 g_2 + (1-p) f_3 g_3)^2}{g_2^2 + (1-p) g_3^2} \right). \quad (7)$$

(ii) If $\hat{c} < c_L$, the principal offers the bonuses

$$\hat{b}_1^D = \frac{f_1 g_1 + \frac{f_2 g_2}{2c_L} + p \frac{f_3 g_3}{c_L} + (1-p) \frac{f_3 g_3}{2c_L}}{g_1^2 + p \frac{g_3^2}{c_L} + \frac{1}{4c_L^2} (g_2^2 + (1-p) g_3^2)}, \quad \hat{b}_2^D = \frac{1}{2} \frac{\hat{b}_1^D}{c_L} \quad (8)$$

and his profit is

$$\hat{\Pi}^D = \frac{1}{2} \frac{\left(f_1 g_1 + \frac{f_2 g_2}{2c_L} + p \frac{f_3 g_3}{c_L} + (1-p) \frac{f_3 g_3}{2c_L} \right)^2}{g_1^2 + p \frac{g_3^2}{c_L} + \frac{1}{4c_L^2} (g_2^2 + (1-p) g_3^2)}. \quad (9)$$

When the principal chooses the optimal bonuses, he has to balance two objectives: First, Agent 1 performs task 3 with probability p and Agent 2 with probability $1-p$, implying two different congruity problems that need to be addressed. Second, the bonuses need to ensure that Agent 1 prefers to perform task 3 himself whenever he has low costs. In case (i) of Lemma 3, the two objectives are not in conflict, i.e., the bonuses that optimally address the congruity problems also induce the desired task assignment. Accordingly, the optimal bonuses b_1^D and b_2^D weight the efficient single-task incentives, $\frac{f_i}{g_i}$, paying attention to the congruity problems and the probability with which they occur. By contrast, in case (ii), the optimal bonuses \hat{b}_1^D and \hat{b}_2^D reflect the trade-off between the two objectives.

To understand the situation in which case (i) occurs, note that $\hat{c} = \frac{1}{2} \frac{b_1^D}{b_2^D}$. Hence, by Lemma 2, the condition $c_L \leq \hat{c} \leq c_H$ describes the situation where the bonuses b_1^D and b_2^D have the appropriate relative size to induce Agent 1 to perform task 3 if and only if

he has low costs. In the special case of a perfectly congruent performance measure, i.e., $\frac{f_1}{g_1} = \frac{f_2}{g_2} = \frac{f_3}{g_3}$, the bonuses do not need to address any congruity problems and the principal therefore wants to pay both agents the same bonus, $b_1^D = b_2^D$. Hence, $\hat{c} = \frac{1}{2}$ and we are in case (i) whenever $c_L \leq \frac{1}{2}$. When the performance measure is not congruent, the bonuses b_1^D and b_2^D differ. For example, assume that the efficient single-tasking incentives for tasks 1 and 2 are identical, but task 3 calls for lower incentives, i.e., $\frac{f_1}{g_1} = \frac{f_2}{g_2} > \frac{f_3}{g_3}$. Then, by (6), the bonus b_1^D focusses more on task 3 the higher p and the smaller c_L , i.e., the more likely it is that Agent 1 performs task 3 and the more productive he is in this task. At the same time, a higher p makes b_2^D focus more on task 2. Hence, for sufficiently high p and small c_L , we have $b_1^D < b_2^D$. Then, the condition for case (i) holds for a smaller range of values for c_L compared to a perfectly congruent performance measure.

Lemma 3 does not consider situations with $c_H < \hat{c}$, where Agent 1 always wants to perform task 3 under the bonuses b_1^D and b_2^D , even if he has high costs. We omit this case also in the remainder of the article because it would not lead to any new insights. This means that we focus on a situation where c_H is sufficiently large, or the congruity problem is not so severe that it calls for a bonus b_1^D that is more than twice as large as the bonus b_2^D . As long as $\hat{c} = \frac{1}{2} \frac{b_1^D}{b_2^D} < 1$ or $\frac{b_1^D}{b_2^D} < 2$, the case $c_H < \hat{c}$ cannot occur because $c_H > 1$.

5 Optimal Job Design

5.1 Perfectly Congruent Performance Measure

In order to determine the optimal job design, we first focus on a perfectly congruent performance measure, i.e., $\frac{f_1}{g_1} = \frac{f_2}{g_2} = \frac{f_3}{g_3}$. Without loss of generality, assume that $\frac{f_\ell}{g_\ell} = 1$ for all ℓ . First consider a centralized job design. Applying Lemma 1 from Section 3, the principal's profit under centralization is

$$\Pi^C = \frac{1}{2} (f_1^2 + f_2^2 + f_3^2 \cdot \max\{1, \gamma\}).$$

If $\gamma > 1$, the principal will assign task 3 to Agent 1. Otherwise, Agent 2 performs the task. Since there is no congruity problem, the only inefficiency arises from the fact that it is not always the agent with the lower costs who carries out task 3. The principal might therefore benefit from delegating the job design to Agent 1 in order to obtain a situation where this agent performs task 3 if and only if his costs are low, as discussed in Lemma 3 in the previous section. The following proposition describes the optimal job design and the associated bonus rates.

Proposition 1 *Assume that the performance measure is perfectly congruent such that $\frac{f_\ell}{g_\ell} = 1$ for all ℓ .*

(i) *If $c_L \leq \frac{1}{2}$, the principal implements delegation. He pays the bonuses $b_1^D = b_2^D = 1$ and thereby induces the first-best solution.*

(ii) *If $c_L > \frac{1}{2}$, there exists a threshold $\bar{c} \in (\frac{1}{2}, 1)$ such that the principal prefers delegation if*

and only if $c_L \leq \bar{c}$. Under delegation, the principal pays the bonuses $\hat{b}_1^D > 1$ and $\hat{b}_2^D < 1$.

Under centralization, the agents' bonuses are equal to 1. Delegation and incentives are thus complements.

Proof. See Appendix. ■

The two cases of Proposition 1 correspond to the two cases of Lemma 3 because, with a perfect performance measure, we have $\hat{c} = \frac{1}{2}$. We see that, in contrast to centralization, delegation can implement the first-best solution (case (i)). This situation arises when Agent 1 potentially has sufficiently low costs ($c_L \leq \frac{1}{2}$) and, consequently, is willing to multitask in the low-cost case under the efficient bonuses of 1. When the low cost parameter exceeds the threshold of $\frac{1}{2}$ (case (ii)), the principal first maintains delegation but has to adapt the bonus payments to ensure that Agent 1 chooses the desired task allocation. The reason is that, if $\frac{1}{2} < c_L$, Agent 1 will never perform task 3 himself under bonus rates of 1. Instead, he prefers Agent 2 to perform the task to save effort costs. In order to motivate Agent 1 to carry out the third task when he has lower costs than Agent 2, the principal needs to increase the bonus of Agent 1 and lower the bonus of Agent 2 relative to the efficient bonus rate of 1. The larger c_L , the stronger the bonuses need to be distorted. As a consequence, when c_L exceeds a certain threshold \bar{c} , it is no longer profit-maximizing to induce delegation and the principal switches to centralization, accepting an inefficient task allocation, but again providing efficient incentives. Delegation and incentives are thus complements: If Agent 1 is made responsible for the task assignment, he also obtains a higher bonus to make him exercise his authority in the desired way. This implies that the agent with authority works even harder than in the first-best, while the agent without authority always works less than

in the first-best.

5.2 Incongruent Performance Measure

Assume now that the principal has only an incongruent performance measure available for contracting with the agents. We proceed by discussing two questions: (1) When does the principal prefer decentralization over centralization in the presence of a congruity problem? And, (2), does the principal still employ delegation and incentives as complements? We start by analyzing question (1) and, for simplicity, restrict attention to case (i) in Lemma 3, i.e., we focus on the case $c_L \leq \hat{c} \leq c_H$. By comparing the principal's profit under centralization and delegation, Π^C from (5) and Π^D from (7), respectively, we obtain the following result.

Proposition 2 *Assume that $c_L \leq \hat{c} \leq c_H$. Decentralization strictly dominates centralization if and only if $\Pi^D > \Pi^C = \max\{\Pi^{C_1}, \Pi^{C_2}\}$ or, equivalently,*

$$\frac{\left(f_1 g_1 + \frac{p}{c_L} f_3 g_3\right)^2}{g_1^2 + \frac{p}{c_L} g_3^2} + \frac{(f_2 g_2 + (1-p) f_3 g_3)^2}{g_2^2 + (1-p) g_3^2} > \max \left\{ f_2^2 + \frac{(f_1 g_1 + \gamma f_3 g_3)^2}{g_1^2 + \gamma g_3^2}, f_1^2 + \frac{(f_2 g_2 + f_3 g_3)^2}{g_2^2 + g_3^2} \right\}. \quad (10)$$

From the previous section, we know that if $c_L \leq \hat{c} \leq c_H$, delegation leads to the first-best solution and thus dominates centralization when the performance measure is congruent. Hence, if the principal prefers centralization over delegation with an incongruent performance measure, i.e., condition (10) does not hold, this must be due to relatively more severe congruity problems under delegation. Recall that the congruity problem arising when Agent i performs task 3 is characterized by the term $\Delta_{i3} = (f_3 g_i - f_i g_3)^2$. Under centralization, only one type of incongruity, i.e., either Δ_{13} or Δ_{23} , matters depending on which agent performs

task 3. By contrast, under delegation, each agent can be the multitasking agent and thus, both Δ_{13} and Δ_{23} affect the expected profit. The relative impact of the two congruity problems on the delegation profit can be nicely seen from the derivative of Π^D with respect to p ,

$$\frac{\partial \Pi^D}{\partial p} = \frac{1 - c_L}{c_L} f_3^2 + \frac{g_2^2}{(g_2^2 + (1 - p)g_3^2)^2} \Delta_{23} - \frac{c_L g_1^2}{(c_L g_1^2 + p g_3^2)^2} \Delta_{13}. \quad (11)$$

As p increases, Agent 1 is more likely to be more cost-efficient than Agent 2 and will thus perform task 3 under delegation. This has three different effects on Π^D , which are given by the three terms on the right-hand side of (11). First, there is a positive effect due to lower effort costs. Second, if there is a congruity problem with Agent 2, i.e., $\Delta_{23} \neq 0$, there is another positive effect because it becomes less likely that this agent has to deal with both task 2 and task 3. Third, if there is a congruity problem with Agent 1, i.e., $\Delta_{13} \neq 0$, there is a negative effect because this agent now multitasks more often. Because the last effect may dominate, a higher p can actually be detrimental under delegation. By contrast, the centralization profit Π^C is always weakly increasing in p (compare Lemma 1) because p only has a direct advantageous effect on Agent 1's effort costs. This difference between the two job designs can even lead to a situation where centralization dominates delegation for all values of p .

Corollary 1 *If there is a congruity problem with Agent 1 but not with Agent 2, i.e., $\Delta_{13} > 0$ and $\Delta_{23} = 0$, and c_L is sufficiently close to 1, then (10) does not hold and centralization dominates delegation.*

Figure 2 depicts a situation as described in Corollary 1. Under the preconditions of the corollary, (11) is negative, i.e., the delegation profit is always decreasing in p . Under

centralization, the principal will assign task 3 to Agent 2 because this job design does not entail a congruity problem and the cost advantage of Agent 1 is negligible. Hence, we have $\Pi^C = \Pi^{C_2}$ and the profit under centralization is independent of p .

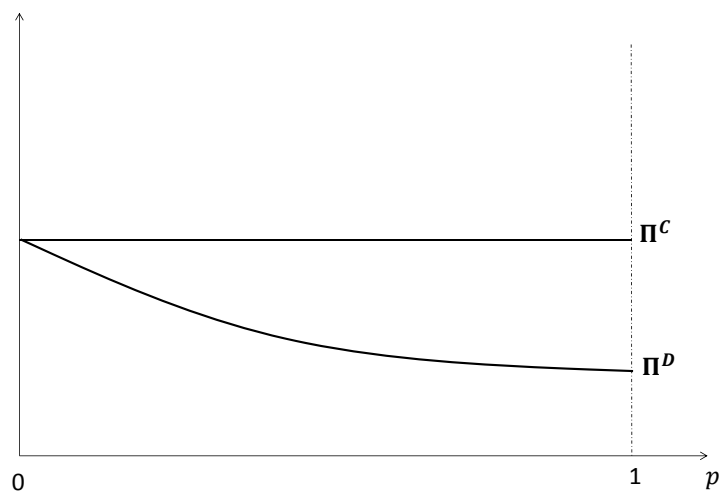


Figure 2: Centralization dominates delegation.

We now describe a situation where (10) holds and thus delegation dominates centralization.

Corollary 2 *Assume that there is a congruity problem with Agent 2 but not with Agent 1, i.e., $\Delta_{23} > 0$ and $\Delta_{13} = 0$. Further, assume that $\Pi^{C_2} > \Pi^{C_1}$ for $p = 0$. Then delegation dominates centralization for sufficiently low values of p .*

Under the assumptions of Corollary 2, Π^D is always increasing in p . Recall that, under centralization, the principal prefers to assign task 3 to Agent 1 iff p exceeds a certain threshold p_C . The assumption $\Pi^{C_2} > \Pi^{C_1}$ for $p = 0$ ensures that $p_C > 0$, i.e., the congruity problem with Agent 2 is not so severe that he should not perform task 3 under centralization even

if he always has lower costs than Agent 1. This case is illustrated in Figure 3, which sketches a situation where centralization becomes optimal for high values of p . It is, however, also possible that the principal prefers delegation for all values of p . Delegation allows to take advantage of low effort costs when they are realized. This comparative advantage is particularly strong when low costs occur only with a small probability because then the principal does not want to always assign task 3 to Agent 1 under a centralized organization structure.

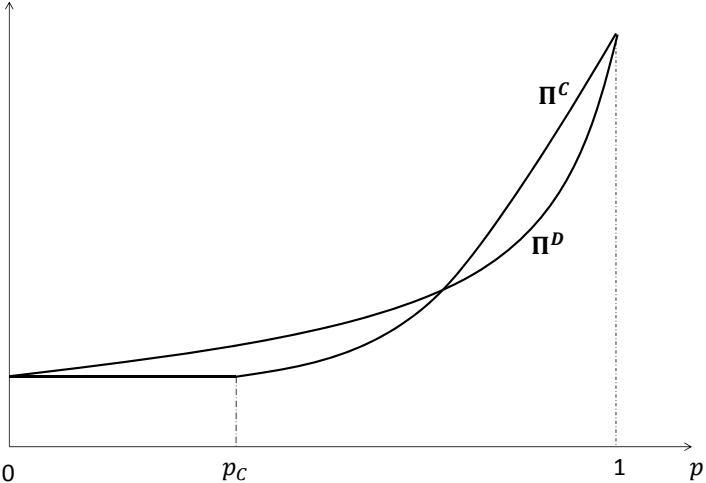


Figure 3: Delegation dominates centralization for small p .

Overall, with an incongruent performance measure, delegation tends to be the optimal job design when the agent with the task assignment authority is unlikely to perform the task to be assigned (p is small), but if he does, the congruity problem is relatively small. In other words, if the situation allows the principal to separate the loss of control from delegation and the effort allocation problem (or if this problem is not too severe), delegation is beneficial.

Related to our illustrative example, assume that the relative contributions of production management (Agent 1's regular task) and answering customer complaints to the firm value are well reflected by the performance measure. If Agent 1's probability for low effort costs is low, the principal prefers delegation, because even if Agent 1 should decide to answer customer complaints, the effort allocation problem is negligible and the principal does not suffer from a bundling of the control problem and the effort allocation problem.

We now turn to the second question from above, that is, whether delegation and incentives are still used as complements when the performance measure is incongruent. To discuss this issue, assume we start from a situation as illustrated in Figure 2, where Agent 2 performs task 3 under centralization. According to (3), the optimal bonus rates are then given by

$$b_1^{C_2} = \frac{f_1}{g_1} \text{ and } b_2^{C_2} = \frac{g_2^2}{g_2^2 + g_3^2} \frac{f_2}{g_2} + \frac{g_3^2}{g_2^2 + g_3^2} \frac{f_3}{g_3}.$$

Now suppose that c_L decreases so that the overall situation changes to Figure 3 and p is such that delegation becomes optimal. Hence, the optimal bonus rates are now given by (6), i.e.,

$$b_1^D = \frac{g_1^2}{g_1^2 + \frac{p}{c_L} g_3^2} \frac{f_1}{g_1} + \frac{\frac{p}{c_L} g_3^2}{g_1^2 + \frac{p}{c_L} g_3^2} \frac{f_3}{g_3} \text{ and } b_2^D = \frac{g_2^2}{g_2^2 + (1-p)g_3^2} \frac{f_2}{g_2} + \frac{(1-p)g_3^2}{g_2^2 + (1-p)g_3^2} \frac{f_3}{g_3}.$$

Comparing $b_1^{C_2}$ and b_1^D , we see that Agent 1 may obtain a smaller bonus when the task assignment authority is delegated to him. This is the case if and only if $\frac{f_3}{g_3} < \frac{f_1}{g_1}$, i.e., the efficient single-task incentives for task 3 are smaller than for task 1. The principal then decreases Agent 1's bonus under delegation to optimally balance the incentives for task 1 and task 3. Hence, with an incongruent performance measure, the delegation of decision

making authority and the performance of an additional task can entail a lower bonus. Agent 2 performs task 3 less often under delegation than under centralization. The efficient incentives for task 3 thus get less weight under delegation and Agent 2's bonus increases if and only if $\frac{f_3}{g_3} < \frac{f_2}{g_2}$. Hence, even though it becomes less likely that Agent 2 has to perform an additional task, his bonus may increase.

The following proposition summarizes the possible relationships between delegation and incentives.

Proposition 3 *Assume that $c_L \leq \hat{c} \leq c_H$. Further suppose that, due to an exogenous decrease of c_L , the principal switches from centralization with Agent 2 as the multitasking agent to delegation. Delegation and incentives then interact as follows:*

- (i) *If $\frac{f_3}{g_3} < \min \left\{ \frac{f_1}{g_1}, \frac{f_2}{g_2} \right\}$, i.e., the efficient single-task incentives for task 3 are lower than for the other two tasks, delegation and incentives are **substitutes**. Agent 1 (Agent 2) gets a lower (higher) bonus under delegation than under centralization.*
- (ii) *If $\frac{f_3}{g_3} > \max \left\{ \frac{f_1}{g_1}, \frac{f_2}{g_2} \right\}$, i.e., the efficient single-task incentives for task 3 are higher than for the other two tasks, delegation and incentives are **complements**. Agent 1 (Agent 2) gets a higher (lower) bonus under delegation than under centralization.*
- (iii) *If $\frac{f_1}{g_1} > \frac{f_3}{g_3} > \frac{f_2}{g_2}$, both agents obtain lower incentives under delegation.*
- (iv) *If $\frac{f_2}{g_2} > \frac{f_3}{g_3} > \frac{f_1}{g_1}$, both agents receive higher incentives under delegation.*

To complete the analysis, now consider centralization with Agent 1 being the multitasking agent as starting point and assume the principal switches to delegation due to an exogenous shock. A comparison of (1) and (6) shows that Agent 1's bonus decreases iff $\frac{f_3}{g_3} > \frac{f_1}{g_1}$ and

Agent 2's bonus increases iff $\frac{f_3}{g_3} > \frac{f_2}{g_2}$. Hence, all the interactions described in 3 can occur as well.

The results presented in Proposition 3 offer a potential explanation for the mixed empirical evidence with respect to the relation between the delegation of decision-making authority and monetary incentives. In our model, delegation and incentives are complements in three different situations: First, the performance measure is congruent (compare Proposition 1). Second, the agent who receives the decision making authority will also perform more tasks on average and the efficient single-task incentives for the task to be assigned are higher than for the other tasks (see Proposition 3, case (ii)). Third, the agent with the decision making authority performs fewer tasks on average and the efficient single-task incentives for the task to be assigned are lower than for the other tasks (compare the previous paragraph). A complementary relationship between delegation and incentives corresponds to the results obtained, e.g., in Wulf (2007); Nagar (2002), and DeVaro and Kurtulus (2010). It is also consistent with the results derived by DeVaro and Prasad (2015) for simple jobs (measured by a lower-level code in the Standard Occupational Classification, SOC) and Jia and van Veen-Dirks (2014) for production managers.

However, when the performance measure is incongruent, we also identify situations where delegation and incentives are substitutes. This corresponds to the result obtained for complex jobs by DeVaro and Prasad (2015). They provide an explanation based on the relation of risk and return of complex jobs. Finally, we also show that delegation may uniformly increase or decrease the incentives of all agents involved (see Proposition 3, cases (iii) and (iv)). Our results thus suggest that, if multiple tasks and agents are involved in the production process, it is mainly an issue of the firm's accounting system and the quality of the delivered

performance measures whether delegation and incentives are complements, substitutes, or lead to a uniform adjustment of incentives for all agents involved.

6 Conclusion

This article studies the optimal allocation of decision authority and corresponding optimal incentive contracts against the background of information asymmetry and different qualities of performance measures available for contracting. The analysis provides an investigation of the benefits of delegation and the adjustment of incentives depending on the organizational design. An intuitive result is that delegation can be beneficial for the principal if information asymmetries are present and the decentralized structure ensure efficient use of this information. We also show how the efficient use of information. However, the results also demonstrate that delegation and the provision of monetary incentives are sometimes used as complements for providing efficient incentives for agents to act in the firm's interest, and sometimes used as substitutes.

The analysis suggests that there are several interdependencies between the information situation, the allocation of decision authority, the quality of performance measurement, and the design of incentive contracts that need to be simultaneously taken into consideration. On the one hand, this has an impact on the design of optimal incentive contracts in practice. On the other hand, empirical compensation studies thus should take into account the allocation of decision authority and the resulting interdependencies. Previous studies often described a complementary effect between the delegation of decision authority and the provision of monetary incentives (e.g., Wulf 2007; Nagar 2002; DeVaro and Kurtulus 2010). The

results in these studies are in line with the result that we derive for a situation in which the performance measures used for incentive design are perfectly congruent. With incongruent performance measures, however, we demonstrate that delegation and incentives can also be substitutes. In part, this result is confirmed by DeVaro and Prasad (2015) and Jia and van Veen-Dirks (2014). DeVaro and Prasad (2015) identify a negative relationship for complex tasks. One could argue that complex tasks are more difficult to measure and thus the employed performance measures tend to be rather imperfect. Jia and van Veen-Dirks (2014) demonstrate a negative interaction for production managers, whose performance is often more difficult to measure than the performance of higher-level managers.

Some words of caution are in order with respect to the generalization of the presented results. First, the optimality of the allocation of authority that translated into different organizational structures was entirely derived on the basis of factors related to the information situation and the contracting environment. Of course, there might be several other factors, e.g., related to the production process or geographic considerations or even to the composition of the workforce, that have an impact on the choice of a specific organizational structure. Second, we assumed that the productivity and sensitivity of the allocatable task was task-sensitive and not influenced by the specific manager that performs the task. Whereas we reflected potential differences in the effort costs of the managers for this task, we did not take into account potential synergies between the allocatable and the managers' regular tasks. Third, we only allowed for an aggregate performance measure that was available for contracting design. Whereas this assumption is well supported by our illustrative example (in this case it could for example be the product's contribution to the firm's total profit), it has a strong impact on the results. In particular, additional performance measures could help

to mitigate the congruity problem and allow for a better fine-tuning of incentives.

Appendix

Derivation of $b_1^{C_1}$ and $b_2^{C_1}$ in (1). We can use the incentive compatibility constraints to eliminate the effort levels e_ℓ from the principal's optimization problem. Using that the fixed payments s_1 and s_2 are optimally chosen to make the agent's individual rationally constraints binding, the principal solves:

$$\max_{b_1, b_2} E \left[f_1 g_1 b_1 + f_2 g_2 b_2 + f_3 \frac{g_3}{c} b_1 - \frac{(g_1 b_1)^2}{2} - \frac{(g_2 b_2)^2}{2} - \frac{(g_3 b_1)^2}{2c} \right]$$

The optimal bonuses $b_1^{C_1}$ and $b_2^{C_1}$ follow from the first-order conditions.

Proof of Lemma 2. Consider stage 4 of the model. When Agent 1 carries out task 3, he chooses effort $e_1 = g_1 b_1$ and $e_3 = \frac{g_3}{c} b_1$, while Agent 2 exerts effort $e_2 = g_2 b_2$. Agent 1's payoff thus is

$$s_1 + (g_1^2 b_1 + g_2^2 b_2 + \frac{g_3^2}{c} b_1) b_1 - \frac{(g_1 b_1)^2}{2} - \frac{(g_3 b_1)^2}{2c} = s_1 + \frac{(g_1 b_1)^2}{2} + g_2^2 b_2 b_1 + \frac{(g_3 b_1)^2}{2c}. \quad (12)$$

If Agent 2 performs task 3, we obtain for Agent 1's payoff

$$s_1 + \frac{(g_1 b_1)^2}{2} + g_2^2 b_2 b_1 + g_3^2 b_2 b_1. \quad (13)$$

At stage 3, Agent 1 decides to perform task 3 himself iff (12) is at least as high as (13), i.e.,

$\frac{1}{2} \frac{b_1}{b_2} \geq c$. This condition implies the three cases described in the lemma.

Proof of Lemma 3. Already taking the agents' incentive and participation constraints into account, the principal's problem is

$$\begin{aligned}
& \max_{b_1, b_2} f_1 g_1 b_1 + f_2 g_2 b_2 + f_3 \left(p \frac{g_3}{c_L} b_1 + (1-p) g_3 b_2 \right) \\
& \quad - \left(\frac{(g_1 b_1)^2}{2} + p \frac{(g_3 b_1)^2}{2c_L} \right) - \left(\frac{(g_2 b_2)^2}{2} + (1-p) \frac{(g_3 b_2)^2}{2} \right) \\
& \text{s.t. } c_L \leq \frac{1}{2} \frac{b_1}{b_2} < c_H
\end{aligned} \tag{14}$$

First assume that the constraints in (14) are not binding. The optimal bonuses are then given by the first-order conditions

$$\begin{aligned}
f_1 g_1 + p f_3 \frac{g_3}{c_L} - \left(g_1^2 b_1 + p \frac{g_3^2 b_1}{c_L} \right) &= 0, \\
f_2 g_2 + (1-p) f_3 \frac{g_3}{c_L} - \left(g_2^2 b_2 + (1-p) g_3^2 b_2 \right) &= 0,
\end{aligned}$$

from which we obtain b_1^D and b_2^D as given in the lemma. We can now characterize under what circumstances the constraints in (14) are not binding: if $c_L \leq \frac{1}{2} \frac{b_1^D}{b_2^D} \leq c_H$. Defining $\hat{c} := \frac{1}{2} \frac{b_1^D}{b_2^D}$, case (i) of the lemma follows. Now assume that $\hat{c} < c_L$. The first inequality in (14) is then binding. Hence, the optimal solution comprises $b_2 = \frac{1}{2} \frac{b_1}{c_L}$. Using this relationship to replace b_2 in the principal's objective function, the optimal b_1 maximizes

$$\begin{aligned}
& f_1 g_1 b_1 + f_2 g_2 \left(\frac{1}{2} \frac{b_1}{c_L} \right) + f_3 \left(p \frac{g_3}{c_L} b_1 + (1-p) g_3 \left(\frac{1}{2} \frac{b_1}{c_L} \right) \right) \\
& - \left(\frac{(g_1 b_1)^2}{2} + p \frac{(g_3 b_1)^2}{2c_L} \right) - \left(\frac{\left(g_2 \left(\frac{1}{2} \frac{b_1}{c_L} \right) \right)^2}{2} + (1-p) \frac{\left(g_3 \left(\frac{1}{2} \frac{b_1}{c_L} \right) \right)^2}{2} \right).
\end{aligned}$$

From the first-order condition we obtain \hat{b}_1^D as given in the lemma.

Proof of Proposition 1. Case (i) of the Proposition follows directly from Lemma 1 and case (i) of Lemma 3, using that $f_\ell = g_\ell$ for all ℓ . Now consider case (ii) of the proposition.

By Lemma 1 and case (ii) of Lemma 3, delegation dominates centralization iff

$$\frac{\left(f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2)\frac{1}{2c_L}\right)^2}{f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2)\frac{1}{4c_L^2}} > f_1^2 + f_2^2 + f_3^2 \cdot \max\{1, \gamma\}. \quad (15)$$

First consider the case $\gamma < 1$. It can be shown (e.g., using Mathematica) that the left-hand side of condition (15) is decreasing in c_L for $c_L > \frac{1}{2}$. To prove the claim on the optimality of delegation, it thus suffices to show that condition (15) holds as c_L approaches $\frac{1}{2}$ but does not hold as c_L goes to 1. We obtain

$$\begin{aligned} \lim_{c_L \rightarrow \frac{1}{2}} \frac{\left(f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2)\frac{1}{2c_L}\right)^2}{f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2)\frac{1}{4c_L^2}} &= \frac{(f_1^2 + 2pf_3^2 + (f_2^2 + (1-p)f_3^2))^2}{f_1^2 + 2pf_3^2 + (f_2^2 + (1-p)f_3^2)} \\ &= f_1^2 + 2pf_3^2 + (f_2^2 + (1-p)f_3^2) > f_1^2 + f_2^2 + f_3^2. \end{aligned}$$

As c_L goes to 1, we have

$$\begin{aligned} \lim_{c_L \rightarrow 1} \frac{\left(f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2)\frac{1}{2c_L}\right)^2}{f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2)\frac{1}{4c_L^2}} &= \frac{(f_1^2 + pf_3^2 + (f_2^2 + (1-p)f_3^2)\frac{1}{2})^2}{f_1^2 + pf_3^2 + (f_2^2 + (1-p)f_3^2)\frac{1}{4}} \\ &= \frac{(f_1^2 + \frac{1}{2}f_2^2 + \frac{1}{2}f_3^2 + \frac{1}{2}pf_3^2)^2}{f_1^2 + \frac{1}{4}f_2^2 + \frac{1}{4}f_3^2 + \frac{3}{4}pf_3^2} \end{aligned}$$

The last expression is smaller than $f_1^2 + f_2^2 + f_3^2$ iff

$$\begin{aligned} & \left(f_1^2 + \frac{1}{2}f_2^2 + \frac{1}{2}f_3^2 + \frac{1}{2}pf_3^2 \right)^2 - \left(f_1^2 + \frac{1}{4}f_2^2 + \frac{1}{4}f_3^2 + \frac{3}{4}pf_3^2 \right) (f_1^2 + f_2^2 + f_3^2) < 0 \\ & \Leftrightarrow -\frac{1}{4} (f_1^2 + pf_3^2) (f_2^2 + f_3^2 - pf_3^2) < 0, \end{aligned}$$

and the last condition clearly holds.

Now consider the case $\gamma \geq 1$. The principal then prefers delegation to centralization iff

$$\frac{\left(f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2) \frac{1}{2c_L} \right)^2}{f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2) \frac{1}{4c_L^2}} - (f_1^2 + f_2^2 + \gamma f_3^2) > 0. \quad (16)$$

The left-hand side of (16) is decreasing in c_L for $c_L > \frac{1}{2}$ (Mathematica). We further obtain

$$\begin{aligned} & \lim_{c_L \rightarrow \frac{1}{2}} \left[\frac{\left(f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2) \frac{1}{2c_L} \right)^2}{f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2) \frac{1}{4c_L^2}} - (f_1^2 + f_2^2 + \gamma f_3^2) \right] \\ & = f_1^2 + 2pf_3^2 + (f_2^2 + (1-p)f_3^2) - \left(f_1^2 + f_2^2 + \left(2p + \frac{1-p}{c_H} \right) f_3^2 \right) > 0. \end{aligned}$$

Above, we have shown that

$$\lim_{c_L \rightarrow 1} \frac{\left(f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2) \frac{1}{2c_L} \right)^2}{f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2) \frac{1}{4c_L^2}} - (f_1^2 + f_2^2 + f_3^2) < 0.$$

Hence, because $\gamma \geq 1$, we also have

$$\lim_{c_L \rightarrow 1} \left[\frac{\left(f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2) \frac{1}{2c_L} \right)^2}{f_1^2 + p\frac{f_3^2}{c_L} + (f_2^2 + (1-p)f_3^2) \frac{1}{4c_L^2}} - (f_1^2 + f_2^2 + \gamma f_3^2) \right] < 0.$$

By case (ii) of Lemma 3, under delegation the principal pays the bonuses

$$\hat{b}_1^D = \frac{f_1^2 + \frac{f_2^2}{2c_L} + p\frac{f_3^2}{c_L} + (1-p)\frac{f_3^2}{2c_L}}{f_1^2 + p\frac{f_3^2}{c_L} + \frac{1}{4c_L^2}(f_2^2 + (1-p)f_3^2)}, \quad \hat{b}_2^D = \frac{1}{2} \frac{\hat{b}_1^D}{c_L}. \quad (17)$$

We obtain that $\hat{b}_1^D > 1 \Leftrightarrow c_L > \frac{1}{2}$ and $\hat{b}_2^D < 1 \Leftrightarrow c_L > \frac{1}{2}$. Since the lemma focusses on the case $c_L > \frac{1}{2}$, the claim follows. By the formulas in (1) and (3), the bonuses under centralization are equal to 1.

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