MULTITASKING AND THE OPTIMALITY OF TEAM ACCOUNTABILITY UNDER IMPLICIT CONTRACTS*

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ABSTRACT. We characterize the optimal job design in a multitasking environment when the firm relies on implicit incentive contracts (i.e., bonus payments). Two natural forms of job design are compared: (i) individual accountability, where each agent is assigned to a particular job and assumes full responsibility for its outcome; and (ii) team accountability, where a group of agents share responsibility for a job and are jointly accountable for its outcome. The key trade-off is that team accountability mitigates multitasking problem but may weaken the implicit contracts. Optimal job design follows a cut-off rule: firms with sufficiently high reputation concerns opt for team accountability. Team accountability is more likely the more acute is the multitasking problem. However, the cut-off rule need not hold if the firm combines implicit incentives with explicit pay-per-performance contracts.

1. INTRODUCTION

Firms frequently give work assignments to a group of employees (or "teams") and hold them jointly accountable for the outcome of the assignment. In fact, firms often adopt such a strategy even when it is technologically feasible to assign each worker to a particular task, and hold him solely accountable for his own performance (Bartol and Hagmann, 1992; Shaw and Schneier, 1995). Such a practice may seem counterintuitive because team performance can obscure individual contributions and blunt incentives. While there is a vast literature in agency theory that studies the optimal incentive provisions in teams, Corts (2007) is perhaps the first to explore how, in a multitasking environment, team accountability may arise *endogenously* when individual accountability is still a technologically feasible option. Corts argues that team accountability may optimally balance the trade-off between mitigating the multitasking problem and exposing the workers to a higher performance volatility.

This article contributes to the recent literature on endogenous job design by drawing out the implications for team accountability in the presence of implicit contracts—an informal promise of the firm to reward its worker(s) that is sustained through the threat of future retaliation of the worker(s) should the firm renege on its promise.[1] Indeed, it is not hard to find real life examples where the firms offer implicit incentives in an environment where both multitasking and job design also play a crucial role. Consider the mutual fund industry. Managing a mutual fund may require a fund manager to exert effort to find new investment opportunities as well as to gather information about the risks associated with such investments. Even though both risks and returns significantly affect the overall profitability of

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[1]Such contracts are also referred to as "relational" contracts (Levin, 2003; Rayo, 2007) and "self-enforcing implicit" contracts (Bull, 1987).

the firm, a fund manager may be tempted to undertake high return investments without paying sufficient attention to the underlying risks.[2] Traditionally each fund was individually managed by an assigned manager. However, there is a recent trend to move towards "co-managed" and/or "team managed" funds where a group of employees are jointly responsible for the performance of a set of funds (see, e.g., Prather and Middleton, 2000; Chen, et al., 2004; and Massa, 2008).[3] Implicit contracts, in the form of bonus payments, are ubiquitous in this industry.

As is the case with the mutual fund industry, there are two natural job designs: (i) individual accountability, where each agent is assigned to a particular job. He performs all of the tasks associated with the job, and is solely responsible for the outcome of job he has been assigned to. (ii) Team accountability, where a group of agents share the responsibility for a job. Each agent performs a subset of tasks associated with the job and all agents are jointly accountable for the job outcome.

We argue that while team accountability may mitigate the multitasking problem, it may make implicit contracts more difficult to sustain. The key trade-off associated with the team accountability is as follow: The primary benefit of the team accountability is that it enriches the set of performance signals available to the firm and helps mitigating the multitasking problem. Because multiple agents contribute to different tasks associated with a job, different agents can be paid differently based on the job outcome. That is, even though all agents are compensated based on the outcome of the job in which they have contributed to, the firm can vary the power of the bonus incentives offered to each of the team members in order to align an agent's incentive with the task he has been assigned to. Such manipulation of incentives (and hence, effort) across tasks alleviates the multitasking problem. In contrast, under individual accountability, the firm must induce an agent to work on *all* tasks associated with a job by offering a single bonus payment that is based on the outcome of the job in which the agent has been assigned to. This leaves no room for any manipulation of incentives (and effort) across multiple tasks associated with the job. Consequently, the multitasking problem prevails.

Team accountability, however, also inflicts a cost on the firm: It weakens the firm's ability to sustain implicit incentives. Under team accountability, the firm must commit to each of the team members a separate bonus payment for *each* of the tasks the agent has been assigned to. So, the firm must credibly commit to a larger bonus pool (i.e., the sum of all bonus amounts promised to *each* team members for *each* task he has been assigned to) to elicit effort in all tasks. But unless the firm has significantly high reputation concerns, it may not be able to make such a credible commitment. In contrast, under individual accountability, the firm only needs to credibly promise a bonus payment to the agent responsible for each job, and it motivates the agent to exert effort in *all* tasks associated with that job. Thus, even by committing to a small bonus pool, the firm can ensure that the agent will exert some effort in all tasks, and the total effort provision, aggregated across all tasks, might be sizeable. In other words, under individual accountability, the firm can offer stronger implicit incentives even when it has limited reputation concerns.[4]

[2]This might be particularly the case where the manager is primarily interested in increasing the fund's returns in the short run. The most visible signal of the manager's performance is perhaps the fund's returns over the last few quarters rather than the composition of the fund and the underlying risks it bears.

[3]In some case, however, the difference between the two may not be one of job design but merely an issue of whether the firm is willing to share the credit (and blame) of the fund's performance with its employees. See Massa, et al. (2008) for more discussion on this topic.

[4]This effect is in sharp contrast with the credibility of promise discussed in the models of multilateral implicit contracts (Bernheim and Whinston, 1990; Levin, 2003). In these models implicit contracts are easier to sustain when promises are multilateral rather than bilateral. We will further elaborate on this issue in Section 3.

The aforementioned benefit of team accountability has been discussed by several authors (Dewatriport, et al., 2000; Corts, 2007). The novel part of our analysis is to highlight the cost of team accountability in terms of weaker implicit incentives, and to draw out the implications of the trade-off between mitigating multitasking problem and weaker implicit incentives on the firm's job design decisions.[5]

We consider a stylized model where an infinitely lived firm hires two infinitely lived agents. Each agent, in each period, exerts effort to perform two jobs (say, managing two funds). Both jobs involve two tasks each (i.e., there are four tasks in total). The effort exerted in each of the four tasks cannot be observed by the firm, which gives rise to a moral hazard problem. However, each of the two jobs yields an observable performance measure. The firm can offer incentives by tying an agent's compensation to the observed performance in the job(s) he has been assigned to. We further assume that the outcome of both the jobs are non-verifiable. Thus, the firm can only offer an implicit contract (i.e., bonus payment) to provide incentives for the two jobs.

The effort exerted in all four tasks has the same marginal benefit to the firm. But the effort spent on each of the two tasks related to any particular job affects the observed job performance differently. This gives rise to a multitasking problem. If the firm offers an incentive tied to the observed job performance, the agent will exert more effort on the task that has the higher marginal impact on the observed job performance and neglect the other task. At the beginning of the game, the firm chooses between two alternative job designs: individual accountability and team accountability.

In the basic model we assume away any substitutability or complementarity across efforts in different tasks. This specification rules out any externalities originating form the interdependency of efforts, which may potentially impact the trade-off between mitigating multitasking problem and weaker implicit incentives. In such a setting, we characterize the optimal job design as a function of the firm's discount factor that parameterizes its reputation concerns.

We show that the optimal job design follows a cut-off rule—team accountability is strictly optimal only if the firm's discount factor is sufficiently high. The intuition behind this result is simple. Recall that while team accountability allows the firm to overcome the multitasking problem, it requires the firm to credibly commit to a larger bonus pool in order to elicit efforts in all tasks. If the firm's discount factor (δ) is sufficiently high, the threat of future punishment is significantly large for the firm, which, in turn, allows the firm to credibly promise to a high level of bonus payments. Consequently, team accountability becomes optimal. However, for low δ, the firm may not have credibility to offer large bonus payments. In such a setting, the firm might be better off by resorting to individual accountability. Under individual accountability, even a small bonus payment may give sharper incentives because it elicits effort in all tasks associated with a particular job. The sharper incentives may outweigh the inefficiencies originating from the multitasking problem.

Given this basic intuition on how job design may interact with the implicit incentive provisions, we consider a more general setting where the workers' performances in a subset of jobs are indeed verifiable. In such an environment the firm may opt to provide incentives to its workers though a combination of explicit and implicit incentives. It may offer explicit pay-per-performance contracts to agents assigned to the jobs where contractible performance measures are available, and promise implicit contracts to others.

[5]We do not claim that the aforementioned trade-off is the only trade off the firms face while choosing the optimal job design. There can be several other benefits of team accountability (e.g., facilitating mutual cooperation) as well as other costs (e.g., exposure to larger performance volatility). However, we abstract away from these other costs and benefits to stay focused on the trade-off between multitasking and implicit incentives.

To fix ideas, consider the case of the commercial insurance industry. The insurers rely on the agents (brokers) to perform two key jobs: (i) search for (commercial) clients who is willing to buy insurance coverage (i.e., search job), and (ii) elicit information about the clients' risk and coverage requirement to ensure that the insurer's offered coverage matches the clients' needs (i.e., match job).[6] The performance of an agent on the search job has a contractible measure—the amount of business he brings to the insurer—and compensated through an explicitly contracted commission rate. The performance in the match job is, however, relatively hard to verify. Often, the agents are compensated for the match job through an implicitly promised bonus payment, or "contingency fee."[7] Both search and match jobs may involve multitasking problems. Effective search may require active solicitation of new business from existing clients as well as advertising the insurer's products to a broader cliental. Similarly, effective matching may require that the agent not only to advice the client on the appropriate coverage, but also to elicit accurate information about the risks borne by the clients.[8]

The scenario described above can be readily accommodated in our basic model. We can simply reinterpret the two jobs as the "search" and the "match" job, where the agent(s) assigned to the search job is compensated by an explicit pay-per-performance contract and the agent(s) assigned to the match job continue(s) to receive bonus incentives. However, a new effect originates in the presence of the explicit contract: team accountability makes implicit incentives more fragile by enhancing the firm's punishment payoff. Following a breakdown of the implicit contract, the firm may only rely on the explicit contract for motivating agent on the punishment path. That is, the firm's punishment payoff is simply the profit it earns from the search job (which is compensated by an explicit contract). The profits from the search job is higher under team accountability as it mitigates the multitasking problem. Thus, the firm's punishment payoff of the firm is also higher under team accountability. In other words, the punishment threats are weaker under team accountability, which, in turn, increases the firm's temptation to cheat on its bonus promises.

This new effect invalidates the cut-off rule discussed above. Instead, we find that the optimal job design must be one of the following: (i) Only the firms with very high or very low δ opt for team accountability. (ii) Team accountability is optimal for all δ. The former is the case when the extent of the multitasking problem is low, while the latter is the case when the multitasking problem is severe.

The intuition behind this result is similar to the case of the cut-off result discussed above, particularly when δ is not too small. For high δ the firm can offer strong bonus incentives even under team accountability. Thus, team becomes optimal because it alleviates the multitasking problem. For moderate δ, the feasible bonus payments are low, and bonus incentives elicit more effort under individual accountability, which may outweigh the inefficiencies of multitasking. But what drives the optimality of teams for low δ? For δ sufficiently small, the firm has little reputation concerns, and hence, the implicit incentives are infeasible under

[6]Commercial insurance coverage can often be a complex product, and it may be difficult for the client to assess his exact needs and the best suitable coverage. An important role of the agents is offer 'risk analysis,' i.e., to infer the type and degree of risk borne by the client, and advice her on the appropriate coverage.

[7]The success in the match job is can be measured by observing how a particular client's account has performed in a given time period. One may expect that if the agents were successful in eliciting the information on the level of risk borne by the client, the insurer would tailor its offered coverage appropriately, and would set the premium rate accordingly, so that the account is a profitable one. Even though this measure is observable, it is often not verifiable. Insurance claims may take several years to settle. The insurer can manipulate reported performance of the account in a given financial year by using discretion on when and how to enter the claim record in its books.

[8]"Misselling" of products is indeed a major concern in the insurance, and, in general, in the financial sector (see Indrest and Ottavianni, 2008).

both types of job designs. The firm's profit under team accountability is higher because the explicit incentive can elicit more search effort under team setting by mitigating the multitasking problem. However, if the multitasking problem is sufficiently large, then even for a moderate δ, the stronger implicit incentives under individual accountability need not be enough to compensate the associated multitasking problem. In this case, team accountability remains optimal for all values of δ.

The main results of the article also yield interesting comparative statics predictions by interlinking the key parameters to the firm's job design decision. For example, the cut-off result discussed above indicates that when only implicit incentives are available, team accountability becomes more likely when the firm's reputation concerns increases. As we will elaborate later, this result also implies that team accountability is more likely to be the optimal job design when the extent of the multitasking problem is severe. This finding, however, is quite intuitive because the key benefit of team accountability that we highlight in this model is that of overcoming the multitasking problem. Thus, when the multitasking problem is severe, it favors team accountability over individual accountability.

Related literature: This article relates to two broad strands of literature in agency theory—incentives in team and implicit contracts—and highlights how team accountability may arise endogenously as the optimal job design in the presence of implicit contracts.

Both explicit and implicit contracts in teams are well studied in the literature (Holmström, 1982; Itoh, 1991; Che and Yoo, 2003; Rayo, 2007). However, this literature generally assumes that the team accountability arises exogenously and focuses solely on the incentive issues that may arise in teams. One important exception is Itoh (1991), who argues that teamwork may indeed orginate endogenously. But his argument relies on the need to foster collaborations among employees rather than on teams' effectiveness to overcome multitasking problem. Our article is perhaps more closely related to Corts (2007) who studies how team accountability may endogenously emerge as the optimal job design in a multitasking environment. Corts shows that in the presence of explicit contracts and risk-averse agents, team accountability might be the optimal job design when the extent of multitasking problem is high and/or the extent of risk aversion among the agents is low. Our article complements Corts' article by highlighting a different trade-off associate with the team accountability in the presence of implicit incentives. Drawing parallel to Corts, we find that team accountability emerges as an optimal job design when the extent of multitasking problem is large and/or the firm's concerns for future reputation (as represented by its discount factor) is high.

Another paper that is closely related to our research is Levin (2002). Levin discusses the costs and benefits of multilateral contracting over bilateral contracting in employment relationships. In a multilateral contracting, similar to team accountability, the firm makes commitments to a large group of employees whereas under bilateral contracting, similar to individual accountability, the firm makes commitments to individuals or small groups. There is no multitasking issue in Levin's model, and he highlights the trade-off that while multilateral contracting are difficult to adjust in response to exogenous shocks to the business environment, it facilitates implicit contracts. The latter effect is in sharp contrast with our article where team accountability hinders implicit incentive provisions. We will revisit this issue in Section 3.

Finally, our article is also related to two "sub-branches" of the agency theory literature: (i) multitasking (Holmström and Milgrom, 1991; Dewatripont, et al., 2000; Besanko, et al., 2005) and (ii) interaction between explicit and implicit incentives (Gibbons and Murphy, 1992; Baker, et al., 1994). In contrast with our article, the existing literature on multitasking primarily focuses on the explicit incentives. And the literature on the interaction between incentives primarily discusses the characteristics of the optimal contract (that emerges from

such interplay between incentives) and is silent about its potential implications on job design in a multitasking environment. On exception to this is Schottner (2008). She addresses the question of how to split a fixed number of tasks between two agents when both explicit and implicit contracts can be used. This question is distinctly different from the question of the optimality of team accountability that we highlight in this paper. Consequently, the trade-offs associated with team accountability that we discuss here are absent in Schottner's article.

The article is organized as follows. Section 2 discusses the basic model and section 3.3 characterizes the optimal job design. The role of explicit contracts is discussed in section 4 introduces explicit contracts. Finally, section 5 discusses the empirical implications and the robustness of our main results and concludes.

2. The Basic Model

Players. A long-run firm, F, hires two long-run agents, A and B, to manage two funds.[9]

Stage game

In what follows we will describe the stage game that is played between the firm and the agents in each period. The stage game is defined in terms of its four key ingredients: *technology*, *job design*, *contracts*, and the players' *payoffs*. We elaborate below on each of these four ingredients.[10]

Technology. The technology is modelled after the canonical task allocation model of Dewatripont et. al (2000). There are three central features to this class of models: (i) The firm only cares about the impact of the agents' effort to its bottom line (defined below as V); however, V is not observed by the agents, (ii) the agents' compensations are based on a set of performance measures (defined below as x) that are observable but are distinct from the firm's bottom line, and (iii) the marginal impact of the agents' efforts on V and x are different, giving rise to a multitasking problem (we will elaborate on this below).[11] The detailed description of the model is as follows.

Suppose F owns two funds, say 1 and 2, where in each period a fund performance can either be good or bad. Let $x_i \in \{0,1\}$ be the index for the fund's performance, where $x_i = 1$ if the fund's performance is good and $x_i = 0$ if it is bad $(i = 1, 2)$. We define managing a fund as a "job" (thus there are two jobs in total). Each job consists of two tasks: (i) finding investment opportunities that yield higher returns, and (ii) assessing the underlying risks associated with such an investment opportunity. We denote tasks 1 and 2 as the tasks required for job 1, and the tasks 3 and 4 are required for job 2. Task $j \in \{1,2,3,4\}$ requires an effort level of $e_j \in [0,1]$. Let the cost of effort in task j be $c(e_j) = e_j^2/2$. The tasks affect the value, V, that F receives from the two funds, where

$$V(\mathbf{e}) = \phi \times (e_1 + e_2 + e_3 + e_4),$$

[9]The reference to the mutual fund industry is only to maintain a parallel with the example discussed in the introduction. The model presented here does not purport to be a model of mutual fund but a general model of multitasking with implicit incentives.

[10]For the sake of clarity, while describing the stage game we will suppress the time suffix t associated with each variable.

[11]A similar model is also adopted in Corts (2007). Another important feature of this modeling approach is that it abstracts away from the issue of effort substitution to highlight how the availability of performance measure for individual tasks (or the lack thereof) shapes the optimal job design in a multitasking environment.

and $\phi > 0$. The value V is not observable to the agents. One may interpret V as the impact of the agent's effort in various tasks to the bottom line of the firm's profitability. This value accrues directly to the firm and may not be clearly observed through all rank-and-file of a hierarchical organization. Furthermore, efforts are also unobservable, but each of the two jobs has performance measures, x_1 and x_2, that are observable. The efforts in each of the two jobs determine their performance as follows:

$$\begin{aligned} \Pr(x_1 = 1 \mid \mathbf{e}) &= e_1 + \gamma e_2, \\ \Pr(x_2 = 1 \mid \mathbf{e}) &= e_3 + \gamma e_4, \end{aligned} \tag{1}$$

where $\gamma > 1$. While x_1 and x_2 are observable, none of them are verifiable.[12] The parameter γ measures the extent of multitasking problem. An agent who is compensated on the basis of x_1 (or x_2) has incentives to substitute away from e_1 (or e_3) and concentrate more on e_2 (or e_4), even though all tasks have the same marginal impact on the firm's value (V). We assume the following parametric restriction to ensure that the probabilities in equation (1) are well-defined (i.e., lies between 0 and 1) in any equilibrium of this game:

Assumption 1. $\phi < 1/(1+\gamma)$.

Assumption 1 requires ϕ to be small when γ is large and vice versa. This restriction also simplifies the firm's optimization problem by ruling out corner solutions.

An important issue to note about this technology specification is that it rules out all interactions across efforts in different tasks. The costs (c) and value (V) are additively separable in efforts ruling out any substitutability or complementarity across tasks. The assumption of additive separability streamlines the model and improves the exposition of the key trade-off between multitasking and implicit incentives. This trade-off itself is not driven by this assumption, and we will discuss the impact of relaxing this assumption later in Section 5.

JOB DESIGN. Each agent is responsible for exactly two tasks. The type of allocation of tasks between the two agents is referred to as the job design. The firm chooses between two alternative job designs: individual accountability and team accountability. The agents have individual accountability when one is assigned to the tasks 1 and 2, and the other is assigned to the tasks 3 and 4. Thus, under individual accountability, one agent is responsible for job 1 (i.e., sole responsibility of managing fund 1), while the other one is responsible for job 2 (i.e., fund 2). Without loss of generality, we assume that under individual accountability, A is responsible for job 1 (i.e., task 1 and 2), while B is responsible for job 2 (i.e., task 3 and 4). In contrast, a team is formed when one agent, say, agent A, is assigned to the tasks 1 and 4, while the other one (i.e., agent B) is assigned to tasks 2 and 3. This is to say that in a team, both agents have responsibility for both jobs.[13]

Assumption 2. *F decides on the job design at the beginning of the game, and it's decision irreversible.*

[12] We will relax this assumption later in Section 4.

[13] To form teams one can also consider grouping task {1 and 3} and {2 and 4}. This configuration yields the same surplus to the firm as the one discussed here. We assume the grouping {1 and 4} and {2 and 3} to maintain a parallel with the case of individual accountability where each agent is responsible for exactly one "γ-task" (i.e., task 2 or 4).

Once a particular design is chosen, it is prohibitively costly to change it in a future date. This assumption simplifies the analysis of the firm's punishment payoff, and allows us to draw out the implications of the key trade-off between multitasking problem and sustenance of implicit contract more succinctly.

Contracts. Because the performance in both jobs are non-verifiable, the firm can only offer an implicit contract promising (in each period) a bonus payment if the fund performance turns out to be good.[14] So, under individual accountability (where agent A is assigned to job 1, and B is assigned to job 2), a contract offered to agent A (in each period) is a tuple (W_A, β_A), where W_A is a lump sum wage and β_A an implicitly contracted bonus payment that is offered only if $x_1 = 1$. The contract offered to agent B is also of similar form. In contrast, in a team setting, a contract offered to agent $k \in \{A, B\}$ (in each period) is a tuple (W_k, β_{ki}), where W_k is a lump sum wage and β_{ki} is an implicitly contracted bonus payment that is offered only if $x_i = 1$.

Payoffs. The payoff of the firm is simply the overall value that the firm receives from the two funds net of its expected wage payments. The payoff of an agent is the expected wages he receives net of the cost of effort. The exact expressions for the payoffs will depend on the job design. Under individual accountability, the firm's payoff in each period is

$$\pi^I = V(\mathbf{e}) - W_A - \beta_A \Pr(x_1 = 1 \mid \mathbf{e}) - W_B - \beta_B \Pr(x_2 = 1 \mid \mathbf{e}),$$

where the payoffs of agent A and B are defined as

$$\begin{aligned} u_A^I &= W_A + \beta_A \Pr(x_1 = 1 \mid \mathbf{e}) - c(e_1) - c(e_2), \\ u_B^I &= W_B + \beta_B \Pr(x_2 = 1 \mid \mathbf{e}) - c(e_3) - c(e_4), \end{aligned}$$

respectively. In contrast, under team accountability, F's payoff is

$$\pi^T = V(\mathbf{e}) - \sum_{k \in \{A,B\}} \left[W_k + \beta_{k1} \Pr(x_1 = 1 \mid \mathbf{e}) + \beta_{k2} \Pr(x_2 = 1 \mid \mathbf{e}) \right],$$

the payoff of the agent A and B who are assigned to the tasks {1 and 4}, and {2 and 3} are

$$\begin{aligned} u_A^T &= W_A + \beta_{A1} \Pr(x_1 = 1 \mid \mathbf{e}) + \beta_{A2} \Pr(x_2 = 1 \mid \mathbf{e}) - c(e_1) - c(e_4), \\ u_B^T &= W_B + \beta_{B1} \Pr(x_1 = 1 \mid \mathbf{e}) + \beta_{B2} \Pr(x_2 = 1 \mid \mathbf{e}) - c(e_2) - c(e_3), \end{aligned}$$

respectively. The outside option of both agents is assumed to be 0.

Repeated game

The repeated game is simply the aforementioned stage game repeated in each period. Both the firm and the agents discounts the future payoff at a common per period rate of $\delta \in [0, 1)$.

Strategies and Equilibrium. We will focus on pure strategy equilibria due to their analytical tractability. The strategy of F has two components: (i) At the beginning of the game, F decides on the job design, (ii) in each period, depending on the history of the game, F offers a contract to each agent (the form of the contract depends on the choice of the job

[14] Note that we are implicitly assuming that the agents' compenstion can only depend on the x signals and cannot be conditioned on the overall value V. In fact, the multitasking problem arises because the firm *cannot* compensate the agents based on V.

design, as discussed above). The strategy of an agent is to choose whether to accept F's contract, and if he accepts, how much effort to exert (in each period) in the tasks he has been assigned to.

We will use *Subgame Perfect Nash Equilibrium in trigger strategies* as a solution concept. Under individual accountability, if the firm reneges on an agent, *only* the agent who has been cheated on reverts back to his static best response. Under team setting, *both* agents revert back to their static best responses if the firm reneges on its bonus promises to *any* of the team members.[15,16]

3. Optimal Job design

The optimal job design is derived by comparing the firm's payoff under individual and team accountability when the associated incentive contracts are optimally chosen. Therefore, a characterization of the optimal job design requires a characterization of the optimal contracts. But before we do so, we briefly discuss the first best solution to the firm's contracting problem.

The first best solution serves as a benchmark for comparing the efficacy of each of the two job designs. The first best solution is the one that maximizes the joint surplus between the firm and the agents. That is, the first best effort levels solve $\max_{\mathbf{e}} V(\mathbf{e}) - \sum c(e_j)$, or, equivalently, must satisfy the first-order conditions

$$\phi = e_j \quad \forall j. \tag{2}$$

Equation (2) suggests that at the first best effort in all four tasks should be the same and equal to ϕ, the marginal benefit of effort to the firm.

We now focus on the optimal contracting under individual and team accountability and compare the efficiency of such contracts with the first best outcome. The following lemma (a la Levin, 2003) simplifies the analysis by ensuring that without loss of generality, one can restrict attention to the class of stationary contracts; i.e., we can characterize the optimal contract in the repeated game as a tuple $(W_A, W_B, \beta_A, \beta_B)$ under individual accountability and $(W_A, W_B, \beta_{A1}, \beta_{B1}, \beta_{A2}, \beta_{B2})$ under team setting, where the optimal contract does not vary over time. (We omit the proof as it directly follows from the proof of Theorem 2 in Levin's article)

Lemma 1. *(Levin, 2003) If an optimal contract exists, there exists a stationary contract that is also optimal.*

Based on this observation we characterize below the optimal contracts under different job designs.

[15]In other words, we implicitly assume that under individual accountability, if the firm reneges on its promise to *only* one agent, the other agent does not observe the firm's deviation, and hence, does not trigger the punishment. However, in a team setting it is more intuitive to assume that each agent learns about the firm's behavior towards other members of the team. Team production requires close collaboration among its members and it is natural to assume that such collaborations would facilitate communication among team members. Thus, if the firm renege on its promise to one agent, the other agents would learn about the defection and trigger punishment.

[16]One can also assume different specifications—e.g., only the cheated agent punishes irrespective of the job design—without any loss of generality. However, we adopt this specification as it is perhaps more natural to assume that the firm's relation with any of the team members affects the overall moral of the team. Similar assumptions were also used in models of multilateral contracting (see, e.g., Levin, 2002).

3.1. **Individual Accountability.** The optimal contract must satisfy three constraints: (i) Individual rationality (IR), i.e., the contract must offer both agents rents at least as large as their outside options. (ii) Incentive compatibility (IC), i.e., given the incentives, both agents chooses their efforts to maximizes their expected payoffs. And finally, (iii) dynamic restriction (DR), i.e., the firm's promise of bonus payments must be credible. We elaborate on each of these constraint below.

As the outside options of both agents are equal to 0, given any contract (W_k, β_k) and a prescribed effort level $\mathbf{e}$, the (IR) constraints for agent A and B are:

$$(IR_A^I) \qquad W_A + \beta_A \Pr(x_1 = 1 \mid \mathbf{e}) - c(e_1) - c(e_2) \geq 0,$$

$$(IR_B^I) \qquad W_B + \beta_B \Pr(x_2 = 1 \mid \mathbf{e}) - c(e_3) - c(e_4) \geq 0.$$

Next, consider the (IC) constraint. As we have discussed above, under individual accountability, agent A is responsible for the tasks 1 and 2 (i.e., job 1), and B is responsible for the two tasks 3 and 4 (i.e., job 2). Given the implicitly contracted bonus payments β_A (offered if $x_1 = 1$) and β_B (offered if $x_2 = 1$), the optimization problems for the two agents are:

$$\begin{aligned} &\max_{e_1,e_2} \; W_A + \beta_A \Pr(x_1 = 1 \mid \mathbf{e}) - c(e_1) - c(e_2), \\ &\max_{e_3,e_4} \; W_B + \beta_B \Pr(x_2 = 1 \mid \mathbf{e}) - c(e_3) - c(e_4). \end{aligned}$$

Thus, for any credible promise of bonus amounts, the agents' effort choice must satisfy the following incentive compatibility conditions

$$(IC_A^I) \qquad \beta_A = e_1 = e_2/\gamma$$

$$(IC_B^I) \qquad \beta_B = e_3 = e_4/\gamma.$$

The (IC) constraints above highlights the multitasking problem. Consider the case of job 1 that is assigned to agent A (the case of job 2 is analogous). Given that both task 1 and 2 are compensated based on the performance in job 1, the effort exerted in these two tasks are linked by the relation $e_1 = e_2/\gamma$. Because $\gamma > 1$, for any value of β the agent will exert more effort in task 2 and less effort in task 1. And there cannot exist any value of β that can ensure the first best allocation $e_1 = e_2 = \phi$.

Finally, consider the dynamic restriction (DR) constraint. If the bonus promises are to be credible, the discounted value of the firm's payoff stream from offering such bonus payments (i.e., equilibrium payoff) must be greater than the discounted value of the payoff stream the firm may earn if it reneges on its promise to one or both agents (i.e., punishment payoff). Thus, construction of the (DR) constraint requires a careful study of the punishment payoff of the firm.

Clearly, if the firm reneges on its promise to both agents, both agents revert back to their static best response, and do not exert any effort. Therefore, the firm earns 0 in the punishment phase. Consequently, we must have

$$(DR_1^I) \qquad \frac{\delta}{1-\delta}\pi^I \geq \beta_A + \beta_B$$

to ensure that reneging on both agents is not a profitable deviation. Similarly, one must also ensure that reneging to only one of the two agents is not a profitable deviation either. This

deviation is relevant only when it is sequentially rational for the firm to continues to maintain its implicit contract with the other agent once it renege its promise to one (else, the firm will always renege on both). Let $\underline{\pi}_k^I$, $k \in \{A, B\}$, be the payoff of the firm if it reneges on its promise to agent k but continues to maintain its implicit contract with the other agent. If reneging to only one agent is unprofitable, it must be the case that for $k, l \in \{A, B\}$ and $k \neq l$,

$$\frac{\delta}{1-\delta}\left(\pi^I - \underline{\pi}_k^I\right) \geq \beta_k \tag{DR_2^I}$$

and

$$\frac{\delta}{1-\delta}\underline{\pi}_k^I \geq \beta_l \tag{DR_3^I}$$

The constraint $\left(DR_2^I\right)$ implies that reneging promise to one agent and continuing the implicit contract with the other agent is not a profitable deviation, and $\left(DR_3^I\right)$ ensures that it is sequentially rational to continue the contract with the other agent once the firm reneges its promise with one. Therefore, the (DR) constraint requires that the optimal contract must satisfy the inequalities $\left(DR_1^I\right)$, $\left(DR_2^I\right)$ and $\left(DR_3^I\right)$. The optimal contracting problem can now be written as follows:

$$\max_{\mathbf{e}, W_A.W_B, \beta_A, \beta_B} V(\mathbf{e}) - W_A - W_B - \beta_A \Pr\left(x_1 = 1 \mid \mathbf{e}\right) - \beta_B \Pr\left(x_2 = 1 \mid \mathbf{e}\right)$$
$$s.t.$$
$$\left(IR_A^I\right),\ \left(IR_B^I\right),\ \left(IC_A^I\right),\ \left(IC_B^I\right),\ \left(DR_1^I\right),\ \left(DR_2^I\right)\ \textit{and}\ \left(DR_3^I\right).$$

This problem can be simplified as follows by eliminating W_ks and $\mathbf{e}$ by using the (IR) and (IC) constraints:

$$\max_{\beta_A, \beta_B}\ \pi^I\left(\beta_A, \beta_B\right) = \phi\left(1+\gamma\right)\left(\beta_A + \beta_B\right) - \tfrac{1}{2}\left(1+\gamma^2\right)\left(\beta_A^2 + \beta_B^2\right)$$

$$\begin{array}{ll} s.t. & \frac{\delta}{1-\delta}\pi^I\left(\beta_A, \beta_B\right) \geq \beta_A + \beta_B \qquad \left(DR_1^I\right) \\ & \textit{For } k, l \in \{A, B\} \textit{ and } k \neq l,\ \frac{\delta}{1-\delta}\left[\pi^I\left(\beta_A, \beta_B\right) - \underline{\pi}_k^I\right] \geq \beta_k \qquad \left(DR_2^I\right) \\ & \textit{For } k \in \{A, B\},\ \frac{\delta}{1-\delta}\underline{\pi}_k^I \geq \beta_l. \qquad \left(DR_3^I\right) \end{array}$$

We can further simplify this problem by using the fact that $\pi^I\left(\beta_A, \beta_B\right)$ is additively separable in β_A and β_B. By definition, $\underline{\pi}_A^I \equiv \pi^I\left(0, \beta_B\right)$ and $\underline{\pi}_B^I \equiv \pi^I\left(\beta_A, 0\right)$. Thus, by additive structure of the cost and value function, for any β_A and β_B, $\pi^I\left(\beta_A, \beta_B\right) = \pi^I\left(\beta_A, 0\right) + \pi^I\left(0, \beta_B\right)$. Using this fact, we readily find that $\left(DR_3^I\right)$ implies $\left(DR_2^I\right)$ and $\left(DR_1^I\right)$. Moreover, the additive separability also implies that for any β, $\pi^I\left(\beta, 0\right) = \pi^I\left(0, \beta\right)$. Consequently, the above maximization problem can be separated into two identical maximization problem—one with respect to β_A and the other with respect to β_B. This implies that at the optimal, $\beta_A = \beta_B \equiv \beta$ (say), and the firm's optimal contracting problem can be written as:

$$\mathcal{P}_I : \begin{cases} \pi_*^I \equiv \ \max\limits_{\beta}\ 2\left[\phi\left(1+\gamma\right)\beta - \frac{1}{2}\left(1+\gamma^2\right)\beta^2\right] \\ \\ s.t. \quad \frac{\delta}{1-\delta}\left[\phi\left(1+\gamma\right)\beta - \frac{1}{2}\left(1+\gamma^2\right)\beta^2\right] \geq \beta. \qquad \left(DR^I\right) \end{cases}$$

In order to solve the above program $\mathcal{P}_I$ we proceed as follows. Note that we can rewrite the (DR) constraint as

$$R^I(\beta) := \phi(1+\gamma)\beta - \frac{1}{2}(1+\gamma^2)\beta^2 \geq r\beta, \tag{3}$$

where $r = (1-\delta)/\delta$.

The function $R^I(\beta)$ can be interpreted as the "reputation capital" (or per-period reputational capital) given the implicit incentive β. Solving the maximization problem above is equivalent to finding the highest β that satisfies the (DR) constraint. When $\beta > 0$, $R(\beta)$ is positive, increasing and concave. Furthermore, $R^I(0) = 0$. If r is too large (i.e., δ is too low), such that $r > R^{I\prime}(0)$, $R^I(\beta)$ is always below $r\beta$, and the only value of β that satisfies the (DR) is $\beta = 0$. Otherwise, the optimal β is the maximal β at which $R^I(\beta)$ intersects $r\beta$ as long as the unconstrained argmax value of β is obtained (i.e., as long as the first best profit is reached). The optimal β as a function of r, say $\beta^I_*(r)$ is given as follows:

$$\beta^I_*(r) = \begin{cases} \phi(1+\gamma)/\left(1+\gamma^2\right) & if \quad r \leq \frac{1}{2}\phi(1+\gamma). \\ (2\phi(1+\gamma) - 2r)/\left(1+\gamma^2\right) & if \quad \frac{1}{2}\phi(1+\gamma) < r < \phi(1+\gamma) \\ 0 & if \quad r \geq \phi(1+\gamma) \end{cases}. \tag{4}$$

The optimal profit under individual accountability can now be obtained by plugging the value of $\beta^I_*(r)$ in π^I. This is stated below in Lemma 2 (we omit the proof as the argument has already been discussed above).

Lemma 2. *The optimal profit under individual accountability is a continuous and monotonically decreasing function in r given as follows:*

$$\pi^I_*(r) = \begin{cases} \phi^2(1+\gamma)^2/\left(1+\gamma^2\right) & if \quad r \leq \frac{1}{2}\phi(1+\gamma). \\ 4\left(\phi(1+\gamma)r - r^2\right)/(1+\gamma^2) & if \quad \frac{1}{2}\phi(1+\gamma) < r < \phi(1+\gamma) \\ 0 & if \quad r \geq \phi(1+\gamma) \end{cases}. \tag{5}$$

For r sufficiently large (i.e., δ sufficiently low), the optimal profit is simply equal to the punishment profit of the firm because no implicit incentives are feasible even on the equilibrium path. As r decreases (i.e., for larger values of δ) the firm gains more credibility in promising implicit contracts. The resulting stronger implicit incentive induces to greater effort, and leads to an increase in the firm's profit until the maximal profit under individual accountability is achieved.[17]

Having characterized the optimal contract and the associated profit of the firm under individual accountability, we next analyze the case of team accountability.

[17]Observe that the maximal profit under individual accountability is less than the profit associated with the first best because the multitasking problem continues to prevail irrespective of how strong an implicit incentive the firm can credibly offer.

3.2. **Team Accountability.** Under team accountability, agent A is responsible for tasks 1 and 4, while B is responsible for the other two (task 2 and 3). As in the case with individual accountability, we first discuss the (IR), (IC), and (DR) constraints associated with the optimal contracting problem. The (IR) constraints are analogous to the case of individual accountability and are given as follows:

$$(IR_A^T) \qquad W_A + \beta_{A1} \Pr(x_1 = 1 \mid \mathbf{e}) + \beta_{A2} \Pr(x_2 = 1 \mid \mathbf{e}) - c(e_1) - c(e_4) \geq 0,$$

$$(IR_B^T) \qquad W_B + \beta_{B1} \Pr(x_1 = 1 \mid \mathbf{e}) + \beta_{B2} \Pr(x_2 = 1 \mid \mathbf{e}) - c(e_2) - c(e_3) \geq 0.$$

However, the nature of the (IC) and the (DR) constraints is significantly different compared to the previous case. Consider the (IC) constraint first. Given the bonus payments β_{A1}, β_{B1} (offered if $x_1 = 1$) and β_{A2}, β_{B2} (offered if $x_2 = 1$), the optimization problem for the two agents are:

$$\max_{e_1, e_3} \; W_A + \beta_{A1} \Pr(x_1 = 1 \mid \mathbf{e}) + \beta_{A2} \Pr(x_2 = 1 \mid \mathbf{e}) - c(e_1) - c(e_4),$$

$$\max_{e_2, e_4} \; W_B + \beta_{B1} \Pr(x_1 = 1 \mid \mathbf{e}) + \beta_{B2} \Pr(x_2 = 1 \mid \mathbf{e}) - c(e_2) - c(e_3).$$

Thus, the (IC) constraints that the optimal contract must satisfy are:

$$(IC_A^T) \qquad \beta_{A1} = e_1, \; \beta_{A2} = e_4/\gamma,$$

$$(IC_B^T) \qquad \beta_{B1} = e_2/\gamma, \; \beta_{B2} = e_3.$$

In contrast with the case of individual accountability, the (IC) constraints above highlight how team accountability can mitigate the multitasking problem. Consider the case of job 1 where task 1 is performed by agent A and task 2 performed by agent B (the case of job 2 is analogous). Under team accountability the firm can vary the power of the incentives offered to agent A and B for each of the two tasks associated with job 1. Because two different agents are performing the two tasks, they can be paid differently for the same performance outcome in job 1 (i.e., β_{A1} need not be equal to β_{B1}). Thus, the effort exerted in tasks 1 and 2 are no longer interlinked (as is the case with individual accountability), and for $\beta_{A1} = \phi$, $\beta_{B1} = \phi/\gamma$ the first best allocation ($e_1 = e_2 = \phi$) can be attained.

Finally, consider the dynamic restriction (DR) constraint. Recall that under team accountability, both agents become aware of the firm's deviation (and hence, triggers punishment) even if the firm reneges its promise only with one of the two agents. Thus, if the firm considers a deviation, it will renege on both agents, and the punishment payoff of the firm would be 0. Consequently, the relevant (DR) constraint is

$$(DR^T) \qquad \frac{\delta}{1-\delta} \pi^T \geq \beta_{A1} + \beta_{B1} + \beta_{A2} + \beta_{B2}.$$

The optimal contracting problem can now be formulated as follows:

$$\max_{\mathbf{e},W_A.W_B,\boldsymbol{\beta}} \; V(\mathbf{e}) - W_A - W_B - (\beta_{A1}+\beta_{B1})\Pr(x_1=1 \mid \mathbf{e}) - (\beta_{A2}+\beta_{B2})\Pr(x_2=1 \mid \mathbf{e})$$

$$s.t. \qquad \left(IR_A^T\right),\ \left(IR_B^T\right),\ \left(IC_A^T\right),\ \left(IC_B^T\right),\ and\ \left(DR^T\right).$$

Using the (IR) and (IC) constraints to eliminate Ws and $\mathbf{e}$, we can rewrite the problem as:

$$\max_{\beta_{A1},\beta_{B1},\beta_{A2},\beta_{B2}} \; \pi^T \equiv \phi\left(\beta_{A1}+\gamma\beta_{B1}+\beta_{B2}+\gamma\beta_{A2}\right) - \tfrac{1}{2}\beta_{A1}^2 - \tfrac{1}{2}\gamma^2\beta_{B1}^2 - \tfrac{1}{2}\beta_{B2}^2 - \tfrac{1}{2}\gamma^2\beta_{A2}^2$$

$$s.t. \;\; \tfrac{\delta}{1-\delta}\pi^T \geq \beta_{A1}+\beta_{B1}+\beta_{A2}+\beta_{B2}. \qquad \left(DR^T\right)$$

This problem can further be simplified by virtue of the following observation: because, the agents are *ex ante* symmetric, and π^T is concave and additively separable in βs, at the optimum, we must have $\beta_{A1}=\beta_{B2}$ and $\beta_{B1}=\beta_{A2}$. Using this fact, we can rewrite the firm's problem as:

$$\mathcal{P}_T: \begin{cases} \pi_*^T \equiv \max\limits_{\beta_{A1},\beta_{B1}} \; 2\left[\phi\left(\beta_{A1}+\gamma\beta_{B1}\right) - \tfrac{1}{2}\left(\beta_{A1}^2+\gamma^2\beta_{B1}^2\right)\right] \\ s.t. \;\; \tfrac{\delta}{1-\delta}\left[\phi\left(\beta_{A1}+\gamma\beta_{B1}\right) - \tfrac{1}{2}\left(\beta_{A1}^2+\gamma^2\beta_{B1}^2\right)\right] \geq \beta_{A1}+\beta_{B1}. \quad \left(DR^T\right) \end{cases}$$

The above optimization program $\mathcal{P}_T$ is similar in spirit to its individual accountability counterpart $\mathcal{P}_I$. However three issues are important to note:

First, the $\left(DR^T\right)$ constraint offers a neat representation of the key trade-off associated with the team accountability. The $\left(DR^T\right)$ constraint indicates that to elicit the same levels of effort, the firm must commit to a larger bonus pool under team accountability (because a separate bonus payment must be offered for each task). Consequently, team accountability makes implicit contracts difficult to sustain. However, given an aggregate bonus pool (i.e., $\beta_{A1}+\beta_{B1}$) the firm can vary the power of incentives offered for the two tasks (i.e., β_{A1} and β_{B1} need not have to be equal to each other) and overcome the multitasking problem.[18]

Second, the $\left(DR^T\right)$ constraint is in sharp contrast with the dynamic restrictions discussed in the models of multilateral implicit contracts (Bernheim and Whinston, 1990; Levin, 2003). In the latter models, the dynamic restriction under multilateral contracts simply requires that the dynamic restriction under bilateral contract must hold at the *aggregate level* (i.e., summed over all agents). Thus, in these models, multilateral implicit contracts are easier to sustain. In contrast, in the current setting, $\left(DR^T\right)$ is *not* an aggregate version of $\left(DR^I\right)$ (i.e., the (DR) constraint under individual accountability as given in the program $\mathcal{P}_I$).

[18]One may also ask whether team accountability may involve an additional cost by encouraging free riding. In this model, the free riding problem can be mitigated by choosing the power of the incentive contracts appropriately, and therefore, this effect is already embedded in the optimization problem through the incentive compatibility constraint.

As shown by Holmsrtom (1982), free riding problem necessarily leads to a loss of efficiency in absence of any "budget breaker" (i.e., under the constraint that the total wage bill for the team must be equal to the total output produced). Indeed, in our model the firm is the residual claiment and works as the "budget breaker." Therefore, if the firm can offer sufficiently strong incentive, there is no loss of surplus due to free riding and the first best can be achieved (as we will discuss below).

Third, the solution technique is relatively convoluted because of the fact that now the firm needs to maximize with respect to two bonus amounts, β_{A1} and β_{B1}, instead of one (as is the case in $\mathcal{P}_I$). We solve this problem in two steps. First, for a given value of *total* bonus payments $\beta = \beta_{A1} + \beta_{B1}$ we characterize the optimal individual bonus payments β_{A1} and β_{B1}. Second, given the optimal β_{A1} and β_{B1} as a function of β, we find the optimal β that the firm can sustain.

The maximum reputational capital that can be achieved for a given β, can be solved from the following program:

$$R^T(\beta) := \max_{\beta_{A1},\beta_{B1}} \phi(\beta_{A1} + \gamma\beta_{B1}) - \tfrac{1}{2}\left(\beta_{A1}^2 + \gamma^2\beta_{B1}^2\right)$$

$$s.t. \qquad \beta_{A1} + \beta_{B1} \leq \beta,\ \beta_{A1} \geq 0,\ and\ \beta_{B1} \geq 0$$

As before, $R^T(\beta)$ denotes the reputational capital that is achievable given total bonus β. Using the standard optimization procedures, we find the following solutions to β_{A1} and β_{B1} in terms of the total bonus β:

$$\begin{array}{lll} \beta_{A1}^{T*} = 0, & \beta_{B1}^{T*} = \beta & if \quad \beta < \phi\frac{\gamma-1}{\gamma^2} \\ \beta_{A1}^{T*} = \frac{\gamma^2\beta+\phi(1-\gamma)}{1+\gamma^2}, & \beta_{B1}^{T*} = \frac{\beta-\phi(1-\gamma)}{1+\gamma^2} & if \quad \phi\frac{\gamma-1}{\gamma^2} \leq \beta < \phi\frac{\gamma+1}{\gamma} \\ \beta_{A1}^{T*} = \phi, & \beta_{B1}^{T*} = \frac{\phi}{\gamma} & if \quad \beta \geq \phi\frac{\gamma+1}{\gamma}. \end{array} \tag{6}$$

The above equation suggests that when the size of the available bonus pool (β) is small, the firm should optimally give incentives only for the "γ-task" (i.e., task 2). However, as the amount of total available bonus increases, the firm starts offering bonus for both tasks, eventually reaching the first best effort levels.

The intuition behind this finding is as follows: for a dollar of bonus payment (offered if $x_1 = 1$) the marginal benefit of effort is higher if the effort is spent on the γ-task, i.e., task 2 (recall that $\gamma > 1$). Thus, as long as the marginal cost of effort is moderate, a dollar promised for task 2 elicits more effort from the agent than a dollar promised for task 1. When the firm cannot offer large bonus payments, the associated effort level is low, and so is the marginal cost of effort. Thus, in such a scenario the firm is better off by offering the entire sum on task 2. But as a larger sum of bonus is offered, more effort is spent on task 2 and the marginal cost of effort associate with this task increases. Consequently, the marginal return of a dollar of bonus payment (in terms of the increment in effort induced) on task 2 decreases. In such a scenario, the firm finds it optimal to split the available bonus pool between the two tasks such that the marginal returns from bonus dollar offered for each task are equal. When the available bonus pool is significantly large, both β_{A1} and β_{B1} can be chosen appropriately so that the first best effort levels become available.

Given these solutions, we can explicitly write $R^T(\beta)$ as follows:

$$R^T(\beta) = \begin{cases} \phi\gamma\beta - \frac{1}{2}\gamma^2\beta^2 & if \quad \beta < \phi\frac{\gamma-1}{\gamma^2} \\ \left(2\phi\gamma\beta(1+\gamma) + \phi^2(1-\gamma)^2 - \gamma^2\beta^2\right)/2\left(1+\gamma^2\right) & if \quad \phi\frac{\gamma-1}{\gamma^2} \leq \beta < \phi\frac{\gamma+1}{\gamma} \\ \phi^2 & if \quad \beta \geq \phi\frac{\gamma+1}{\gamma} \end{cases}.$$

Now the firm's optimization problem boils down to the problem of finding the largest value of β subject to the (DR) constraint: $R^T(\beta) \geq r\beta$. This problem is similar to the one discussed in the case of individual accountability, and analogously, the optimal β can be derived as follows:

$$\beta_*^T(r) = \begin{cases} \frac{1}{\gamma}\phi(\gamma+1) & if \quad r \leq \frac{\phi\gamma}{\gamma+1} \\ \frac{1}{\gamma^2}K(r) & if \quad \frac{\phi\gamma}{\gamma+1} < r \leq \frac{1}{2}\phi(\gamma+1) \\ \frac{2}{\gamma^2}(\phi\gamma - r) & if \quad \frac{1}{2}\phi(\gamma+1) < r < \phi\gamma \\ 0 & if \quad r \geq \phi\gamma \end{cases}, \tag{7}$$

where the function $K(r) = \phi\gamma(1+\gamma) - r(1+\gamma^2) + \left[\left(\phi\gamma(1+\gamma) - r(1+\gamma^2)\right)^2 + \gamma^2(1-\gamma)^2\phi^2\right]^{1/2}$. The optimal profit under individual accountability can now be obtained by plugging the value of $\beta_{ki}^{T^*}$s in π_T. This is stated below in Lemma 3 (we omit the proof as the argument has already been discussed above).

Lemma 3. *The optimal profit under team accountability is a continuous and monotonically decreasing function in r given as follows:*

$$\pi_*^T(r) = \begin{cases} 2\phi^2 & if \quad r \leq \frac{\phi\gamma}{\gamma+1} \\ 2rK(r)/\gamma^2 & if \quad \frac{\phi\gamma}{\gamma+1} < r \leq \frac{1}{2}\phi(\gamma+1) \\ 4r(\phi\gamma - r)/\gamma^2 & if \quad \frac{1}{2}\phi(\gamma+1) < r < \phi\gamma \\ 0 & if \quad r \geq \phi\gamma \end{cases}, \tag{8}$$

where the function $K(r)$ is as given in equation (7)*.*

For r sufficiently large (i.e., δ sufficiently small) the firm has little reputation concern, and hence, cannot credibly commit to any bonus payments. Consequently, it cannot induce any effort and makes zero profit. When r decreases (i.e., δ increases) firm can credibly commit to some but a small amount of bonus payment. As discussed in the context of equation (6) above, when the firm can only commit to a small amount of bonus payments, it offers bonus *only* for the γ-tasks (e_2 and e_4). As r decreases even further, the firm finds it optimal to offer bonus for both tasks, and finally, for r sufficiently small the first best effort level becomes feasible.

Equipped with the complete characterization of the firm's profit under team and individual accountability, we can now address the issue of the optimal job design.

3.3. **Optimal job design.** The optimal job design for a given value of r (and hence, for a given δ) is the one that yields the highest profit to the firm. A comparison between the optimal profits under individual and team accountability leads to the following characterization of the optimal job design.

Proposition 1. *There exists a value of r, say r^*, such that team accountability is strictly optimal if and only if $r < r^*$.*

The above proposition suggests that the optimal job design follows a cut-off rule: team accountability is optimal only for the firms with sufficiently high reputation concerns, i.e., sufficiently high δ (or, equivalently, sufficiently low r). And individual accountability is optimal otherwise. The key idea behind Proposition 1 is shown in Figure 1 below. Figure 1 plots the optimal payoff from team $\left(\pi_*^T\right)$ and individual accountability $\left(\pi_*^I\right)$ as a function of the firm's discount rate represented by r. The optimal payoff functions intersect each

other at only one point, r^*, where the payoff from team lies above the payoff from individual accountability for all $r < r^*$.

The intuition behind this result is simple. Recall that while team accountability allows the firm to overcome the multitasking problem, it requires the firm to credibly commit to a larger bonus pool in order to elicit effort in all tasks. If the firm's discount factor (δ) is sufficiently high, the threat of future punishment is significantly large for the firm, which, in turn, allows the firm to credibly promise to a high level of bonus payments. Thus, team accountability becomes optimal. However, for low δ, the firm may not have credibility to offer high bonus payments. In such a setting, the firm might be better off by resorting to individual accountability. Under individual accountability, even a small bonus payments may give sharper incentives as it elicits effort in all tasks associated with the particular job. The sharper incentives may outweigh the inefficiencies originating from the multitasking problem.

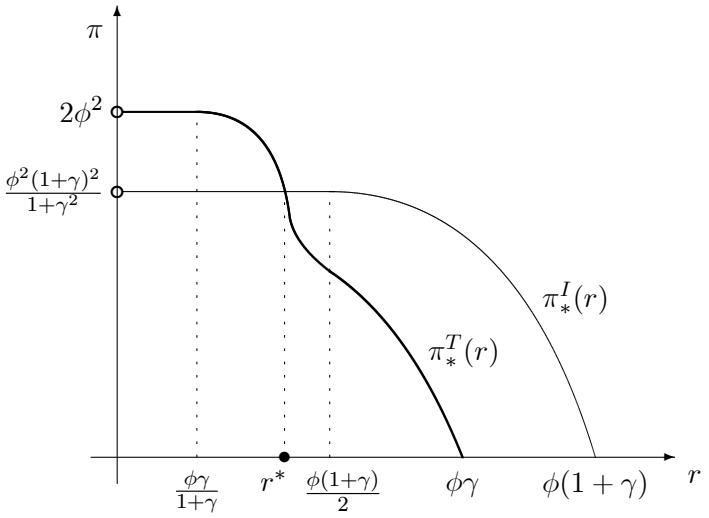

Figure 1. The maximal profits under team and individual accountability (team is optimal for $r < r^*$)

Proposition 1 highlights how the optimal job design depends on the firm's reputation concerns, δ. But it is also instructive in understanding how job design depends on the extent of the multitasking problem, as captured by the parameter γ.

Corollary 1. *The threshold r^* is increasing in γ.*

The corollary above suggests that as the multitasking problem becomes more severe, the set of r for which team accountability is optimal job design expands . In other words, team accountability is more likely to be the optimal job design as γ increases. This finding is quite intuitive because the key benefit of team accountability is that it mitigates the multitasking problem. Thus, the more acute is the multitasking problem, the more likely it is that the firm will opt for teams.

4. Interaction between explicit and implicit incentives

The previous section is instructive in drawing out the key trade-off associated with team accountability. But it does so under a simple framework where implicit contracts are the *only* form of incentives available. However, in many real life scenarios, firms augment implicit contracted bonus incentives with explicit pay-per-performance contracts.[19] How would the presence of explicit contracts affect the optimal job design? This section discusses this issue.

In order to accommodate for explicit incentives in the our model, one can simply "relabel" job 1 as the verifiable job and job 2 as the non-verfiable job. In other words, we assume that x_1 is a verifiable signal while x_2 continues to be non-verifiable. Let the piece-rates associated with job 1 under individual accountability be b_A and under team accountability be b_{A1} and b_{B1}. Thus, the firm now chooses the tuple (W_A, W_B, b_A, β_B) under individual accountability, and the tuple $(W_A, W_B, b_{A1}, b_{B1}, \beta_{A2}, \beta_{B2})$ under team accountability.

Observe that for given values of bs and βs, the presence of explicit contracts do not change the incentives faced by the agents in any substantive way (compared to the case where all incentives are implicit). It is merely an matter of relabelling βs as bs. Thus, it does not affect the (IR) and (IC) constraints. However, the (DR) constraint changes substantially due to two reasons. First, instead of both jobs, only the incentives associated with job 2 is now implicitly contracted up on. Second, and more importantly, presence of explicit contracts changes the firm's punishment payoff. This is due to the fact that the firm can continue to rely on the explicit incentives to elicit some effort from the agents even on the punishment path (this is issue is similar to the one discussed in Baker et al., 1994). Therefore, while discussing below the optimal contracts under individual and team accountability, we will primarily focus on the (DR) constraint.

Consider first the case of individual accountability. On the punishment path, agent B reverts back to static best response and do not exert any effort, i.e., $e_3 = e_4 = 0$. Consequently, the optimal explicit contract on the punishment path simply solves the following program (after eliminating Ws and es using (IR) and (IC)):

$$\max_{b_A} \ \hat{\underline{\pi}}^I \equiv b_A\phi(1+\gamma) - \frac{1}{2}b_A^2(1+\gamma^2).$$

The optimal b thus obtained is $\underline{b}_A^I = \phi\,(1+\gamma)\,/\,\left(1+\gamma^2\right)$, and the optimal punishment payoff is:[20]

$$\hat{\underline{\pi}}^I = b_A^*\phi(1+\gamma) - \frac{1}{2}b_A^{*2}(1+\gamma^2) = \frac{1}{2}\phi^2\frac{(1+\gamma)^2}{1+\gamma^2}. \tag{9}$$

Now, analogous to the program $\mathcal{P}_I$ (the optimization problem of the firm when both jobs are implicitly contracted, as discussed in the previous section) the firm's optimization problem can be written as (again, after eliminating Ws and es using (IC) and (IR)):

[19] For example, recall the case of commercial insurance discussed in the introduction.

[20] Observe that this solution is always feasible, since under Assumption 1, the implied value of $e_1 + \gamma e_2$ (which is the probability that $y = 1$) is always less than 1.

$$\hat{\mathcal{P}}_I : \begin{cases} \hat{\pi}_*^I \equiv \max\limits_{b_A,\beta_B} \ \hat{\pi}^I\left(b_A,\beta_B\right) = \phi\left(1+\gamma\right)\left(b_A+\beta_B\right) - \frac{1}{2}\left(1+\gamma^2\right)\left(b_A^2+\beta_B^2\right) \\ s.t. \qquad \frac{\delta}{1-\delta}\left[\hat{\pi}^I\left(b_A,\beta_B\right) - \underline{\hat{\pi}}^I\right] \geq \beta_B. \qquad (\widehat{DR}^I) \end{cases}$$

It is important to note the following about $\hat{\mathcal{P}}_I$: As before, $\hat{\pi}^I\left(b_A,\beta_B\right)$ is additively separable in b_A and β_B. Thus, fixing β, the optimal b, say b_A^*, is independent of β and is exactly equal to $\underline{b}_A^I$. In other words, the firm continues to offer the same explicit contract on both the equilibrium and the punishment path. An implication of this observation is that $\hat{\mathcal{P}}_I$ can be rewritten as:

$$\begin{aligned} \hat{\pi}_*^I \equiv \max_{\beta_B} \ \hat{\pi}^I\left(b_A^*,\beta_B\right) &= \phi\left(1+\gamma\right)\left(b_A^*+\beta_B\right) - \tfrac{1}{2}\left(1+\gamma^2\right)\left(b_A^{*2}+\beta_B^2\right) \\ &= \phi\left(1+\gamma\right)\beta_B - \tfrac{1}{2}\left(1+\gamma^2\right)\beta_B^2 + \underline{\hat{\pi}}^I \\ s.t. \qquad \frac{\delta}{1-\delta}\left[\phi\left(1+\gamma\right)\beta_B - \tfrac{1}{2}\left(1+\gamma^2\right)\beta_B^2\right] &\geq \beta_B. \qquad (\widehat{DR}^I) \end{aligned}$$

But this program is identical to the program $\mathcal{P}_I$ except the fact that the objective function in $\hat{\mathcal{P}}_I$, $\hat{\pi}^I\left(b_A^*,\beta_B\right)$, is a linear transformation of the objective function in $\mathcal{P}_I$. Thus, one readily obtains the following relationship between the profits associated with the optimal contracts in the two scenarios:

$$\hat{\pi}_*^I = \frac{1}{2}\pi_*^I + \underline{\hat{\pi}}^I. \tag{10}$$

The above equation is quite intuitive given the additive separability of the firm's optimization problem with respect to the incentives offered to each of the two agents. There only two key differences between the cases where both agents face implicit contracts and the where explicit and implicit incentives are combined: (i) Only *one* of the two agents face implicit incentives and the strength of implicit incentives is the same across the two cases. Hence, he generates a profit of $\pi_*^I/2$. (ii) The other agent, one who is responsible for job 1, faces explicit incentive contract which does not change on the punishment path. Hence, he generates a profit of $\underline{\hat{\pi}}^I$.

The same logic holds in the case of team accountability. But of course, the punishment payoff under team accountability is different from its individual accountability counterpart. On the punishment path under team accountability both agents exert effort only in response to the explicit incentives. Thus, $e_3 = e_4 = 0$ as job 2 is compensated only through implicit contracts. For efforts associated with job 1, the (IC) constraints for the agents implies that $e_1 = b_{A1}$, and $e_2 = \gamma b_{B1}$. Therefore, analogous to the case of individual accountability, the optimal explicit contract on the punishment path simply solve the following program (after eliminating Ws and es using (IR) and (IC)):

$$\max_{b_{A1},b_{B1}} \ \underline{\hat{\pi}}^T \equiv \phi(b_{A1}+\gamma b_{B1}) - \frac{1}{2}(b_{A1}^2+\gamma^2 b_{B1}^2).$$

The optimal bs thus obtained are $\underline{b}_{A1}^T = \phi$, and $\underline{b}_{B1}^T = \phi/\gamma$, and the optimal punishment payoff is:

$$\underline{\hat{\pi}}^T = \phi^2. \tag{11}$$

Now, analogous to equation (10), the equilibrium payoff under team accountability, say, $\hat{\pi}_*^T$, is given as follows:

$$\hat{\pi}_*^T = \frac{1}{2}\pi_*^T + \underline{\hat{\pi}}^T \tag{12}$$

Equations (10) and (12) offer a simple characterization of the firm's equilibrium payoff under team and individual accountability when explicit contracts are combined with implicit incentives. Using these relationships, the following proposition shows that the optimal job design no longer follows a cut-off rule in the presence of explicit incentives.

Proposition 2. *If γ is sufficiently large, team accountability is optimal for all values of r. Else, there exist two values of r, say r_1 and r_2, such that individual accountability is strictly optimal for all $r \in [r_1, r_2]$, and team accountability is strictly optimal otherwise.*

The intuition behind this result is similar to the cut-off result discussed in proposition 1, particularly when r is not too large. For r sufficiently small (i.e., δ sufficiently large), the firm's reputational capital is sufficiently large. Thus, the firm can offer strong implicit incentives even under teams accountability. Consequently, team accountability becomes optimal because it overcomes the multitasking problem. In contrast, for moderate values of r, individual accountability dominates. This is due to the fact that for a moderate r, the firm has some reputational capital that allows it to offer implicit incentives. In such a scenario, the implicit incentives are sharper under individual accountability. This is because the firm only needs to promise a bonus payment to one of the two agents, and hence, can credibly promise a larger bonus amount than what it can do if it were to promise a bonus payment to each of the two agents (as is the case with team accountability). When the multitasking problem is not too large (i.e., moderate γ), this incentive effect outweighs the multitasking problem associated with individual accountability. But what drives the optimality of teams for sufficiently large r? For r sufficiently large (i.e., δ sufficiently small), the firm has little reputation concerns, and hence, the implicit incentives are infeasible under both types of job designs. The firm's profit under team accountability is higher because the explicit incentive can elicit more search effort under team setting by mitigating the multitasking problem.

However, if the multitasking problem is sufficiently large, then even for a moderate r, the stronger implicit incentives under individual accountability need not be enough to compensate for the associated multitasking problem. In this case, team accountability remains optimal for all values of r.

Figure 2 below depicts the case where individual accountability is optimal for intermediate values of r.

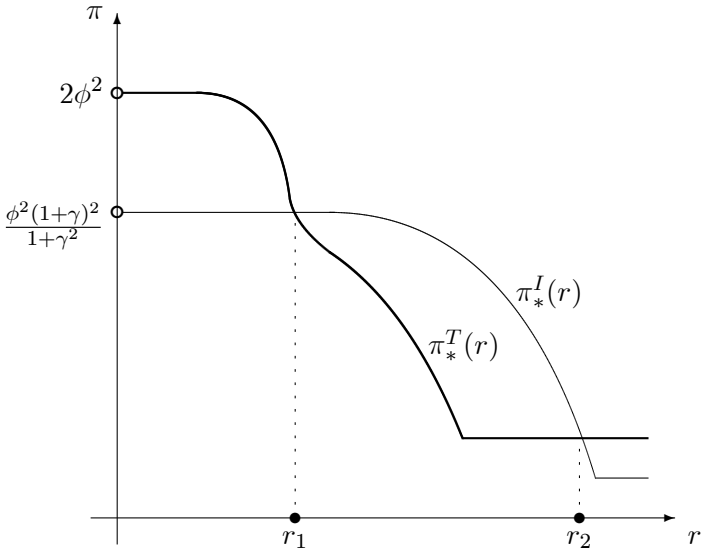

Figure 2. The maximal profits under team and individual accountability in the presence of explicit incentives: The case where γ is small (team is optimal for $r < r_1$ and $r > r_2$)

The following corollary presents a comparative statics with respect to the γ

Corollary 2. *Both r_1 and r_2 are increasing in γ. Moreover, there exists two threshold values of γ, say $\underline{\gamma}$ and $\overline{\gamma}$, such that (i) for $\gamma < \overline{\gamma}$, $r_2 - r_1$ (the size of the interval for which individual accountability is optimal) may increase or decrease in γ, (ii) for $\underline{\gamma} < \gamma < \overline{\gamma}$, $r_2 - r_1$ decreases in γ, and (iii) for all $\gamma > \overline{\gamma}$, team accountability is always optimal.*

The corollary above suggests that if γ is *not* too small to begin with, team accountability becomes *more* likely to be the optimal job design as the extent of multitasking problem (γ) increases. Indeed, when γ is sufficiently large, individual accountability is never optimal. This result is similar in spirit to corollary 1, but with one caveat: for sufficiently low γ, an increase in the extent of the multitasking problem may favor individual accountability. This happens due to the following reason. An increase in γ has two effects on the firm's payoff: (i) *Incentive effect:* It increases the effort level in the γ-task as the marginal benefit of task 2 and task 4 increases with γ. This effect favors both individual and team accountability.[21] However, it is *a priori* unclear under which job design this effect is more pronounced. (ii) *Multitasking effect:* It accentuates the multitasking problem, and, therefore, increases the loss of efficiency due to the misallocation of effort across tasks. This effect works in favor of team accountability. When γ is sufficiently small, the loss of surplus due to multitasking problem is small. Thus, if the underlying parameters are such that the incentive effect is significantly stronger under individual accountability, it may dwarf the multitasking effect. Therefore, an increase in γ when γ is sufficiently small to begin with, may favor individual accountability.

[21]It is straightforward to see this effect from the agents' (IC) constraints. For example, for agent A, under individual accountability, $\left(IC_A^I\right)$ implies $e_2 = \gamma\beta_A$ and $\left(IC_A^T\right)$ implies $e_4 = \gamma\beta_{A2}$. Thus, in equilibrium, an increase in γ increases both e_2 and e_4.

5. Discussion and conclusion

The results discussed in the previous sections (propositions 1 and 2) offer a sharp characterization of the optimal job design. However, as noted in description of the basic model, these results are derived under a technology specification that rules out any interaction between efforts in different tasks. To what extent are the key results robust to an alternative technology specification that allows interaction between efforts? This final section begins with a discussion on this issue. It also explores some of the salient empirical implications of the results and ends with a few concluding remarks.

5.1. **Substitutability between efforts in different tasks.** Many of the multitasking models in the current literature assume that efforts in different tasks are substitutes in the agents' cost functions (e.g., Holmström and Milgrom, 1991). In these models, substitutability of effort is one of the main sources of the multitasking problem. In contrast, in the model used above the cost of effort is assumed to be additively separable. While such additive separability improves the analytical tractability of the model, it rules out any room for substitutability between efforts in different tasks. However, it turns out that the key insights of our basic model (as discussed in the context of Proposition 1) continue to hold even if one allows for substitutability between efforts in the agents' cost function. The purpose of this subsection is to illustrate this point.

In order to introduce substitutability between effort, we insert an interaction term in the agent's cost function. Keeping all other aspects of the model unchanged, we assume that the total cost of effort for agent $k \in \{A, B\}$ when he is assigned to task i and j is

$$c(e_i, e_j) = \frac{1}{2}e_i^2 + \frac{1}{2}e_j^2 + \theta e_i e_j,$$

where $\theta \in (0, 1]$ is a measure of substitutability between efforts in different tasks. Thus, agent A's total cost of effort under individual accountability (when he is assigned to task 1 and 2) is $c(e_1, e_2) = e_1^2/2 + e_2^2/2 + \theta e_1 e_2$, and under team accountability (when he is assigned to task 1 and 4) is $c(e_1, e_4) = e_1^2/2 + e_4^2/2 + \theta e_1 e_4$ (similarly for agent B). Note that when $\theta = 0$, we revert back to the basic model. And at the other extreme, when $\theta = 1$, the two tasks become perfect substitutes. The following proposition highlights that the key insights of the basic model continue to hold even when efforts are substitutes in the agent's cost function.

Proposition 3. *For $\theta > 1/\gamma$, team accountability is always optimal. Else, there exists a value for r, say $\hat{r}$, such that team accountability is optimal for all $r < \hat{r}$, and individual accountability is optimal otherwise.*

The proposition above is similar in spirit to Proposition 1 with one important addition: for θ sufficiently large, team accountability is *always* optimal. The intuition behind this finding is as follows. Recall that the parameter θ measures the extent of substitutability between efforts in different tasks in the agents' cost function. Thus, when θ is high, high effort in one task significantly increases the marginal cost of effort in the other task. This effect makes the multitasking problem more severe. The agent now has stronger incentive to focus on the "γ-task" (at the expense of the other task) not only because the effort in the γ-task has higher marginal impact on the performance signal, but also for the fact that high effort in the γ-task makes the effort in the other task more costly.

In such a scenario, team accountability is even more effective (compared to the case in the basic model) in eliciting higher efforts in both tasks. As discussed before, team accountability helps the firm to overcome the multitasking problem emanating from the fact that the efforts

in the two tasks has different marginal impacts on the performance signal (modelled through the parameter γ). In addition, by varying the incentives for effort in the two tasks, team accountability can also offset the effort substitution towards the "γ-task" emanating from the substitutability of effort in the agents' cost function (modelled through the parameter θ). For example, the firm can leave the incentives for the "γ-task" unchanged, but increase the incentive for the other task ("non-γ-task") in order to compensate the agent for the higher marginal cost of effort in the "non-γ-task" that stems from the high effort in the "γ-task." This effect makes team accountability more desirable when efforts are strong substitutes in the agents' cost function.

Corollary 3. *When efforts are perfect substitutes in the agents' cost function (i.e., when $\theta = 1$), team accountability is always optimal.*

This observation follows directly from Proposition 3. As $\gamma > 1$, when $\theta = 1$, the condition $\theta > 1/\gamma$ is trivially satisfied, which ensures optimality of team accountability irrespective of the firm's reputation concerns.

5.2. **Empirical implications.** Proposition 1 and 2, along with their corollaries, not only offer an characterization of the optimal job design, but they also have important empirically implications. They highlight how some of the key parameters that defines the economic environment, such as the extent of multitasking problem (γ) and the discount rate (δ), may govern the firm's choice of job design. First and foremost, it is important to note that the relationship between these parameters and the optimal job design depends on the type(s) of incentives (i.e., explicit and/or implicit) that are in place. This is particularly relevant for the comparative statics with respect to δ. When only implicit incentives are feasible, team accountability is more likely for firms with higher δ. In contrast, when both implicit and explicit contracts are in place, team accountability becomes more likely for firms *either* with sufficiently low *or* with sufficiently high δ. However, the comparative statics with respect to γ is relatively simple. For a given δ, team accountability is more likely when multitasking problem is more severe (i.e., firms with high γ).

It might be difficult to obtain the appropriate empirical measures of γ and δ in a given industry. Also, in many cases the job design may be an artifact of the underlying production technology, rather than a choice available to the firm. However, the results of this model can be put to test in the context of certain industries where these measures are perhaps easier to obtain. The mutual funds industry may be one such candidate. Indeed, as discussed in the introduction of this article, mutual funds often classify themselves as "co-managed" and/or "team managed" funds where a group of employees are jointly responsible for the performance of a set of funds (Massa, 2008). One may also use a fund's liquidation probability as a measure of δ (Getmansky et al., 2004). However, finding an empirical measure of γ is more challenging. Information on the types of investments the fund is used for may be indicative of the extend of the multitasking its managers are exposed to. For example, a fund that is primarily invested in government bonds and treasury bills faces lower risks compared to a fund that is entirely invested in the stock market. One may argue that the manager of the latter fund faces a higher multitasking problem because she is not only responsible for increasing the returns of the investment but also have to pay close attention to the risks the fund is bearing.

The key results discussed in this article also shed light on the relative profitability of the individual and team-managed funds (Prather and Middleton, 2002; Massa, 2008). Consider the basic model when all incentives are implicit. Proposition 1 suggests that firms with higher δ are more likely to opt for team accountability. In other words, the firms that adopt team accountability are also the firms who can offer stronger implicit incentives, and therefore,

earn higher profits. An empirical investigation of the profitability of the individual and team-managed funds that ignores this "endogeneity" issue is likely to overestimate the gains from team accountability.

5.3. **Concluding remarks.** In many industries, firms often adopt team accountability even when individual accountability remains a technologically viable option. While incentives in teams is well-studied in the contract theory literature, there has been little research on the endogenous formation of team accountability. Only recently, some authors have argued how team accountability may emerge as the optimal job design in the face of a multitasking problem (Corts, 2007). This article contributes to this nascent literature on endogenizing team accountability by focusing on a multitasking environment where the firm relies on implicit contracts (i.e., bonus payments, as is the case, for example, in the mutual fund industry). In the presence of implicit contracts, team accountability involves an interesting trade-off: it alleviates the multitasking problem but weakens the implicit incentives. The contribution of this article is to formalize this trade-off and to draw out its implications on the firms' optimal job design policy.

The key result is that the optimal job design follows a cut-off rule. Only the firms with high enough reputation concerns (i.e., discount factor) opt for team accountability. The more acute is the multitasking problem the more likely it is that the firm would opt for team. However, when in addition to implicit contracts, explicit pay-per-performance contracts are also feasible, the cut-off rule stated above is no longer optimal. In such a scenario, firms with both sufficiently high and sufficiently low reputation concerns opt for team while firms with moderate reputation concerns opt for individual accountability.

Overcoming the multitasking problem need not be the only driver of a firm's job design decision. For example, team accountability may emerge to manipulate career concerns of the agents by obscuring their individual contributions to the project's overall performance (Massa et al., 2008). Teams may also originate from the need to facilitate cooperation within organization (Shaw and Schneier, 1995). However, the results highlighted in this article attempt to extend our understanding of how job design interacts with implicit contracts, and how firms may profit from adopting team accountability in a multitasking environment when they must rely implicit incentives.

Appendix

Proof of Proposition 1. The proof is given by the following steps.

Step 1. We first show that for $r \in [\phi(1+\gamma)/2, \phi\gamma]$, $\pi_*^I(r)$ and $\pi_*^T(r)$ cannot intersect. To prove this fact we proceed as follows: If π_*^I intersects π_*^T at a value of r in $[\phi(1+\gamma)/2, \phi\gamma]$, π_*^I must intersect from above. This is because $\left|\partial\pi_*^I/\partial r\right| > \left|\partial\pi_*^T/\partial r\right|$ for $r \in [\phi(1+\gamma)/2, \phi\gamma]$. But $\pi_*^I(\phi\gamma) > \pi_*^T(\phi\gamma) = 0$. Therefore, π_*^I cannot intersect π_*^T when $\phi(1+\gamma)/2 < r < \phi\gamma$.

Step 2. For $r \in [\phi\gamma/(1+\gamma), \phi(1+\gamma)/2]$, $\pi_*^I(r)$ and $\pi_*^T(r)$ must intersect at an unique point. To see this, note that for all $r \in [\phi\gamma/(1+\gamma), \phi(1+\gamma)/2]$, $\pi_*^I(r) = \phi^2(1+\gamma)^2/\left(1+\gamma^2\right)$. But $\partial\pi_*^T/\partial r < 0$ for $r \in [\phi\gamma/(1+\gamma), \phi(1+\gamma)/2]$ and $\pi_*^T(\phi(1+\gamma)/2) = \phi^2\left(1-\gamma^{-2}\right) < \phi^2(1+\gamma)^2/\left(1+\gamma^2\right) < 2\phi^2 = \pi_*^T(\phi\gamma/(1+\gamma))$. So, by Mean Value Theorem, there must exist a value of $r \in [\phi\gamma/(1+\gamma), \phi(1+\gamma)/2]$, say r^*, such that $\pi_*^T(r^*) = \pi_*^I(r^*) = \phi^2(1+\gamma)^2/\left(1+\gamma^2\right)$. Finally, r^* is unique as π_*^T is monotone for $r \in [\phi\gamma/(1+\gamma), \phi(1+\gamma)/2]$. ■

Proof of Corollary 1. As shown in the proof of Proposition 1, r^* solves $2r^*K(r^*)/\gamma^2 = \phi^2(1+\gamma)^2/\left(1+\gamma^2\right)$. This equation has two solution for r. Using the fact that $r^* < \phi\gamma/(\gamma+1)$, the only admissible solution is $r^* = \gamma\phi(1+\gamma)^2/4\left(1+\gamma^2\right)$. Observe that $\partial r^*/\partial\gamma = \phi\left(1+\gamma\left(4+2\gamma+\gamma^2\right)\right)/4\left(1+\gamma^2\right)^2 > 0$. ■

Proof of Proposition 2. The proof is similar in spirit to the proof of Proposition 1, and it is given by the following steps.

Step 1. We first show that $\forall r \in [\phi(1+\gamma)/2, \phi\gamma]$, $\hat{\pi}_*^I(r)$ and $\hat{\pi}_*^T(r)$ can intersect at most once. To prove this fact we proceed as follows: For $r \in [\phi(1+\gamma)/2, \phi\gamma]$ denote $\Delta(r) = \hat{\pi}_*^T - \hat{\pi}_*^I$. Thus, if $\hat{\pi}_*^I(r)$ and $\hat{\pi}_*^T(r)$ intersect for any value of r, say $\hat{r}$, $\Delta(\hat{r}) = 0$. Now, $\Delta'(r) = -2(2r + \phi\gamma(\gamma - 1))/\left(\gamma^2 + \gamma^4\right) < 0$. Thus, there cannot exist more than one value of r such that $\Delta(r) = 0$.

Step 2. Because $\Delta'(r) < 0$, and $\phi\gamma > \phi(1+\gamma)/2$, we need to consider three cases: (i) $\Delta(\phi\gamma) > 0$ ($\Rightarrow \Delta(\phi(1+\gamma)/2) > 0$), (ii) $\Delta(\phi\gamma) < 0$, $\Delta(\phi(1+\gamma)/2) > 0$, and (iii) $\Delta(\phi(1+\gamma)/2) < 0$ ($\Rightarrow \Delta(\phi\gamma) > 0$). The rest of the proof characterizes the nature of intersection of $\hat{\pi}_*^I(r)$ and $\hat{\pi}_*^T(r)$ in each of these three cases.

Step 3. If $\Delta(\phi\gamma) > 0$ (which is the case if γ is sufficiently large) $\Delta(r) > 0$ for all $r \in [\phi(1+\gamma)/2, \phi\gamma]$. In this case $\hat{\pi}_*^T(r) > \hat{\pi}_*^I(r)$ $\forall r$. To see this, note that $\forall r \in (0, \phi(1+\gamma)/2]$, $\hat{\pi}_*^I(r) = \hat{\pi}_*^I(\phi(1+\gamma)/2) < \hat{\pi}_*^T(r)$ (where the last inequality follows from the fact that $\hat{\pi}_*^T(r)$ is a (weakly) decreasing function in r, and $\Delta(\phi(1+\gamma)/2) > 0 \Leftrightarrow \hat{\pi}_*^T(\phi(1+\gamma)/2) > \hat{\pi}_*^I(\phi(1+\gamma)/2)$). Similarly, $\forall r \in (\phi\gamma, \infty)$, $\hat{\pi}_*^T(r) = \hat{\pi}_*^T(\phi\gamma) > \hat{\pi}_*^I(r)$ (where the last inequality follows from the fact that $\hat{\pi}_*^I(r)$ is a (weakly) decreasing function in r, and $\Delta(\phi\gamma) > 0 \Leftrightarrow \hat{\pi}_*^T(\phi\gamma) > \hat{\pi}_*^I(\phi\gamma)$).

Step 4. If $\Delta(\phi\gamma) < 0$ but $\Delta(\phi(1+\gamma)/2) > 0$, then $\hat{\pi}_*^I(r)$ and $\hat{\pi}_*^T(r)$ intersect at exactly two points. By Mean Value Theorem, there exists an value of r, say $r_1 \in [\phi(1+\gamma)/2, \phi\gamma]$ such that $\Delta(r_1)$. Also, for the argument discussed in Step 3 above, there cannot exist any value of $r < \phi(1+\gamma)/2$ such that $\Delta(r) = 0$. However, there must exist another value of $r \in (\phi\gamma, \infty)$, say r_2, such that $\Delta(r_2) = 0$. The argument is as follows: $\forall r \in (\phi\gamma, \infty)$, $\hat{\pi}_*^T(r) = \phi^2$. But $\hat{\pi}_*^I(\phi\gamma) > \phi^2 = \hat{\pi}_*^T(\phi\gamma)$ (because we start with the premise that $\Delta(\phi\gamma) < 0$) and $\hat{\pi}_*^I(\phi(1+\gamma)) = \phi^2(1+\gamma)^2/2\left(1+\gamma^2\right) < \phi^2 = \hat{\pi}_*^T(\phi(1+\gamma))$. As $\hat{\pi}_*^I$ is continuous and monotone, by Mean Value Theorem, there must exist a unique value of r, say r_2, such that $\hat{\pi}_*^I(r_2) = \phi^2 = \hat{\pi}_*^T(r_2)$.

Step 5. Finally, consider the case where $\Delta(\phi(1+\gamma)/2) < 0$. Because $\Delta'(r) < 0$ $\forall r \in [\phi(1+\gamma)/2, \phi\gamma]$, there cannot exist any value of $r \in [\phi(1+\gamma)/2, \phi\gamma]$ such that $\Delta(r) = 0$. However, there must exists a value of $r \in (0, \phi(1+\gamma)/2)$, say r_1, such that $\Delta(r_1) = 0$. The argument is as follows: For $r \leq \phi\gamma/(1+\gamma)$, $\hat{\pi}_*^T(r) = 2\phi^2 > \phi^2(1+\gamma)^2/\left(1+\gamma^2\right) = \hat{\pi}_*^I(r)$, and by assumption, $\hat{\pi}_*^T(\phi(1+\gamma)/2) < \hat{\pi}_*^I(\phi(1+\gamma)/2) = \phi^2(1+\gamma)^2/\left(1+\gamma^2\right)$. As $\hat{\pi}_*^T(r)$ is continuous and monotonically decreasing, by Mean Value Theorem, there exists a unique value of r, say r_1, such that $\Delta(r_1) = 0$. Also, by the argument discussed in Step 4, there must exists a unique value of $r \in (\phi\gamma, \infty)$, say r_2, such that $\Delta(r_2) = 0$. This observation completes the proof. ■

Proof of Corollary 2. The proof is given in the following steps.

Step 1. *(comparative statics for r_1)* Recall from the proof of Proposition 2, that if $r_1 < \phi(1+\gamma)/2$, r_1 solves

$$\phi^2(1+\gamma)^2/\left(1+\gamma^2\right) = \phi^2 + r_1 K(r_1)/\gamma^2, \tag{13}$$

whereas if $r_1 \geq \phi(1+\gamma)/2$, r_1 solves

$$\phi^2 + 2r_1(\phi\gamma - r)/\gamma^2 = \left(\phi^2(1+\gamma)^2 + 4\phi(1+\gamma)r - 4r^2\right)/2\left(1+\gamma^2\right). \tag{14}$$

If $r_1 < \phi(1+\gamma)/2$, then $\hat{\pi}_*^T(\phi(1+\gamma)/2) < \hat{\pi}_*^I(\phi(1+\gamma)/2)$. This holds only if $\gamma < 4.015\,4$. From equation (13) one obtains $r_1 = 2\phi \times (\gamma^2/(\gamma^2+1)) \times ((\sqrt{2}+1)/(3+2\sqrt{2}-\gamma))$ (this is the only root of equation (13) in the relevant interval of values of r, i.e., in $[\phi\gamma/(\gamma +$

$1), \phi(\gamma+1)/2])$. Now, from direct inspection of r_1, it follows that r_1 is an increasing function of γ in the interval $(1, 4.0154)$.

If $r_1 > \phi(1+\gamma)/2$, from equation (14) one obtains $r_1 = \frac{1}{2}(\sqrt{2}-1)\phi\gamma(\gamma-1)$ (this is the only positive root of equation (14)). Now, $\partial r_1/\partial\gamma = \frac{1}{2}(\sqrt{2}-1)\phi(2\gamma-1) > 0$.

Step 2. *(comparative statics for r_2)* Recall from the proof of Proposition 2, that r_2 solves

$$\phi^2 = \left(\phi^2(1+\gamma)^2 + 4\phi(1+\gamma)r_2 - 4r_2^2\right)/2(1+\gamma^2). \tag{15}$$

The only positive root of equation (15) is $r_2 = \frac{1}{2}\phi(1+\sqrt{\gamma})^2$. Thus, $\partial r_2/\partial\gamma = \frac{1}{2}\phi(1+1/\sqrt{\gamma}) > 0$.

Step 3. *(Upper threshold for γ)* Define $\overline{\gamma}$ as the value of γ for which $r_1 = \phi\overline{\gamma}$. Now, for all $r \neq r_1$, $\pi_*^T > \pi_*^I$. To see this, note the following: for $r > r_1$, $\pi_*^T > \pi_*^I$ as π_*^I is decreasing in r for $r \in (\phi(1+\overline{\gamma})/2, \phi(1+\overline{\gamma}))$ but, by definition of r_1, for all $r > r_1 = \phi\overline{\gamma}$, $\pi_*^T(r) = \pi_*^T(r_1) = \pi_*^I(r_1)$ (note that this implies $r_1 = r_2 = \phi\overline{\gamma}$). Also, for $r < r_1$, $\pi_*^T > \pi_*^I$. The argument is as follows. Because $\pi_*^T(\phi\overline{\gamma}) = \pi_*^I(\phi\overline{\gamma})$, and for all $r \in (\phi(1+\overline{\gamma})/2, \phi\overline{\gamma})$, $\pi_*^{T\prime}(r) < \pi_*^{I\prime}(r)$ (see step 1 of the previous proof), $\pi_*^T(\phi(1+\overline{\gamma})/2) > \pi_*^I(\phi(1+\overline{\gamma})/2)$. Now, for all $r < \phi(1+\overline{\gamma})/2$, $\pi_*^T(r) > \pi_*^T(\phi(1+\overline{\gamma})/2) > \pi_*^I(\phi(1+\overline{\gamma})/2) = \pi_*^T(r)$. Now, because $r_1 > \phi(1+\gamma)/2$, for $\gamma = \overline{\gamma}$, r_1 must solve (14). But such an r_1 is increasing in γ (by step 2). So, for all $\gamma > \overline{\gamma}$, $r_1 > \phi\overline{\gamma}$, which is inadmissible by definition of r_1. Thus, $\pi_*^T > \pi_*^I$ for all r.

Step 4. *(Lower threshold for γ)* Define $\underline{\gamma}$ as the value of γ for which $r_1 = \phi(1+\underline{\gamma})/2$, or $\underline{\gamma} = 4.0154$. For $\gamma > \underline{\gamma}$ (and $\gamma < \overline{\gamma}$), r_1 must solve equation (14) (see Step 1 of this proof). Now, for $\gamma \in (\underline{\gamma}, \overline{\gamma})$, r_1 is given by the solution to equation (14) and r_2 is given by the solution to equation (15). Therefore, $r_2 - r_1 = \frac{1}{2}(\sqrt{2}-1)\phi\gamma(\gamma-1) - \frac{1}{2}\phi(1+\sqrt{\gamma})^2$.

Step 5. Finally, compute $\partial(r_2-r_1)/\partial\gamma = \frac{1}{2}(1/\sqrt{\gamma} + 2\gamma - \sqrt{2}(2\gamma-1))$. Observe that $\partial(r_2-r_1)/\partial\gamma < 0$ for $\gamma = \underline{\gamma} = 4.0154$, and $\partial^2(r_2-r_1)/\partial\gamma^2 < 0$. Therefore, for all $\gamma > \underline{\gamma}$, $\partial(r_2-r_1)/\partial\gamma < 0$. ■

Proof of Proposition 3. This proof closely follows the proof of Proposition 1. So, for the sake of brevity, we omit some of the details that are already discussed in the proof of Proposition 1, and highlight the key difference between this case and the proof of Proposition 1.

The key difference lies in the agents' (IC) constraints. With substitutability between efforts, one obtains the following:

$$(IC_A^I) \qquad \begin{cases} e_1 = \frac{\beta_A(1-\theta\gamma)}{1-\theta^2}, & e_2 = \frac{\beta_A(\gamma-\theta)}{1-\theta^2} & if\ \theta < 1/\gamma \\ e_1 = 0 & e_2 = \gamma\beta_A & if\ \theta \geq 1/\gamma \end{cases}$$

(the IC_B^I is obtained from IC_A^I by substituting β_A by β_B, e_1 by e_3 and e_2 by e_4), and

$$(IC_A^T) \qquad \begin{cases} e_1 = 0, & e_4 = \gamma\beta_{A2} & if\ \beta_{A1} < \gamma\theta\beta_{A2} \\ e_1 = \frac{\beta_{A1}-\theta\gamma\beta_{A2}}{1-\theta^2}, & e_4 = \frac{\gamma\beta_{A2}-\theta\beta_{A1}}{1-\theta^2} & if\ \gamma\theta\beta_{A2} < \beta_{A1} < \frac{\gamma}{\theta}\beta_{A2} \\ e_1 = \beta_{A1}, & e_4 = 0 & if\ \beta_{A1} > \frac{\gamma}{\theta}\beta_{A2} \end{cases}$$

(the IC_B^T is obtained from IC_A^T by substituting β_{A1} by β_{B2}, β_{A2} by β_{B1}, e_1 by e_3 and e_4 by e_2). Given this, by following the same steps as in Section 3, one obtains the firms' optimal profit functions.

Under individual accountability, the firm's optimal profit function is as follows. For $\theta < 1/\gamma$,

$$\pi_*^I(r) = \begin{cases} \phi^2\xi(\gamma+1)\eta & if \quad r \leq \phi\xi/2 \\ 4r(\phi - r(\theta+1) + \gamma\phi)\eta & if \quad \phi\xi/2 < r \leq \phi\xi \\ 0 & if \quad r > \phi\xi \end{cases},$$

where $\xi = (\gamma+1)/(\theta+1)$ and $\eta = (1-\theta)/(\gamma^2 - 2\theta\gamma + 1)$. For $\theta \geq 1/\gamma$,

$$\pi_*^I(r) = \begin{cases} \phi^2 & if \quad r \leq \gamma\phi/2 \\ 4r\left(\gamma\phi - r\right)/\gamma^2 & if \quad \gamma\phi/2 < r \leq \gamma\phi \\ 0 & if \quad r > \gamma\phi \end{cases} . \tag{16}$$

In both cases, $\pi_*^I(r)$ is a continuous and decreasing function of r.

Under team accountability, the firm's optimal profit function is as follows. Let $\sigma = \left(2\theta\gamma + \gamma^2 + 1\right)(1-\theta)/(\theta+1)$. For $\sigma < \gamma^2$,

$$\pi_*^T(r) = \begin{cases} 2\phi^2/(\theta+1) & if \quad r \leq \gamma\phi/((\theta+1)(\gamma+1)) \\ r(\rho + (\rho^2+\vartheta)^{1/2})/\gamma^2 & if \quad \gamma\phi/((\theta+1)(\gamma+1)) < r \leq r_0 \\ \phi^2 & if \quad r_0 < r \leq \gamma\phi/2 \\ 4r\left(\gamma\phi - r\right)/\gamma^2 & if \quad \gamma\phi/2 < r \leq \gamma\phi \\ 0 & if \quad r > \gamma\phi \end{cases} , \tag{17}$$

where $\rho = 2\gamma\phi(\gamma+1) - 2r\left(2\theta\gamma + \gamma^2 + 1\right)$, $\vartheta = (2\gamma\phi(\gamma-1))^2(1-\theta)/(\theta+1)$ and $r_0 = \gamma\phi/(2(\gamma+1-\sigma^{1/2}))$. For $\sigma > \gamma^2$,

$$\pi_*^T(r) = \begin{cases} 2\phi^2/(\theta+1) & if \quad r \leq \gamma\phi/[(\theta+1)(\gamma+1)] \\ r(\rho + [\rho^2+\vartheta]^{1/2})/\gamma^2 & if \quad \gamma\phi/[(\theta+1)(\gamma+1)] < r \leq r_1 \\ 4r\left(\gamma\phi - r\right)/\gamma^2 & if \quad r_1 < r \leq \gamma\phi \\ 0 & if \quad r > \gamma\phi \end{cases} ,$$

where $r_1 = \phi(\gamma + 2\theta\gamma + \gamma^2 - \chi^{1/2})/(2(2\theta+\gamma))$ and $\chi = 2\gamma\theta(\theta+\gamma-1)\left(2\theta\gamma+\gamma^2+1\right)/(1+\theta)$. In both cases, $\pi_*^T(r)$ is a continuous and decreasing function of r. The reminder of the proof is given in the following steps.

Step 1. We first show that for $\theta \geq 1/\gamma$, $\pi_*^I(r) \leq \pi_*^T(r)$. Note that $\theta > 1/\gamma$ implies that $(1+\theta)/(1-\theta) > \left(2\theta\gamma + \gamma^2 + 1\right)/\gamma^2$, which is equivalent to $\sigma < \gamma^2$. Thus one has to compare $\pi_*^I(r)$ as given in (16) with $\pi_*^T(r)$ as given in (17). For $r > \gamma\phi/2$, $\pi_*^I(r) = \pi_*^T(r)$. For $r \leq \gamma\phi/2$, $\pi_*^T(r) \geq \phi^2$, since $\pi_*^T(r)$ is decreasing in r and $\pi_*^T(\gamma\phi/2) = \phi^2$. Thus, for $r \leq \gamma\phi/2$, $\pi_*^T(r) \geq \phi^2 = \pi_*^I(r)$.

Step 2. We next show that for $\theta < 1/\gamma$, $\pi_*^T(r)$ and $\pi_*^I(r)$ must intersect at a unique point for $r \in [0, \max\{\gamma\phi, \phi\xi\}]$. First note that when $\theta < 1/\gamma$, $\pi_*^T(0) = 2\phi^2/(\theta+1) > \phi^2\xi(\gamma+1)\eta = \pi_*^I(0)$. Also note that when $\theta < 1/\gamma$, $\gamma < \xi$, implying that $\gamma\phi < \phi\xi$. Thus, $\pi_*^I(\gamma\phi) > 0 = \pi_*^T(\gamma\phi)$. So, by Mean Value Theorem, there must exist a value of $r \in [0, \phi\xi]$, say $\widehat{r}$, such that $\pi_*^T(\widehat{r}) = \pi_*^I(\widehat{r})$. Furthermore, independent of whether $\sigma < \gamma^2$ or $\sigma > \gamma^2$, when $\theta < 1/\gamma$, $\pi_*^T(\phi\xi/2) < \pi_*^I(\phi\xi/2)$. Hence, $\widehat{r} \in (0, \phi\xi/2)$. In $(0, \phi\xi/2)$, $\pi_*^I(r)$ is constant and $\pi_*^T(r)$ is either constant or decreasing. Moreover, $\forall\ r \in (0, \phi\xi/2)$ such that $\partial\pi_*^T(r)/\partial r = 0$, $\pi_*^T(r) \neq \pi_*^T(r)$. Thus, $\pi_*^T(r)$ and $\pi_*^I(r)$ intersect only once in $(0, \phi\xi/2)$. Finally, note that $\left|\partial\pi_*^T(r)/\partial r\right| \geq \left|\partial\pi_*^I(r)/\partial r\right|$ $\forall\ r \in (\phi\xi/2, \phi\xi)$, implying that $\pi_*^T(r)$ and $\pi_*^I(r)$ do not intersect for $r \in (\phi\xi/2, \phi\xi)$. ■

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