Accounting Conservatism and Relational Contracting[1]

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Abstract

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Conservatism is a pervasive feature of accounting but has also been the subject of much criticism – by regulators, standard setters, and academics. In this paper, we develop a positive role for accounting conservatism in fostering relational contracts between two agents in a two-period model of moral hazard. Building on Kreps (1996), the principal in our model designs a conservative measurement system and optimal contracts to create multiple equilibria that foster a team culture. Conservatism increases each agent's stake in the future of the relationship when it matters most – when it is going badly. This makes staying in the relationship worthwhile for the agents, even if they plan to play a low payoff equilibrium in the second period to punish first-period free-riding. In turn, this allows the principal to use lower-powered (and less costly) team incentives rather than higher-powered individual incentives in the first period of the relationship. In contrast, deferred compensation increases each agent's stake in the future of the relationship when it is going well, making it a less natural tool to use in fostering relationships in our model.

1 Introduction

Conservatism is a pervasive feature of accounting (Basu, 1997) but has also been the subject of much criticism – by regulators, standard setters, and academics. For example, Paton and Paton (1952) write, "[i]s there anything essentially conservative ... in a valuation scheme that merely shifts income from one period to the next."

While much of the recent literature on accounting conservatism emphasizes its role in capital markets, conservatism pre-dates capital markets. For example, Francesco di Marco of Prato's accounts of 1406 contained a write-down of inventories (Vance, 1943). The early roots of accounting conservatism seem to be in balance sheet valuations designed with the mindset that "all assets will be converted into cash and should not be stated at an amount greater than their cash equivalent" (Hoffman, 1962 as cited in Mueller, 1964). As Watts (2003) notes, to the extent that payouts to some stakeholders are tied to balance sheet valuations, conservatism protects other stakeholders who do not receive those payouts. Viewed in this way, the dividend problem (protecting creditors) and the earnings-based compensation problem (protecting non-manager stakeholders) are essentially the same (Watts, 2003, p. 213). Conservatism fosters trust and long-term relationships that would be jeopardized by more aggressive measurement.

In this paper, we develop a positive role for accounting conservatism in fostering relational (self-enforcing) contracts between two agents in a principal-multiagent model of moral hazard. Conservatism increases the agents' stake in the future of the relationship when it matters most – when it is going badly. The role of conservatism is to foster a punishment equilibrium in the second period the agents can use in response to first-period free-riding. Conservatism makes the second-period punishment equilibrium individually rational and increases the payoff associated with second-period equilibrium play, creating a large enough payoff gap between equilibrium and punishment play that free-riding in the first period can be deterred. Accounting conservatism creates room for a team culture when the culture would otherwise be an individualistic one.

It is tempting to view conservatism as a form of deferred compensation. However, deferred compensation makes the value of retaining the relationship high when it is going well rather than when it is going badly. One might also expect optimal conservatism to be maximal conservatism. However, maximal conservatism turns the relationship into the equivalent of two one-shot encounters.

We study a two-period model with two agents who work closely enough with each other to observe each other's actions, as in Arya, Fellingham, and Glover (1997). It is the team setting and its free-riding problem that gives rise to a demand for conservatism in fostering relational contracting between the team members. We see team production and its free-riding problem as generic features of firms (Alchian and Demsetz, 1972) and hope our analysis will spur a new direction of inquiry related to accounting and corporate culture.

Arya, Fellingham, and Glover (1997) and Che and Yoo (2001) show that aggregating individual performance measures and using only the aggregate in rewarding agents can be optimal in fostering team incentives. In this paper, we show that the (partial) *intertemporal* aggregation of good news introduced by accounting conservatism can also play a role in fostering team incentives.

We study deferred compensation as an alternative mechanism of fostering team incentives. In contrast to conservatism, deferred compensation makes the punishment equilibrium credible when the relationship is going well rather than when it is going badly, which makes it less well suited as a tool to use in fostering relationships. In our model, conservatism dominates deferred compensation.

We also study an overlapping generations model in which agents play as junior managers for one period and then as senior managers before they retire. The senior is offered individual (Nash) incentives, while the junior is offered team incentives. Again, conservatism is used to foster a more team-based and long-run oriented culture over an individualistic and myopic one. Junior managers work in order to avoid being punished once they become senior managers by the new junior. In our overlapping generations model, leaders model the behavior they would like their subordinates to adopt.

The link we develop between accounting measurement and corporate culture builds on Kreps (1996), which treats corporate culture as the coordination on the play of one of multiple equilibria. In our model, accounting conservatism promotes a team culture over an individualistic one by creating a credible threat (an additional equilibrium that satisfies the agents' individual rationality constraints) that can be used to punish free-riding. Conservative measurement also increases the payoff associated with the good (working) equilibrium. The key is that conservatism increases the gap in the agents' payoffs from maintaining the existing relationship (with both agents working) vs. playing a punishment equilibrium in the second period. The multiple equilibria in the agents' second-period subgame creates the team-oriented equilibrium in the agents' overall two-period game. The overall game also has multiple equilibria, including an individualistic one that has both agents shirking in the first period. In their overall game, we appeal to Pareto optimality as a way of predicting the agents' choice to coordinate on a particular equilibrium that has them working in both periods. While the payoffs in Kreps (1996) are exogenous, the principal in our model designs an optimal measurement system and contracts to create those payoffs and multiple equilibria. The role of accounting measurement and contracting is to set the stage for the emergence of team-oriented play, but the agents themselves have to coordinate on that play instead of on other (Pareto-dominated) equilibria.

Over the past 20 or so years, information economics has been used to study accounting conservatism.[1] Closest to our paper is the line of research that studies the role of conservatism in labor contracts subject to moral hazard. In Kwon et al. (2001), accounting aggregates underlying continuously-distributed transactions into binary accounting reports. Conservative measurement imposes a tougher threshold for reporting a high accounting report. Whether conservatism reduces or increases the cost of providing incentives depends on the likelihood

[1] The role of accounting conservatism in equity valuation has also been the subject of extensive theoretical and empirical research in accounting. See, for example, Zhang (2000), Penman and Zhang (2002), and Penman and Zhang (2018).

ratios induced by the accounting cutoff and whether the agent is risk averse or risk neutral (and subject to bankruptcy constraints). Gigler and Hemmer (2001) study the interaction between mandatory and voluntary financial reporting (communication of the agent's post-decision private information) in a model of moral hazard when the mandatory accounting report that disciplines the agent's communication is liberal, unbiased, or conservative.

The models of accounting conservatism in information economics have largely employed single-period settings. A recent exception is Glover and Lin (2018), which studies the intertemporal properties of conservatism with a focus on managerial incentives. In their model, a conservative bias is a possible understatement of performance that will be reversed in a second period. Bias distorts the information content of the performance measures, so is costly (relative to unbiased accounting) if different agents are employed in each period. However, if the first-period agent is retained in the second period, the reversal of any understated first-period performance in the second period allows conservative accounting to replicate the performance of unbiased accounting. In our paper, the principal strictly prefers conservative to unbiased measurement because of its role in fostering relational incentives between agents.

Another line of research studies the role of conservatism in debt contracting. Gigler et al. (2009) and Li (2013) build on and challenge arguments made by Basu (1997) and Watts (2003) about the role of conservatism in debt contracting and the relationship between accounting earnings and stock prices (the role of accounting in providing information to equity markets rather than merely capturing information already impounded in stock prices). Bigus and Hakenes (2017) study the role of conservatism in enhancing relationship lending. In their model, early lending is essentially a loss a leader bank offers to obtain an information advantage over other lenders, thereby generating future rents when the borrower raises additional debt. The role of conservatism in their paper is to create opacity in the financial statements provided to non-relationship banks rather than to facilitate a relational contract.

The remainder of the paper is organized into 5 sections. Section 2 presents a motivating example. Sections 3 and 4 present the model and main results, respectively. Section 5 studies an overlapping generation model, and Section 6 concludes.

2 Motivating example

Consider a principal who contracts with two agents, A and B. All three are risk-neutral. The contracting relationship is subject to moral hazard. The principal would like to motivate each agent to choose high effort rather than low effort. However, effort cannot be contracted on and is personally costly to each agent. High effort has a personal cost to each agent of 1, while low effort has a personal cost to each agent of 0. The agents work in close proximity to each other and observe each other's effort, while the principal observes only a team performance measure, high (H) or low (L), which is verifiable and, hence, can be contracted on.

The contracting relationship is at-will. At the start of each period, the principal offers each agent a contract that specifies a bonus rate (and possibly a salary) for that period. To be attractive, the contract must provide each agent with a utility of at least his reservation utility of 0 in each period. At the end of the first period, each agent is free to quit or continue the relationship into the second period.

The probability of a high realization of the performance measure depends on the agents' actions. If they both choose high effort, the probability is $p_H = 0.5$; if one chooses high effort and the other low effort, the probability is $p = 0.2$; if they both choose low effort, the probability is $p_L = 0$.

One possibility is for the principal to ignore the agents' potentially repeated encounter and to offer each a bonus of $\frac{1}{p_H - p} = 10/3$ for a success. Each agent obtains $5/3 - 1$ by working and $2/3 - 0$ by shirking if the other agent is working, so $(work, work)$ is a Nash equilibrium of the one-shot game. This contract also provides each agent with a utility level greater than his reservation level in each period.

Individual (Nash) Incentives

A\B	1	0
1	$\frac{2}{3}, \frac{2}{3}$	$\frac{-1}{3}, \frac{2}{3}$
0	$\frac{2}{3}, \frac{-1}{3}$	0, 0

The first (second) entry in each cell is the A's (B's) payoff.

Can the principal do better? Notice that the bonus of 10/3 creates two Nash equilibria. If both are working, neither wants to unilaterally deviate to shirking. If both are shirking, neither wants to unilaterally deviate to working: $0 > 2/3 - 1$. This can be used to the principal's advantage. In the first period, she can offer the agents a smaller bonus – one that ensures that $(work, work)$ is only Pareto optimal rather than a Nash equilibrium. That is, the first-period bonus can be lowered to $\frac{1}{p_H - p_L} = 2$ using a team (or group) incentive constraint of $(0.5)2 - 1 \geq (0)2 - 0$. Under team incentives in the first period, each agent has incentives to free-ride and obtain $(0.2)2 - 0 = 0.4$ by shirking when the other is working. However, the threat of switching from the $(work, work)$ to the $(shirk, shirk)$ equilibrium in the second period provides a punishment that more than offsets this benefit from free-riding: $(5/3 - 1) - 0 = 2/3 > 0.4$. This is the main idea in Arya, Fellingham, and Glover (1997).

Team Incentives

A\B	1	0
1	$0, 0$	$\frac{-3}{5}, \frac{2}{5}$
0	$\frac{2}{5}, \frac{-3}{5}$	0, 0

The first (second) entry in each cell is the A's (B's) payoff.

Now, suppose that each agent's per-period reservation utility is not 0 but instead 0.3. In this case, the $(shirk, shirk)$ equilibrium no longer satisfies the agents' individual rationality constraints so is no longer a credible threat in the second period (in the Individual Incentives

Game). While a (costly) salary could be used to restore the $(shirk, shirk)$ equilibrium, the principal has no incentive to offer such a salary at the start of period two, since the agents' first-period actions are sunk. This is where conservatism comes in.

A conservative bias can be thought of as an accounting system that imposes higher verification standards on the reporting of early good news than on the reporting of early bad news. Hence, a conservative system has the tendency to delay the recognition of good performance, co-mingling current-period true good performance with true good performance from previous periods whose recognition was delayed because of the asymmetric verification standard. To capture this idea simply, suppose that true first-period high performance is delayed and reported in period two with probability c, while true first-period low performance is always reported early. Continue to ignore the cost of producing information, taking c as given for now.

Suppose $c = 0.4$. This value of c restores the (*shirk, shirk*) equilibrium when the first-period performance report is low. Suppose one agent free-rides in the first period and performance is measured as low. Using Bayes Rule, the agents will believe there is a $0.4 * 0.2/(0.4 * 0.2 + 0.8) \approx 9\%$ chance that there will be a reversal of understated first-period performance in period two, or an expected bonus of $0.09 * 10/3 = 0.3$. This makes the $(shirk, shirk)$ equilibrium individually rational in period two. The extra expected bonus triggered by the bias reversal does not depend on the agents' second-period actions. So, the difference the agents receive from playing (*work, work*) vs. (*shirk, shirk*) in period two continues to be 2/3. The key role of conservatism is in maintaining this gap in payoffs.[2] However, this punishment of 2/3 comes into play only when first-period performance is measured as low, which occurs with probability $(1 - p) + p * c = 0.8 + 0.2 * 0.4 = 0.88$ under first-period free-riding. The expected second-period punishment of $0.88 * 2/3 \approx 0.59$ is greater than the first-period benefit of free-riding of 0.4.

[2]If quitting is a punishment the agents can impose on each other (e.g., quitting shuts down the firm) instead of as a constraint on payoffs (as we model it), then conservatism plays the same role – to increase the gap in payoffs between equilibrium and punishment play, so that lower-powered team incentives can be employed in the first period. We study this alternative interpretation of quitting in Section 4.4.

If $c = 1$, then high first-period performance is always recognized in the second period. Since the principal cannot disentangle first- and second-period high performance, the principal would have to pay a bonus of 10/3 for all high performance. That is, $c = 1$ effectively turns the relationship into the equivalent of two one-shot encounters in which individual incentives are provided to the agents. However, there exist a region of c values, starting from $c = 0.4$, which enable the principal to foster team incentives. At $c = 0.6$, the second-period bonus rate of 10/3 times 0.6 is equal to the optimal first-period team incentive bonus rate of 2 (that is, $\frac{1}{p_H - p_L}$). c above 0.6 is costly to the principal, since she is effectively replacing low-powered team incentives with high-powered individual incentives.

Relaxing our assumption of period-by-period at-will contracts, consider the alternative of using deferred compensation and unbiased accounting ($c = 0$). If an agent free-rides in the first period, there is a $p = 0.2$ chance he will be awarded a (team-based incentive) bonus of 2 in the first period. Suppose this bonus is not paid out in the first period but instead deferred to the second period. The deferred bonus is more than enough to make the (*shirk, shirk*) equilibrium individually rational when first-period performance is high. However, the probability that first-period performance will be high under free-riding is too small to make the punishment effective in deterring free-riding: $0.2 * 2/3 < 0.4$.

3 Model

A principal contracts with two ex ante identical agents, $i = A, B$, over two periods. The agents simultaneously provide personally costly efforts/actions $a_t^i = \{0, 1\}$ in period $t = 1, 2$. Let $\mathbf{a}_t = (a_t^A, a_t^B)$. In a joint and stochastic fashion, these efforts result in concurrent team output, $x_t \in \{L, H\}$ with $L = 0 < H$. The production technology is stationary. Let

$$\begin{aligned} p_H \equiv Pr(x_t = H \mid \mathbf{a}_t = (1,1)) \quad &> \quad p \equiv Pr(x_t = H \mid a_t^A \neq a_t^B) \\ &> \quad p_L \equiv Pr(x_t = H \mid \mathbf{a}_t = (0,0)). \end{aligned}$$

The agents' efforts exhibit a productive complementarity, defined as $p_H - p \geq p - p_L$. The productive complementarity implies that agent i's marginal productivity is higher if the other agent is also working than shirking. Cross-functional teams and, more generally, modern manufacturing environments are often described as having such productive complementarities.[3] We normalize the probability $p_L = 0$ to economize on notation and simplify the analysis.

Neither the principal nor the agents observe the team output x_t. Instead, they observe a verifiable accounting report y_t. The first-period accounting report y_1 is subject to mis-measurement. If $x_1 = L$, $y_1 = H$ with probability b. If $x_1 = H$, $y_1 = L$ with probability c. Any mis-measurement in the first period will reverse in the second period. That is, the sum of the two periodic accounting reports equals the total output.

$$x_1 + x_2 = y_1 + y_2.$$

b and c capture the imprecision and bias of the accounting system. To focus on the role of accounting conservatism, we set $b = 0$ throughout the remainder of the paper but allow for $c > 0$.[4] We ignore the cost associated with decreasing c. That is, we ignore the cost of producing information.

All players are risk-neutral. For simplicity, we also ignore the time value of money in our two-period game. The agents are protected by limited liability. That is, the wage agent i receives in period t must satisfy $w_t^i \geq 0$. Agent i's payoff in period t is $w_t^i - a_t^i$. Over the two periods, the principal's payoff is $x_1 + x_2 - \sum_i (w_1^i + w_2^i)$. We assume the agents' efforts are important enough that the principal finds it optimal to elicit high effort from each agent in each period.

The contracting relationship is at-will. At the beginning of each period, the principal offers each agent a short-term linear contract consisting of a fixed salary α_t^i and a bonus

[3] See, for example, Milgrom and Roberts (1995).

[4] Setting $b = 0$ is without loss of generality in our model because the principal would optimally set $b = 0$ upfront when both b and c are later treated as control variables.

component β_t^i that is linear in the reported performance y_t. That is, agent i's total compensation in period t is $w_t^i = \alpha_t^i + \beta_t^i \times y_t$. In our setting, it is without loss of generality to confine attention to linear symmetric contracts, i.e., $\alpha_t^i = \alpha_t, \beta_t^i = \beta_t$ for $\forall i$. (We will drop the agent superscript i whenever it does not cause confusion.) However, the restriction to short-term contracts is a critical one (intended to make the co-mingling of performance across periods more meaningful), which we relax in Section 4.5.

An agent can earn a reservation utility $\bar{U}$ in each period if he accepts employment elsewhere. Therefore, at the beginning of the first period, the contract must provide each agent with a total payoff across the two periods of at least $2\bar{U}$ on the equilibrium path. That is, playing (*work, work*) in both periods must satisfy the following individual rationality constraint:

$$\alpha_1 + p_H(1-c)\beta_1 H + \alpha_2 + (p_H + p_H c)\beta_2 H - 2 \geq 2\bar{U}. \qquad \text{(Overall IR)}$$

The left-hand side (LHS) is the payoff each agent receives on the equilibrium path if the agents play *(work, work)* in both periods. The reason c shows up in the calculation is that, under conservative accounting ($c > 0$), a high output in the first period $x_1 = H$ is understated as $y_1 = L$ with probability c and rewarded under bonus rate β_2 (instead of β_1) when the accrual reverses in the second period.

The second period is the last period of the game. Therefore, the seond-period contract must ensure that the equilibrium action profile $\mathbf{a}_2 = (1, 1)$ is incentive compatible, i.e.,

$$p_H \, \beta_2 \, H - 1 \geq p \, \beta_2 \, H, \qquad \text{(Period-2 Nash)}$$

and individually rational following any accounting report y_1:

$$\alpha_2 + \Pr\left(x_1 - y_1 = H | y_1, \mathbf{a}_1 = (1,1)\right) \beta_2 \, H + p_H \, \beta_2 \, H - 1 \geq \bar{U}, \, \forall y_1. \qquad \text{(Period-2 IR)}$$

The term $\Pr(x_1 - y_1 = H | y_1, \mathbf{a}_1 = (1,1))\, H$ in the constraint above captures the expected reversal of under-reported first period performance that is carried forward to (reversed in) the second period.

Team incentives in the first period

The agents work closely enough that they observe each other's actions, while the principal observes only the verifiable accounting report y_t, which imperfectly captures the agents' actions. The repeated relationship creates room for the two agents to mutually monitor each other. The demand for mutual monitoring using implicit/relational contracts in our model is similar to Arya, Fellingham, and Glover (1997) and Che and Yoo (2001). The principal can relax the agents' Nash incentive constraints, which are based on the performance measures only, by instead using those performance measures to set the stage for the agents to mutually monitor each other.[5] In order for the agents to have incentives to mutually monitor each other, the principal needs to ensure that, from the agents perspective, both working is preferred by the agents to both shirking in the first period. That is,

$$p_H(1-c)\beta_1 H + cp_H\beta_2^* H - 1 \geq p_L(1-c)\beta_1 H + cp_L\beta_2^* H. \qquad \text{(Pareto Dominance)}$$

The LHS is each agent's payoff when they play $\mathbf{a}_1 = (1,1)$. The accounting system reports $y_1 = H$ with probability $p_H(1-c)$, in which case the two agents receives a bonus according to the first period bonus rate β_1. With probability $p_H c$, the two agents produce a high output x_1 in the first period, but accounting conservatism causes it to be reported as $y_1 = L$. In this case, the understated report reverses in period two, and the two agents are rewarded according to the bonus rate β_2^* that will be paid out in period 2. We use the notation β_2^* to emphasize that, in designing the period-one contract, the principal takes the optimal

[5]Following the literature on mutual monitoring in repeated relationships, we assume communication from the agents to the principal is blocked. The verifiable accounting report y_t in each period is the only report on which the agents' wage payments can depend. This rules out the kind of ratting mechanisms studied in the implementation literature (e.g., Ma, 1988), which is intentional but can also be viewed as an avenue for future research. We are not aware of any studies on how tacit side-contracts in multi-period models constrain such ratting/peer evaluation mechanisms.

contract/solution to the Period-2 Program (α_2^* and β_2^*) as given.

The principal also needs to provide a means for the agents to punish each other in the second period if either agent unilaterally deviates from the (*work, work*) equilibrium play in the first period. Without loss of generality, we confine attention to a grim trigger strategy that, following any unilateral deviation, calls for the harshest punishment that can be sustained as a stage-game equilibrium in the second/last stage. Denote by $U_t(\mathbf{a}_t, \mathbf{a}_{t-1}, y_{t-1}) = E[w_i|\mathbf{a}_t, \mathbf{a}_{t-1}, y_{t-1}] - a_t^i$ agent i's payoff received in period t when the current-period action profile is $\mathbf{a}_t$ and agents' observed history is $(\mathbf{a}_{t-1}, y_{t-1})$. Let $\mathbf{a}_2^P$ be the punishment agent j imposes on agent i in the second period for unilaterally shirking in the first period (i.e., free-riding on agent j's effort). The following condition ensures that the second-period punishment triggered by first period free-riding is greater than the benefit of free-riding:

$$\Pr\left(U_2(\mathbf{a}_2^P, a_1^i \neq a_1^j) \geq \bar{U}\right)\left(U_2(\mathbf{a}_2 = (1,1)) - U_2(\mathbf{a}_2^P)\right) \geq (p-p_H)(1-c)\beta_1 H + (p-p_H)c\beta_2^* H + 1. \tag{Monitoring}$$

The LHS is the expected cost/punishment triggered by first period free-riding. We multiple by the probability $\Pr\left(U_2(\mathbf{a}_2^P, a_1^i \neq a_1^j) \geq \bar{U}\right)$ in calculating the expected punishment that agent j can impose on agent i in the second period. This is because the punishment $\mathbf{a}_2^P$ can only be used if it is individually rational for the agents to continue the relationship even if they will play the punishment equilibrium. Therefore, in making his free-riding decision ex ante at $t = 1$, each agent understands that the subsequent punishment threat will not be credible ex post if $U_2(\mathbf{a}_2^P, a_1^i \neq a_1^j) < \bar{U}$, in which case he will not be punished. The uncertainty about whether $U_2(\mathbf{a}_2^P, a_1^i \neq a_1^j)$ will be greater than $\bar{U}$ arises because the first-period accounting report y_1 is unknown when an agent chooses his first period effort. Once y_1 is realized at the end of period one, $U_2(\mathbf{a}_2, \mathbf{a}_1, y_1)$ is fully determined. Therefore,

$$\Pr\left(U_2(\mathbf{a}_2^P, a_1^i \neq a_1^j) \geq \bar{U}\right) = \sum_{y_1 \in \{H,L\}} \Pr(y_1 | a_1^i \neq a_1^j, c) \text{ s.t. } U_2(\mathbf{a}_2^P, a_1^i \neq a_1^j, y_1) \geq \bar{U}. \tag{1}$$

The notation $\Pr(y_1|a_1^i \neq a_1^j, c)$ emphasizes its dependence on accounting conservatism c.

We will characterize the grim-trigger punishment $\mathbf{a}_2^P$ shortly. The RHS of (Monitoring) is agent i's first-period benefit from unilateral deviating from (*work, work*). Because of the inter-temporal connection between the performance measures introduced by accounting conservatism, each agent's first-period effort affects payoffs in *both* periods. Therefore, each agent evaluates the payoffs from both periods in determining the benefit of his first-period free-riding.

As we will show in the next section, it is sometimes infeasible to provide team incentives. In this case, the principal must instead ensure that $\mathbf{a}_1 = (1, 1)$ is a stage-game equilibrium in the first period:

$$(p_H - p)(1 - c)\beta_1 H + (p_H - p)c\,\beta_2^* H \geq 1. \qquad \text{(Period-1 Nash)}$$

4 Analysis

4.1 Principal's problem

We solve for the optimal contracts using backward induction. Since the contracting relationship ends after two periods, the second-period contracting problem is essentially a one-shot moral hazard problem. We summarize the principal's second-period optimization problem (for any reported performance y_1) as follows.

Period-2 Program

$$\min_{\beta_2,\alpha_2} \quad \alpha_2 + \beta_2 \, E(y_2|y_1)$$

$s.t.$

Period-2 Nash

Period-2 IR (2)

$\alpha_2, \beta_2 \geq 0.$

If the (Period-2 IR) Constraint does not bind, the solution to Period-2 Program is $\alpha_2^* = 0$ and $\beta_2^* = \frac{1}{(pH-p)H}$ for any y_1. Even if (Period-2 IR) binds, there is a solution with $\alpha_2 = 0$ since the agent is risk neutral and the principal can substitute α_2 with β_2. (To avoid the trivial case that the role of compensation is only to satisfy the agents' individual rationality constraints, we assume throughout the paper that the second-period individual rationality constraint is satisfied if both agents work: $\bar{U} \leq \frac{p}{p_H - p}$.) Taking the solution to the program above as given, the principal then designs the first-period salary α_1 and bonus rate β_1. In designing the first-period contract, the principal can choose to provide individual incentives (as in the second period) or instead to provide team incentives, i.e., to provide the agents with incentives to mutually monitor each other's effort. The level of accounting conservatism $c \in [0, 1]$ is also a choice variable for the principal. The principal's first move is to publicly (and irrevocably) choose the measurement system. Importantly, the agents know which c the principal has installed before they decide whether or not to accept their compensation contracts.

As we discussed in the model setup, providing team incentives requires the optimal contract to ensure the agents (i) are better off both working than both shirking in the first period and (ii) have a means of punishing each other in the second period if one of the agents shirks in the first period. The following lemma characterizes the punishment.

Lemma 1 *The punishment has the agents playing the stage-game equilibrium (*shirk, shirk*) in the second period whenever it is individually rational, i.e.,* $\mathbf{a}_2^P = (0, 0)$*.*

Intuitively, the assumed productive complementarity $p_H - p > p - p_L$ ensures that neither agent has an incentive to unilaterally deviate from (*shirk, shirk*) in the second period, since his marginal productivity is lower when the other agent is shirking than when he is working. Therefore, playing (*shirk, shirk*) is a stage-game equilibrium in the second period and can be used as a punishment if it satisfies individual rationality. In the event that the $(shirk, shirk)$ punishment equilibrium is not credible, we assume the agents will play the $(work, work)$ equilibrium. That is, rather than quit, the agents will continue as part of the team as long as there is some equilibrium that satisfies their individual rationality constraints. Here, we take the typical view that individual rationality is a constraint on payoffs rather than modeling quitting as a means of punishment. (We will study quitting as a punishment in Section 4.4.)

Using the arguments developed so far, we can summarize the principal's first-period program as the following integer program. It is an integer program because the variable T takes a value of either zero or one: $T = 1$ (or $T = 0$) means that the principal designs the contract to provide team incentives (or individual incentives) in the first period. In either case, the contract needs to ensure that, on the equilibrium path, the agents' payoffs are at least as high as their reservation utilities.

Period-1 Program

$$\min_{\alpha_1,\beta_1,c\in[0,1],T=(0,1)} \quad \alpha_1 + p_H(1-c)\beta_1 + p_H\, c\, \beta_2^*$$

s.t.

$(1-T)\times$ Period-1 Nash

$T\times$ Pareto Dominance

$T\times$ Monitoring

Overall IR

$\alpha_1, \beta_1 \geq 0$

$0 \leq c \leq 1.$

4.2 Optimal contract

The provision of team incentives depends on whether the agents can credibly punish each other in order to deter free-riding behavior. We start by analyzing a benchmark case in which the agents' reservation utility $\bar{U}$ is 0. In this case, the (*shirk, shirk*) punishment is always individually rational, and there is no beneficial role for accounting conservatism.

Proposition 1 *For $\bar{U} = 0$, an optimal contract provides team incentives ($T = 1$), sets accounting conservatism $c^* = 0$, and sets $\alpha_1^* = \alpha_2^* = 0$, $\beta_1^* = \frac{1}{(p_H - p_L)H}$, and $\beta_2^* = \frac{1}{(p_H - p)H}$.*

In contrast, if $\bar{U} > 0$ and $c = 0$, (*shirk, shirk*) is no longer individually rational when $y_1 = H$ is reported.[6] However, by setting the level of conservatism $c > 0$ sufficiently large, the (*shirk, shirk*) punishment can be made individually rational when $y_1 = L$. A large c ensures that, when $y_1 = L$, there is a large enough probability that $x_1 = H$ was under-reported as $y_1 = L$ and will be reversed/corrected in the next period. For the $\bar{U} > 0$ case,

[6] It is easy to verify that following $y_1 = H$, $U_2\left(\mathbf{a}_2^P = (0,0), a_1^i \neq a_1^j, y_1 = h\right) = p_L \beta_2^* H = 0 < \bar{U}$.

the (Monitoring) Constraint can be restated as:

$$\Pr(y_1 = L|a_1^i \neq a_1^j)\left(\frac{p_H - p_L}{p_H - p} - 1\right) \geq (p - p_H)(1-c)\beta_1 H + (p - p_H)c\beta_2^* H + 1, \tag{Mutual Monitoring}$$

and

$$\Pr(x_1 = H|a_1^i \neq a_1^j, y_1 = L) \times \beta_2^* H + p_L \beta_2^* H \geq \bar{U}. \tag{Credible Punishment}$$

The next lemma summarizes the optimal contract for the $\bar{U} > 0$ case, taking the degree of accounting conservatism as given. The results highlight the non-monotonic relationship between conservatism and its ability to foster team incentives. The analysis provides a foundation to use in deriving the optimal level of conservatism. (We assume $\bar{U} > 0$ throughout the remainder of the paper.)

Lemma 2 *Fixing an exogenous level of conservatism c, the optimal contract is* ($\alpha_1 = \alpha_2^* = 0$ *and* $\beta_2^* = \frac{1}{(pH-p)H}$ *in all cases):*

i. For $c < \underline{c} = \frac{(1-p)[\bar{U}(p_H-p)-p_L]}{p(p\bar{U}-p_H\bar{U}+p_L+1)}$*, the optimal contract provides individual incentives* $T = 0$*, and* $\beta_1 = \beta_2^*$*. The expected payments* $\pi = 2\frac{2p_H}{p_H-p}$*.*

ii. For $\underline{c} \leq c \leq \bar{c} = \frac{p_H-p}{p_H-p_L}$*, the optimal contract provides team incentives* $T = 1$ *and* $\beta_1 = \frac{-cp_H+cp_L-p+p_H}{(c-1)H(p-p_H)(p_H-p_L)} < \beta_2^*$*. The expected payments* $\pi = 2(\frac{p_H}{p_H-p_L} + \frac{p_H}{p_H-p})$*, and* $\frac{d\beta_1}{dc} < 0$*.*

iii. For $\bar{c} < c \leq 1$*, the optimal contract provides team incentives* $T = 1$ *and* $\beta_1 = 0$*. The expected payments* $\frac{d\pi}{dc} > 0$ *and equals the cost of individual incentives* $2\frac{2p_H}{p_H-p}$ *at* $c = 1$*.*

On the equilibrium path, the agents' risk-neutrality makes it costless for the principal to replace positive salaries with higher bonuses. The only potential role for a salary is in the second period to ensure that (*shirk*, *shirk*) is credible, i.e., that (*shirk*, *shirk*) satisfies

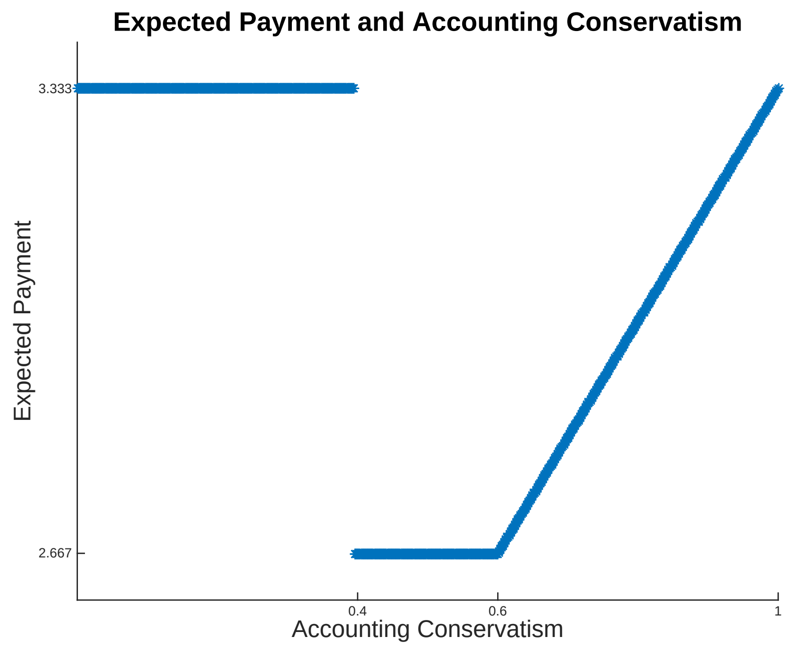
(Period-2 IR). Since, the second-period salary is set after the agents have taken their first-period actions, the principal has no incentive to offer a fixed salary to ensure $(shirk, shirk)$ is credible in the second period.

Part (i) of the lemma shows that team incentives are infeasible when the level of conservatism is low, i.e., $c < \underline{c}$. As accounting conservatism increases from zero, the performance measures y_1 and y_2 reported in each of the two periods become increasingly intertwined because of the mis-measurement and its subsequent reversal. Conservatism changes the informativeness of the period-one accounting report in a way that, upon observing a low report $y_1 = L$, each agent understands that a low report may be due to understated first-period high performance that will be reserved in the second period. The higher the level of conservatism c, the higher the likelihood $\Pr(x_1 = H | y_1 = L, a_1^i \neq a_1^j)$ the agents will receive a windfall carried over from period one to period two, making it more likely for the punishment strategy $\mathbf{a}_2^P = (0, 0)$ to be individually rational.

As c increases to $\underline{c} = \frac{(1-p)[\bar{U}(p_H-p)-p_L]}{p(p\bar{U}-p_H\bar{U}+p_L+1)}$, the expected windfall carried over from period one is just high enough to satisfy (Credible Punishment) as an equality. For $c > \underline{c}$, playing the punishment strategy $\mathbf{a}_2^P = (0, 0)$ upon observing $y_1 = L$ and $a_1^i \neq a_1^j$ will continue to be individually rational because higher conservatism c shifts even more payments from period one to period two. Since the agents are now equipped with a credible punishment, the principal can design the period-one bonus rate β_1 to ensure the agents are better off both working than both shirking in the first period, i.e., the principal can provide team incentives in the first period. The optimal $\beta_1 = \frac{-cp_H+cp_L-p+p_H}{(c-1)H(p-p_H)(p_H-p_L)}$ is chosen to ensure (Pareto Dominance) holds as an equality. Since the agents' period-one efforts $\mathbf{a}_1 = (1, 1)$ are rewarded in period two more often for a higher c, the principal can reduce the bonus rate β_1 to save unnecessary rents, i.e., $\frac{d}{dc}\beta_1 < 0$. At $c = \bar{c}$, the principal optimally sets $\beta_1 = 0$.

It may be tempting to think that a higher level of conservatism always increase contracting efficiency. However, Part (iii) of Lemma 2 shows that this is not the case. In fact, contracting efficiency strictly decreases as conservatism is increased above $\bar{c}$. Shifting high performance from period one to period two can be costly because the second-period bonus rate β_2 is higher than the first-period bonus rate β_1 (see Part (ii)). When the level of conservatism is low (i.e., $c < \bar{c}$), the principal can react to a higher c by lowering β_1 and avoid an overall increase in compensation cost. However, β_1 is already reduced to zero at $c = \bar{c}$. Hence, even greater conservatism would increase the compensation cost because more first-period performance would be paid out at the higher bonus rate β_2 (instead of β_1). In other words, increasing the level of conservatism beyond $\bar{c}$ essentially substitutes team incentives with individual incentives by moving performance from period one to period two and paying the agents based on the individual incentive rate β_2. At the maximum level of conservatism $c = 1$, all performance generated in the first period is deferred and paid out at the individual incentive rate β_2, making the incentive scheme equivalent to relying solely on individual incentives. Figure 1 illustrates Lemma 2 via our earlier numerical example with $p_H = 0.5, p = 0.2, p_L = 0$, and $\bar{U} = 0.3$.

Figure 1: Contracting Efficiency and Accounting Conservatism
($p_H = 0.5, p = 0.2, p_L = 0, \bar{U} = 0.3$)



Lemma 2 and Figure 1 demonstrate the non-monotonicity of conservatism on contracting efficiency, measured by the expected compensation cost. The following proposition endogenizes the optimal level of conservatism c^*.

Proposition 2 *The optimal level of conservatism c^* is:*

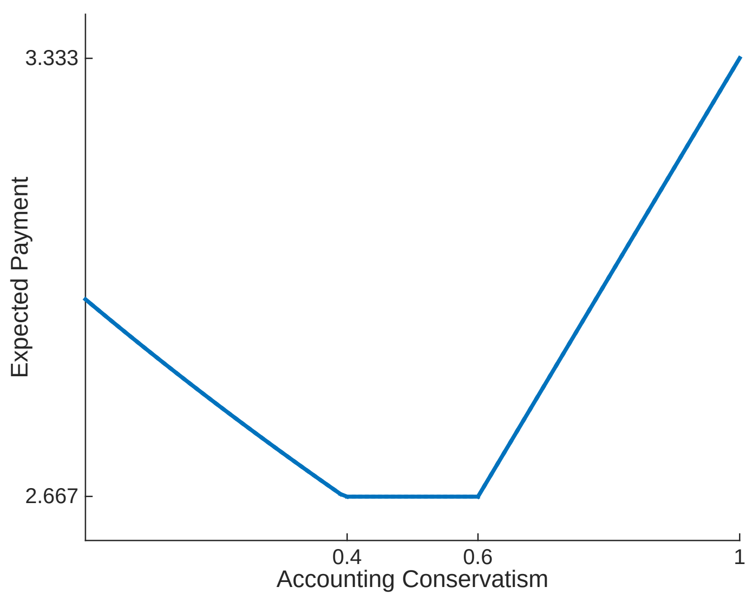
- *For $\bar{U} \in (0, \frac{p}{2(p_H - p)}]$, c^* is any $c \in [\underline{c}, \bar{c}]$ where $0 < \underline{c} < \bar{c} < 1$ are characterized in Lemma 2. The bonus rates are $\beta_1^* = \frac{-cp_H + cp_L - p + p_H}{(c-1)H(p-p_H)(p_H-p_L)} < \beta_2^* = \frac{1}{(pH-p)H}$.*
- *For $\bar{U} > \frac{p}{2(p_H-p)}$, $c^* = \frac{p_H(1+2\bar{U})-2p(1+\bar{U})}{p_H}$ increases in $\bar{U}$ and equals one when $\bar{U} = \frac{p}{p_H-p}$. The bonus rates are $\beta_1^* = 0 < \beta_2^* = \frac{1}{(pH-p)H}$.*

Part (i) of the proposition shows that, as long as $\bar{U}$ is not too high, there is a range of accounting conservatism the principal can choose to ensure that the agents receive team incentives in period one and individual incentives in period two. In particular, the principal can reward the agents only in the second period by setting $\beta_1 = 0$ and $c = \bar{c}$. The role of $c > 0$ is to satisfy (Credible Punishment). The solution is non-unique because there is a range of c values that The key constraint in determining the cost of first-period incentives is (Pareto Dominance).

The payoffs the agents receive (on the equilibrium path) under the contract characterized in Part (i) will be less than their reservation utility when $\bar{U}$ is sufficiently high. This is the case summarized in Part (ii) of the proposition. To satisfy (Overall IR), the principal must either start using a first-period salary (while maintaining c at $\bar{c}$) or further increase the level of conservatism to defer more performance to the second period in which the higher bonus rate β_2 is employed. We have chosen to characterize the second solution.

We have assumed that the principal offers a linear contract (α_1, β_1) and (α_2, β_2) sequentially at the beginning of each period. Now, suppose the principal can commit to both periods' linear contracts (α_1, β_1) and (α_2, β_2) upfront (just after c is installed). Building on the same numerical example used in Figure 1, the following figure demonstrates how the compensation cost varies as a function of the level conservatism in this case. Comparing Figures 1 and 2, one can see that the ability to commit to a second period contract (α_2, β_2) upfront allows the principal to always provide some team incentives, even for $c < \underline{c}$. The reason is that the principal can commit to a positive fixed salary $\alpha_2 > 0$ to raise the agents' payoff in the second period, making the (*shirk, shirk*) a credible punishment strategy. Nonetheless, both the range of optimal conservatism C^* and the optimal contracting cost are not affected by the principal's ability to commit to the short-term contract (α_t, β_t) upfront. In other words, the commitment of the short-term contract does not affect the optimal contract or the demand for conservatism.

Figure 2: Contracting Efficiency With Commitment ($p_H = 0.5, p = 0.2, p_L = 0, \bar{U} = 0.3$)



4.3 Conservatism vs. deferred compensation

In our model, conservatism fosters team incentives by *partially* deferring first-period high performance to the second period (and aggregating it with second-period high performance). One may wonder if our conservatism-based mechanism can be replicated by a deferred compensation scheme (under unbiased measurement) in which the bonus for a high period-one performance $\beta_1 \times H$ is not paid out until period two.

Similar to a conservative accounting system, deferred compensation also shifts period-one pay to the second period, which has the potential benefit of making $\mathbf{a}_2 = (0, 0)$ a credible punishment. However, the two schemes are qualitatively different in terms of the conditions under which each agent expects the deferral of payments. Under conservatism, the agents expect that some payments will be deferred to period two when the reported period-one performance is low, i.e., $y_1 = L$. Under the deferred compensation scheme coupled with unbiased accounting, the agents receive payments deferred from period one only if $y_1 = H$ in the first period. This difference turns out to be important. We next show that an optimal conservatism-based scheme dominates any deferred compensation scheme in our model.

Proposition 3 *The principal strictly prefers optimal accounting conservatism and the related optimal contracts to a deferred compensation scheme coupled with unbiased accounting.*

To understand the difference between conservatism and deferred compensation, we can substitute an optimal solution $c^* = \bar{c}, \beta_1^* = 0$ and $\beta_2^* = \frac{1}{(p_H - p)H}$ from Proposition 2 and simplify (Mutual Monitoring) in the main model as

$$\Pr(y_1 = L | a_1^i \neq a_1^j) \left(\frac{p_H - p_L}{p_H - p} - 1 \right) \geq 1 - (p_H - p)\bar{c}\beta_2^* H, \qquad \text{(Conservative Scheme)}$$

where the left-hand side (right-hand side) is the cost (benefit) of free-riding.

If the principal instead relies on a deferred compensation scheme coupled with unbiased accounting (i.e., $c = 0$), she needs to ensure the following to provide the agents with incentives to mutually monitor each other in the first period:

$$\Pr(y_1 = H | a_1^i \neq a_1^j) \left(\frac{p_H - p_L}{p_H - p} - 1 \right) \geq 1 - (p_H - p)\beta_1^D H, \qquad \text{(Deferred Scheme)}$$

where $\beta_1^D \geq 0$ is the period-one bonus rate under the deferred compensation scheme.

To illustrate the intuition, fix $\beta_1^D = \frac{1}{p_H H}$ so that the benefit of free riding is the same under the conservatism and deferred compensation regimes. That is, the right-hand sides of (Conservative Scheme) and (Deferred Scheme) are the same for $\beta_1^D = \frac{1}{p_H H}$. Setting $\beta_1^D = \frac{1}{p_H H}$ also equates the expected compensation cost between the two compensation regimes.

Having fixed the benefit of free riding (and the cost of compensation), we can demonstrate the advantage of accounting conservatism over deferred compensation by comparing the expected punishment the agents can impose on each other. Under the conservatism regime, the (*shirk, shirk*) punishment strategy is credible only after $y_1 = L$, which occurs with probability $\Pr(y_1 = L | a_1^i \neq a_1^j) = 1 - p + p\bar{c}$. Under the deferred compensation scheme, the (*shirk, shirk*) punishment is credible when $y_1 = H$, which occurs with probability $\Pr(y_1 = H | a_1^i \neq a_1^j) = p$. Because the agents' joint production exhibits productive complementarity, i.e., $p < \frac{p_H + p_L}{2}$, the shirking agent is punished more often under the conservatism setup than under the deferred compensation scheme.

4.4 Punishing by quitting

So far, we have treated individual rationality as a constraint on payoffs rather than as an action. In this subsection, we study quitting as an action the agents can use to punish each other. If either agent quits at the end of the first period, both receive their reservation utilities in the second period. When the agents can punish each other by quitting, then the

(Mutual Monitoring) Constraint can be rewritten as follows:

$$p_H \beta_2^* H - 1 + p_H\, c\beta_2^* H - \bar{U} \geq (p - p_H)(1-c)\beta_1 H + 1. \qquad \text{(Monitor by Quit)}$$

The right-hand side is benefit from free-riding derived in period one, while the left-hand side is the punishment an agent can impose on a free-rider by quitting and, hence, terminating the game. The condition is equivalent to ensuring that the agents' equilibrium payoff across two periods $2U(1,1) = [p_H(1-c)\beta_1 H + p_H c\beta_2^* H - 1] + (p_H \beta_2^* H - 1)$ is greater than $p(1-c)\beta_1 H + \bar{U}$, which is the payoff he would receive from free-riding and triggering termination of the game.

The alternative formulation in (Monitor by Quit) does not affect the Period-2 Program characterized in the main model. However, we need to reformulate the principal's Period-1 Program as follows.

$$\min_{\alpha_1, \beta_1, c \in [0,1], T=(0,1)} \quad \alpha_1 + p_H(1-c)\beta_1 + p_H\, c\, \beta_2^*$$

s.t.

$(1-T) \times$ Period-1 Nash

$T \times$ Pareto Dominance

$T \times$ Monitor by Quit

Overall IR

$\alpha_1, \beta_1 \geq 0,\ 0 \leq c \leq 1.$

We also drop the (Credible Punishment) Constraint because quitting and receiving one's reservation utility is by definition individually rational. The following proposition summarizes the optimal solution to the reformulated program presented above.

Proposition 4 *If the agents can punish each other by quitting, the optimal contract specifies* $\beta_2^* = \frac{1}{(p_H - p)H}$ *and:*

- *For* $\bar{U} \in (0, \frac{p}{2(p_H - p)}]$, $\beta_1^* = \frac{c(p_L - p_H) - p + p_H}{(c-1)H(p - p_H)(p_H - p_L)}$ *and any* $c^* \in [c_1, \bar{c}]$ *is optimal, where* $c_1 = \max\{0, \frac{p_H^2 \bar{U} - p^2 - p p_H \bar{U}}{p p_H}\}$ *and* $\bar{c} = \frac{p_H - p}{p_H - p_L} < 1$.
- *For* $\bar{U} > \frac{p}{2(p_H - p)}$, $\beta_1^* = 0$ *and* $c^* = \frac{p_H(1+2\bar{U}) - 2p(1+\bar{U})}{p_H}$, *which is increasing in* $\bar{U}$ *and equals* 1 *when* $\bar{U} = \frac{p}{p_H - p}$.

Comparing Propositions 4 and 2, the expected compensation cost does not depend on whether the agents punish each other by quitting or by playing the stage-game equilibrium $(shirk, shirk)$. Whether the punishment is from $(shirk, shirk)$ or quitting, the role of conservatism is to create a sufficiently large gap between the equilibrium and punishment payoffs, so that free-riding can be prevented and team incentives can be offered in the first period.

4.5 Long-term contracts

The main takeaway of our paper is that the inter-temporal aggregation of good news introduced by accounting conservatism can foster long-term, team-oriented incentives. So far, we have confined attention to short-term linear contracts (α_t, β_t), which create an additional contracting friction by requiring the principal to reward all high performance equally and, in particular, by co-mingling first-period high performance that a conservative treatment deferred to the second period with actual second-period high performance. As we show in this subsection, if the principal can instead commit to a long-term contract, the first-best can be achieved. Nevertheless, conservatism continues to be part of the solution–in this case, the optimal solution is maximal conservatism ($c = 1$).

Denote by $\mathbf{L} = \{S, w_L, w_H, w_{2H}\}$ the long-term contract, where $S \geq 0$ is a fixed salary and the bonuses (w_L, w_H, w_{2H}) depend only on the total outcome $x_1 + x_2 = \{L, H, 2H\}$ accumulated across the two periods. We place no restriction on the form of this bonus (e.g., linearity). This long-term contract $\mathbf{L}$ is coupled with maximally conservative reporting $c = 1$. Given the long-term contract $\mathbf{L}$, the principal needs to ensure the following two conditions to motivate the agents to mutually monitor each other's effort in the first period:

$$U(\mathbf{a}_1 = (1,1), \mathbf{a}_2 = (1,1)) \geq U(\mathbf{a}_1 = (0,1), \mathbf{a}_2 = (0,0)), \qquad \text{(Mutual Monitoring LT)}$$

and

$$S + pp_L w_{2H} + [p(1-p_L) + (1-p)p_L]w_H + (1-p)(1-p_L) \geq \bar{U}. \quad \text{(Credible Punishment LT)}$$

(Mutual Monitoring LT) prevents the agent from unilaterally shirking in the first period and, hence, triggering the (*shirk, shirk*) punishment. (Credible Punishment LT) ensures that the punishment strategy is individually rational after observing $\mathbf{a}_1 = (0,1)$. The following program summarizes the principal's design of the optimal long-term contract $\mathbf{L}$:

$$\min_{S, w_L, w_H, w_{2H} \geq 0} S + p_H^2 w_{2H} + 2p_H(1-p_H)w_H + (1-p_H)^2 w_L.$$

s.t.

Mutual Monitoring LT

Credible Punishment LT (3)

Period-2 Nash

Overall IR

(Period-2 Nash) in the program above ensures that (*work, work*) is a stage-game equilibrium in the second period of the game if the agents played (*work, work*) in the first period of the game, and (Overall IR) ensures that agents earn at least their two-period reservation utilities $2\bar{U}$ on the equilibrium path. Both constraints are qualitatively similar to their counterparts in the main model, and, hence, are omitted for brevity. One difference between the short-term and long-term contracting settings is that the (*shirk, shirk*) equilibrium of the agents' second-period game is the unique equilibrium of the second-period game if they did not play (*work, work*) in the first period. So, the punishment here is not a choice to play the worst of multiple equilibria in the second-period game but rather to play the unique equilibrium that results from their diminished prospects of achieving high performance ($2H$) if (*work, work*) was not played in the first period.

Observation 1 *If the principal can commit to a long-term contract, it is optimal for the principal to set* $w_H = w_L = 0, w_{2H} = \frac{2}{p_H^2}, S = 2\bar{U}$*, and* $c = 1$*. The optimal long-term contract provides the principal with the first-best payoff.*

Here, conservatism plays a similar although not identical role to the role it played in our main model. Maximal conservatism ($c = 1$) is equivalent to measuring total performance (the sum of first- and second-period performance) only at the end of the game or "ship accounting." Under long-term contracting, the role of conservatism is solely in hiding first-period bad performance (L) from the agent. In our main model, the role of conservatism includes both affecting the agents' beliefs and shifting rents from the first to the second period to create multiple equilibria the agents can use to punish each other. Here, the second-period equilibrium depends on the first-period play but is unique.

We see the main model as the more natural one for studying conservatism because the co-mingling of performance across periods is the essential feature of conservatism we set out to study. Under long-term (unrestricted) contracting, there is only a benefit to increasing conservatism. Under short-term (linear) contracting, conservatism becomes costly above a threshold level. Our approach is also in keeping with the view that first-best solutions are best seen as benchmarks.

5 Overlapping generations model

Consider an overlapping generations model in which each agent works for two periods. An agent is a Junior in the first period of his employment and becomes a Senior in the second period in which a new Junior agent is hired. In each period, a Senior agent works with a

Junior agent. Given their effort choices (a_t^S, a_t^J) at time t, where the superscript S (J) stands for Senior (Junior), the team production technology is the same as in our main model:

$$\begin{aligned}\Pr(x_t = H|(a_t^S, a_t^J) = (1,1)) = p_H \quad &> \quad \Pr(x_t = H|a_t^S \neq a_t^J) = p \\ &> \quad \Pr(x_t = H|(a_t^S, a_t^J) = (0,0)) = p_L = 0.\end{aligned}$$

Each agent has a reservation utility of $\bar{U}$ in each period. The principal offers contracts $\alpha^J + \beta^J y_t$ to the Junior and $\alpha^S + \beta^S y_t$ to the Senior, where α is the fixed salary, β is the bonus rate, and y_t is the period t performance that the accounting system reports.

Each period, there is an agent in waiting (e.g., an apprentice) to become next period's Junior. The key assumption is that the apprentice observes the current players' efforts (a_t^S, a_t^J) and the reported performance y_t. The principal can potentially use this observability by the agent in waiting to offer a lower-powered team incentive β^J to the current Junior, since the agent in waiting may be able to punish the current Junior's shirking. However, the principal must use individual incentives to reward the current Senior, i.e., $\alpha^S = 0$ and $\beta^S = \frac{p_H}{(p_H - p)H(1-c)}$, since this period is the last period of play for the current Senior.

In each period, conservatism c shifts some of the current period's high performance to the next period but may also shift some of the previous period's high performance to the current period. Current period performance y_t depends on the current and previous period's output $(x_t, x_{t-1} \in \{0, H\})$ and the previous period's accounting report $y_{t-1} \in \{0, H, 2H\}$ as follows.

$$y_t = \max\{0, x_{t-1} - y_{t-1}\} \text{ if } x_t = 0,$$

and if $x_t = H$, then $y_t \in \{0, H, 2H\}$ and

$$y_t = \begin{cases} \max\{0, x_{t-1} - y_{t-1}\} & \text{with probability } c, \\ H + \max\{0, x_{t-1} - y_{t-1}\} & \text{with probability } 1 - c, \end{cases}$$

where $\max\{0, x_{t-1} - y_{t-1}\}$ is the performance understated in period $t-1$ and will be reserved in t.

Accounting conservatism $c > 0$ creates an inter-temporal relationship between the reported performances y_t. The ongoing impact of c quantitatively affects both the optimal bonus rates (β^J and β^S) and the optimal level of conservatism (the values of $\underline{c}$ and $\bar{c}$). Nevertheless, our previous results are qualitatively unchanged. We first present the optimal contracts under unbiased accounting $c = 0$ and then under conservatism $c > 0$ via a numerical example.

S\J	1	0
1	$\frac{2}{3}, 0$	$\frac{-1}{3}, \frac{2}{5}$
0	$\frac{2}{3}, \frac{-3}{5}$	$0, 0$

Table 1: $p_H = 0.5, p = 0.2, p_L = 0, c = 0$ (the optimal contract is $\beta^J = 2$ and $\beta^S = 10/3$.)
The first (second) entry in each cell is the Senior's (Junior's) payoff.

S\J	1	0
1	$\frac{2}{3} + \frac{16}{35}, 0$	$\frac{-1}{3} + \frac{16}{35}, \frac{2}{5}$
0	$\frac{2}{3} + \frac{16}{35}, \frac{-3}{5}$	$0 + \frac{16}{35}, 0$

Table 2: $p_H = 0.5, p = 0.2, p_L = 0, c = \bar{c} = 3/8$ (optimal contract: $\beta^J = 0$ and $\beta^S = \frac{16}{3}$.)

The games presented above assume that the previous generation of agents played ($work, shirk$) in the previous period, and the reported performance y_{t-1} was L. That is, the Senior in the current period t free-rode when he was the Junior in the previous period $t-1$. It is clear that, for $c = 0$ as shown in Table 1, it is not individually rational for the Senior to play the (*shirk, shirk*) punishment for any $\bar{U} > 0$. Without a credible punishment, the principal has to rely on providing individual incentives to both the Junior and Senior. Now assume accounting conservatism $c = 3/8$ (whose closed-form is characterized in Proposition 5). Given $y_{t-1} = L$ and free-riding in the period $t-1$, the probability that $x_{t-1} = H$ is $(1/5)(3/8)/[(1/5)(3/8) + (4/5)] = 3/35$. Since the Senior's bonus rate β^S is 16/3, the expected increase in period t payoffs to the Senior is $(3/35)(16/3) = 16/35$. As a result, setting conservatism $c = 3/8$ makes it plausible for the principal to provide Junior with a team incentive (and, hence, lower compensation cost) so long as the reservation utility $\bar{U} < 16/35$.

Given the productive complementarity, i.e., $p_H - p > p - p_L$, we know that (*shirk, shirk*) is a stage game equilibrium and can be used as a punishment as long as it is individually rational. If the agents play the $(shirk, shirk)$ punishment strategy, the entering Junior will *not* expect a reversal of good performance in the next period when he becomes the Senior, since $p_L = \Pr(x_t = H|shirk, shirk) = 0$. So, if (*shirk, shirk*) is to be used as an individually rational punishment, it cannot be played in two consecutive periods. That is, for a Junior to be willing to punish a Senior who misbehaved in the previous period, that Junior must expect that the corporate culture will return to the $(work, work)$ equilibrium once the required punishment has been imposed – a culture that punishes misbehavior but does not get stuck in a punishment mode. The reason that the usual grim trigger strategy is not employed seems to be a combination of the non-stationary nature of the game (in part, created by conservatism) and the individual rationality constraint. If we again allow for punishment by contract rejection (the potential Junior refuses to take the job), then the punishment is consistent with a grim trigger. In this case too, conservatism is needed to create a large enough gap in payoffs between the equilibrium and punishment play.

Accounting conservatism affects the agents' assessments of a likelihood of a reversal occurring. Denote by $\Pr(R|h_{t-1}, h_t)$ the likelihood of a reversal in $t+1$ given the observed history in periods $t-1$ and t, with $h_t = \{a_t^S, a_t^J, y_t\}$. These posterior assessments are important because they partially determine whether (*shirk, shirk*) satisfies the individual rational constraint. For instance, if a Junior free-rides in period t and observes $y_t = 2H$, he knows that $y_t = 2H$ already captures the high output from both periods t and $t-1$ and, therefore, rules out any potential reversal when he becomes a Senior in $t+1$. While calculating $\Pr(R|h_{t-1}, h_t)$ is straightforward when $y_t = 2H$, characterizing and comparing the agents' posterior beliefs under *all* possible histories is non-trivial. We use the following relation to discuss the intuition and defer a complete comparison to the appendix.

$$\begin{aligned}\Pr(\mathrm{R}|\mathbf{a}_{t-1} = 1, a_t^S \neq a_t^J, y_{t-1} = 2H, y_t = L) &> \Pr(\mathrm{R}|\mathbf{a}_{t-1} = 1, a_t^S \neq a_t^J, y_{t-1} = L, y_t = H) \\ &> \Pr(\mathrm{R}|\mathbf{a}_{t-1} = 1, a_t^S \neq a_t^J, y_{t-1} = H, y_t = H) > 0.\end{aligned}$$

That is, the shirking Junior is less likely to receive a reversal in $t+1$ if the observed performances (y_{t-1}, y_t) are (H, H) than if they are (L, H). Intuitively, the agents can receive a reversal after observing $(y_{t-1}, y_t) = (H, H)$ only if accounting conservatism has under-reported the underlying high outcome three periods in a row (for $t-2, t-1$ and t). However, if $(y_{t-1}, y_t) = (L, H)$, the agents can receive a reversal if the underlying high outcome is under-reported for two periods ($t-1$ and t), which is more likely to occur than misreporting thee periods in a row.

Accounting conservatism c introduces a more complex inter-temporal relationship (more complex histories) in the over-lapping generation setup than in the two-period setup we investigated in the main model. Nevertheless, the key idea that conservatism can foster team incentives continues to hold. The following proposition presents a sufficient condition for conservatism to foster team incentives in the overlapping generation model.

Proposition 5 *For* $0 < \bar{U} < \frac{p(p_H - p)^2}{p_H^2(p_H - 2p(p_H - p))}$, *it is optimal to set the level of conservatism* $c^* = \bar{c} = \frac{p_H - p}{2p_H - p}$, $\alpha^{J*} = \alpha^{S*} = \beta^{J*} = 0$, *and* $\beta^{S*} = \frac{1}{(p_H - p)(1-c)}$.

Note the close resemblance between the optimal contracts characterized in Proposition 5 and Proposition 2 in the main model. In both cases, the principal uses accounting conservatism to change the informativeness of the periodic performance measures y in order to foster long-run oriented team incentives.[7] Compared to $\beta_2^* = \frac{1}{(pH-p)H}$ in the two-period model, β^{S*} in Proposition 5 is scaled up by $\frac{1}{1-c}$ to incorporate the fact that there is no final period in the over-lapping generation model and, hence, the Senior will only be rewarded for the high outcome of his senior period with probability $1-c$. As in Proposition 2, there is a range of interior levels of conservatism c that are optimal in the overlapping generations model, over which one can increase c^* and lower β^{J*} (with $\beta^{J*} < \beta^{S*}$ for all c). In Proposition 5, we choose $c = \bar{c}$, the maximum level of conservatism, which sets $\beta^{J*} = 0$.

6 Conclusion

This paper explores the role of accounting conservatism in fostering relationship incentives. This, in turn, reduced the cost of providing explicit incentives. Conservatism in our model is bias followed by bias reversal, and an interior bias is always optimal. Either no bias or a maximal bias reduces the problem to a twofold repetition of a one-shot relationship in which the principal must provide the agents with high-powered individual rather than low-powered team incentives.

Our model is one of hidden actions rather than asymmetric information. We see asymmetric information (e.g., about the fit between the agent(s) and the firm and/or each other) as a natural next step to explore. Bias would presumably make assessing fit and deciding when to end vs. continue the relationship more difficult. This would introduce a cost of conservatism, which is absent from our model.

Partners in a relationship may be able to take actions to improve their fit (e.g., by acquiring skills that are valued by the other party). In a standard one-shot hold-up problem, partners underinvest in their relationships because the cost will be sunk and, hence, ignored when they bargain over the surplus created by their investments in the relationship. Relational contracting can mitigate this underinvestment problem. Agents can find it optimal to

[7] The sufficient condition $0 < \bar{U} < \frac{p(p_H-p)^2}{p_H^2(p_H-2p(p_H-p))}$ ensures that playing (*shirk, shikr*) is credible even when the reported the performance pairs are $(y_{t-1}, y_t) = (H, H)$.

make themselves vulnerable so that the gap between the existing and a new relationship is expanded, which increases the punishment the agents can impose on each other by terminating the relationship (Halac, 2015). Conservatism plays a similar role in our model. This increased penalty is valuable because it increases the agents' ability to enforce promises, which they will keep only if the punishment they will endure by separating is larger than the benefit of reneging on the promise. It is unclear whether a measurement bias is a natural substitute for or complement to such costly investments in relationships.

We studied the connection between conservatism and corporate culture. In particular, conservative measurements were used to foster a team-based and long-run oriented culture rather than individualistic and myopic culture. In general, the link between accounting and corporate culture seems an under-explored topic. A common criticism of accounting conservatism is that it reinforces short-termism, inhibiting managers from engaging in long-term investments with positive NPVs. However, conservatism treats investments that create certain (or near certain) future cash inflows differently from those that create uncertain ones, typically creating assets for the former but not the latter. Risky projects increase the probability that relationships will end, including bankruptcy. Does accounting conservatism play a beneficial role in fostering stability to enhance the value of the firm viewed as a nexus of relationships? Do firms for which stability plays a more crucial role (including but not limited to capital structure), employ greater accounting conservatism?

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Appendix

Proof of Lemma 1. Since period-2 is the last period of the game, we know that the optimal contract ensures that (Period-2 Nash) is satisfied as an equality. That is,

$$U_2(\mathbf{a}_2 = 1, 1)) = \frac{p_H}{p_H - p} - 1 = \frac{p}{p_H - p} = U_2(\mathbf{a}_2 = (0, 1)).$$

Similarly, we can express $U_2(\mathbf{a}_2 = (0,0)) = \frac{p_L}{p_H - p}$, and $U_2(\mathbf{a}_2 = (1,0)) = \frac{p}{p_H - p} - 1$. It is easy to verify that (*shirk, shirk*) is a punishment in that, for any $p_L < p$,

$$U_2(\mathbf{a}_2 = (0,0)) = \frac{p_L}{p_H - p} < \frac{p}{p_H - p} = U_2(\mathbf{a}_2 = (0,1)) \leq U_2(\mathbf{a}_2 = 1, 1)).$$

It remains to show that (*shirk, shirk*) is a stage-game equilibrium and hence self-enforcing.

$$\begin{aligned} U_2(\mathbf{a}_2 = (1,0)) - U_2(\mathbf{a}_2 = (0,0)) &= \frac{p}{p_H - p} - 1 - \frac{p_L}{p_H - p} \\ &= \frac{2p - (p_H + p_L)}{p_H - p} < 0, \end{aligned}$$

where the inequality follows from the productive complementarity $p_H - p > p - p_L$. ■

Proof of Proposition 1. For $\bar{U} = 0$, the first period free-rider can always be punished in the second period because the punishment (*shirk, shirk*) strategy satisfies IR and is a stage-game equilibrium (recall Lemma 1). Given the optimal contract in the second period $\alpha_2 = 0, \beta_2 = \frac{1}{(p_H - p)H}$ and $c = 0$, one can derive $\beta_1 = \frac{1}{(p_H - p_L)}$ by solving (Pareto Dominance) as a binding constraint. This is clearly an optimal contract because the contract only reimburse their effort cost in the first period. ■

Proof of Lemma 2. For Part (i), one can use Bayes' Rule to derive the left-hand side of (Credible Punishment) as follows

$$\left[\Pr(x_1 = H | a_1^i \neq a_1^j, y_1 = L) + p_L\right] \beta_2^* H = \left(\frac{pc}{pc + 1 - p} + p_L\right) \beta_2^* H.$$

Substituting $\beta_2^* = \frac{1}{(p_H-p)H}$, one can verify that $\left(\frac{pc}{pc+1-p} + p_L\right)\beta_2^* H$ equals $\bar{U}$ at $c = \underline{c} = \frac{(1-p)[\bar{U}(p_H-p)-p_L]}{p(p\bar{U}-p_H\bar{U}+p_L+1)}$. ($\underline{c} > 0$ is ensured under the maintaining assumption $\bar{U} \leq \frac{p}{p_H-p}$.) Since $\left(\frac{pc}{pc+1-p} + p_L\right)\beta_2^* H$ is monotonically increasing in the level of conservatism c, it follows that (Credible Punishment) is violated for any $c < \underline{c}$, making the punishment strategy $\mathbf{a}_2^p = (0,0)$ shown in Lemma 1 not a credible punishment. Without a credible punishment in the second period, the principal cannot implement team incentives in the first period. As a result, the principal offers the same individual incentive contract $\alpha_t = 0, \beta_t = \frac{1}{(p_H-p)H}$ in both periods $t = 1, 2$. The total expected payment across the two periods is $\frac{2p_H}{(p_H-p)}$ for each agent.

For Parts (ii) and (iii) of the lemma, we first solve the optimal contract from a *relaxed* program in which we ignore the (Mutual Monitoring) constraint. We then verify that the solution derived from the relaxed program satisfies (Mutual Monitoring). Let $\mathbf{L}$ be the Lagrangian of the relaxed program.

$$\begin{aligned}\mathbf{L} = \quad & (\alpha_1 + p_H(1-c)\beta_1 + p_H c\beta_2^*) - \lambda_{pareto} \times \text{Pareto Dominance} - \lambda_{credible} \times \text{Credible Punishment} \\ & -\lambda_{IR} \times \text{Overall IR} - \mu_\alpha \times \alpha_1 + \mu_\beta \times \beta_1,\end{aligned}$$

where $\beta_2^* = \frac{1}{(p_H-p)H}$ is derived from Period-2 Program, and λ and μ are the Lagrangian multipliers of the corresponding constraints.

For $c \in [\underline{c}, \bar{c}]$, the two binding constraints are (Pareto Dominance) and $\alpha_1 = 0$, yielding the optimal solution of

$$\alpha_1 = 0 \text{ and } \beta_1 = \frac{-cp_H + cp_L - p + p_H}{(c-1)H(p-p_H)(p_H-p_L)}.$$

The only non-negative Lagrangian multipliers are

$$\lambda_{pareto} = \frac{p_H}{p_H - p_L} \text{ and } \mu_\alpha = 1.$$

It is easy to show that the β_1 monotonically decreases in c, and $\beta_1 = 0$ as c incases to $\bar{c}$. In the last step, one can verify that the optimal solution α_1 and β_1 satisfy (Mutual Monitoring) – the constraint that is ignored in the relaxed program. This completes the proof of Part (ii).

For $c > \bar{c} = \frac{p_H - p}{p_H - p_L}$, setting $\alpha_1 = \beta_1 = 0$ satisfy all the constraints. This is clearly the solution that minimizes the expected payment, since $\alpha_2^* = 0$ and $\beta_2^* = \frac{1}{(p_H - p)H}$ are independent of the choice of β_1. The expected payment $\pi(c) = (p_H c + p_H)\beta_2^* H = \frac{p_H c + p_H}{(p_H - p)}$ increases in c, and it is easy to verify that $\pi(c = 1) = \frac{2p_H}{(p_H - p)}$.

In the last step, we substitute the optimal contracts derived from the relaxed program back to the the (Mutual Monitoring) constraint and verify that the constraint is satisfied under the corresponding regions of c. This completes the proof. ■

Proof of Proposition 2. Part (i) of the proposition follows Lemma 2: we know that each agent's expected compensation cost, as a function of the conservatism c, is as follows:

$$\pi(c) = \begin{cases} B^{Individual} = \frac{2p_H}{p_H - p}, & c < \underline{c}, \\ B^{Team} = \frac{2p_H - p}{p_H - p}, & c \in [\underline{c}, \bar{c}], \\ B^{Mixture} = \frac{p_H c + p_H}{(p_H - p)}, & c > \bar{c}, \end{cases}$$

where $\underline{c}$ and $\bar{c}$ are characterized in Lemma 2. Straightforward comparison of the expected payments proves the proposition.

For $\bar{U} > \frac{p}{2(p_H - p)}$, the optimal contract specified in Part (i) is infeasible because it violates the (Pareto Dominance) constraint. One can solve the optimal c^* as shown in the text to satisfy (Pareto Dominance) as a binding constraint. ■

Proof of Proposition 3. We know from the earlier discussion that team incentives $T = 1$ is strictly preferred by the principal to individual incentives $T = 0$. If the principal wants to implement team incentives using a deferred compensation coupled with an unbiased performance measure, she faces the same Period-2 Program and Period-1 Program studied in the main model. However, we need to restate (Mutual Monitoring) and (Credible Punishment) as follows:

$$\Pr(y_1 = H | a_1^i \neq a_1^j) \left(\frac{p_H - p_L}{p_H - p} - 1 \right) \geq 1 - (p_H - p)\beta_1^D H, \qquad \text{(Deferred Scheme)}$$

and

$$\beta_2^* H + p_L \beta_2^* H \geq \bar{U}. \qquad \text{(Credible Punishment under Deferred)}$$

We know that the expected compensation cost given the optimal conservatism is $1 + \frac{p_H}{p_H - p}$. Let $\beta_1^D = \frac{1}{p_H H}$ so that the expected compensation cost is also $1 + \frac{p_H}{p_H - p}$ under the deferred compensation regime. Substituting $\beta_1^D = \frac{1}{p_H H}$ back to (Deferred Scheme), we know the constraint is satisfied if and only if

$$p > \frac{p_H}{1 + p_H}.$$

This condition, however, is shown below to be contradictory to the productive complementarity:

$$p < \frac{p_H + p_L}{2} = \frac{p_H}{2} < \frac{p_H}{1 + p_H},$$

where the inequality uses the definition of productive complementarity $p_H - p > p - p_L$. Our analysis show shows that (Deferred Scheme) is infeasible if $\beta_1^D = \frac{1}{p_H H}$. Therefore, a necessary condition for the principal to make (Deferred Scheme) feasible (and hence, induce team incentives) is to further increase β_1^D beyond $\frac{1}{p_H H}$. This results in a higher expected compensation cost under the deferred compensation scheme (without conservatism) than under the conservatism scheme characterized in Proposition 2. ■

Proof of Proposition 4. We first characterize the optimal contract, fixing an exogenous level of conservatism c, and then endogenous the optimal conservatism c^*. Let **L** be the Lagrangian of the program formulated in Section 4.4 (when $T = 1$).

$$\begin{aligned}\mathbf{L} = \quad & (\alpha_1 + p_H(1-c)\beta_1 + p_H c \beta_2^*) - \lambda_{pareto} \times \text{Pareto Dominance} - \lambda_{team} \times \text{Monitor by Quit} \\ & -\lambda_{IR} \times \text{Overall IR} - \mu_\alpha \times \alpha_1 + \mu_\beta \times \beta_1,\end{aligned}$$

where $\beta_2^* = \frac{1}{(p_H - p)H}$ is derived from Period-2 Program, and λ and μ are the Lagrangian multipliers of the corresponding constraints.

Sol1: for $\frac{p_H^2 \bar{U} - p^2 - p p_H \bar{U}}{p p_H} \leq c \leq \bar{c}$ and $\bar{U} \leq \frac{p}{2(p_H - p)}$, the binding constraint is (Pareto Dominance), from which we derive the optimal solution as

$$\alpha_1 = 0 \text{ and } \beta_1 = \frac{c(p_L - p_H) - p + p_H}{(c-1)H(p - p_H)(p_H - p_L)}.$$

The only non-negative Lagrangian multiplier is $\lambda_{pareto} = 1$. Note that β_1 decreases in c and the condition $c < \bar{c}$ ensures $\beta_1 \geq 0$. The (Monitor by Quit) constraint imposes the lower bound $c \geq \frac{p_H^2 \bar{U} - p^2 - p p_H \bar{U}}{p p_H}$. (Overall IR) requires $\bar{U} \leq \frac{p}{2(p_H - p)}$.

Sol2: for $c < \min\{\frac{p_H^2 \bar{U} - p^2 - p p_H \bar{U}}{p p_H}, \frac{(2p - p_H)(p + p\bar{U} - p_H \bar{U})}{p p_H}\}$, the binding constraint is (Monitor by Quit), from which we derive

$$\beta_1 = \frac{p_H(c - \bar{U} - 1) + p(\bar{U} + 2)}{(c-1)H(p - p_H)^2},$$

and the only non-negative Lagrangian multiplier is $\lambda_{team} = 1$. The two upper bounds on c are required by (Pareto Dominance) and by (Overall IR), respectively. Straightforward algebra verifies that $\min\{\frac{p_H^2 \bar{U} - p^2 - p p_H \bar{U}}{p p_H}, \frac{(2p - p_H)(p + p\bar{U} - p_H \bar{U})}{p p_H}\} = \frac{p_H^2 \bar{U} - p^2 - p p_H \bar{U}}{p p_H}$ if and only if $\bar{U} \leq \frac{p}{2(p_H - p)}$.

Sol3: for $\bar{U} > \frac{p}{2(p_H - p)}$ and $c \in (\frac{(2p - p_H)(p + p\bar{U} - p_H \bar{U})}{p p_H}, \frac{p_H + 2p_H \bar{U} - 2p(1 + \bar{U})}{p_H}]$, the binding constraint is (Overall IR), from which we derive

$$\beta_1 = \frac{p_H(c - 2\bar{U} - 1) + 2p(\bar{U} + 1)}{(c-1)Hc(p_H - p)},$$

which decreases in c and $c \leq \frac{p_H + 2p_H \bar{U} - 2p(1 + \bar{U})}{p_H}$ ensures $\beta_1 \geq 0$. The other upper bound on c is imposed by (Monitor by Quit). The non-negative Lagrangian multiplier is $\lambda_{Pareto} = 1$.

We endogenize the value of accounting conservatism c in the second step. For $\bar{U} \leq \frac{p}{2(p_H - p)}$, one can compare the objective value of Sol1 and Sol2 and verify Part (i) of the Proposition. For $\bar{U} > \frac{p}{2(p_H - p)}$, we can compare Sol3 and Sol2 to conclude that Sol3 is more cost efficient.

One can therefore verify Part (ii) of the proposition by substituting $c = \bar{c}$ into Sol3 and derive $\beta_1^* = 0$. ■

Proof of Observation 1. Equating (Mutual Monitoring LT), $w_H = w_L = 0$, and (Overall IR), one can solve for $w_H = w_L = 0, w_{2H} = \frac{2}{p_H^2 - pp_L}, S = 2(\bar{U} - \frac{pp_L}{p_H^2 - pp_L})$. It is straightforward to verify the solution satisfy the following (Period-2 IR) constraint if and only if $p \leq \frac{p_H^2}{2p_H - pL}$.

$$U_2(\mathbf{a}_2 = (1,1)|\mathbf{a}_1 = (1,1)) \geq U_2(\mathbf{a}_2 = (0,1)|\mathbf{a}_2 = (1,1)). \tag{4}$$

The condition $p \leq \frac{p_H^2}{2p_H - pL}$ is implied by the complementarity of the team production technology $p < \frac{pH + p_L}{2}$ and our normalization $p_L = 0$. The optimality follows because the expected payment under the solution is the first-best level $2(1 + \bar{U})$, which reimburses each agent for his effort cost 1 and reservation utility $\bar{U}$ for two periods. ■

Proof of Proposition 5. Let $\Pr(R|h_{t-1}, h_t)$ be the likelihood for a reversal to occur in $t+1$, given the observed history in periods $t-1$ and t, with $h_t = \{a_t^S, a_t^J, y_t\}$. The posterior probabilities $\Pr(R|h_{t-1}, h_t)$ are important because of their role in determining whether playing (*shirk, shirk*) punishment in $t+1$ is individually rational. In particular, (*shirk, shirk*) punishment is credible if and only if the following condition holds:

$$\Pr(R|h_{t-1}, h_t) \times \beta^S\, H + p_L\, \beta^S\, H \geq \bar{U}. \tag{5}$$

We apply Bayes' rule and show that $\Pr(R|h_{t-1}, h_t)$ satisfies the following:

$$\begin{aligned}
1 &> \Pr(\mathrm{R}|\mathbf{a}_{t-1}=1, a_t^S \neq a_t^J, y_{t-1}, y_t = L) = \frac{pc}{pc+1-p} \quad \forall y_{t-1} \in \{L, H, 2H\}, \\
&> \Pr(\mathrm{R}|\mathbf{a}_{t-1}=1, a_t^S \neq a_t^J, y_{t-1} = L, y_t = H) = \frac{pc^2 p_H}{p_H c[pc+1-p] + (1-p_H)p(1-c)} \\
&> \Pr(\mathrm{R}|\mathbf{a}_{t-1}=1, a_t^S \neq a_t^J, y_{t-1} = H, y_t = H) \qquad (6) \\
&= \frac{pc^3 p_H^2}{p_H c\left[p_H c(pc+1-p) + (1-p_H)p(1-c)\right] + (1-p_H c)p_H p(1-c)^2} \\
&> \Pr(\mathrm{R}|\mathbf{a}_{t-1}=1, a_t^S \neq a_t^J, y_{t-1} = 2H, y_t = H) \\
&= \Pr(\mathrm{R}|\mathbf{a}_{t-1}=1, a_t^S \neq a_t^J, y_{t-1}, y_t = 2H) = 0 \quad \forall y_{t-1}.
\end{aligned}$$

Consider an agent in waiting (apprentice) who observes $h_{t-1} = \{a_{t-1}^J = a_{t-1}^S = 1, y_{t-1}\}$ and decides whether to free-ride at period t when he becomes a Junior agent. It is easy to verify that, for $\bar{U} = \frac{p(p_H-p)^2}{p_H^2(p_H-2p(p_H-p))}$, the solution specified in the proposition satisfies (5) as an equality when the history (h_{t-1}, h_t) is $\left(\mathbf{a}_{t-1}=1, a_t^S \neq a_t^J, y_{t-1} = H, y_t = H\right)$. Therefore, we can use the condition shown in (6) to show that, for $U \in (0, \bar{U}]$, (*shirk, shirk*) punishment is individually rational at $t+1$ for all histories except for $(y_{t-1} = 2H, y_t = H)$ or for $y_t = 2H$.

Having characterized the agents' strategies in period $t+1$, we then reason backwards and show that the solution (β^J, β^S) specified in the proposition prevents the Junior agent from free-riding in period t no matter which (equilibrium path) history he observed in $t-1$. In particular, we complete the proof by showing the following three mutual monitoring conditions.

First, given $y_{t-1} = 2H$,

$$\Pr(y_t = L|\{\mathbf{a}_{t-1}=1, a_t^S \neq a_t^J, y_{t-1} = 2H\})\left(\frac{p_H - p_L}{p_H - p} - 1\right) \geq (p-p_H)(1-c)\beta^J H + (p-p_H)c\beta^S H + 1. \qquad (7)$$

Second, given $y_{t-1} = H$,

$$\Pr(y_t \neq 2H | \{\mathbf{a}_{t-1} = 1, a_t^S \neq a_t^J, y_{t-1} = H\}) \left(\frac{p_H - p_L}{p_H - p} - 1 \right) \geq (p - p_H)(1-c)\beta^J H + (p - p_H)c\beta^S H + 1. \tag{8}$$

Third, following $y_{t-1} = L$,

$$\Pr(y_t \neq 2H | \{\mathbf{a}_{t-1} = 1, a_t^S \neq a_t^J, y_{t-1} = L\}) \left(\frac{p_H - p_L}{p_H - p} - 1 \right) \geq (p - p_H)(1-c)\beta^J H + (p - p_H)c\beta^S H + 1, \tag{9}$$

where the probability on the LHS is the likelihood that $(shirk, shirk)$ punishment is credible as he becomes senior at $t+1$.

To proof (7) - (9), recall from the main model that the following Mutual Monitoring condition is satisfied:

$$[1 - p(1-c)] \left(\frac{p_H - p_L}{p_H - p} - 1 \right) \geq (p - p_H)(1-c)\beta_1^* H + (p - p_H)c\beta_2^* H + 1, \tag{10}$$

where β_1^* and β_2^* are the optimal bonus rates in Proposition 2 and $0 < \left(\frac{p_H - p_L}{p_H - p} - 1 \right) < 1$ follows from the productive complementarity $2p < \frac{p_H + p_L}{2}$. We prove constraints (7), (8), and (9) by showing that (i) their RHS is smaller than the RHS of (10) and (ii) their LHS is at least weakly greater than the LHS of (10). Claim (i) follows from the observation that the bones rates β^J and β^S satisfy $\beta^J = \beta_1^* = 0$ and $\beta^S = \frac{\beta_2^*}{1-c} > \beta_2^*$. Proving Claim (ii) for (7) is easy because $\Pr(y_t = L | \{\mathbf{a}_{t-1} = 1, a_t^S \neq a_t^J, y_{t-1} = 2H\}) = 1 - p(1-c)$. To prove Claim (ii) for (8) and (9), note that $\Pr(y_t = 2H | h_{t-1}, a_t^S \neq a_t^J) \leq p(1-c)$ for any history h_{t-1}. Therefore, $\Pr(y_t \neq 2H | h_{t-1}, a_t^S \neq a_t^J) \geq 1 - p(1-c)$. ■