Cooperation in the Budgeting Process

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Received 27 February 2002; accepted 18 June 2003

ABSTRACT

In this article I analyze the role of cooperation between firm divisions in the budgeting process. I study a setting in which cooperation is a necessary condition for information sharing among division managers, which in turn benefits the principal. The results in this article can help reconcile the differing views between practitioners and academic researchers on the desirability of cooperation in the budgeting process. The results also have implications for some common budgeting processes observed in practice, including bundling budgeting and bottom-up budgeting.

1. Introduction

In this article I analyze the role of cooperation between firm divisions in the budgeting process. I seek to identify conditions under which interdivisional cooperation may or may not be desirable from firm headquarters' perspective. Interdivisional cooperation is defined as division managers (the

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agents) compensating each other with explicit monetary payments, implicit favors, or both, with the intent of hiding information from headquarters (the principal). Therefore, cooperation carries the same interpretation and hence is used synonymously throughout this article as *collusion* in Tirole [1986, 1992].

It is well documented that collusive behavior arises as part of social norms among agents who interact frequently with each other (Dalton [1959]). Because budgeting is a firmwide multidivisional activity and necessitates interactions among division managers, it is likely that firms' budgeting mechanisms are influenced by the agents' collusive behavior. A key question is then whether interdivisional cooperation is desirable from headquarters' perspective. Contrasting views exist between practitioners and academic researchers on cooperative behavior: although managerial accountants often stress the importance of interdivisional cooperation for successful budgets (Dugdale and Kennedy [1999]), academic research shows otherwise. In particular, Tirole [1992] shows that absent contracting frictions (e.g., communication costs between the principal and agents), the revelation principle and the collusion proof principle imply that the principal is always weakly better off without collusion because collusion imposes cost on the principal to obtain information.

In this article I obtain insights regarding the role of cooperation in the firm's budgeting process by studying a setting in which some contracting frictions lead to a beneficial role for cooperation. In my model, the principal delegates different activities to two agents: a worker and a manager. The worker exerts costly personal effort to produce output and the manager has access to a costly investment project. The firm's production technology exhibits strategic complementarities in that the investment project increases the marginal productivity of the worker's effort. The principal designs a budgeting system that determines whether to invest and, if so, the payment to the manager to implement the investment project. The budgeting system also specifies a production and compensation schedule for the worker. I consider only cases in which, absent information asymmetries, the investment project has a positive net present value and will always be undertaken.

A key result is that collusion may be desirable to the principal because without it, the agents have no incentive to communicate their private information to each other. Two conditions are needed for this result to hold: (1) strategic complementarities exist between the investment and production activities, and (2) the principal make the investment decision before he or she contracts with the worker (i.e., sequential contracting). In general, strategic complementarities suggest that the optimal investment decision will depend nontrivially both on the agents' reports when the agents possess private information about the investment and on production activities. Thus, when the principal has to make the investment choice before contracting with the worker, the investment may be inefficient relative to when the principal can condition the investment decision on both agents' reports.

The extent of the inefficiency depends on whether the manager observes the worker's private information and whether collusion exists between the agents.

More specifically, I find that conditional on the manager observing the worker's private information, collusion imposes an additional cost on the principal to obtain the agents' private information relative to when the agents cannot collude. When the manager does not observe the worker's private information, however, collusion is a necessary condition for the worker to share his or her private information with the manager. Intuitively, this result obtains because without collusion, the manager is better off volunteering the worker's private information to the principal if he or she observes this information, which in turn implies that the worker would not share his or her information with the manager in the first place. I show that it is possible that, as a group, the agents obtain a higher total expected payoff when they cooperate. More important, the principal can also improve investment and production efficiency by taking into account the information (about the worker) contained in the manager's report.

Prior studies analyze the effects of strategic complementarities and sequential contracting on general issues regarding organizational designs. For example, Milgrom and Roberts [1990, 1995] argue that many modern production environments exhibit strategic complementarities. Marschark and Radner [1972] and Radner [1992], among others, suggest that communication costs permeate organizations and influence organizational design. Sequential contracting represents a specific type of communication cost. It can arise in many situations including, for example, when the end-user of an investment (the worker in my model) cannot commit to staying with the firm, or when information about postinvestment environments is unavailable or difficult to articulate, which is likely when investments are irreversible and have uncertain outcomes (Dixit and Pindyck [1991]).

Casual observation suggests that some observed budgeting practices are influenced by strategic complementarities and sequential contracting. I discuss two examples here: bundling budgeting and bottom-up budgeting. In bundling budgeting, budgets are set for a group of activities rather than for individual activities.¹ The underlying premise is that the bundled activities are complements to each other. In bottom-up budgeting, lower level plant managers initiate the budgeting process by reporting their information to middle-level management; the latter then submits a formal report to headquarters. This practice is consistent with communication costs between headquarters and lower level managers. For bundling budgeting, my analysis identifies a situation under which cooperation can help exploit gains from production complementarities. My results also suggest that policies prohibiting side payments may reduce the effectiveness of bottom-up

¹ For example, Caterpillar shifted its capital budgeting practice from "considering incremental asset purchase proposals to considering proposals to purchase sets of diverse but mutually reinforcing assets ('investment bundles')." (Miller and O'Leary [1997, p. 261]).

systems when communication from lower level managers is essential to exploit production synergies.

Most research on optimal budgeting mechanisms under asymmetric information focuses on either the role of budgeting as a communication channel between headquarters and division managers (e.g., Baiman and Evans [1983], Kirby et al. [1991]) or the impact of information asymmetry on the efficiency (or the lack thereof) of a firm's internal capital-allocation process (e.g., Harris, Kriebel, and Raviv [1982], Antle and Eppen [1985], Harris and Raviv [1996, 1998], Bernardo, Cai, and Luo [2001]). This article contributes to this literature by analyzing budgeting processes with multiple divisions, emphasizing the role of interdivision cooperation in encouraging communication between division managers. This article is closely related to Kanodia [1993], who shows that participative budgets (i.e., budgets based on all divisions' reports) help coordinate activities across divisions. It complements Kanodia's study by focusing on situations in which full participative budgets are not feasible and by identifying a potential role for cooperation in alleviating the inefficiency caused by the (exogenously given) communication costs. In this sense, this article is similar to Melumad, Mookherjee, and Reichelstein [1992, 1995], who also take communication costs as given and analyze their effects on the desirability of delegation.

This article also relates to several studies on collusion (e.g., Tirole [1986, 1992], Kofman and Lawarree [1993]). Similar to these studies, I sidestep the exact mechanisms in the agents' collusive agreements. Unlike these studies (in which only one agent performs productive activity and has private information), both agents in my model perform productive tasks and privately observe their own information. Demski and Sappington [1984] study a setting in which both agents perform identical tasks and have correlated private signals.² The agents in my model have different tasks and their private information is uncorrelated; the only connection between the agents is the production complementarities.

The rest of the article is organized as follows. Section 2 sets up the basic model and obtains the first-best solution as a benchmark. Section 3 assumes that the agents cannot collude via side payments and derives the optimal contracts for situations both when the principal is constrained to sequential contracting and when he or she is not. Section 4 analyzes the situation in which one agent (the manager) observes the other agent's (the worker's) private information and the agents can make side payments. Section 5 concludes.

² See Ma, Moore, and Turnbull [1988] for a refinement of the mechanism proposed in Demski and Sappington [1984], and Rajan [1992] for an application of the mechanism in designing cost-allocation schemes. Other related works include Laffont and Martimort [1997] and Villadsen [1995], who study the impact of collusion on the benefits of relative performance measures and delegation. Suh [1987] studies how cost allocation can be used to prevent agents from colluding in a moral hazard setting, where agents do not hold precontracting private information.

2. Model Setup

Consider a firm with two divisions, say, a manufacturing and a research and development (R&D) division. The manager of the manufacturing division (referred to as the worker) carries out production activities by exerting costly effort $e \geq 0$ to generate output Y , given by:

$$Y = \theta + t(I) \cdot e. \quad (1)$$

θ is an exogenous parameter that affects total output, and t captures the (marginal) productivity of the worker's effort, which can be improved by implementing an investment project I . Specifically, without loss of generality, assume that the firm's existing $t(I)$ equals 1 and can increase to $t > 1$ if the principal invests in a productivity-enhancing project. That is,

$$\begin{aligned} t(I) &= t > 1 & \text{if } I = 1, \\ &= 1 & \text{if } I = 0, \end{aligned} \quad (2)$$

where I equals 1 if the investment is implemented, and 0 otherwise. The investment can only be carried out by the manager of the R&D division (referred to as the manager³) at a cost of k . I assume that only the worker knows the true value of θ (and e) and only the manager knows the true investment cost k . It is common knowledge that θ equals $\bar{\theta}$ with probability p and $\underline{\theta}$ with probability $1 - p$, where $\bar{\theta} > \underline{\theta} > 0$, and that k is distributed according to distribution $F(\cdot)$ with density $f(\cdot)$ and support $[0, K] \in R^+$.

All three parties are risk neutral. The principal is the residual claimant of the profit, defined as the total output net of the payments to the agents. The worker's utility is $U(W, e) = W - C(e)$, where W is the wage paid by the principal, and $C(e)$ is the worker's personal monetary cost of effort with $C'(\cdot) > 0$, $C''(\cdot) > 0$, and $C'''(\cdot) \geq 0$. The manager's utility is $V(\kappa, k) = \kappa - I \cdot k$, where κ is the principal's payment to the manager (or alternatively, the capital allocated to the investment project). Both agents' reservation utility is normalized to zero for simplicity.

Both the final output level (Y) and whether the investment is implemented (I) are observable and, therefore, contractible. I focus on situations in which the investment decision is made before the principal contracts with the worker.⁴ The timing of events is as follows: at time 1, each agent observes his or her private information; at time 2, the principal makes the investment decision based on the manager's report of the investment cost; at time 3, the principal chooses production plans based on the worker's report provided after the investment takes place; and at time 4, the output is realized and the contracts are executed.

³ The terms *worker* and *manager* are for notational convenience only and do not imply any hierarchical relationship between the agents.

⁴ I derive the optimal contracts when the principal can condition his or her investment decision on both agents' signals in Proposition 3.

The first-best investment and production levels solve the following problem:

$$\max_{(e, I)} \Pi = E(\theta) + t(I) \cdot e - C(e) - I \cdot k.$$

The first-best effort level, e^{fb} , is given by

$$\frac{\partial C(e^{fb})}{\partial e} \equiv C'(e^{fb}) = t(I),$$

where $I \in \{0, 1\}$. Strategic complementarities between the investment and the production effort imply that the optimal effort level depends on whether the investment is implemented. For notational ease, throughout the article an upper bar (lower bar) to a variable denotes that the variable pertains to the worker who observes a high (low) θ and a subscript $I \in \{0, 1\}$ to a variable indicates that the variable depends on the investment. For example, $\bar{e}_0$ is the effort level for the high- θ worker when no investment has taken place, and $\underline{e}_1$ is the effort level for the low- θ worker when the investment has taken place.

The optimal investment decision is obtained by comparing the marginal benefit with the marginal cost of investing. Let $R^{fb}(I) \equiv t(I)e_I^{fb} - C(e_I^{fb})$ be the expected revenue (total output net of the cost of effort) for a given investment $I \in \{0, 1\}$. The marginal benefit of investing is given by

$$\Delta R^{fb} \equiv R^{fb}(1) - R^{fb}(0).$$

Without loss of generality, I assume that all investments have positive net present values without information asymmetries, that is, $\Delta R^{fb} = K$.⁵ Also, as is standard in the literature, I assume that the distribution function for the investment cost has a monotone hazard rate, that is,

$$\frac{d(f/F)}{dk} < 0,$$

which implies decreasing returns to scale in investment projects. Most usual distributions—uniform, normal, logistic, chi-squared, exponential, and Laplace—satisfy this condition. Finally, I assume that the agents are wealth constrained; therefore, the principal cannot sell the firm to them *ex ante*. This is not an unrealistic assumption given that we seldom observe headquarters selling the entire firm to a single division.

3. No Collusion Between Agents

In this section I analyze the principal's optimal investment and production choices when the agents cannot collude by making side payments. As a benchmark, I first establish the principal's optimal investment strategy assuming that he or she observes the worker's private information θ but not

⁵ Assuming equality is only for computational ease. Replacing the equality sign with a greater than or equal to sign does not change the qualitative conclusions.

the manager's private information k . I then derive the optimal contracts when the principal does not observe either θ or k , both when the contracts are sequential and when they are not. I end this section by discussing the implications of sequential contracting and collusion. All proofs are in the Appendix.

When the principal observes the worker's private information θ , he or she can always implement the first-best effort level by paying the worker exactly the cost of effort. Thus, given the assumption that all investment projects have non-negative values in the first-best situation, the principal should invest for all k . However, if the principal commits to investing in all projects and if k is privately observed by the manager, the manager has no incentive to report any cost but the maximum K . In this case, the principal obtains no surplus from the investment. On the other hand, the principal can obtain a positive expected payoff by committing to invest only when the manager reports a cost lower than K . The following proposition states this result formally.

PROPOSITION 1. *When the principal observes the worker's private information θ but does not observe the manager's investment cost k , the principal will invest and pay the manager his or her reported cost k iff the manager reports a cost $k \leq \kappa^\theta$. Otherwise, the principal will not invest. The optimal κ^θ solves the equation*

$$\kappa^\theta = \Delta R^{fb} - \frac{F(\kappa^\theta)}{f(\kappa^\theta)}, \quad \text{and} \quad \kappa^\theta < \Delta R^{fb} = K.$$

Rearranging

$$\kappa^\theta = \Delta R^{fb} - F(\kappa^\theta)/f(\kappa^\theta)$$

yields $f(\kappa^\theta)(\Delta R^{fb} - \kappa^\theta) = F(\kappa^\theta)$, which has the following intuitive interpretation. For any κ^* , the manager obtains an expected overpayment (i.e., information rent) as a result of his or her private information about k , given by

$$E(V(\kappa^*)) = F(\kappa^*)[\kappa^* - E(k | k \leq \kappa^*)] = \int_0^{\kappa^*} F(c) dc. \quad (3)$$

Because this overpayment is a deadweight loss to the principal and is increasing in

$$\kappa^*, \quad (\text{i.e., } \partial E(V(\kappa^*))/\partial \kappa^* = F(\kappa^*) \geq 0),$$

the principal can reduce it by lowering κ^* . The marginal cost to the principal is the foregone incremental value from investing, measured by $f(\kappa^*)(\Delta R^{fb} - \kappa^*)$. The marginal benefit and marginal cost are equal at κ^θ with $f(\kappa^\theta)(\Delta R^{fb} - \kappa^\theta) = F(\kappa^\theta)$. The cutoff point investment rule resembles a hurdle rate rule, a commonly observed capital budgeting practice. Firms often set a hurdle rate higher than their external costs of capital and accept only investment proposals whose expected returns exceed the hurdle rate (Poterba and Summers [1992]).

I now consider the situation where the principal does not observe either k or θ . Proposition 1 implies that the optimal cutoff point is an increasing function of the incremental benefit from investing, which depends on the optimal effort level for the worker. When the principal does not observe θ , the incremental value will not be ΔR^{fb} as in Proposition 1 because the first-best effort levels will not be optimal. The following provides a brief description of why this is the case.

Notice that for a given I , the principal needs to pay the low- θ worker $C(\underline{e}_I)$ for producing an output of $\underline{Y} = \underline{\theta} + t(I) \cdot \underline{e}_I$. However, because only output (not effort or θ) is observable, the high- θ worker can produce the same output $\underline{Y}$ by exerting effort of only $\underline{e}_I - \frac{\Delta\theta}{t(I)}$ and, therefore, get paid for more than his or her cost of effort

$$(\text{i.e., } C(\underline{e}_I) > C(\underline{e}_I - \Delta\theta/t(I))).$$

Formally, define

$$\Phi_I(\underline{e}_I) \equiv C(\underline{e}_I) - C\left(\underline{e}_I - \frac{\Delta\theta}{t(I)}\right) > 0, \quad (4)$$

and

$$\Phi'_I(\underline{e}_I) \equiv \frac{\partial \Phi(\underline{e}_I)}{\partial \underline{e}_I} > 0. \quad (5)$$

That is, $\Phi_I(\underline{e}_I)$ ($I \in \{0, 1\}$) captures the amount of information rent accrued by the high- θ worker for a given I and $\underline{e}_I$. This information rent is a dead-weight loss to the principal and is increasing in $\underline{e}_I$ (as shown in (5)). The principal, therefore, can increase his or her expected profit by reducing $\underline{e}_I$. The optimal $\underline{e}_I$ is obtained by trading off the benefit of reducing the high- θ worker's rent with the cost of a lower than first-best effort level by the low- θ worker. Such trade-offs, in turn, affect the incremental value from investing and hence the principal's optimal cutoff point for investment. The next proposition formalizes the preceding discussion, assuming that the principal has to make the investment decision before contracting with the worker. The superscript s stands for sequential.

PROPOSITION 2. *The following relations characterize the principal's optimal effort and investment choices when he or she does not observe the agents' private information and has to make the investment decision before contracting with the worker.⁶*

⁶ This proposition characterizes the optimal contracts in terms of the effort levels and wage payment for both high- θ and low- θ workers. Equivalently, the principal can offer a pair of contracts for the worker to choose from, with each contract specifying an output level and a wage payment. For example, one contract would specify that the worker be paid $\bar{W}_I^s = C(\bar{e}_I^s) + \Phi_I(\underline{e}_I^s)$ if and only if the worker produces an output level of $\bar{Y}_I^s = \bar{\theta} + t(I)\bar{e}_I^s$, where $\bar{e}_I^s$ and $\underline{e}_I^s$ are given by (6) and (7). The worker would get no payment if the observed output is not $\bar{Y}_I^s$. In equilibrium, only the high- θ worker would choose to take this contract. The low- θ worker would choose the contract that pays $\underline{W}_I^s$ for an output level of $\underline{Y}_I^s = \underline{\theta} + t(I)\underline{e}_I^s$.

- (i) For a given investment level $I \in \{0, 1\}$,

$$t(I) = C'(\bar{e}_I^s), \bar{W}_I^s = C(\bar{e}_I^s) + \Phi_I(\underline{e}_I^s), \quad (6)$$

$$t(I) = C'(\underline{e}_I^s) + \frac{p}{1-p} \Phi_I'(\underline{e}_I^s), \underline{W}_I^s = C(\underline{e}_I^s), \quad (7)$$

$$\Delta\Phi^s \equiv \Phi_1(\underline{e}_1^s) - \Phi_0(\underline{e}_0^s) > 0, \quad (8)$$

where Φ_I and Φ_I' are defined in (4) and (5), respectively.

- (ii) The principal will pay the manager κ^s to implement the investment if and only if the principal's reported cost is less than κ^s . Let ΔR^s denote the incremental value for the principal from investing under the effort choices as specified in (i). Then, κ^s is given by

$$\kappa^s = \Delta R^s - \frac{F(\kappa^s)}{f(\kappa^s)}, \quad (9)$$

and

$$\kappa^s < \kappa^\theta < K. \quad (10)$$

- (iii) Let Π^s be the principal's expected payoff with the preceding contracts. The principal's expected profit is strictly greater than Π^s if either θ or k is observed.

Equations (6) and (7) are standard results in models with precontracting asymmetric information. Equation (7), together with $\Phi_I' > 0$ and $C'' > 0$, implies that the optimal effort level for the low- θ worker is lower than the first-best level. Equation (6) shows that the high- θ worker earns a positive rent as his or her wage is higher than the cost of effort. Furthermore, equation (8) shows that the high- θ worker's rent is higher with the investment implemented, which suggests that everything else constant, the high- θ worker would be willing to pay up to $\Delta\Phi^s$ to guarantee that the principal invests. As will be clear soon, this incremental rent is the source of gain for the agents to collude.

Equation (10), shows that the principal adopts a lower cutoff point for investment when θ is not observed than when it is. This result occurs because when the principal does not observe θ , he or she pays a positive rent ($\Phi_I(\underline{e}_I) > 0$) to the high- θ worker, reducing the investment benefit relative to when the principal observes θ . Result (iii) is straightforward: observability of either agent's private information benefits the principal because it eliminates the information rent the principal has to pay the agent.

Sequential contracting imposes a constraint on the principal's investment choice. Specifically, sequential contracting does not allow the principal to condition the investment decision on the worker's private information. As shown in the next proposition, this constraint is likely to be binding, implying that the principal would achieve a higher expected payoff if he or she could condition the investment choice on both agents' reports.

PROPOSITION 3. *When the principal can contract with both agents before making an investment decision, (i) his or her expected payoff is at least as high as Π^s from Proposition 2, and (ii) the optimal cutoff point will depend on the worker's private information and is not necessarily higher or lower than κ^s or ΔR^s .*

Furthermore, sequential contracting (especially (10) from Proposition 2) provides the agents with incentives to reveal the other's private information to the principal if they observe such information, as the following corollary shows.

COROLLARY 1. *Under sequential contracting, when the principal does not observe either agent's private information and when the agents cannot collude by making side payments to each other, if one of the agents observes the other agent's private information, he or she will voluntarily disclose the other agent's information to the principal.*

Corollary 1 is easily proved by noticing two points: (1) both the manager's *ex ante* expected rent (given by equation (3)) and the worker's expected rent (given by $E(W(\kappa^*)) = p[\Phi_0(\underline{e}_0^*) + F(\kappa^*)\Delta\Phi]$) are increasing in the investment cutoff point κ^* , and (2) both the cutoff point when the principal observes θ but not k (i.e., κ^θ) and the cutoff point when the principal observes k but not θ (i.e., $\kappa^k = \Delta R^s$) are higher than the cutoff point when the principal does not know either θ or k (i.e., κ^s).⁷ Therefore, neither agent will hesitate to reveal the other's private information to the principal if they observe such information.

Both sequential contracting and no collusion are needed for Corollary 1. Without sequential contracting, Proposition 3 implies that an agent's *ex ante* expected rent is not necessarily increasing when the principal observes the other agent's information. When collusion is possible, the agents will not necessarily volunteer each other's private information. To see this, suppose the manager observes the worker's private information. Then, his or her expected gain from disclosing this information to the principal is

$$E(V(\kappa^\theta)) - E(V(\kappa^s)) = \int_{\kappa^s}^{\kappa^\theta} F(c) dc.$$

The worker, on the other hand, would lose his or her entire expected rent of $p[\Phi_0(\underline{e}_0^s) + F(\kappa^s)\Delta\Phi^s]$. If the agents can make side payments, as long as

$$p[\Phi_0(\underline{e}_0^s) + F(\kappa^s)\Delta\Phi^s] > \int_{\kappa^s}^{\kappa^\theta} F(c) dc,$$

the worker would always have the incentive (and the means) to bribe the manager to withhold information from the principal.

There are two sides to Corollary 1. On the one hand, Corollary 1 shows that when the agents cannot collude, the principal can obtain for free their

⁷ That ΔR^s is the optimal cutoff value when the principal observes only k follows immediately by noticing that ΔR^s is the incremental benefit to the principal when only k is observed.

information about the other agent's private information. Proposition 2 shows that the principal's expected profit is the lowest when he or she does not observe any agent's information, and Corollary 1 implies that if one agent observes the other's private information, collusion imposes additional cost for the principal. On the other hand, Corollary 1 implies that when the agents cannot make side payments, they will not have incentives to enter into any *ex ante* agreement to share private information. This result suggests that to the extent that collusion facilitates information sharing between the agents and to the extent the principal can take advantage of agents' shared information, collusion may benefit the principal. The next section explores this possibility.

4. Collusion Between Agents

In this section I characterize the principal's optimal contracts under sequential contracting, assuming that the agents can collude via side payments between themselves. Sequential contracting implies that the principal has to contract with the manager first; thus, I consider only the case where the manager observes the worker's private information for exogenous reasons before contracting with the principal. The worker does not observe the manager's private information but may be able to make side payments to the manager to lie for him or her. Following Tirole [1992], I assume that such collusive behavior takes the form of the agents' signing a side contract before they observe their private information and apply the collusion-proof principle in Tirole [1992] to solve for the optimal allocations. The collusion-proof principle says that any final allocation that can be achieved by the agents' side payments can be achieved by the principal; therefore, there is no loss of generality in focusing on mechanisms that induce no side payments between the agents. Before characterizing the optimal allocations, I make the following observation.

OBSERVATION. *When the manager observes the worker's private information and when the agents can make side payments between themselves, the principal can achieve at least the same expected profit as that from Proposition 2 (i.e., Π^s).*

Consider the following strategy. Ask the manager to report both k and θ . Adopt the same investment decision rule as in Proposition 2 (i.e., invest and pay the manager κ^s iff he or she reports $k \leq \kappa^s$). In addition, pay the manager a bonus whenever he or she reports θ . The bonus is set at $\Phi_1(\underline{e}_1^s)$ if the investment is implemented, and $\Phi_0(\underline{e}_0^s)$ otherwise, where $\underline{e}_I^s$ and Φ_I ($I = 0, 1$) are defined in Proposition 2. Because Φ_I is the maximum amount the worker would be able to pay the manager to lie for him or her, the preceding strategy guarantees that the manager truthfully reveals θ even when the worker is able to make side payments. In short, the principal achieves Π^s simply by reallocating the worker's rent to the manager.

The principal can, however, achieve a higher expected payoff than Π^s . Notice that the preceding mechanism does not consider how the bonus

for reporting θ affects the manager's reporting behavior with regard to his or her own cost k . In fact, as long as the bonus for reporting θ is not the same with investment as without investment (i.e., $\Delta\Phi \equiv \Phi_1(\underline{e}_1^*) - \Phi_0(\underline{e}_0^*) \neq 0$), the manager's report of k will depend on both k and θ . As a result, the manager's report of k conveys additional information about θ , which benefits the principal. To see how the principal can use this information, notice that for a given cutoff κ^* , the manager's report k will be as follows:

$$\begin{aligned}\hat{k} &= \kappa^* \quad \text{if } k \leq \kappa^* + \Delta\Phi \quad \text{and } \theta = \bar{\theta}, \quad \text{or } k \leq \kappa^* \quad \text{and } \theta = \underline{\theta}, \\ &= K \quad \text{if } k > \kappa^* + \Delta\Phi \quad \text{and } \theta = \bar{\theta}, \quad \text{or } k > \kappa^* \quad \text{and } \theta = \underline{\theta}.\end{aligned}$$

Recall that when the manager does not observe θ , he or she would never report a cost lower than the actual cost. If there is an extra bonus for reporting a high θ (i.e., $\Delta\Phi > 0$), however, the manager could use the bonus to cover some of the investment cost. Thus, when $\theta = \bar{\theta}$, as long as $k \leq \kappa^* + \Delta\Phi$, the manager is better off reporting κ^* than reporting K .⁸

When designing the optimal contract, the principal takes advantage of the fact that a report of κ^* is more likely to come from a manager who has observed a high θ . Intuitively, the ability of the worker and the manager to collude changes the manager's behavior such that his or her report of k conveys information about θ . This insight drives the allocations induced under the optimal mechanism, formalized in Proposition 4.

PROPOSITION 4. *Assume that the manager observes θ and that the agents can make side payments between themselves. Under sequential contracting, (i) the principal invests if and only if the manager reports a cost $k \leq \kappa^c$, where κ^c is determined by the following relations:*

$$\kappa^c + \frac{F(\kappa^c)}{f(\kappa^c)} = [te_1^c - C(\underline{e}_1^c)] - [\underline{e}_0^c - C(\underline{e}_0^c)],$$

with

$$C'(\underline{e}_1^c) = t - \frac{\lambda}{pF(\kappa^c)} \frac{p}{1-p} \Phi_1'(\underline{e}_1^c), \quad (11)$$

$$C'(\underline{e}_0^c) = t - \frac{(p-\lambda)}{p(1-F(\kappa^c))} \frac{p}{1-p} \Phi_0'(\underline{e}_0^c), \quad (12)$$

where $0 < \lambda < p$; and (ii) there exists a $\lambda^* = pF(\bar{\kappa}^*)$, with $\bar{\kappa}^*$ given by equation (A10) in the Appendix, such that the principal can achieve the same final allocations as in Proposition 3.

Similar to the results in Proposition 2, where the agents cannot collude and the manager does not observe the worker's private information, the high- θ worker's effort is always set at the first-best level (shown in the proof

⁸ This is because when $\theta = \bar{\theta}$, the manager's payoff is $\kappa^* + \Phi_1 - k$ if reporting κ^* and Φ_0 if reporting K ; and $\kappa^* + \Phi_1 - k \geq \Phi_0$ if $k \leq \kappa^* + \Delta\Phi$.

in the Appendix). The effort levels for the low- θ worker, given by (11) and (12), are also determined by a similar trade-off: to balance the marginal benefit of the low- θ worker's effort (i.e., $t(I)$) with the marginal cost, which includes both the monetary cost of effort ($C'(e)$) and the cost of information asymmetry about θ (i.e., $\frac{p}{1-p}\Phi'_I$). Furthermore, (11) and (12) show that the cost of information asymmetry is multiplied by a factor of

$$\frac{\lambda}{pF(\kappa^c)} \left(\text{resp. } \frac{(p-\lambda)}{p(1-F(\kappa^c))} \right),$$

when $I = 1$ (resp. 0). The multiplier terms reflect the fact that the principal can update his or her prior about θ after receiving the manager's report of k . Consequently, the low- θ worker's effort level now depends on the cutoff point for the investment.

Result (ii) shows that the principal can achieve the same allocations as when the contracts are not constrained to be sequential. Intuitively, this result occurs because the principal can circumvent the constraint imposed by sequential contracting by using the information contained in the manager's report about the worker's θ . Another way to see this is to note that λ is the shadow price for inducing the manager to tell the truth about θ when the investment is implemented. When the manager does not observe θ , λ is fixed; when the manager observes θ , the principal can choose λ to achieve the optimal balance between investment (in)efficiency and production (in)efficiency. Furthermore, given that Φ_1 is the maximum bribery the worker can pay, and given $\frac{\partial \Phi_1}{\partial t} < 0$, it is relatively easier to induce truth telling when t is high, which implies that $\partial \lambda / \partial t < 0$; that is, the principal benefits more from the manager's knowledge of θ when the complementarities between the agents' tasks are high.

Proposition 2 and Corollary 1 imply that under sequential contracting and no collusion, the principal obtains a higher expected payoff when the manager observes the worker's private θ than when the manager does not observe θ . Proposition 4 further shows that this result holds even when the worker can potentially bribe the manager to lie.⁹ The following corollary shows that the agents as a group obtain a higher expected payoff when the manager observes θ than when the manager does not observe θ .

COROLLARY 2. *The agents' expected collective rent is higher under the contracts from Proposition 4 than that under the contracts from Proposition 2.*

Recall that Corollary 1 shows that the worker would not share private information with the manager without collusion. Corollary 2 suggests that

⁹ Note that this is not the same as saying that collusion itself makes the principal better off. As shown in Proposition 2, the principal achieves higher profit if the agents share information but cannot make side payments to each other. The problem, however, is that without collusive agreement, no agent wants the other agent to know his or her private information (Corollary 1).

it is possible that each agent can be made better off if the worker shares his or her private information with the manager. Corollary 2 is a necessary condition for side contracts between the agents. Because lower benefits for the agents as a group imply that at least one agent is strictly worse off by agreeing to such side contracts, it follows that the agents would not agree on side contracts in the first place. Corollary 2 is not a sufficient condition for side contracts. Furthermore, Corollary 2 does not imply that the contracts in Proposition 4 induce the worker to share private information with the manager. In fact, the contracts in Proposition 4 assume that the manager observes the worker's θ for exogenous reasons and the analysis is silent on how the manager learns the worker's type.

In general, it is difficult to obtain a closed-form solution for the contracts under Proposition 4. I provide a numerical example here. Let $p = 0.1$, $\bar{\theta} = 1$, $\underline{\theta} = 0.1$, and $t = 3$. Assume that the cost function for effort is quadratic $C(e) = 0.5e^2$ and the investment cost k follows uniform distribution between 0 and 4. Under the contracts in Proposition 2, the optimal effort for the low- θ worker is $\underline{e}_1^s = 2.9667$ and $\underline{e}_0^s = 0.9$. At the optimal cutoff point of $\kappa^s = 1.98$, the principal's expected payoff is $\Pi^s = 1.4351$ and the agents' joint expected rent is 0.5523. Under the contracts in Proposition 4, the optimal effort levels for the low- θ worker are $\underline{e}_1^c = 2.9882$ and $\underline{e}_0^c = 0.838$. At $\lambda = 0.017$, the cutoff point is $\kappa^c = 1.96$. The principal's expected payoff is $\Pi^c = 1.4533 > \Pi^s$, and the agents' joint expected rent is 0.765, higher than their expected rent of 0.5523 from Proposition 2.

One caveat here is that I implicitly assume, as is standard in the literature, that the principal cannot enter an *ex ante* side contract with the agents before the agents observe their private information. Intuitively, this can be because such side contracts are informal by nature and hence are unlikely to be compatible with the innate distrust between the agents and the principal regarding each other's credibility of honoring implicit contracts. Although interesting, endogenizing the enforceability of side contracts lies outside the scope of this study. For the budgeting issues addressed here, it is an empirical question whether such side contracts are more likely to be honored at the division level or between headquarters and divisions.

5. Conclusion

This article demonstrates the value of cooperation for communication between divisions when the contracts are sequential and when strategic complementarities exist in the production technology. I take the perspective that information is decentralized and that budgeting systems facilitate decision making by providing communication channels, both between headquarters and divisions and among divisions. In my model, effective communication of information in the budgeting process affects the efficiency of a firm's internal resource allocation. In particular, the principal's investment decision depends on information known by the agents (the manager and the worker) about investment costs and effort.

I focus on whether and under what circumstances firms should establish policies that encourage cooperation. I find that although production and investment efficiencies can be improved if the agents observe each other's private information, the agents have no incentive to voluntarily share this information when they cannot observe each other's private information, if collusion is not permitted. However, if collusion is allowed, such information sharing may occur. Because information sharing makes the principal better off (by allowing him or her to condition the investment decision on more information) and does not make the agents as a group worse off, all parties may be better off with cooperation than without it.

Several issues remain for future research. For example, the mechanism the agents use to enforce their side contracts is not modeled. It would be interesting to examine whether different information structures affect the efficiency of these side contracts, and what performance measures can be designed to facilitate or discourage such side contracts.

APPENDIX

*Proof of Proposition 1.*¹⁰ When the principal observes θ , he or she can always implement the first-best effort level (e_1^*) for any given investment level. Under the revelation principle, the principal's problem is equivalent to selecting an investment strategy based on the manager's reported cost to maximize expected total payoff. Let $\hat{k}$ be the manager's reported cost, $\mu(\hat{k})$ be the probability of investment given $\hat{k}$, and $\kappa(\hat{k})$ be the payment to the manager who reports $\hat{k}$. The principal's problem is to maximize

$$\max_{\mu(k)} \int_0^K \{ \mu(k) [te_1^* - c(e_1^*)] + (1 - \mu(k)) [te_0^* - c(e_0^*)] - \kappa(k) \} f(k) dk, \quad (A1)$$

subject to the manager's individual rationality (*IR*) constraint

$$\kappa(k) - \mu(k)k \geq 0, \forall k, \quad (A2)$$

and incentive compatibility (*IC*) constraint

$$\kappa(k_1) - \mu(k_1)k_1 \geq \kappa(k_2) - \mu(k_2)k_1, \forall k_1, k_2. \quad (A3)$$

Define $V(k) \equiv \kappa(k) - \mu(k)k$. Then, (A3) can be written as

$$V(k_1) \geq V(k_2) - \mu(k_2)[k_1 - k_2], \forall k_1, k_2,$$

which can be further reduced to (see Myerson and Satterthwaite [1983])

$$V'(k) = -\mu(k) \quad \text{and} \quad \mu'(k) < 0.$$

Therefore, I have

$$V(k) = V(K) + \int_k^K \mu(t) dt \Leftrightarrow \kappa(k) = V(K) + \mu(k)k + \int_k^K \mu(t) dt. \quad (A4)$$

¹⁰ I thank the referee for suggesting the following proof.

Taking expectation on both sides of the preceding equation yields

$$\int_0^K \kappa(k) f(k) dk = V(K) + \int_0^K \mu(k) k f(k) dk + \int_0^K \int_k^K \mu(k) dt f(k) dk.$$

Integration by parts yields

$$\begin{aligned} \int_0^K \int_k^K \mu(k) dt dF(k) &= F(k) \int_0^K \mu(k) dt \Big|_0^K - \int_0^K F(k) d \left(\int_k^K \mu(t) dt \right) \\ &= \int_0^K F(k) \mu(k) dk. \end{aligned}$$

Substitution and rearranging the terms gives:

$$\int_0^K \kappa(k) f(k) dk = V(K) + \int_0^K \mu(k) \left[k + \frac{F(k)}{f(k)} \right] f(k) dk,$$

which can be substituted into the principal's objective function (A1) and simplified as

$$\begin{aligned} \max_{\mu(k)} \int_0^K &\left\{ \mu(k) [te^*(1) - c(e^*(1))] + (1 - \mu(k)) [e^*(0) - c(e^*(0))] \right. \\ &\left. - \mu(k) \left[k + \frac{F(k)}{f(k)} \right] \right\} f(k) dk. \end{aligned}$$

The $\mu(k)$ that maximizes the integrand is the maximizer for the objective function. Define κ^θ by

$$[te_1^* - c(e_1^*)] - [e_0^* - c(e_0^*)] = \Delta R^{fb} = \kappa^\theta + \frac{F(\kappa^\theta)}{f(\kappa^\theta)}.$$

Then, the first-order condition for the principal's optimization yields:

$$\mu(k) = 1 \quad \text{if } k \leq \kappa^\theta, \quad \text{and} \quad \mu(k) = 0 \quad \text{if } k > \kappa^\theta.$$

Furthermore, (A4) implies that the payment for the manager is such that

$$\kappa(k) = k + \int_k^{\kappa^\theta} dt = \kappa^\theta \quad \text{if } k \leq \kappa^\theta, \quad \text{and} \quad \kappa(k) = 0 \quad \text{if } k > \kappa^\theta.$$

Substituting optimal κ^θ back into the objective function, one can show that the principal's expected profit is

$$\Pi^\theta = R^{fb}(0) + \frac{F^2(\kappa^\theta)}{f(\kappa^\theta)} > R^{fb}(0). \quad \text{Q.E.D.}$$

Proof of Proposition 2. Let $W(\theta', \theta)$ and $e(\theta', \theta)$ be the θ worker's payment and effort level if he or she reports θ' . For any given investment level I , the principal chooses the optimal effort and wage levels for the worker to

maximize the expected revenue subject to the *IR* constraint

$$W(\theta, \theta) - C(e(\theta, \theta)) \geq 0, \forall \theta,$$

and incentive compatible (*IC*) constraint

$$W(\theta, \theta) - C(e(\theta, \theta)) \geq W(\theta', \theta) - C(e(\theta', \theta)), \forall \theta.$$

These constraints can be further written as

$$\bar{W} - C(\bar{e}) \geq 0, \underline{W} - C(\underline{e}) \geq 0, \quad (\text{A5})$$

$$\bar{W} - C(\bar{e}) \geq \underline{W} - C\left(\underline{e} - \frac{\Delta\theta}{t(I)}\right), \underline{W} - C(\underline{e}) \geq \bar{W} - C\left(\bar{e} + \frac{\Delta\theta}{t(I)}\right). \quad (\text{A6})$$

And the principal's problem is to choose $(\bar{e}, \bar{W})$, $(\underline{e}, \underline{W})$ to maximize

$$\max_{(\bar{e}, \bar{W}), (\underline{e}, \underline{W})} R^I = p(\bar{\theta} + t(I)\bar{e} - \bar{W}) + (1-p)(\underline{\theta} + t(I)\underline{e} - \underline{W}),$$

subject to (A5) and (A6). The solution follows the standard steps (see Laffont and Tirole [1993]). First, $C'' > 0$ implies that $\underline{W} - C(\underline{e} - \frac{\Delta\theta}{t(I)}) > \underline{W} - C(\underline{e})$, which, together with *IR* for low- θ worker and *IC* for high- θ worker implies that *IR* for high θ is not binding. Second, summing the two *IC* constraints, one obtains

$$C\left(\bar{e} + \frac{\Delta\theta}{t(I)}\right) - C(\bar{e}) > C(\underline{e}) - C\left(\underline{e} - \frac{\Delta\theta}{t(I)}\right),$$

which implies $\bar{e} > \underline{e}$. Third, *IC* for high θ must be binding. Suppose not, then the principal can benefit by reducing $\bar{W}$ slightly without disturbing the other constraints. This is feasible because *IR* for high θ is not binding, as shown earlier, and reducing $\bar{W}$ actually eases the *IC* for low θ . Last, when *IC* for high θ is binding and $\bar{e} > \underline{e}$, it is straightforward to show that *IC* for low θ is not binding. Substituting the binding constraints into the objective function and using the Kuhn-Tucker theorem, one can derive the optimal effort levels as:

$$C'(\bar{e}_I) = t(I), \bar{W}_I = C(\bar{e}_I) + \Phi_I(\underline{e}),$$

$$C'(\underline{e}_I) = t(I) - \frac{p}{1-p}\Phi'_I(\underline{e}), \underline{W}_I = C(\underline{e}_I),$$

$$\Phi_I(\underline{e}) = C(\underline{e}_I) - C\left(\underline{e}_I - \frac{\Delta\theta}{t(I)}\right) > 0.$$

The corresponding output levels are given by $\bar{Y}^I = \bar{\theta} + t(I)\bar{e}_I$ and $\underline{Y}^I = \underline{\theta} + t(I)\underline{e}_I$ for the high- and low- θ worker, respectively.

Let $R^s(I)$ denote the principal's revenue under the optimal contracts with the worker when θ is unobservable (s stands for sequential). Define $\Delta R^s = R^s(1) - R^s(0)$. Then, the optimal cutoff point solves the program

similar to that in Proposition 1 and can be simplified as:

$$\begin{aligned}\max_{\kappa} \Pi^s &= F(\kappa)(R^s(1) - \kappa) + (1 - F(\kappa))R^s(0) \\ &= R^s(0) + F(\kappa)(\Delta R^s - \kappa).\end{aligned}$$

Again, setting the first-order condition to zero yields the optimal cutoff point:

$$\kappa^s = \Delta R^s - \frac{F(\kappa^s)}{f(\kappa^s)}.$$

Substituting this expression into the principal's objective function shows that the maximum expected profit for the principal is:

$$\Pi^s(\kappa) = R^s(0) + \frac{F^2(\kappa^s)}{f(\kappa^s)}.$$

The convexity of the effort cost function implies that $\Delta R^s < \Delta R^{fb}$. Together with the assumption that $\frac{F(k)}{f(k)}$ is increasing in k , it follows that $\kappa^s < \kappa^\theta$.

Q.E.D.

Proof of Proposition 3. When investment is conditional on both k and θ , the principal's problem is to maximize (A1) subject to both agents' IR and IC constraints by choosing two investment rules: one $\mu(k)$ for each report of θ . For a report k , let $\bar{\mu}(k)$ (resp. $\underline{\mu}(k)$) be the probability of investment when receiving a report of $\bar{\theta}$ (resp. $\underline{\theta}$). Substituting in the constraints, the principal maximizes

$$\begin{aligned}\max_{\bar{\mu}(k), \underline{\mu}(k), \bar{e}_1, \underline{e}_1} p \int_0^K &\left\{ \bar{\mu}(k)[t\bar{e}_1 - c(\bar{e}_1) - \Phi_1(\underline{e}_1)] + (1 - \bar{\mu}(k)) \cdot \right. \\ &\left. [\bar{e}_0 - c(\bar{e}_0) - \Phi_0(\underline{e}_0)] - \bar{\mu}(k) \left[k + \frac{F(k)}{f(k)} \right] \right\} f(k) dk \\ + (1 - p) \int_0^K &\left\{ \underline{\mu}(k)[t\underline{e}_1 - c(\underline{e}_1)] + (1 - \underline{\mu}(k)) \cdot \right. \\ &\left. [\underline{e}_0 - c(\underline{e}_0)] - \underline{\mu}(k) \left[k + \frac{F(k)}{f(k)} \right] \right\} f(k) dk. \quad (A7)\end{aligned}$$

It is easy to show that $\bar{e}_1$ and $\bar{e}_0$ are given by $C'(\bar{e}_1) = t$, $C'(\bar{e}_0) = 1$.

The first-order condition with respect to $\underline{e}_1$ is given by

$$\begin{aligned}0 &= (1 - p) \int_0^K \underline{\mu}(k)[t - C'(\underline{e}_1)] f(k) dk - p \int_0^K \bar{\mu}(k) \Phi_1(\underline{e}_1) f(k) dk \\ &\Rightarrow (1 - p)[t - C'(\underline{e}_1)]F(\underline{\kappa}) - p\Phi_1(\underline{e}_1)F(\bar{\kappa}) = 0.\end{aligned}$$

Thus,

$$C'(\underline{e}_1) = t - \frac{pF(\bar{\kappa}^*)}{(1 - p)(1 - F(\underline{\kappa}^*))} \Phi_1(\underline{e}_1), \quad (A8)$$

and

$$C'(\underline{e}_0) = 1 - \frac{p(1 - F(\bar{\kappa}^*))}{(1 - p)(1 - F(\underline{\kappa}^*))} \Phi_0(\underline{e}_0), \quad (A9)$$

where $\bar{\kappa}^*$ and $\underline{\kappa}^*$ are the optimal cutoff point when θ is high and low. Similar to Proposition 1, one can show that the principal's optimal investment rule is

$$\begin{aligned}\bar{\mu}(k) &= 1 \quad \text{if } k \leq \bar{\kappa}^*, \quad \text{and} \quad \bar{\mu}(k) = 0 \quad \text{if } k > \bar{\kappa}^*, \\ \underline{\mu}(k) &= 1 \quad \text{if } k \leq \underline{\kappa}^*, \quad \text{and} \quad \underline{\mu}(k) = 0 \quad \text{if } k > \underline{\kappa}^*,\end{aligned}$$

where $\bar{\kappa}^*$ (resp. $\underline{\kappa}^*$) is the payment to the manager if investment takes place and if the worker reports $\bar{\theta}$ (resp. $\underline{\theta}$), given by

$$[t\bar{e}_1 - c(\bar{e}_1) - \Phi_1(\underline{e}_1)] - [\bar{e}_0 - c(\bar{e}_0) - \Phi_0(\underline{e}_0)] = \bar{\kappa}^* + \frac{F(\bar{\kappa}^*)}{f(\bar{\kappa}^*)}, \quad (\text{A10})$$

and

$$[t\underline{e}_1 - c(\underline{e}_1)] - [\underline{e}_0 - c(\underline{e}_0)] = \underline{\kappa}^* + \frac{F(\underline{\kappa}^*)}{f(\underline{\kappa}^*)}. \quad (\text{A11})$$

In general, the left-hand sides of the preceding equations are not equal, nor is one always larger (or smaller) than the other; thus, $\bar{\kappa}^* \neq \underline{\kappa}^*$. Because κ^* is constrained to be the same for both θ s in sequential contracting, the principal cannot do any better than his or her expected payoff under (A7). As before, for an investment I , the payment to the high- θ worker is $C(\bar{e}_I^{fb}) + \Phi_I(\underline{e}_I)$, where $\Phi_I(\underline{e}_I)$ is given in (4) and $\underline{e}_I$ is given in (A8) and (A9). The low- θ worker is paid his or her cost of effort $C(\underline{e}_I)$.

Proof of Proposition 4. Under the collusion-proof principle, I can restrict my attention to mechanisms that induce no side payments between the agents in equilibrium. That is, in addition to each agent's *IR* and *IC* constraints, the principal must satisfy a collusion incentive compatible (*CIC*) constraint:

$$\begin{aligned}\kappa(\theta, k) - \mu(k) \cdot k - [\kappa(\theta', k) - \mu(k) \cdot k] \\ \geq W(\theta', \theta) - C(e(\theta', \theta)) - (W(\theta, \theta) - C(\theta, \theta)),\end{aligned} \quad (\text{A12})$$

where $\kappa(\theta, k)$ is the payoff to the manager who reports θ and k , and $W(\theta', \theta)$ and $e(\theta', \theta)$ are the payments and effort choices for the θ worker with a report of θ' . The right-hand side of (A12) is the potential gain (if there is any) for the worker if the manager lies for him or her, and the left-hand side of the constraint is the gain to the manager if he or she tells the truth.

The principal's problem can be simplified by noticing the following points. First, because in equilibrium the manager will tell the truth about θ , there is no point leaving the worker any information rent. That is, the worker's *IR* constraints are binding. Second, the *CIC* constraints are not binding for the low- θ worker as the low- θ worker never has an incentive to lie. The principal can adopt the following strategy: pay the manager κ^c to invest iff the manager reports a cost no greater than κ^c , and pay the manager an extra of Φ_1 iff he or she reports a high θ . If the manager reports $k > \kappa^c$, then do not invest and pay the manager Φ_0 iff he or she reports a high θ . For any given investment decision, pay the worker $C(e_I)$ for effort e_I . That

is, the principal chooses κ^c , Φ_1 , $\bar{e}_I$, and $\underline{e}_I$ with $I \in \{0, 1\}$ to

$$\begin{aligned} \max \Pi^c = & pF(\kappa^c + \Phi_1 - \Phi_0)[\bar{\theta} + t\bar{e}_1 - C(\bar{e}_1) - \kappa^c - \Phi_1] \\ & + (1-p)F(\kappa^c)[\underline{\theta} + t\underline{e}_1 - C(\underline{e}_1) - \kappa^c] \\ & + p(1-F(\kappa^c + \Phi_1 - \Phi_0))[\bar{\theta} + t\bar{e}_0 - C(\bar{e}_0) - \Phi_0] \\ & + (1-p)(1-F(\kappa^c))[\underline{\theta} + \underline{e}_0 - C(\underline{e}_0)], \end{aligned} \quad (\text{A13})$$

subject to

$$\Phi_I \geq C\left(\underline{e}_I - \frac{\Delta\theta}{t(I)}\right), \quad \text{with } I \in \{0, 1\}. \quad (\text{A14})$$

The first term is weighed by $F(\kappa^c + \Phi_1 - \Phi_0)$ because the manager will report $\hat{k} \leq \kappa^c$ iff $k \leq \kappa^c + \Phi_1 - \Phi_0$. Constraints (A14) are the *CIC* constraints. Let λ and ν be the Lagrangian multipliers for (A14) when $I=1$ and 0 , respectively. For notational ease, denote $\Delta\Phi^c \equiv \Phi_1 - \Phi_0$, $F^\Delta \equiv F(\kappa^c + \Delta\Phi^c)$, $F \equiv F(\kappa^c)$, $f^\Delta \equiv f(\kappa^c + \Delta\Phi^c)$, and $f \equiv f(\kappa^c)$. Then, the first-order conditions with respect to the worker's efforts are given as:

$$\begin{aligned} \frac{\partial L}{\partial \bar{e}_1} &= pF^\Delta(t - C'(\bar{e}_1)), \quad \frac{\partial L}{\partial \bar{e}_0} = p(1 - F^\Delta)(1 - C'(\bar{e}_0)), \\ \frac{\partial L}{\partial \underline{e}_1} &= pF(\kappa^c)(t - C'(\underline{e}_1)) - \lambda\Phi'_1(\underline{e}_1), \\ \frac{\partial L}{\partial \underline{e}_0} &= (1-p)(1 - F(\kappa^c))(1 - C'(\underline{e}_0)) - \nu\Phi'_0(\underline{e}_0). \end{aligned}$$

Setting them to zero yields

$$t(I) = C'(\bar{e}_I^c),$$

$$t(1) = C'(\underline{e}_1^c) + \frac{\lambda}{pF(\kappa^c)} \frac{p}{1-p} \Phi'_1(\underline{e}_1^c), \quad (\text{A15})$$

and

$$t(0) = C'(\underline{e}_0^c) + \frac{\nu}{p(1-F(\kappa^c))} \frac{p}{1-p} \Phi'_0(\underline{e}_0^c). \quad (\text{A16})$$

The first-order conditions with respect to Φ_1 and Φ_0 are given by

$$\begin{aligned} \frac{\partial L}{\partial \Phi_1} &= p\{f^\Delta(K - \kappa^c - \Delta\Phi) - F^\Delta\} + \lambda, \\ \frac{\partial L}{\partial \Phi_0} &= -p\{f^\Delta(K - \kappa^c - \Delta\Phi) - F^\Delta\} - p - \nu. \end{aligned}$$

Setting the preceding to zero gives $\nu = p - \lambda$. Comparing (A15) and (A16) with (A8) and (A9), we can see that setting $\lambda = pF(\bar{\kappa}^*)$ and $\kappa^c = \underline{\kappa}^*$ (with $\bar{\kappa}^*$ and $\underline{\kappa}^*$ given in (A10) and (A11)) will yield the same effort level for the low- θ worker as in Proposition 3, which is the best the principal can do without observing the agents' private information. Because $\bar{e}_I^c$ is

set at the first-best level, it follows that κ^* is the optimal cutoff point. Thus, the principal's expected total profits must be the same as those in Proposition 3. Q.E.D.

Proof of Corollary 2. When the agents cannot collude and cannot share information, for a given cutoff point κ^* , their joint expected rent, denoted as JR^s , is given by

$$\begin{aligned} JR^s &= F(\kappa^s)[\kappa^s - E(k | k \leq \kappa^s)] + p[F(\kappa^s)\Phi_1 + (1 - F(\kappa^s))\Phi_0] \\ &= \int_0^{\kappa^s} F(x) dx + p[F(\kappa^s)\Delta\Phi + \Phi_0]. \end{aligned}$$

When the agents can collude, their joint expected rent is given by

$$\begin{aligned} JR^c &= pF(\kappa^* + \Delta\Phi)[\kappa^* + \Delta\Phi - E(k | k \leq \kappa^* + \Delta\Phi)] \\ &\quad + (1 - p)F(\kappa^*)[\kappa^* - E(k | k \leq \kappa^*)] + p[1 - F(\kappa^* + \Delta\Phi)]\Phi_0 \\ &= p \int_0^{\kappa^* + \Delta\Phi} F(x + \Delta\Phi) dx + (1 - p) \int_0^{\kappa^*} F(x) dx + p\Phi_0 \\ &= \int_0^{\kappa^*} F(x) dx + p \left[\int_0^{\kappa^* + \Delta\Phi} F(x + \Delta\Phi) dx - \int_0^{\kappa^*} F(x) dx + \Phi_0 \right]. \end{aligned}$$

Because the principal can always implement the contracts from Proposition 2 even when the agents can make side payments, on the margin, we can compare JR^s with JR^c at the same cutoff point κ^s . Using Taylor expansion, we have

$$\begin{aligned} JR^c(\kappa^s) - JR^s &= p \left[\int_0^{\kappa^s + \Delta\Phi} F(x + \Delta\Phi) dx - \int_0^{\kappa^s} F(x) dx - F(\kappa^s)\Delta\Phi \right] \\ &> p\Delta\Phi[F(\kappa^s + \Delta\Phi) - F(\kappa^s)] > 0. \end{aligned}$$

Q.E.D.

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